Mike Follows

Are airships making a comeback?

Hot air balloons over Quebec, Canada

*When hot air balloons are propelled through the air rather than just being pushed along by the wind they are known as airships or dirigibles. The heyday of airships came to an abrupt end when the Hindenburg crashed dramatically in 1937. But, as **Mike Follows** explains, modern airships may have a role in the future.*

Key words

density

forces

Newton's laws

aircraft

According to Archimedes' Principle, any object immersed in a fluid receives an upthrust equal to the weight of the fluid it displaces. This can be applied to lighter-than-air balloons: a balloon will descend if its weight exceeds that of the air displaced and rise if its weight is less.

We can also think of this in terms of density. A balloon will rise if its overall density (balloon + air inside) is less than the density of the surrounding air. In hot-air balloons, the volume is constant and the density of air is varied by changing its temperature. Heating the air inside the envelope using the open flame from a burner in the gondola suspended beneath causes the air to expand and escape out through the bottom of the envelope. The top of the balloon usually has a vent of some sort, enabling the pilot to release hot air to slow an ascent. Colder, denser air will enter through the hole at the bottom of the envelope.

Burning gas to give a hot air balloon greater lift

Airships of the past

Airships used lifting gas like helium because it is less dense than air. There are rigid, semi-rigid and non-rigid airships. A metal framework maintains the shape of rigid airships. Semi-rigid airships have a rigid hull but the envelope needs to be pressurised 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 and, because air is heavier than the lifting gas, ballonets act like ballast tanks on a submarine, affecting altitude and pitch.

In the 1920s, Zeppelins regularly crossed the Atlantic and, by 1929, they were circumnavigating the globe in a little over 21 days. Designers wanted to use helium as the lifting gas because, unlike hydrogen, it is not flammable. But helium was scarce and the USA, with 80% of global production, banned its export under the Helium Control Act of 1927.

The Germans were forced to use hydrogen. The fact that no passengers had been killed or injured in a German airship led to the mistaken belief that Germany had mastered the safe use of hydrogen. This myth was shattered on 6 May 1937 when the Hindenburg burst into flames and crashed to the ground in just over half a minute killing 35 of the 97 passengers and crew, along with one member of the ground crew.

The dangers of using a flammable fuel – the Hindenburg disaster of 1937

Airships in the modern era

There is no way that airships can compete for passengers with aeroplanes partly because they cruise at less than 200 km h^{-1} compared to a passenger jet's speed of around 1000 km h^{-1}. However, there are now several innovative modern airships. One of them is the Airlander, designed and built in Britain by Hybrid Air Vehicles (HAV) for the US Army as a surveillance platform, intended for deployment over Afghanistan. But after US defence budget cuts led to cancellation of these LEMVs (Long Endurance Multi-intelligence Vehicles), HAV bought the airship back from the Americans and it now operates from the famous Number One shed at Cardington near Bedford, UK, where the doomed R101 airship was built.

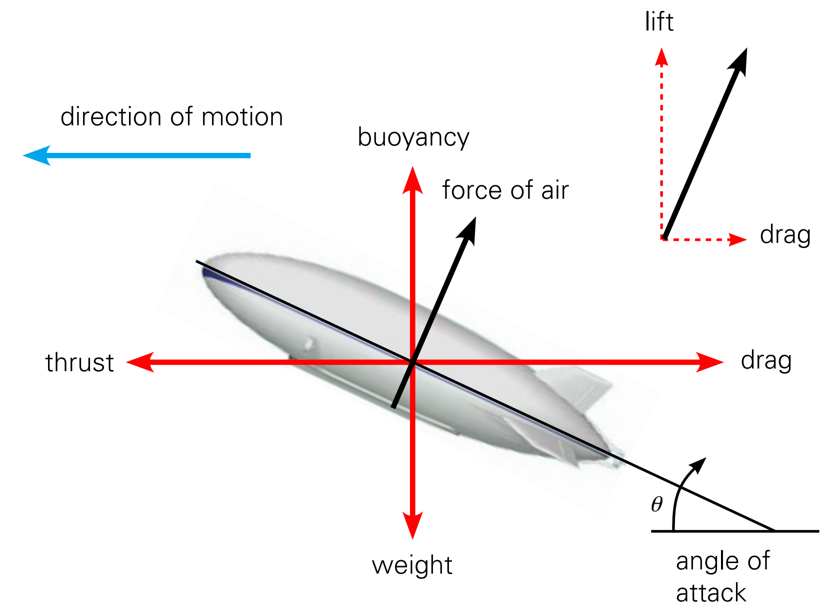
The Airlander, a modern hybrid airship

Airlander is 92 m long, 34 m wide and 26 m high and is known as a 'hybrid airship' because lift is provided by a combination of buoyancy and aerodynamics. The helium lifting gas provides 60 per cent of the lift and gives the blimp its shape. It looks like three cigars sewn together and this aerofoil shape means that it can also generate lift just as an aeroplane wing does.

Generating lift

Any aircraft requires lift, the upward force that acts against the downward force of gravity. To generate lift, an aircraft pushes downwards on the air so that the air pushes upwards on the aircraft. That's an example of Newton's Third Law of Motion. So how does a fixed-wing aircraft or an airship like the Airlander push down on the air?

The diagram on page 18 shows an airship which is moving to the left. It is tilted slightly upwards at the front; we say that there is an 'angle of attack', θ, between the longitudinal axis of the airship and the horizontal. As the airship moves forwards (propelled by its engines), the air it strikes is deflected downwards and forwards. The result is an equal and opposite force on the aircraft. You can see that this force has both upwards (lift) and backwards (drag) components.



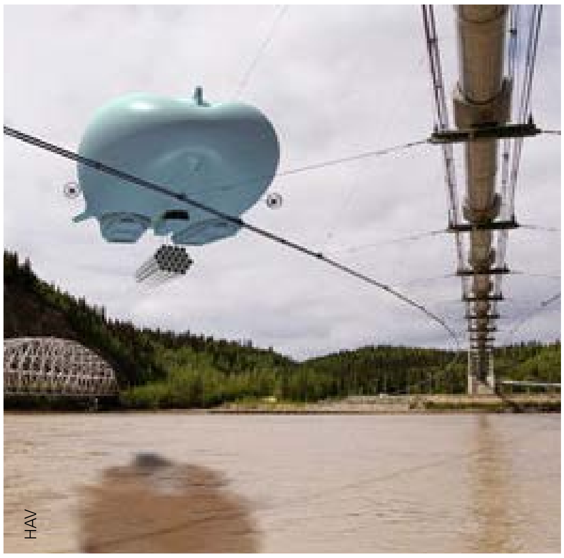
The forces on an airship as it moves horizontally: the airship's weight is balanced by the buoyancy of the balloon and also by the vertical (lift) component of the force created as the airship pushes air downwards. (The angle of attack is exaggerated in this diagram.)

Forward motion is needed to generate lift. As an aircraft slows down, the required angle of attack must increase to maintain lift. But increasing the angle of attack also increases drag, which slows the aircraft further, reducing lift. The stall speed is the speed at which increasing the angle of attack can no longer be used to generate lift, so the aircraft descends. But the Airlander has another trick up its sleeve. It can rotate its jet engines so that they provide downward thrust allowing the airship to hover and land just like a jump jet or helicopter.

Why heavier-than-air?

A drawback with traditional airships was the manpower required to 'dock' and handle them, with 1920s zeppelins needing more than 200 ground staff. Because it is heavier than air a large ground crew is not required for the Airlander and it can fly with only two aircrew. A true lighter-than-air craft relies solely on buoyancy to provide lift. This limits the load it can carry and creates problems with stability during loading and unloading because rapid changes in weight upset the craft's buoyancy if not counterbalanced. Hybrid airships are heavier, and therefore more stable in adverse conditions.

Airships offer the flexibility of a helicopter and the range of a fixed-wing aircraft, and have operating costs lower than both. They can transport goods all the way to the point of delivery because they do not require infrastructure like runways – the Airlander can land on any reasonably flat surface, including water. It is capable of vertical take-off and landing (VTOL) or hovering like a helicopter. It can stay in the same spot for 21 days at an altitude of up to 5 km to provide a stable platform for communications, geological survey, surveillance or filming. It can even fly over hostile territory because it can stay airborne even if its outer skin is riddled with bullet holes.



An Airlander airship can deliver heavy loads in difficult terrain.

Airships like Airlander are designed to carry up to 50 tonnes of equipment to any area in the world, making it ideal for disaster relief or delivering heavy equipment to remote corners of the world for oil or mining companies. Transport aircraft normally run out of space for cargo before their payload makes them too heavy to fly. This would not be an issue with the Airlander as the capacity of the gondola can be modified – unlike the fuselage of a fixed wing aircraft.

The Airlander is fitted with four turbine engines which together can deliver 8 MW of power. It has a range of about 5000 km so it could access many of the most remote locations on the planet.

But there are disadvantages. As already mentioned, airships are slow compared to jet aircraft and they suffer from the 'Hindenburg effect' – the perception that airships are dangerous, even though inert helium is usually used as a lift gas. There is unlikely to be a huge demand to carry regular freight as cargo ships already carry goods whose delivery is not time-critical and about half of airfreight is already transported as 'belly' freight in passenger aircraft.

Mike Follows teaches Physics.