

Airships

For many of us, airships occupy a sort of odd speculative space left open where materials science, aviation, engineering, computerization, and air traffic control have all improved massively while airships themselves have seen comparatively little use. That leaves a lot of room for argument and a handful of startups that promise that everything is fixed now and they can slot neatly into this low carbon, slower than planes, faster than ships, with fewer transfers, cargo or passenger niche.

The interesting thing is that airships didn't actually vanish with the Hindenburg. Airships in various forms have been operating in military, research, and development/prototype roles right up to the present day, and industry and the public sector have continued to evaluate their performance and relevant technological developments. These airships give us some solid evidence to use when evaluating claims from startups, and planning how we depict modern airships in fiction.

Misconceptions

Airships are unsafe

Airships had a number of high-profile accidents in the early 20th century that stunted their development considerably, but it's very easy to forget that airplanes at the time were far less safe. Not only did airplanes of the 1900s-1930s crash at a higher rate than airships, but when they did, their fatality rate was about double. Those crashes were far more significant for airships, though, because they were like the jumbo jets, supersonic airliners, or space shuttles of their time—huge, resource-intensive megaprojects that aren't really able to be iterated on and tried again so easily as a relatively tiny airplane design.

even hydrogen airship accidents (which are far more lethal than helium airship accidents) were about half as lethal as airplane crashes of the same time period. Considering this was the 1900s-1930s, that's a really low bar—aviation didn't become even remotely safe until about the 1970s—but it's worth noting that Zeppelin's been flying its NT model airships for nearly 30 years without a single fatal accident.

Hydrogen and Modern Airships From the data ranging from 1900-1945, we can see that hydrogen airships started off being about 10 times safer than airplanes (engines were horrendously unreliable back then, and an airship reverting to being a balloon, even a flammable balloon, during engine failure was preferable to becoming a plummeting brick), until gradually airplanes became safer at an even faster rate than hydrogen airships were improving, catching up to them in safety around the mid-1930s. Then the Hindenburg disaster happened in 1937, and hydrogen ceased being used shortly thereafter. As helium blimps were being used in World War II in large numbers, the data show they were about four times safer than hydrogen airships, and also general aviation of the same time period. Even today, though airships are quite rare, they remain considerably safer than the average aircraft of their same general mass and regulatory category.

No airships have ever been engineered to the unbelievably exacting and expensive degree that a modern commercial airliner is, though, and those are like night and day compared to general aviation safety—in other words, airships tend to be safer than private planes, but of a similar cost and complexity, and neither hold a candle to the astounding safety record of commercial airliners.

The potential for airships to be designed as safe as commercial airliners exists, I believe. If airplanes could overcome their early deficiencies to achieve the absurd safety of commercial airliners, and likewise submarines could be engineered from an absolute deathtrap far more unsafe than even hydrogen-filled World War One airships to the exceedingly sound military vessels they are today (with the U.S. Navy's last fatal submarine loss being in 1968), then I don't see why not.

That being said, it would take a huge amount of testing to make sure that a hydrogen airship was fireproof under all edge cases and conceivable flight conditions. It would require active fire suppression systems (alarms, hydrogen and oxygen detectors, fire extinguishers, etc.) and even more extensive passive measures (proper electrical conductivity, fireproof materials, a double hull of inert gas like helium or nitrogen and/or a direct gaseous mixture to alter the hydrogen's explosive and ignition range even when exposed to air, etc.) to achieve a sufficient level of safety. Such things are possible—airliners and fuel tankers now explode far less often, thanks to inerting the fuel vapors in their tanks with nitrogen or carbon dioxide.

Airships are slow and unmaneuverable

It's true that the overwhelming majority of airships were hideously underpowered. That's down to the lacking engines of the time period, though. Some airships carried as much as 17 tons worth of engine, but none made more than 4,500 horsepower collectively. The airship pictured above has 32 electric motors, totaling about 10,000 horsepower, for a collective weight of less than half a ton. The reason airships are only just now beginning to be built again (with the largest airship built since 1938 being an electric rigid airship undergoing tests right now in San Francisco) is because aviation is a fiendishly difficult, expensive, and risk-averse industry to attempt a startup in, and airships being far more efficient than planes or helicopters was not considered an important enough thing to prioritize to justify spending hundreds of millions to get them going again.

Airships are more vulnerable to strong winds than other aircraft

That hasn't been true since the 1950s. The U.S. Navy demonstrated that a properly designed airship can actually operate in blizzards and thunderstorms far more reliably than fixed-wing and rotary-wing aircraft, with a mission readiness rate of 88% in inclement weather.

An airship's ability to land and take off in strong winds is directly proportional to its speed. Back in the '50s and '60s, U.S. Navy radar blimps were taking off and landing in blizzards and thunderstorms with over 40-knot winds. In practice, all-weather Navy airships were able to operate in worse weather conditions (besides just wind) than Navy helicopters because airships had a number of other characteristics that made it safer for them to do so, such as having more stability, being able to divert far greater distances to alternate landing zones, and having vastly greater endurance before running out of fuel, allowing them to wait for better visibility, precipitation, or wind conditions.

Hence, Navy blimps were able to operate in blizzards and thunderstorms that grounded all fixed-wing and rotary-wing aircraft. There wasn't anything particularly special about the Navy blimps either — they had de-icing gear, variable-pitch propellers, sturdy tricycle landing gear, and reasonably powerful engines that gave them a top speed of 82 knots. As a rule of thumb, an airship can land and take off in wind speeds that are about half its top speed.

An airship designed to have a 200-knot top speed could thus theoretically land and take off even in a 100+ knots hurricane, though obviously no one would ever be crazy enough to do such a thing, nor

would it be desirable — just because its engines could make enough headway in a hurricane to be able to land or get in the air doesn't mean that it would appreciate being blasted with a bunch of flying debris near the ground. In practice, it would do what all airships and helicopters have done when confronted with a hurricane—simply go around or wait it out.

Even historical airships, which were incredibly crude aircraft with structural insufficiencies we can now readily identify, managed some impressive feats in high winds: The *Graf Zeppelin* once intentionally steered into a typhoon over the Pacific Ocean to try and pick up a tail wind to help speed it on its way during its round-the-world flight in late summer of 1929.

airships have already been used to carry entire scientific platforms to the tops of rainforest canopies, which would have been damaged by a helicopter's downwash? Or that landing only one landing wheel on a small circle and the pilot picking up a champagne bottle from a narrow plinth are both games used in recreational airship sport-flying competitions? The airships that did so didn't even have thrust vectoring. Something like the LCA60T pictured above devotes an entire 66% of its propulsive power to vertical and lateral thrust vectoring, and has the same operational wind limits as a helicopter airframe and a normal tower crane as a result. The LCA60T — an airship currently under development as a flying crane, that has the same operating wind limits as a helicopter or conventional crane. It can do its hovering cargo operations 250-320 days out of the year, depending on the location.

They're proportionally more affected by the wind because they're slower than airplanes, but that doesn't mean an airship has to be as fast or powerful as a plane to be able to operate in similar wind conditions. In fact, the Navy's radar airships during the Cold War were able to fly in 60-knot blizzards and thunderstorms that grounded all other military and civilian planes, with an astounding inclement weather availability rate of 88%. They were able to operate like that because they didn't fear crosswinds or stalls while landing, and could wait for days if necessary without running out of fuel, and thus could afford to take it slow.

Airships have buoyancy balancing problems when loading or unloading cargo

Modern airships address changes in weight in several ways, probably the simplest of which (aside from releasing the lift gas, or heating it during flight and letting it cool on the ground) being to just fly the ship heavier than air by the weight of the payload. With the structure still buoyed by helium, it remains quite efficient even while supporting the cargo with aerodynamic lift and/or vectored thrust, and then you can simply offload the payload at the destination, assuming it's not able to take on any return cargo or extra fuel or water ballast or anything of the kind — sort of a "deliver your max payload to the middle of nowhere and come back" solution, which should hopefully not be needed too much in practice.

Airships aren't fuel efficient

In terms of transport coefficient, a helicopter has a value of about 1, an airplane has a value of 4, and even airships from over 100 years ago could have values over 16. They are very fuel efficient, nearly as much as a ship. For a 200-ton gross weight airship like the one pictured above, it only takes about 600 horsepower to go 40 mph, 4,300 horsepower to go 80 mph, and 23,000 horsepower to go 140 mph—and a cargo plane like the Atlas A400M has 44,000 horsepower. It's got a top speed of 513 mph, sure, but it also carries only a little over half as much cargo as the Flying Whales airship, 37 tons vs. 66 tons. So not only does it burn a lot more fuel, but it also has to take multiple trips to carry the same amount, and that's against an airship designed as a precision flying crane rather than for cargo

transportation.

The remaining hurdles are in terms of the lack of available experts and sufficient funding to undergo a years-long research and development program for a large airship, but it has long been established in World War II and the Cold War that airships can be engineered to serve as safe, practical, low-cost alternatives to conventional aircraft where speed isn't a priority.

Much in the same way we know that it is possible to build reliable, profitable high-speed rail, even if the concept of such a thing seems wildly out of reach to people in places where it doesn't exist.

Types of Modern Airship Design

This section gathers broad categories of design and intended use

Flying Cranes:

The LCA60T and Flying Whales

This particular airship is highly specialized for maneuverability and aircrane operations at the expense of speed and range. It has the same operating wind limits as a normal crane or helicopter. 75% of its 32 electric motors and propellers are fixed in place exclusively for thrust vectoring purposes, only 25% are fixed for forward propulsion (and even those can use differential thrust for steering). Turning quickly isn't really an issue in this case, as compared to classical Zeppelins that had only their rudders to turn with.

Similarly, large ships used to be cripplingly dependent on tugboats to maneuver, and were incredibly slow to turn, before the invention of things like azimuth propulsors and bow thrusters that now allow a cruise ship to pivot 360° within its own length.

this particular ship is highly specialized for air crane operations over short distances, not efficient transport from A to B. It's quite slow, even for an airship, with a top speed of about 60 mph. An actual dedicated cargo transport airship would be bigger, sleeker, and more powerful, with an optimal cruising speed anywhere between 70 and 170 miles per hour depending on the route length, and a payload in the hundreds of tons.

designed for maneuverability and transporting oversized loads, and is not suitable for long-distance rapid or heavy freight transport

Kelluu The Finnish company Kelluu has a small fleet of autonomous hydrogen-lifted and hydrogen-powered survey airships. They are much safer to use hydrogen with, as unlike other airships, they are designed to have no internal areas where oxygen and hydrogen could mix and become flammable.

<https://canadiandefencereview.com/arctic-sovereignty-airships-for-the-arctic/>

The Airship Niche

Don't forget the exponential growth curve of the square-cube law. It's a double-edged sword. Small airships are not competitive with other aircraft or trucks, but large ones are. Small and midsized

airships are indeed niche, but the largest modern airships under consideration have payloads of 200-1,000 tons, depending on the design and manufacturer. The largest cargo planes today carry about 100-150 tons of cargo. That, in concert with large airships' increased efficiency, would allow them to pose a credible threat to a decent chunk of shipping, particularly for higher-value cargoes and somewhat more time-sensitive ones, such as fresh fruit and seafood. It would be more expensive than a ship, but cheaper than a plane, and currently the gulf between those two modes of transport is so vast that there are several profitable efficiencies to be found, once they're actually built out. The "built out" is the hard part. Additionally, airships' optimal speed increases drastically over shorter route lengths, due to the effects of fuel weight on payload and productivity. For 5,000 nautical miles, a typical rigid airship carrying 100 tons of cargo has an optimal cruising speed of 63 knots/72 mph. For 2,000 nautical miles, it's 82 knots/94 mph. And for short-haul trips of 300 nautical miles, it's 145 knots/167 mph. Do note those are the optimal cruising speeds, not the top speeds. Airships benefit from having reserve power capacity to account for headwinds without losing speed, in this case, the NASA study assumed a 15 knot headwind was reasonable, and calculated the optimal cruising speed (accounting for engine size, structural weight, fuel, etc.) accordingly. However, this study was done some time ago (mid-1970s), and modern propulsive systems have gone down in weight and up in efficiency tremendously since then. That could change the optimal cruising speed and feasible degree of excess power capacity for an airship, since those speeds are primarily dictated by the trade-off between fuel load and speed of cargo throughput. More fuel burn means faster, but also less cargo carried due to the weight of the fuel, hence why the optimum for shorter range is so much faster. For example, some modern airship designs assume a cruising speed of 115 mph is ideal over distances of several thousand nautical miles, rather than the 1970s optimum of 72-94 mph over similar distances. That's not a trivial difference—to take an airship to 115 mph requires about four times as much power as that same airship traveling at 72 mph. Some modern designs just go ahead and keep the efficiency gains as savings rather than pressing to go faster, though. It really depends on the application.

Modern airships can outperform helicopters in pretty much every respect save for size. That's why modern cargo airship designs are targeting the roles currently held by heavy transport helicopters first and foremost—in the most difficult and expensive part of getting a business off the ground, they perceive that as the matchup that is most favorable to them. An airship is overwhelmingly more efficient than a helicopter, can carry vastly more, and costs less to operate. They have far greater range, and operate in similar or worse weather conditions than a helicopter. They're also far easier to convert to zero-emissions operations. The practical upper speed limit for a rigid airship is 200 knots, whereas most cargo helicopters cruise between 80-160 knots. With thrust vectoring, modern airships like the Zeppelin NT are also capable of maneuvering like a helicopter, which aids greatly in VTOL operations. Even in terms of speed, airships and airplanes have remained in similar positions since the 1930s—the cruising speed of a DC-3 is about 180 knots, and for an airship of that time period, it was 70 knots, or about 40% the speed. Today, the cruising speed for most airliners like the 737 is around 0.8 Mach, or 453 knots, but a Boeing study found the most productive cruising speeds for an airship carrying 100 tons for 300 nautical miles is 180 knots, which is still about 40% the speed. Granted, the optimal cruising speed for an airship does dip considerably over greater distances, with that same 100-ton-payload airship design's optimal cruising speed dipping to 110 knots over 5,000 nautical miles, but many planes don't fly that far anyway, and it'd still handily beat a helicopter carrying only 8 tons at 140 knots, but which would have to stop 17 times to refuel over that same distance, or over 200 times to carry the same amount the same distance.

Aside from carrying more weight, they could also carry things far larger, like wind turbine blades, prefab buildings, radio towers, etc. They can also hover, which is very useful, as evidenced by the fact that extreme STOL airplanes haven't successfully replaced helicopters despite being wildly superior in practically every other way.

Navy airships I mentioned had about 1/3-1/2 the operating costs of planes with a similar payload capacity. More to the point, though, airships wouldn't necessarily be competing with cargo planes primarily, but rather cargo helicopters—which cost at least ten times as much as normal air freight per tonne/km. They can also just plain do things that no airplane or helicopter can do at any cost, such as carry giant wind turbine blades and other outsized cargoes.

With ships, they can compete sometimes (fresh food, high-value manufactured goods, etc), with freight trains, definitely not, but trucks? The largest airships can compete with trucks in terms of cargo cost per ton/mile, and are considerably faster, in addition to their capability to carry things too bulky and/or too heavy for a truck. That won't detract from trucks' ability to transport things last-mile, of course, but there's certainly some useful applications.

when it comes to comparing transport capacities to trains or ships, the real question is what you're transporting.

Ships and trains are unbeatable when it comes to transporting cargo that is both extremely cheap and extremely heavy, such as crude oil and raw mineral ore. But that's not all or even most of what they're tasked with carrying. More expensive cargoes like finished manufactured goods and fresh food are often limited by volume, not weight, and vehicles carrying human passengers are always limited by volume, not weight. The average Amtrak passenger train and average ferry both carry around 300 passengers, with outliers carrying 1,000 and 5,200 people, respectively.

If we are to assume the practical economic limit for an airship's size to be around that of the Hindenburg, past which it would be more practical to just use two airships rather than an ultra-huge one, then the limits of an airship's capabilities would be ably demonstrated by Lockheed-Martin's slightly smaller hybrid rigid airship concept from 1999. It would have a range of 4,000 nautical miles, a cruise speed of 150 knots/180 miles per hour, a cargo capacity of 500 tons, and a cargo area of 65,000 square feet. That would put it just shy of the largest ferries in terms of passenger capacity, with space per passenger more similar to a train than a plane. However, it would be ten times faster than the ferry, and four times faster than Amtrak.

Relevant Technological Advancements

Safety Features

Gas cells are a very important safety feature as they introduce redundancy, similar to the watertight bulkheads in a ship or submarine. They've allowed several historic airships to survive catastrophic damage that would have destroyed a plane or nonrigid airship, such as attacks on World War One Zeppelins like the LZ-39, which survived repeated bombings by airplane. 20-lb high explosive bombs are akin to a modern Sidewinder missile's warhead, and it managed to survive four of them and keep flying. It also helped during accidents, like when the British R33 collided with its own mast during a storm, and whose skeleton crew managed to fly it through the storm safely despite missing most of its bow.

double hull of inert gas to keep out the oxygen that hydrogen needs to mix with in order to form a flammable or explosive mixture. That's how fuel tankers were rendered safer after the SS Sansinena explosion, and airliners as well after the TWA Flight 800 explosion. Carbon dioxide and nitrogen, respectively, are used to inert the empty spaces in partially full fuel tanks, which would become giant fuel-air bombs otherwise.

What can you expect from a modern airship?

Airships actually benefit far more from electrification than other aircraft, for a number of reasons—which are many and varied, but basically boil down to the advantages of electric propulsion not being particularly helpful to airplanes and helicopters, while the disadvantages exacerbate their greatest weaknesses.

For airships, it's the reverse—they're greatly aided by the benefits of electrification, and the disadvantages of electrification aren't particularly harmful to airships, or are even beneficial instead.

For example, airplanes and helicopters are greatly disadvantaged by the fact that batteries and fuel cells either don't lighten at all or lighten far less than a kerosene fuel tank, which can be reduced by tens of tons over the course of a flight, making it much more efficient. By contrast, airships greatly appreciate a constant, unchanging weight since that allows them to operate more efficiently without having to compensate for changes in buoyancy.

Movement Speed

Lift Gas Types, Sources, and Storage Requirements

Helium

Cheap, abundant helium won't run out until natural gas does, or possibly even after—since helium is often found in otherwise completely economically useless pockets of underground nitrogen, not just natural gas. In other words, nothing to worry about for hundreds of years. The shortages we currently face are an infrastructure problem, not a supply problem. Even once that's gone, you can still get helium from the atmosphere, but presumably by that point we'd have implemented fireproofing methods to safely contain hydrogen. There are already two main methods to do so, it's just a matter of properly engineering, testing, and certifying them.

Helium makes up a relatively constant portion of the atmospheric gas mixture, and has for hundreds of millions of years, due to its constant production via radioactive decay in the earth's core. The atmosphere is like a full bucket underneath a dripping spigot—it's constantly losing water over the edge, yes, but it's also not being emptied either.

The problem is that we waste literally 99% of the helium present in natural gas, simply because we don't have the infrastructure installed to extract it before use. You could also distill helium from the air itself, but that takes about 3-5 times more energy due to the lower concentration, and with our current atmospheric fractional distillation capacity we'd only be able to meet about 1% of global helium demand (coincidentally about the portion that airships use).

People are actually drilling helium wells now, it is non-refundable but quite abundant.. Other deposits exist in Alberta and Wyoming, just within north America.

<https://www.minnpost.com/other-nonprofit-media/2024/07/what-to-know-about-minnesotas-richest-in-the-world-helium-deposit/>

Hydrogen

Oh the humanity!

The astronomical improvements in aviation safety would more than make up for the difference in safety between hydrogen and helium, such that a properly designed modern hydrogen airship would be incomparably safer than a historical helium one, but that doesn't change the fact that hydrogen is always going to be more dangerous.

The other downside is that while hydrogen is not a greenhouse gas in itself but it competes for hydroxyl ions in the atmosphere with methane, a powerful greenhouse gas. Basically, every hydrogen molecule in the atmosphere extends the lifespan of one methane molecule. [The hydroxyl radical is often referred to as the "detergent" of the troposphere because it reacts with many pollutants, often acting as the first step to their removal.](#)

Docking Facilities

Traditionally Airships had to dock at a mooring mast (of which there were several types) or shelter inside a hangar. This is because an unpowered airship is basically a huge sail, and is likely to drift. Landing them on the ground was a huge and dangerous undertaking which involved landing parties of hundreds of men physically pulling the airship down to the ground by ropes. Attaching them to a mooring mast involved the tower crew and the airship crew both lowering lines which would be linked together by a ground crew so the tower could winch the airship in.

With improvements to maneuverability and control over buoyancy modern airships are far more controllable and can dock or land on their own.

Option 1: Just land on the ground

Not all airships are designed to land, but those that do have such a light footprint they often land on completely unimproved grassy fields. A modern airship like the Lockheed-Martin P-791 can use its landing gear to stay fixed in place on the ground without any external support equipment with up to 40 knots of wind down the nose or 25 knots of wind from any other direction. A Cessna needs to be tied down at 25 knots to keep from being flipped over. They have also landed on lakes, beaches, swamps, ice floes, and aircraft carriers. Some of the new designs, such as those of Lockheed-Martin, have no ground infrastructure or crew requirements whatsoever.

Option 2: Mooring Masts

Not all Airships are designed to land. Some, like flying crane designs such as the LCA60T, will dock at a mooring mast instead. The idea here is that the airship attaches nose-first to the tower and is allowed to freely rotate around it like a weathervane in the wind. This ensures that it always has the lowest possible exposure to the wind.

Modern mooring masts are almost disappointingly simple and are often deployed as part of a large truck.

When hooked up to a mast truck, airships can stay put in 70-90 knots of wind — and anything past that, they'd have to evacuate the area, because higher wind speeds than that would be a hurricane or tornado.

Option 3: Both?

A new option that allows the best of both worlds is a large rotating platform design called a Boyant Aircraft Rotating Terminal or Depot (BART or [BARD](#)). This design allows for the convenience of landing (perhaps for loading and unloading cargo) while still allowing the airship (and the platform it's anchored to) to turn so it's facing into the wind.

Option 4: Hangars

Hangars are to airships as drydocks are to ocean vessels — they can be located on cheap land, since they don't need to be visited very often except during initial construction or intensive tear-down maintenance overhauls/refits, which only happen rarely. Modern Airships are designed to spend almost their entire lives outside.

Further Reading:

The best layman-accessible compendium on the various airship projects over the years, past and current, is Peter Lobner's excellent "Modern Airships" series of articles, which are given a handy index and general airship industry overview/airship science summary [here](#).

The best source for understanding airship science, economics, and design from a far more technical perspective is the [Feasibility Study of Modern Airships](#), a vast, multi-phase, multi-part study for NASA and the Department of Commerce conducted in many separate parts by Boeing and Goodyear Aerospace. These can be found on NASA's archives for free.

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Last update: **2025/11/13 16:39**

