This report was made as the conclusion of the four week LOCAL-RE program on renewable energy and sustainability. The report gives insights to the possibility of using airships for energy efficient transportation of commuters in the Los Angeles area, and outsized cargo loads.
Abstract

**Title:** Airship Mass Transit feasibility study by Paul Brown, Peter Vu, Anders Handlos Grauslund and Alessandro Setti. All participants followed the LOCAL-RE summer program in California (summer 2009)

**Background:** The idea of using airships for energy efficient transportation of passengers or cargo has become increasingly popular in aeronautics communities during the last ten years. The concepts of energy savings and carbon emissions decrease via large scale airship transportation, has also awoken interest in popular media. Oversimplification of the challenging scientific and engineering problems has left the general public, and to a certain degree the scientific communities, with the false perception that solutions are readily at hand. This report reviews the various difficulties associated with Aeronautics technology, energy efficiency and social impacts within the area.

**Results:** The use of airships could not be calculated to have superior emissions characteristics when compared to normal automobiles. However, on stipulating the costs of infrastructure and other related factors airships might be suited for special applications of transporting high value outsized cargo, such as windmill turbines or other resembling parts, to areas lacking infrastructure.

**Conclusions:** The energy efficient, scalability and inexpensiveness of airship (compared to other aircraft) makes them ideally suited for performing specific purpose transportation. The concept of large scale passenger transportation only appears to be possible in the somewhat distant future – while pilot projects in all applications may pave the way for the airship industry by proving the feasibility of concepts.
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Introduction

In the recent decades people have been getting more and more familiar with the issues that are challenging the society of nowadays. Organizations such as IPCC and EPA have been publishing several reports on the real impact humanity has on the environment and have given proofs on the existing tendency towards a global climate change, along with scenarios exploiting the severe consequences of the current attitude and lifestyle.

It is straightforward that a change in direction is needed, providing more awareness and putting more effort on relevant actions. An example of this happening can be seen in Europe, where the EU appeared very sensitive in this concern and set goals for each country in terms of reduction of pollutant emissions and sustainable development. On a global point of view, noticeable is the importance of the Kyoto Protocol and of COP15, the United Nations Climate Change Conference, which will take place this December in Copenhagen and during which the current situation will be analyzed and plans for the future will be discussed.

Emissions of pollutants such as CO2 and NOx - also known as Green House Gases - are the main responsible for the global warming, other gases and particles harm the environment in different ways, but problems are not to be found looking only at emissions.

The way to follow has to be a sustainable and careful approach, relying on consideration about several indicators that space from Economic (Poverty, Production and Infrastructure) to Social categories (Education, Equity and Individual Conditions) besides the Environmental issues.

With this in mind, it is simple to find the need for alternative solutions when considering for example the uneasiness due to traffic, considering the amount of people commuting to city areas for working purposes every day and the congestion to it related during peak hours.

We focused on solutions for reducing the amount of cars on the highways connecting the cities, confident that this would have had a positive impact on global perspective such as emissions (fewer cars for less time on the streets, if the traffic is more fluent) as well as on the individual perception (less stress giving more productivity and more social encounters compared to a solitary journey).

Our project is a feasibility study regarding the application of airships as an alternative mean of transportation for people commuting to the city. Once having described the technology, additional applications can be considered such as heavy lifting operations, surveillance and disaster relief.

Airships seem to be an effective and viable option for public mass transit as they would reduce energy consumption, alleviate traffic congestion and reduce pollution generated by individual passenger vehicles.

A different application with a relevant positive impact on the environment is the employment of airships in order to substitute light and heavy duty trucks for goods shipping – see deliveries to supermarkets. In California heavy duty trucks account for approximately 30% of the NOx and 65% of the particulate matter (PM) emitted by mobile sources (California Air Resources Band) and a general investment developing the airship system, allowing for a cargo fleet, would also significantly contribute to a reduction in term of pollutants.

The heavy-lift application of airships would allow for over-sized, extremely heavy specialized cargo to be transported where road access is either impossible or unsuitable. Without the need for ground access, the airship would be free to operate in any location (providing that the weather is clement), potentially save on fuel costs, and allow for development projects that would otherwise not be viable.
Similarly, if used for airborne surveillance, the airship would use less fuel than conventional aircraft and would be able to stay on-station for much longer periods of time. In a disaster relief application, the airship(s) would be able to deliver aid and supplies to affected areas where ground access is either difficult or impossible.
Social Impact

Los Angeles and its surrounding metro areas have many difficulties, but for many residents, vehicular traffic is the largest problem and also a substantial contributor to local pollution, especially air pollution\(^1\). Unfortunately it is also one of the most complex and expensive problems to remedy. The entire metro area becomes heavily congested during peak commute and in most cases with anyone who has to commute for a long distance - which many Los Angeles residents do - public transportation is often a poor option. Indeed long distances take very long time via public transportation as there are natural barriers that don’t allow for direct routes.

Unless the destination is nearby a Metrolink Rail line, the commute time by public transportation can add hours to an individual’s day depending on the distance you need to go. Currently, the most efficient way to get around in Los Angeles is in one’s own vehicle, but increased congestion makes that less appealing as time goes on.

![Commute path map]

Figure 1 - Commute path map

Key Factors
Los Angeles has many factors that complicate the flow of vehicular traffic. One of them is its geography. The Santa Monica Mountains separate the L.A. Basin and the San Fernando Valley. The population of Los Angeles County is estimated at 9,862,049 residents, and the population of the San Fernando Valley comprises 17.85% of that, i.e. 1,760,000 residents. So nearly 18% of an already large population is tucked in behind a mountain range, and a significant percentage of that population commutes throughout Los Angeles on a daily basis.

The main issue is that between West Los Angeles and the San Fernando Valley, there is only one main highway that connects the two, and that is the 405 Freeway. Furthermore, commuter traffic from Santa Clarita and Simi Valley will also be encountered during rush hour and that only makes things worse (yellow lines on Figure 1 - Commute path map). Since that highway is in a mountain pass it acts like a bottleneck and in the need of getting to West LA or Santa Monica from Simi Valley, San Fernando, or Santa Clarita, there aren’t many options.

Another key element is the relatively low population density coupled with a wide dispersal of employment hubs as connecting people to job centers scattered over 4,000 miles has been found to be highly expensive. A subway system was attempted, and portions of it were built, but it was an extremely cost prohibitive endeavor that saw many pitfalls. Cave-ins were common during construction due to poor soil stability and budgets routinely ran over throughout the project. Once finished, it was called “the Metro Red Line”. Its service area is relatively small compared to the enormity of the Los Angeles area, and the cost was tremendous:

<table>
<thead>
<tr>
<th>Red Line Facts and Figures</th>
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</thead>
<tbody>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Opening</td>
</tr>
<tr>
<td>Cost</td>
</tr>
</tbody>
</table>

* Wilshire extension opened July 13, 1996; Hollywood extension opened June 12, 1999; North Hollywood extension opened June 24, 2000

So as it appears, Los Angeles spent a total amount of 5.6 billion dollars for only 17 miles of commuter connectivity.

Alternative Options
The need for an expedient and reliable upgrade to mass public transportation was what brought on the idea for this feasibility study. The thought of dedicating major streets to only rapid bus traffic sounded like an excellent option. The city of Curitiba, Brazil had done such a thing and it has been tremendously effective; “75% of the population uses this bus system, and it has also reduced fuel consumption by 30% per capita.” If such a bus system could be done on a large scale in Los Angeles County, would certainly benefit. As it turns out, the Metro Transit Authority in LA County has already done this in a two areas; however, the geographic obstacles of the Santa Monica Mountains and the Hollywood Hills still complicate things quite a bit and we conjured a solution that we felt could work around that: Airships.

We found airships to be an ideal option for freeing up traffic congestion and reducing air pollution, while also providing a form of rapid transit that would interconnect broad systems of already existing public transportation. Areas such as the SF Bay and Los Angeles have geographic obstacles that separate large portions of the local populations. Those obstacles are primarily mountain ranges and large bodies of water. Negotiating these geographic obstacles with tunnels and bridges is both very expensive and very time consuming. Implementing a system of localized air transport would bypass the need for large civil engineering projects, use minimal ground resources, have great flexibility in expanding its service area(s), and could be employed far faster than putting in new subways, bridges or rail lines.

Airships over Los Angeles

All speculation we are doing at this point, for passenger transport, is based on the development of a vehicle that will achieve the capabilities suggested by Worldwide Aeros Corporation: dba Aeroscraft. This is a hybrid vehicle - which characteristics are discussed in the section Technology – that could change many aspects of the transport sector if the proper applications are found.

Per a telephone interview and subsequent consultations with Mr. Edward Pevzner, Business Development Manager for Worldwide Aeros Corp., we were assured that the published specifications for the ML866 were completely reliable. An airship like this would be able to cover speeds and distances which will be immune to rush traffic since it would be airborne, so riders would be able to rely on a very consistent and speedy arrival at their destination. (Not to mention scenic and fun) Most of the proposed airfields suggested are already next to, or nearby, existing and proposed Metrolink stations. After debarking, passengers could transfer to local ground transportation as necessary.

The use of already existing small, municipal airports would decrease the footprint of this proposed air transportation system. Many of Los Angeles’ small airfields have space that could potentially be reallocated for use as air stations, thus negating the need to displace other areas. The Brazilian city of Curitiba serves as a great model for this. It is this type of reuse of existing infrastructure that inspired compelled us to look at the city of Los Angeles through the lens of Curitiba’s innovations. Curitiba’s approach of using resources you already have, but making them
work better was the outlook we went by in selecting this for our scenario. The practicality of these locations and routes warrant much further investigation and assessment, which we plan to do at a later time.

Table 2 - Estimated flight times for proposed route

<table>
<thead>
<tr>
<th>Destination</th>
<th>Length</th>
<th>Time (average speed 75mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burbank – El Monte:</td>
<td>22mi.</td>
<td>17.6 min</td>
</tr>
<tr>
<td>El Monte – Fullerton:</td>
<td>13mi.</td>
<td>10.4 min</td>
</tr>
<tr>
<td>Fullerton – Long Beach:</td>
<td>10mi.</td>
<td>8.0 min</td>
</tr>
<tr>
<td>Long Beach – Torrance:</td>
<td>12mi.</td>
<td>9.6 min</td>
</tr>
<tr>
<td>Torrance – Santa Monica:</td>
<td>22mi.</td>
<td>17.6 min (routed around LAX air traffic)</td>
</tr>
<tr>
<td>Santa Monica – Van Nuys:</td>
<td>18mi.</td>
<td>14.4 min</td>
</tr>
<tr>
<td>Van Nuys – Burbank:</td>
<td>10mi.</td>
<td>8.0 min</td>
</tr>
<tr>
<td>Total Circuit</td>
<td>107mi.</td>
<td>1.5 h</td>
</tr>
</tbody>
</table>

That said, we have calculated what we estimate as the time needed to complete a full circuit of the air stations around the Los Angeles area (see Figure 2 as reference).

The calculated flight times between airfields are as in Table 2.
Logistics

In regards to the amount of space needed to construct a viable airship station, one would need an area at least the size of a standard football field (Length: 360 feet, Width: 160 feet). The ML866 itself is 210’ by 105’ and ample room for landing, along with structural space for passenger ticketing, refueling, etc. would be needed. The exact amount of space necessary for this is impossible for us to determine at this point since much of that information was not available to us. The fact that the ML866 is capable of vertical takeoff and landing reduces the amount of open space needed for its operation, however we can only estimate what that amount of space should be. As Aeroscraft develops their project further, such information should become available.

Another issue that we looked into was air traffic control and FAA standards of certification. In March 2008 FAA awarded Aeroscraft ML866 a brand new type certification, differentiating it from other airships. Process still to be completed involve the new pilot certification standards, safety standards, etc. that will be stipulated in the future.

Regarding air traffic control, we met with Dr. Heinz Erzberger who works at the NASA-AMES research center. Dr. Erzberger conducts research on concepts for improving the safety and efficiency of aircraft and air traffic control operations. In recent years he has designed automated tools to help controllers improve the efficiency and safety of air traffic control and the
FAA has installed his tool for managing arrival traffic, (the Traffic Management Advisor) in major airports in the US. He has won many awards for his achievements in aeronautical science and engineering and his input was very significant.

According to Dr. Erzberger, if the airships we are suggesting were to fly at 10,000 ft. or above, managing them would be relatively easy. At that altitude they would be monitored by the FAA along with all other passenger jet traffic. Collision “avoidance and resolution” software would be used to track the airships, and their flight paths would be monitored in conjunction with other aircraft. All aircraft above 10,000 ft. would have a transponder and thus be easily seen and managed by the presiding regional air traffic control center.

Per Dr. Erzberger, when dealing with air traffic at low altitudes, smaller aircraft are not monitored by the FAA and the risk of a collision is much greater. He went on to reference the collision that occurred over the Hudson River on August 8, 2009 as a perfect example of that risk. In that incident, a single-engine plane and a sightseeing helicopter collided and lives were lost. While military radar would track smaller aircraft such as helicopters, Cessnas, etc., the FAA does not and would be unable to intervene if two aircraft were on a collision course.

Essentially, collision avoidance would rely largely upon the airship pilot and/or the small-craft pilot seeing each other and evading one another respectively. This situation would be even more perilous in low-visibility weather conditions. Furthermore, he referred to Los Angeles airspace as “the Devil” in regards to the high amount of small-craft air traffic in that area. We asked about assigning dedicated flight corridors for the airships to occupy and Dr. Erzberger felt that such a thing would not work since independent pilots may or may not comply. The only option that would open the door for the airship traffic to be safely monitored would be if all aircraft, regardless of size, were to be equipped with transponders and subject to FAA directives and flight path alterations. Until such conditions are implemented, the potential for airship transport is basically nullified unless the situation could be mitigated in some other way.
Markets

Ultimately, the application will determine the feasibility of airship use in modern day society. Depending on the mode of use, whether for public transportation or cargo transport, the business model and potential earning capacity will change along with either application.

What is the value proposition for potential customers?

When looking at the two areas in which airships could potentially be used; personal rapid transit or transportation of cargo, the value proposition changes quite significantly:

Personal rapid transit

The ability to easily drift from one side of a mega-city to the other in rush hour, without being trapped in congestion is a very persuasive selling point, if the logistical and technical feasibilities are ignored. In the context of sustainability, it could reduce emissions on a scale similar to thousands of cars daily.

Cargo

Again, the potential savings on energy would justify the use of comparatively slower airships. While the actual value proposition in this segment is unclear, its profitability lies in the potential transportation of over-sized cargo loads, e.g. parts for windmills, to remote locations that lack sufficient infrastructure.

What is the expected current and future market size?

Again this depends entirely on which application is being examined, but in both cases it holds that to warrant the investment needed to ramp up production of airships, and related materials, and thus build future markets – small scale pilot projects would first have to prove the viability of the concepts. Only thereafter can market sizes be somewhat accurately estimated. The guesstimates that can be done today would appear as such:

Personal rapid transit

In mega-cities such as Los Angeles, the ever expanding population makes the demand for fast, inexpensive and environmentally friendly transportation virtually inexhaustible. This can be attributed to the nonexistence of any present viable alternatives within public transportation (in a city such as Los Angeles). The market size ultimately comes down to the operating costs of the system, which decides for the price pr. Passenger (unless it is subsidized). However, the logistical challenges influence the unfeasibility of intracity transportation. If opted for intercity transportation, the market would become smaller – but perhaps with a more attractive price structure.

Cargo

Transportation of outsized payloads, e.g. windmill parts, to remote areas that lack necessary infrastructure could render airships an economically viable means to move materials around. Unfortunately, the only recent major investment (and later bankruptcy – see next chapter) within an airship company was tied to the development of cargo carriers. The market size is perhaps sufficiently large, given the projected future investments in e.g. windmills, but it is not conceivable that orders would be placed for
airships before they have been sufficiently demonstrated in prototypes and pilot scales. Although special airships, such as the sky hook (airship crane) may be 7-9 times as economically effective as using large helicopters (personal communication with Brian Hall owner of Airship Ventures CA), the viability is still related to the cost of fuel and lease of the helicopter versus the potential and highly theoretical savings of the nonexistent airship.

What would drive sales?

The potential energy savings of lighter than air aircrafts is the best driver. As fuel prices will invariably rise as oil production slows down, new and more economical (although slower) types of transportation will be sought. Airships can potentially be the solution in some markets.

What other approaches are being developed to address this problem? Is there competing technology?

Many other Personal Rapid Transit systems are being looked into. One of such systems is the magnetic levitation system (currently under development at NASA Ames). Such systems also offer on-demand, non-stop transportation, but use small, independent vehicles on a network of specially-built guideways. Several different designs have been proposed, and as a competitor to airships (or vice versa) these systems must prove themselves reliable, inexpensive, practical, implementable and scalable. The system under development at NASA Ames, is projected to be at a cost of 5 million USD pr. km – the question of whether airships can compete with that is crucial.

Is the opportunity a game changing opportunity from the market’s standpoint by offering: New to the world performance features, orders of magnitude improvement?

In many ways the idea of airships in either application is radical and game changing. Considering the personal transportation a spread use of this technology would improve drastically the conditions on a local point of view. In many cities with geographic obstacles such as Los Angeles, this solution would be preferable to large civil engineering projects. The cargo application would open possibilities where infrastructure is lacking or not existing.
Airships and Resources

In attempting to offset congestion problems that invariably arise as cities expand, making comparisons between the infrastructural investment opportunities is far from trivial. Especially when the possible use of non-existing technology (such as commuter airships) is modeled and compared to existing opportunities, the evaluation must rest on a number of assumptions.

In the present work, the use of commuter airships was envisioned to serve as a possible means of negating the congestion-related problems in the Los Angeles area, thus saving energy and ultimately improving effectiveness and productivity of the city as a whole. However, to compare the investment in commuter airships and related infrastructure to the expansion of already existing means of public transportation, the assumption that airships could be viewed as equally good alternatives must be made. Evidently this is not the case today, but the comparisons seen in the present work are only to serve as examples of how the future could look if an actual airship industry would rise from the ashes of the airship heydays of the thirties.

The choice of comparison fell within the most recent infrastructural investment made by the city of Los Angeles, namely the Los Angeles Subway. Although not a topic of the present work it must be mentioned that Los Angeles previously did have an effective public system of transportation. In 1963 all of these transportation facilities had been closed down in favor of using automobiles on an extensive freeway system. With 14 million people in the greater metropolitan area, those automobiles soon created the most traffic-congested city in America. Los Angeles is often portrayed as the example of the car-friendly city. The traditional image of the town is an endless pattern of single family dwellings, interconnected by traffic-clogged freeways, where transit is undeveloped and the air is choked with smog. In the 1980s, Los Angeles County voters approved a half-cent sales tax increase to build a network of metro and light rail lines. Since then, it has progressed in fits and starts, and not without controversy. However, Los Angeles is changing. The city’s Transport Authority has planned in the last years a series of measures aiming to improve quality of life through improving transit and walking and providing alternative to car commuting.

The last measure of this series is Measure $R^7$, approved in November 2008, whose aims are:

- Expand Los Angeles railway system, and connect it to the airport
- Improve roads, making them safer for cyclist and pedestrians
- Reduce highway congestion and improve highway safety
- Expand the bus network, without increasing fares
- Improve quality of life, trough better transportation options.

Measure R is a perfect occasion to rethink the image of Los Angeles, getting rid of its stereotypes. However, plans for expanding some of the existing metro lines have been halted due to a measure passed by voters in 1998, which banned local tax revenues from funding subway tunnel construction.
It remains to be seen if alternatives such as airships could actually attract investors, both public and private. In present work, the comparison with the metro system is only for the purpose of measuring what the equivalent investment would produce in terms of results for the commuters in Los Angeles.

Investment in infrastructure

The first fully underground subway in Los Angeles, called the Red Line, opened in 1993 after seven years of construction. The red line runs from downtown Los Angeles westwards to Hollywood and North Hollywood. As of June 2008, the combined Red and Purple lines averaged a weekday ridership of 153,928, which makes it the ninth busiest rapid transit system in the United States. Taking overall track length into consideration, Metro Rail's subway system transports 8,846 passengers per route mile, making it the sixth busiest per length, but still far behind the transit systems of New York City, Washington D.C., and Boston.

The price of the 17.4 mile system, build by 3 expansions, was $1.4 billion for the first segment, $1.8 billion for the second and $2.4 billion for the third. The total of $5.6 billion (not accounting for inflation) can be used as a measure when comparing with the equivalent value (amount) of infrastructure that could be bought if the same amount of money was allocated to buying airships and related materials.

If $5.6 billion was used for buying airships at a price of $40 million per vehicle, the investment would equate to 140 airships. Naturally this would never be the case as a majority of the money would have to be dedicated to building the necessary ground infrastructure and materials needed for maintaining a fleet of airships. The numbers relating to these investments are not easily found in any publicly accessible documents. However, by interviewing Brian Hall (Airship Ventures CEO, Moffett field, CA), owner of one out of four of the largest airships in existence today (the Zeppelin NT), the answer to these questions was somewhat illuminated.

The running expenses of operating the airship owned by Airship Ventures is not public information; however, it could clearly be seen from visiting the airship that many other investments need to be made in addition to purchasing the airship itself. These mainly consist in:

- Trucks to anchor the airship when on the ground, provided with stabilizers and variable height crane;
- Helium machine, providing the desired amount of helium of a certain purity;
- Helium leakage management, as usual losses amount in 11m³ every couple of days;
- Multiple ground crews (each destination requires a ground crew on site)
- Administrative support staff & airship maintenance staff

Investor willingness

In considering what would warrant investment in the use of airships for transportation (of cargo/people), the question of whether or not any single application of the airship technology, or business model, would create a substantial leap over substitutes in the market needs to be addressed.
Potential investors would probably evaluate the potential of investment by looking strictly on the expected rate of return seen from similar projects. This is not easily done, as there have been very few successful recent businesses involved with airships – and none have involved the use of airships on a large scale.

**CargoLifter story**

The fate of one of the few business ventures engaging in the commercial use of airships, not devoted to tourist leisure flights, can be examined by looking at the now-defunct Cargolifter AG. Cargolifter was a company created to offer logistical services through point-to-point transport of heavy and outsized loads. This service was based on the development of a heavy lift airship, the CL160, a 550,000 m$^3$ vessel designed to carry a 160-tonne payload.

Cargolifter AG was created on 01 September 1996 in Wiesbaden, Germany. A public stock offering took place in May 2000, and the resulting shareholder structure was characterized by a high proportion of small investors, attracted by substantial press coverage of the new breakthrough technologies being promised.

The first CL 160 airship was never built, though a considerable amount of design and development work was undertaken. The technical complexity (something akin to designing an airliner with less vetted technology) along with limited funding (a fraction of the funding available for the development of new airliners), and short development timeline meant that program challenges were underestimated, making the project relatively risky.

The "CL 75 AirCrane" prototype, filled with 110,000 m$^3$ of helium, was taken out of the hangar for the first time in October 2001. It represented a new stage in full-scale experimental purposes. The loadframe of this unit was engineered on behalf of Cargolifter AG by the American company, AdvanTek International LLC. One CL 75 Aircrane was to be sold to the Canadian company Heavy Elevator Canada Inc., along with 25 options (at a unit price of USD $10 million), but the contract never became effective.

On June 7th 2002 the company announced insolvency, and liquidation proceedings began the following month. The fate of parts of the € 300 mil. in shareholder funds from over 70,000 investors is still unclear.

**Effect for future investment**

Although many key references in the existing airship community attribute Cargolifter’s fate to poor management and not to the feasibility of the product, the effect of the bankruptcy and complete loss of investor money has given the airship industry a poor name and made investors particularly careful in this area. According to Dietmar Blasius, chief of special missions within Deutsche Zeppelin-Reederei GmbH, the realistic investor launch cost of creating a new (and successful) company like Cargolifter would be 900 million euro – or $1.3 billion. Evidently, this investment, which has no successful parallel, is unlikely to be funded by means of normal investment money.

For potential investors (both public and private – within all applications) a number of questions would need to be answered before any type of investment would be considered:

*Do we understand the fundamental science behind the technology?*
The concepts are comparatively simple. The energy savings achieved by using gaseous lift, equates to less energy spent keeping the vehicle in air. However, many of the new proposed aircraft have no proof of concept.

*Can we prove (is there) technical feasibility or attractiveness of the business model through simulations or prototypes?*

The heyday of airship technology was in the first half of the twentieth century, and since then not a lot has changed as no significant development has been done in the airship industry. The Hindenburg disaster proved that hydrogen filled airships were not safe, and effectively became the showstopper for further development. Furthermore, as modern aircraft rapidly developed, people no longer considered the use of airships and they became the dinosaurs of aeronautics. For these reasons, and the aforementioned bankruptcy of Cargolifter, neither the technical feasibility nor the attractiveness of any business model (in any application) can be proved at present.

*Is there technical or business capabilities in existence, or can they be acquired, to make the technology reliable and scalable or the business model viable?*

Today’s airship industry is limited to a few companies. When focusing only on actual airship with rigid frames (excluding blimps) the number is further shrunken to one producing company, Deutsche Zeppelin-Reederei GmbH (has produced four Zeppelin NTs) and a number of entrepreneurial airship companies all allegedly working on airship prototypes. There are many experts within aeronautics, but only a few that have worked with airships. Therefore, the reliability and scalability of the few ongoing projects is highly questionable.

*Is the technology related to current technological competencies in the field, and are the existing technology capabilities strong enough to develop the technology?*

Airships do exist today, but only for the purpose of expensive tourist joyrides. The actual existence of the few competencies (persons) means that it would be difficult – but not impossible to develop the technology. However, this development is tied to the hypothetical large scale investment for which the probability is also related to the probability of the acceptable rate of return.

*Can needed technologies and infrastructure be developed or acquired easily and rapidly?*

In focusing initially on personal rapid transit, that question remains to be answered, and many factors play a part in solving for this problem. Even assuming that a fleet of large scale airships transporting 500 persons each could be built, the sheer size of the aircraft themselves would limit the “airship stations” to a few remote locations in the outskirts of urban areas from where passengers would again have to find ways of reaching their destination by other means of transportation, thereby not alleviating congestion problems. The infrastructure would also need to include storage hangars for the entire fleet of airships, in
case severe weather was expected. On a large scale it seems the infrastructure would be difficult to plan for. Inter-city transportation would be more conceivable, as the benefit of time saving would not be terribly offset by subsequently having to commute via other means of transportation.

*What technical hurdles must be overcome? Is there confidence that technical problems can be overcome and feasibility proven?*

There is no proof that airships will be able to perform the massive lifts (cargo/passenger) that the entrepreneurial airship companies stipulate. There is almost no information on the technology that would enable 21st century airships to compete with other means of transportation.

**Conclusions on investment possibilities**

As in all other cases, the principle that “potential return” *rises with an increase in risk*, also holds for investment in airships. Low levels of uncertainty are associated with low potential returns, whereas high levels of uncertainty are associated with high potential returns. According to the risk-return tradeoff, invested money can render higher profits only if it is subject to the possibility of being lost. However, the actual payoff from possible investments is difficult to quantify as there are no recent success stories within the business. This effectively halts the probability of investment in the airship industry barring any obvious, and demonstrated, breakthroughs in airship technology.
Technology

The airship that this project is based around is the Aeroscraft ML866. The ML866 - which specifications are shown in Table 3 - is an airship that is currently in late stages of development, market release is planned for 2011, while other models with bigger capacity are under study. Aeros envisions this airship as sort of a flying luxury hotel or conference space where people can have multi-day conferences in the air, and all the while having the luxuries of a high class hotel. For our applications, though, we will be foregoing all the luxuries, and try to outfit the ship only with accessories useful for the application that the airship is intended to be used for. Calculations regarding the useful payload have led to an estimated passenger allowance up to 75 seats for this airship.

Design of the AerosCraft ML866

The vehicle under consideration belongs indeed to a new category of airship, certified in March 2008 by the Federal Aviation Administration (FAA). The Aeroscraft is based on proprietary Dynamic Buoyancy Management and Structural Technologies that create a completely new class of aircraft. Unlike other airships, the Aeroscraft generates lift through a combination of aerodynamics, thrust vectoring and gas buoyancy generation and management. Control of static heaviness, or COSH, is a system that allows the airship to adjust the component of static lift at any time by changing the volume of the gas envelope in conjunction with the flight profile status. It makes the airship lighter or heavier than air when convenient and compensates consumed fuel or atmospheric conditions without the need for external ballasts.

The helicopter-like vertical takeoff and landing capability, and the ability to operate from unprepared fields, enhances the usefulness of the Aeroscraft by providing access to remote areas anywhere around the world.

The most significant component of any Lighter-than-Air airship is the envelope, which encloses the helium gas, providing the airship's lift. Aeros has developed a new fabric material, weldable on both surfaces, and has characteristics that minimize damage caused during a puncture or tear. This transparent multi-layer fabric is a woven nylon impregnated with polyurethane composition, including two helium protection barriers and double UV coating.

### Table 3 - Specifications of the Aeroscraft ML866

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>210 ft</td>
<td>64 m</td>
</tr>
<tr>
<td>Width</td>
<td>105 ft</td>
<td>32 m</td>
</tr>
<tr>
<td>Height</td>
<td>53 ft 5 in</td>
<td>16 m</td>
</tr>
<tr>
<td>Cabin size</td>
<td>5382 ft²</td>
<td>500 m²</td>
</tr>
<tr>
<td>Max Range</td>
<td>2,670 mi</td>
<td>5,000 km</td>
</tr>
<tr>
<td>Max Speed</td>
<td>126 MPH</td>
<td>222 km/h</td>
</tr>
<tr>
<td>Max weight</td>
<td>34,171 lbs.</td>
<td>15,500 kg</td>
</tr>
<tr>
<td>Top Altitude</td>
<td>12,000 ft</td>
<td>3,657 m</td>
</tr>
</tbody>
</table>

Figure 3: The Aeroscraft ML866
The gondola will have 5,382 ft² (500 m²) of floor space. Unlike most airships (namely the models that Zeppelin currently makes), the gondola appears to be embedded in the structure of the envelope, giving to the airship an appearance much more streamlined, and it most likely plays a part in keeping the whole thing as aerodynamic as possible.

All pilot control and avionics systems will use Fly-by-Light (FBL) technology. The pilot’s commands are fed into a flight control processor and sent to the surface actuators via electrical signals transmitted along fiber optic cables. In Fly-by-Wire (FBW) Systems, wires must be shielded from electromagnetic frequency (EMF) interference, which results in additional weight, cost and maintenance. FBL is immune to EMF interference, such as lightning strikes. The FBL, flight control processor and flight control devices make up the Onboard Data Exchange Managing System (ODEMS). This system means that the flight is mostly automated, with the two-person crew monitoring the flight conditions to ensure safety.

Supplying the cruising power are two Pratt & Whitney PT6A’s. Using current and past airships as an example, we estimated the total fuel consumption rate to be approximately 17 gallons per hour. The fuel that is used in these engines is the kerosene based Jet A, which has been the standard jet fuel in the U.S. since the 1950’s. As far as emissions go, burning one gallon of Jet A fuel produces about 19 lbs. of carbon dioxide.

Cargo Application
The cargo sector is mainly represented by medium and heavy duty trucks which, despite their small population, are disproportionate contributors to pollutant emissions. In a study by CARB (California Air Resources Board) it is stated that Heavy Duty Diesel Vehicles account for approximately 30% of the NOx emissions and 65% of the particulate matter (PM) emitted by mobile sources while comprising only 2% of the on-road vehicle fleet in California. It is important to select the means of transport that provides the lowest cost based on the time, size and weight constraints of what is shipped, along with consideration towards the environment. Availability, punctuality, reliability, security and safety are among the factors to be considered, along with transportation cost, speedy delivery to customer warehouses, inventory demands, product quality and packaging requirements.

The application of airships in this sector would possibly ease the shipping operations and at the same time lower emissions and noise pollution in a considerable amount. The Aeroscraft ML866 prototype currently under construction is characterized by a payload up to 8,000 lbs; this wouldn’t justify the investment in cargo applications since trucks are already easily available and they can load up 80,000 lbs of freight. A focused investment in the airship industry would anyway lead to...
the development of similar bigger models of the Aeroscraft as already planned by Worldwide Aeros Corporations.

The specifications of this model have been modeled and calculated\textsuperscript{16}, and can be seen in Table 4. A solution like this would improve shipments that require multiple shipping vectors, such as truck to ship to truck, truck to aircraft to truck, etc. Operations would benefit from the direct delivery capabilities of the craft, and goods would be shipped in a more timely and efficient manner where infrastructure is limited or does not exist.

The same model of airship could function as a cargo lifter, transporting for example heavy wind turbine blades, getting bigger and heavier with developing technology and at the same time very difficult to be transported without inconveniences and without getting damaged.

**Fuel Efficiency**

Since we are proposing an alternative form of traveling, it is important to compare the efficiency amongst the different forms of transportation. Since all the different forms of transportation have different weight limits, and the type cargo, we decided to devise a unit to sort of “normalize” the measurements. The system is similar to an airplane’s “seat miles” which is the number of filled seats multiplied by the number of miles traveled. For this, we will consider pounds of carbon emitted for every pound transported. For the ML866 and the Boeing 767, the miles per gallon figures weren’t readily available so they were calculated by dividing the gallons per hour burn rate, with the average cruising speed:

\[
\text{ML866: } 75\text{MPH}/17\text{ga/hr} = 4.4\text{mpg}
\]

\[
\text{Boeing 767-300F} = 567.33\text{mph}/1722\text{ga/hr} = 0.33\text{mpg}
\]

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Load Capacity</th>
<th>Fuel Economy</th>
<th>Fuel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeroscraft ML866</td>
<td>11,245lbs</td>
<td>4.4 mpg</td>
<td>Jet A</td>
</tr>
<tr>
<td>Boeing 767-300F</td>
<td>222,000lbs</td>
<td>0.33mpg</td>
<td>Jet A</td>
</tr>
<tr>
<td>Semi-Truck</td>
<td>80,000lbs</td>
<td>6 mpg</td>
<td>Diesel</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>1500lbs</td>
<td>22 mpg</td>
<td>Petrol</td>
</tr>
<tr>
<td>Van</td>
<td>3000lbs</td>
<td>17 mpg</td>
<td>Petrol</td>
</tr>
<tr>
<td>Bus</td>
<td>44,800lbs</td>
<td>8.4 mpg</td>
<td>Diesel</td>
</tr>
</tbody>
</table>

The carbon dioxide release of Jet A, diesel fuel, and petrol is 19lb/gal, 22.2lb/gal, and 19.4lb/gal, respectively\textsuperscript{17}. Nitrogen oxide released for Jet A and diesel is 0.019 lb/gal\textsuperscript{18} and 1.85 lb/gal\textsuperscript{19}. The emissions
per unit of transported weight will be calculated by running them through a 200 mile straight way test run. We are assuming ideal conditions (no wind, no hills, no stops). The amount of fuel consumed during the run will be used to calculate the amount of emissions, which will then be divided by its load capacity.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>CO2 Emissions (200 miles)</th>
<th>CO2 per Pound of Fuel</th>
<th>NOx Emissions (200 miles)</th>
<th>NOx per Pound of Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeroscraft ML866</td>
<td>863.55 lbs</td>
<td>0.077</td>
<td>0.859 lbs</td>
<td>7.64E-5</td>
</tr>
<tr>
<td>Boeing 767-300F</td>
<td>11,515.14 lbs</td>
<td>0.052</td>
<td>11.45</td>
<td>5.16E-5</td>
</tr>
<tr>
<td>Semi-Truck</td>
<td>733.26 lbs.</td>
<td>0.009</td>
<td>3.2</td>
<td>0.0046</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>176.35 lbs.</td>
<td>0.118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Van</td>
<td>228.14 lbs.</td>
<td>0.076</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>523.8 lbs.</td>
<td>0.011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the calculations, airships actually do not offer too much in terms of CO2 emissions savings against other types of cargo transport, NOx trucks appear higher for trucks than for higher means of transportation.
Conclusions

The Aeroscraft ML866 came in a bit below our hopes regarding the amount of passengers it could potentially transport in a single airship. We had initially hoped for 150 – 200 passengers per airship, but after taking a closer look, its capacity topped out at a maximum of 75 passengers. We still find that, even with 75 passengers, it is still worthwhile to move forward with the idea of employing airships as a form of mass transit in an intra-city application, but a greater passenger load capacity would increase its usefulness and appeal. A pilot program employing a few airships to demonstrate the proof of concept would be necessary, and hopefully this can take place at some point. Should Aeroscraft design a somewhat larger “commuter model” of their ML866 that could accommodate 200 or more passengers, the potential to alleviate traffic congestion along with reducing CO2 emissions could have a significant impact.

However, it is important to understand that the actual CO2 emissions savings will come from the dynamic effects that would arise by taking cars off the road making traffic smoother, and saving the expenses (and CO2 from constructing e.g. metro lines). On their own, the projected emissions from airships such as the ML866 are not sufficiently reductive to warrant investment – if the application is for intracity passenger transportation. In other applications the reductions are more impressive. Transportation of high value outsized cargo, e.g. windmill turbine blades, may be more cost-effective – but unfortunately these calculations were not made due to the short time available for the writing of this report.

Appendix

Tailoring for Proposed Applications

We have come up with several possible applications for this airship: mass transportation (local scale), cargo transport, and heavy lift (also known as sky crane). Since this airship was designed for cross country traveling in a luxurious environment, we have identified
some aspects that we could change to better suit our needs. Some of the possible changes we can make are:

- Reducing the amount of fuel to accommodate a larger useful load.
- Replacing fixtures (if any) that might have been included with the airship.

Since we weren't able to receive any concrete info regarding the interior from Edward, our contact at Aeroscraft, we will have to make do with reducing the amount of fuel on board to determine the perfect tradeoff between payload and fuel needed for the current application.

The rated maximum load allowed to us with a full tank of gas was only 7000 lbs. Since this craft was designed to travel cross country, we will not need its maximum fuel potential. Edward from Aeros couldn’t give us solid numbers on some details that we needed, so we had to resort to doing reverse calculations using numbers that we already knew with some numbers that we had to find elsewhere. The one variable that we had to estimate was the fuel consumption, which we found to be about 17 gallons per hour. Using this and the numbers from the specifications, we were able to do some calculations:

The proposed circuit around LA: 107 mi.

Amount of time to travel the circuit at 75MPH: 107/75 = 1.5 hours

Fuel required for 1 circuit (1.5hrs @ 17g/hr) = 25.5 gallons

Fuel weight for 1 circuit (@ 6.735 lb/g) = 171.74 lb

Total fuel weight needed for 3073 mi: (3073/107) x 171.74 = 4932.31 lb

A 6 hour shift requires 4 circuits and 687lb of fuel.

The extra payload we can use is 4932.31 - 687 = 4245.31lb

The new payload limit becomes 7000lbs + 4245.31lb = 11245.31lb

For mass transportation purposes, giving an average weight of 150lb per person, 11,245.31lb translates to:

11,245.31/150 = 74.969 people

which we will round up to 75 people maximum load.
Calculations on the number of airships needed to offset 20% of the emissions in LA

Fuel consumption for three different airships

**Hidenburg** used 27625 L in 77 h = 358L/h = 916kg CO2/h ([http://www.airships.net/hindenburg/size-speed](http://www.airships.net/hindenburg/size-speed))

assuming 0.85g/ml for diesel/kerosene:

In 30 minutes = 197 l and 504 kg CO2

**Zeppelin NT** 15 gallon/h = 57l/h = 145kg CO2/h

in 30 min = 28 l and 73 kg CO2

**Aeroscraft ML866** 17 gallon/h = 64L/h = 163kg CO2/h

30 min = 32 l and 83 kg CO2

General calculations to find the emissions for LA congestion traffic


(2007) REF 3.160 million commuters travelling 29 minutes on average

Average commuting time REF 29min at 20mph (guessimate) = 29 min at 32 km/h = ca. 15 km traveled

15 km = 1,32 L benzine = (2,250 kg CO2/l)

([http://www.transportbudget.dk/DivText/Om_transportbudget.htm](http://www.transportbudget.dk/DivText/Om_transportbudget.htm)) = 2.97 kg CO2 (x 3.160 million people) = 9.32 million kg CO2 (one way) = 18.64 million kg CO2 (two way) = 365X = 6853 mill kg CO2 = 6.85 million tons CO2/year

Calculations to find the amount of airships needed to offset 20% of congestion related CO2

2.97 kg CO2 x2 = 5.94 kg CO2/day/vehicle = 2168 kg CO2/year/vehicle

6.85 million tons / 100 x 20 = 1.37 million tonnes = 20%
1.37 million tons / 2168 kg = 631918 cars = 20%

Airships would have to carry 631918 (assuming 1 person 1 car) people in the morning and likewise in the afternoon in one year to cut out = 20% cut cars/year – IF airships operated for free which they do NOT

**ML 866** 30 min = 32 l and (83 kg CO2 x 365 x 2) / 5.94 kg/day car corresponds = 10200 extra cars to make it free!

631918 + 10200 = 642118 CARS/prs each way.

assuming 75 prs/airship = 8561 airships to save 20%.

Expenditure in yearly emissions = 83 kg CO2 pr/flight (x2) x 365 = 60590 kg/year

Saved pr. airship = (75 cars x 2168 = 162600 kg CO2/year) – (expenditure 60590 kg CO2/year) = 102010 kg = 102 tons CO2 saved pr airship/year.

**Zeppelin NZ** – in 30 min = 28 l and (73 kg CO2 x 365 x 2) / 5.94 kg/day car corresponds = 8971 extra cars to offset expenditures

631918 + 8971 = 640884 cars/prs each way.

assuming 15 prs/airship = 42725 airships to carry 20% of car passengers.

Expenditure in yearly emissions = 73 kg CO2 pr/flight (x2) x 365 = 53290 kg/year

Saved pr. airship = (15 cars x 2168 = 32520 kg CO2/year) – (expenditure kg CO2/year = 53290) = -20770 kg CO2 saved pr airship/year.

**Hindenburg** – 20162 in 30 minutes = 197 l and (504 kg CO2 x 365 x 2) / 5.94 kg/day car corresponds = 61939 extra cars to offset expenditures

631918 + 61939 = 693857 CARS/prs each way.

assuming 75 prs/airship = 9912 airships to carry 20% of car passengers.

Expenditure in yearly emissions = 504 kg CO2 pr/flight (x2) x 365 = 367920 kg/year
Saved pr. airship = (70 cars x 2168 = 151760 kg CO2/year) – (expenditure 367920 kg CO2/year) = -216160kg
CO2 saved pr airship/year

747/400 burn around 10 tons of fuel per hour (chevron)
Frankfurt – new York 7hrs 25 minutes = 8hrs = 80.000kg fuel = 94.110 l
11763L/h
2560 g CO2/l diesel

http://www.transportbudget.dk/DivText/Om_transportbudget.htm

7 (http://www.metro.net/measurer/default.asp)
8 Fred Edworthy, Aeros Vice President, AeroNews Interview, 8-21-2007
10 2008 Business Aircraft
11 Worldwide Aeros Homepage, Design
13 AEL, Summary of Emission Estimates for the Airport Profiles, 2005
15 Edward Pevzner, Aeros Business Management Director
17 EPA Emission Facts, February 2005