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**Interest in lighter-than-air and hybrid craft has increased as they are considered environmentally friendly methods of air transport. But what, if any, are the potential uses for them in today's world? Dr Chris Carey, Dr Oliver Inderwildi and Professor Sir David King of the Smith School of Enterprise and the Environment believe they may have a role to play in certain types of freight transportation.**

**T**HE EARLIEST RELIABLE METHOD OF manned flight was in lighter-than-air vehicles. Before the development of long-range aircraft, the airship was the choice for discerning travellers. In the 1920s, Zeppelins were regularly crossing the Atlantic, and by 1929 circumnavigating the globe in a little over 21 days. However, the development of safer and quicker aircraft reduced airships to tourist rides and mobile advertising boards. Recently, interest has increased in them because they are considered environmentally friendly methods of air transport. This article looks at development, both historical and more recent, and analyses the potential uses for modern airships today.

## History

In much the same way that ships float, lighter-than-air craft rely on buoyancy to operate. While small hot air balloons, called sky lanterns, were used in the third century B.C., it was the Montgolfiere brothers who brought lighter-than-air craft into recent

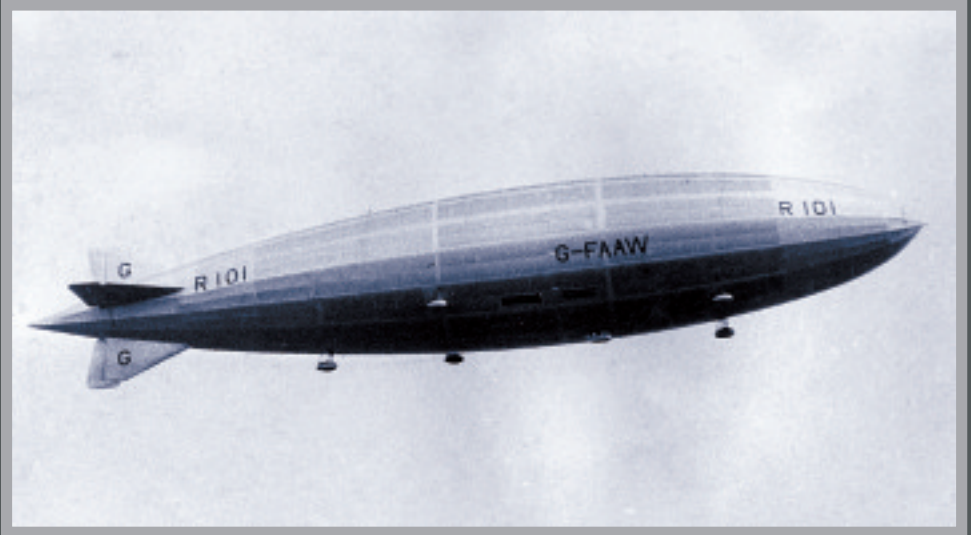


Photo: Victor A. Chapman

history. In 1783, Pilatre de Rozier and Marquis d'Arlandes undertook the first manned flight in a Montgolfiere balloon and started a balloon mania in late 18th century France. For the next sixty years, manned flight was undertaken in balloons, using a mixture of lift gases, including hydrogen. These early craft were not truly navigable due to their shape

and lack of propulsion. In 1852, Henri Giffard attached a small steam powered engine and propeller to an aerodynamically shaped balloon, or envelope, so creating the world's first airship. By replacing steam power with gasoline in 1898, Albert Santos-Dumont produced an airship that was a practical method of flight.

# Just Hot Air?

## The development of lighter-than-air craft and their possible impact

At this point, airship development started to diverge with the production of differing types of envelope (the envelope being the gas containment membrane). These are characterised as rigid, semi-rigid and non-rigid airships. Rigid airships are able to maintain their shape independent of envelope pressure, by a complex rigid metal framework. They are used for designs exceeding a volume of one million cubic feet, because an unsupported envelope of this size would have problems during pressurisation. Semi-rigid airships have a rigid keel with an aerodynamic shape, which carries the primary loads, while relying on the pressurised envelope to maintain the overall shape of the airship.

Non-rigid airships, or blimps, have their shape maintained solely by the pressure within the envelope. The envelope contains the lifting gas, often helium, and ballonets. Ballonets are volumes of pressurised air provided by fans. As air is heavier than the lifting gas, they act like ballast tanks on a submarine, affecting altitude and trim. The lack of any rigid structure means that blimps are easy to design, build and maintain, compared with rigid systems. However, construction of large blimps is difficult due to the long lengths of seaming required of the fabrics, which has an inherent requirement for handling space. Also pressuring large blimps is a delicate procedure because of the relationships between the various structures and the pressurised hull.

Over the next forty years development

continued on all types of airship, with progressively larger models being produced. Of the three types, rigid airships developed most quickly. In 1919 a British airship, R34, crossed the Atlantic and Graf Zeppelin of Germany circumnavigated the globe in 1929. These successes however were overshadowed by several losses, cumulating in the Hindenburg fire in New Jersey in 1937, which ended the golden age of rigid airship construction.

After the Hindenburg, airship research and development languished, but never halted completely. The Goodyear Corporation and US Navy undertook research in the following years and focused on dependable helium-filled non-rigid airships. Various models were considered, though few got past the design stage. The next significant airship to be produced was by Zeppelin Luftschifftechnik in 1997, the NT, a semi-rigid system of which a total of four were completed and used for tourist rides, advertising and special operations such as data transfer and the operation of delicate sensor systems. A further semi-rigid system, also from Germany, was announced in 1996. The Cargolifter CL160 was 260m long, with a 160 tonne capacity compared to a 747-400f, which carries 110 tonnes. The design raised interest, particularly in defence circles where heavy lift airships are seen as a possible replacement for maritime transport, for rapid deployment of heavy forces, such as tanks and other armour, as they could operate from unprepared areas.



In recent years designs have concentrated on the novel or unconventional, particularly in the area of heavy lift systems. The problem with traditional or conventional airships is their low loading capacity, which ranges from -5 per cent to +8 per cent of the airships mass, because they rely on buoyancy as the sole lifting force. Were additional lifting force available, through either aerodynamic or propulsive methods, a higher load percentage is possible, allowing for larger, more useable loads. On this front, a number of unconventional systems have been investigated and developed, looking at differing shapes, lift mechanisms, lifting gases and propulsion mechanisms.

## Shape

Traditional airship shape evolved from the spherical balloon to an elongated tube as a trade-off between maximum possible lift and minimum air resistance. A number of companies, including 21st Century Airships of Canada and CL Cargolifter of Germany, are developing spherical airships for heavy lifting duties because the spherical shape



provides maximum lifting force for a minimum surface area. The reduced size allows operations in confined spaces and much simplified ground handling. They have very high aerodynamic drag, but the proposed applications are for operations which would require minimal horizontal displacement.

Lenticular or lens shaped airships have also been developed because their shape can generate aerodynamic lift and improve the craft's manoeuvrability. However, their high surface-to-volume ratio results in high drag, reducing performance. They are also sensitive to payload changes, which make loading and unloading difficult.

The use of multiple hulls, many gas envelopes joined together, is a promising area of investigation as it gives the opportunity to significantly increase gas volume, and therefore load, without increasing the overall length of the craft. The shorter length reduces the sensitivity of the airship to lateral gusts as well as easing construction and storage. Multiple hulls can also be connected by inboard wings, which act as a source of aerodynamic lift. Multiple hulls also reduce the

likelihood of catastrophic loss of lift due to damage to the envelope.

## Lift Systems

An obvious choice for improving the lift capabilities of an airship with a given volume is to alter the lifting gas. Hydrogen was originally used, but has fallen out of favour due to its flammability. Hydrogen has largely been replaced by helium, which is inert but more expensive and has a 7.3 per cent smaller lifting capacity. Hot air is also used, mainly in small-scale systems, but has 70 per cent less lifting capability of the same volume of hydrogen. Other gases that have been considered are steam, methane, ammonia and natural gas. These all have various challenges being either flammable, corrosive or, in the case of steam, difficult to maintain at a useable temperature.

A true lighter-than-air craft would be just that, relying solely on buoyancy to provide lift. This has a draw back with limited load carrying capability as well as problems with stability during loading and unloading because rapid changes in weight

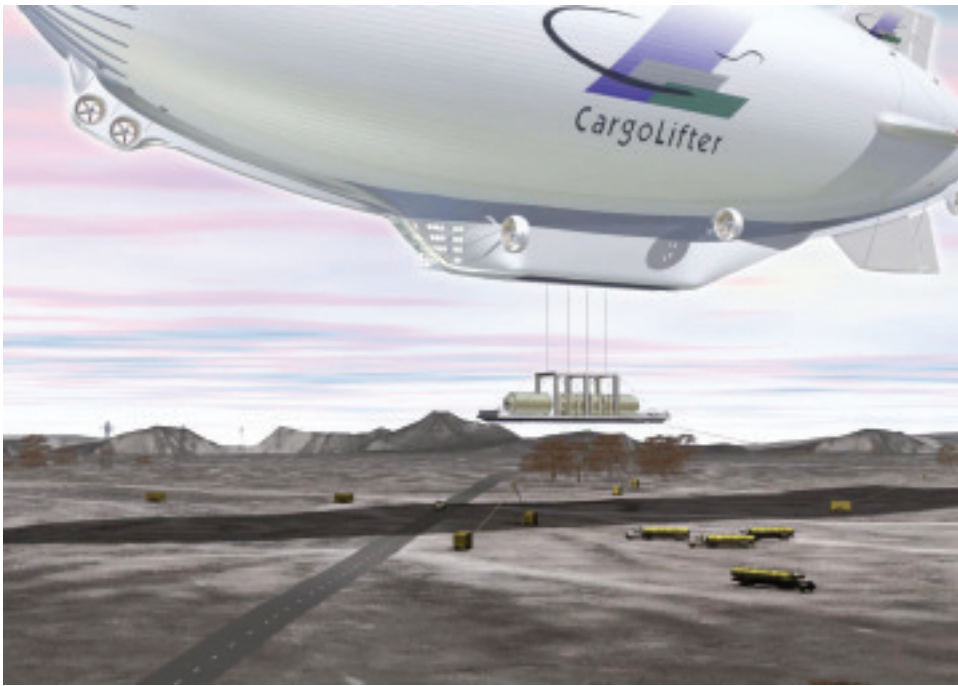
upset the craft's buoyancy if not counterbalanced. While generating additional hydrostatic lift to offset a load has been contemplated, various technical and logistical challenges have blocked progress. A more successful method would be to use either thrust or aerodynamic force to produce additional lift.

A straightforward way of producing additional lift would be to attach a high aspect wing to the main vehicle body. This would produce substantial aerodynamic lift, improve vehicle stability, decrease drag, as well as increase payload capability. The Ames Megalifter was one such craft, bearing a significant resemblance to a traditional tube and wing style aircraft. An airship buoyancy envelope had replaced the fuselage. A number of other designs have been analysed and currently, the Dynalifter by Ohio Airships is under development using this kind of assisted lifting.

The next stage of development is to use multiple hulls, linked by an inboard wing. When compared to the previous design of having aerofoils attached to the outside of a single hull, there are a number of advantages. As stated earlier, the craft can be of smaller length for a given volume, and has improved lateral stability. The inboard wing reduces wing bending and twisting under load while the envelopes prevent vortex wing flow and the related loss of lift, making the lifting surface more efficient.

The next stage in producing aerodynamic lift is to use the whole body, producing a 'flying wing'. The load-carrying capability of this kind of hybrid airships depends on the volume of gas for buoyant lift, and on flight speed and altitude for dynamic lift. Aerostatic lift and motor thrust are used for energy-efficient hovering and horizontal landing. The efficiency of hybrid air vehicles is sensitive to size, with large craft being more efficient than small craft. However efficiency of size comes at a cost with increased drag and reduced performance. A number of modern designs, such as the SkyCat by Advanced Technologies Group Ltd in the UK, and the P-791 by Lockheed Martin in the US, use multiple hulls and the resulting increased span to generate lift. SkyCat reports that 40 per cent of lift is provided aerodynamically, with the P-791 receiving 20 per cent from its aerodynamic shape. However, the reliance on aerodynamically provided lift requires a forward velocity in order to take-off, though the distances and speeds required are much smaller than traditional fixed wing aircraft.

Another method of increased lift is the utilisation of vectored thrust. The Piasecki Aircraft Corporation proposed a heavy lift system, where a traditional streamlined airship was augmented with a number of helicopter rotors to provide additional lift. Goodyear and a number of other



companies designed systems using helicopter rotors, with the placement and percentage of overall lift the varying factor.

A more unusual design was developed in the 1980s. The Aerocrane featured a spherical, helium-filled centrebody with rotating wings mounted on the equator of the body. The rotation of the centrebody powered by the wing tip engines produces lift, turning the craft into a lighter-than-air helicopter. A one-tenth scale dynamic model of a 50-ton payload was built to investigate the stability and control characteristics. The original Piasecki approach has been revived recently, by a Boeing Company and Skyhook of Canada project, the JHL-40. The airship has neutral buoyancy, with four helicopter rotors providing additional lift for payload. The Millennium Airships product, SkyFreighter, uses a similar system with four turbofans as thrust and control systems, providing payload lift and VTOL capabilities. An interesting development is the use of hydrogen as a fuel source. The increased volume that hydrogen requires is not a problem with airships, where it would be on a fixed wing aircraft. Hydrogen provides the same energy level as Jet A1 at 43 per cent of the weight.

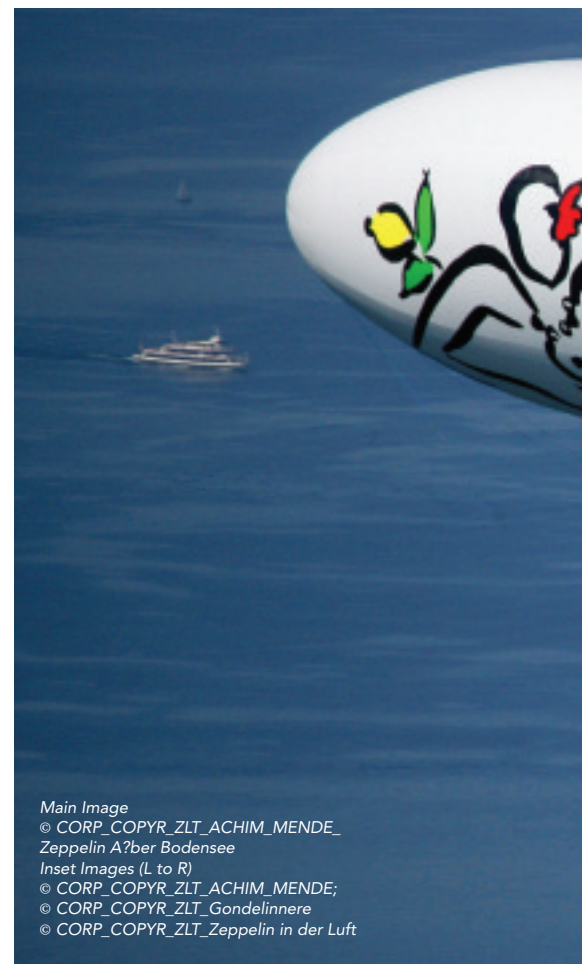
It would be unusual for a craft to use just one of these methods to produce lift. A system that combines all these methods is the Aeroscraft, which generates lift through a combination of aerodynamics, thrust vectoring, and gas buoyancy generation and management. The Aeroscraft uses a novel approach to buoyancy changes during loading by managing the lifting gas pressure within the hull.

## Benefits

But why the interest in airships? The potential advantages are: huge load capacity – more than nine times that of a 747-400F; short or vertical take off and landing from unprepared strips or water, and in some cases even no requirement to land to unload; long range capabilities; and high energy efficiency for a reportedly low cost. But there are disadvantages. Airships have a low maximum velocity when compared with fixed wing aircraft, in the region of 140 kph, due to the large gas envelopes and associated drag. There is also the 'Hindenburg effect' – the preconception that airships are dangerous, even though inert helium is mainly used as a lift gas – and concern with stability in high winds, though by utilising aerodynamic lift, hybrid airships are heavier, and therefore more stable in adverse conditions. Furthermore in order to be certified for commercial use the craft must meet specific operational requirements in adverse conditions. A further drawback with traditional airships was the manpower required to 'dock' and handle them, with 1920s zeppelins needing more than 200 ground staff. This can be overcome by using vectored thrust, managed lifting gases or craft that are heavier than air.

So would there be a market for airships? The slow speed of airships compared to aircraft (140 kph compared to 900 kph) means it is unlikely that airships would encourage passengers to switch away from aircraft where flight time is a

significant factor. However, airfreight is still a large market and according to Airbus, there were approximately 150 billion freight tonne kilometers (FTK) covered in 2008. This is expected to climb by six per cent annually until 2028 over which period 72 per cent of freight aircraft will retire. While this represents only one per cent of global intercontinental freight, it equates to 40 per cent of the total value. This is because time-sensitive products, such as IT components, food and cut flowers, can undergo a significant drop in value in the weeks it might take to transport them by ship. Approximately 50-60 per cent of airfreight is transported as 'belly' freight, carried in passenger aircraft, which leaves at least 60 billion FTK which could be carried by dedicated freight airships. The significant load capacity of some designs – SkyCat 220 reports loads of up to 220 tonnes compared to 110 tonnes in a 747-400F – suggests that a shift away from fixed wing aircraft would be possible. SkyCat reports a 40 per cent reduction in fuel burn per FTK compared with widebody freight aircraft. In combination with the lower altitude that airships fly at, SkyCat claim a 90 per cent reduction in equivalent CO<sub>2</sub> emissions. To



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illustrate this, a hypothetical load of 220 tonnes of air freighted strawberries from Spain to the UK would release around 42 tonnes of CO<sub>2</sub> equivalent. Transporting by airship would release only 4.2 tonnes of CO<sub>2</sub> equivalent.

There are other advantages of using hybrid airships in place of fixed wing aircraft. The V/STOL capabilities of various systems would also allow for changes in supply chain logistics, allowing direct transport from collection centres to distribution centres and removing the road freighting that occurs in between. Airships would not require the use of hard paved runways and produce limited local pollutants meaning they could be operated from sites close to production areas, be they rural or urban. This would free much needed capacity at airports for passenger movements, reducing the need for airport expansion. Also airships operate at much lower altitudes and speeds than fixed wing aircraft, easing their impact on air traffic management systems.

While airships suffer from a comparably low operating speed compared to aircraft, there is a clear advantage over maritime transport whose



**The 'as the crow flies' capability of airships also offers interesting route flexibility over both road and rail and without the large infrastructure requirements of those modes.**

operating speed is 100 kph slower. The 'as the crow flies' capability of airships also offers interesting route flexibility over both road and rail and without the large infrastructure requirements of those modes. In less developed parts of the world, the need for expensive and carbon heavy infrastructure projects could be removed by fleets of 'lorries in the sky' providing multi-drop capability, and connecting distant communities with international markets. This lack of infrastructure also appeals to aid agencies, which see airships as a possible method of delivering significant levels supplies to disaster areas quickly, and at much lower cost, than current multimodal methods.

These advantages look promising, although all the designs discussed here remain under development, with the P-791 the most advanced and undergoing flight tests. A number of projects have stalled through lack of funds. Airships still need to demonstrate their potential. Airships do have very significant advantages, particularly in the transportation of freight where they are inherently very competitive in both economic and environmental impact.

