# 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, although its class of huge, rigid zeppelins did. 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 in that time. These airships and base of research give us some solid evidence to use when evaluating claims from startups, and in planning how we depict modern airships in fiction.

## The Basics

There are three/four broad categories of airship you should know going into this:

### Blimps

These non-rigid airships are basically big balloons that can move under their own power. They rely solely on internal gas pressure to maintain the envelope shape. This makes them comparatively easy to manufacture but places enough limits on their operation that their actual uses are relatively niche things like advertising and tours. Because they use an internal pressure of only about 0.07 PSI to keep their aerodynamic shape, and lack internal nose battens or sufficient pressure to prevent the nose from caving in, blimps can’t exceed about 100 knots or so. The fastest blimps yet built could reach 82 knots, and those weren’t really designed for speed, rather endurance.

There are also thermal/hot air airships, which could have other structures but are currently basically just blimp-shaped hot air balloons with a motor and rudder. They’ve come a long way from their start in the ‘70s, and cost only about 5% as much as a helium blimp but they can’t get past 20 knots or so, due to lacking internal nose battens or sufficient pressure to prevent the nose from caving in. There are a number of more recent technologies that exist in isolation which would be very tantalizing when put together. Far quieter hot air burners. Lightweight insulation membranes that reduces fuel burn for hot air balloons by 70%, increasing payload or flight endurance or both. Pneumatic or collapsible nose battens to raise the cruising speed to a more respectable 30-40 knots. Silent, stern-mounted electric motors that reduce drag, noise, and porpoising, which can also be mounted on a tiller that aids in steering and can be powered by propane fuel cells, like some UAVs do.

### Semi-rigid airships

These airships maintain their shape by internal pressure, but have some form of supporting structure, such as a fixed keel, attached to it.

### Hybrid airships

These are powered aircraft that obtain some of their lift as lighter-than-air (LTA) airships and some from aerodynamic lift. The term “hybrid airship” has also been used to describe an airship comprising a mix of rigid, semi-rigid, and non-rigid construction.

#### Rigid airships (also commonly called Zeppelins)

Briefly gone but not forgotten, these huge airships have a structural framework that maintains the shape of the envelope and carries all structural loads, while the lifting gas is contained in one or more internal gasbags or cells which are generally unpressurized. This structure allows them to be much larger (allowing them to carry more payload) and to travel much faster. Due to these advantages, most of the rest of this resource will focus on rigid airships.

## Misconceptions

There are a number of misconceptions we should address up front, most of which come from the poor performance of historical airships from the dawn of aviation when compared to modern aircraft, or from pop culture:

### 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. 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.

These early 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 weren't as easy to retry and iterate on as a relatively tiny airplane design.

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. After all, if airplanes could overcome their early deficiencies to achieve the absurd safety of modern commercial airliners, and likewise submarines could be engineered from being absolute deathtraps to the exceedingly sound military vessels they are today (with the U.S. Navy’s last fatal submarine loss being in 1968), airships can undergo the same iteration and improvement.

### Airships are more vulnerable to strong winds than other aircraft

This one 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, and were able to fly in 60-knot blizzards and thunderstorms that grounded all other military and civilian planes. In practice, all-weather Navy airships were able to operate in worse weather conditions (besides just wind) than Navy helicopters because the airships had a number of other characteristics that made it safer for them to do so: they had more stability, didn’t fear crosswinds or stalls while landing, they were able to divert far greater distances to alternate landing zones, and had vastly greater endurance before running out of fuel, allowing them to wait for better visibility, precipitation, or wind conditions.

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 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 it's round-the-world flight in late summer of 1929.

#### Airships are slow and unmanuverable

It’s true that the overwhelming majority of historic 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. Modern airships can select from a number of highly-efficient engines or motors and can field far more horsepower for the weight of their systems. For example, the LCT-60A Flying Whale which has 32 electric motors, totaling about 10,000 horsepower, for a collective weight of less than half a ton.

Similarly, due to the Square-Cube Law (discussed below), a larger airship will experience proportionally less drag and be less buffeted by wind and turbulence than a smaller airship. The Navy radar blimps required about twice as much horsepower per unit volume as a large Zeppelin to move at the same speed, they just had more powerful engines to compensate.

#### Airships have bouyancy 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.

Historical airships used water-capture systems to collect ballast from engine exhaust, and airships powered by hydrogen engines can do the same thing.

### Airships aren't fuel efficient

Airships are actually very efficient, but only when they're big enough, and that's the problem:

#### The Square-Cube Law

The economic viability of Airships is ruled by a double-edged sword known as the Square-Cube Law. An airship’s lift scales with its volume, but its drag only scales with its surface area, meaning that as its size goes up, the increase in drag is squared, but increase in capacity is cubed. In other words, they become exponentially more capable and efficient with linear increases in size.

The lift-to-drag ratio and operating costs of a small blimp are similar to that of a helicopter of the same capacity, which is to say atrocious, but since it only moves at 1/3-1/2 the speed of a helicopter, the uses of a small airship are extremely niche.

A large airship, on the other hand, becomes exponentially more efficient and capable with linear increases in size and cost, thus their lift-to-drag ratios and operating costs can eclipse even the largest jet airliners at sufficient sizes. However, a large airship costs almost as much per pound as a large airplane to develop and build, and large airplanes can have development budgets of tens of billions of dollars and unit costs of hundreds of millions each. Thus, a large airship is an almost insurmountably expensive for a startup or small company to develop, even though there are economically viable markets for them in shipping and transit.

Due to the square-cube law, airships are pigeonholed into the same sort of problem that supersonic jets and manned rockets are — in order to be truly practical, at least for mass transit rather than observation or military uses, they have to be huge.

In other words, any early designs are stuck being prestige megaprojects. Small airplanes are useful and cheap in a way that small airships are not. This allows airplanes to start small and iterate, gradually working their way up to bigger and bigger sizes, producing models exclusively for testing (with many losses) to fail often without scuttling the industry, while rigid passenger/cargo airships are stuck trying to go for a *fait accompli*, beginning at the size of ocean liners and trying to figure out all the engineering and piloting principles on a design that that has to make a immediate profit or justify itself with some kind of military use.

It's a hurdle that has stalled the industry for decades, but once the necessary technologies are lined up and the regulatory requirements satisfied, we reach the next misconception:

### Airships can't compete with other forms of transportation

This has some overlap with the **Airship Niche** section below, but it's worth talking about a bit upfront:

### Airplanes

The most obvious competitor, airplanes have had it more or less their own way for a long while now. Planes, especially jets, are significantly faster than airships, but airships have a few advantages for passenger travel and cargo. The big difference in both categories is space. Airships are simply far larger than airplanes.

For cargo, that extra capacity means an airship can do in one trip what an airplane has to do in multiple, so even if the plane is faster per trip, it's slower when moving an equivalent amount of cargo. Per a U.S. military study, cargo airships can actually have a faster throughput than even giant airplanes due to their higher cargo capacity. They found that for a mission that would take 188 sorties with a C-5 Galaxy (the largest military cargo plane in the world) it would take just 17 dedicated cargo airships less than 90 hours to move the same equipment and personnel. Moreover, since they would be traveling far less distance due to not having to take multiple more trips back and forth, the roughly fourfold advantage in fuel efficiency is multiplied yet further.

It also means that they can carry large, awkwardly-shaped cargoes which simply can't fit inside an airplane, such as wind turbine blades.

Their range is another advantage here: even airships from over 100 years ago were capable of performing freight transport missions that no airplane ever built can accomplish today: in WWI Germany sent a midsize Zeppelin (about one-third the size of the Hindenburg by volume) loaded with 17 tons of supplies and enough fuel to give it a range of 9,900 miles. No cargo airplane has enough fuel to travel that kind of distance. The longest-range cargo plane ever built, the AN-225, could travel just over 9,500 miles while carrying nothing else but fuel and pilots. It just serves to demonstrate the fuel-efficiency of even an airship from over a century ago, which can hardly be accused of being optimal.

As for passenger service, it's true that airships are slower, but likely less than you're expecting. On short-haul flights (which account for over 80% of all flights today) of a few hundred miles, the most optimal cruising speed for a rigid airship is around 150-170 mph, which is only about half the speed of the turboprop aircraft that normally do such routes.

For passengers, that may be inconvenient, but there are some nice tradeoffs in return. Airships generally much more comfortable. They’re not pressurized or high-altitude aircraft, so they don't have the same problems with dry, circulated air and strange-tasting food. And they’re far more spacious than airplanes of a similar payload capacity. Expected passenger density for a ferry airship (130 passengers in 2,100 square feet) still puts them at about 16 square feet per passenger, which is 3 times as much space as you get in an economy airline cabin.

Over long distance flights, their speed drops considerably. Historically airships were only used for ultra-long-distance luxury flights in the 1920s and 1930s because airplanes of the time were incapable of flying such routes, making airships the fastest option for crossing oceans. In the modern day, though, long-haul flights only comprise about 5% of all flights.

### Helicopters

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.

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 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.

Aside from carrying more weight, they can also carry things far larger, like wind turbine blades, prefab buildings, radio towers, etc. Hot air 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.

The largest airships are able to approach the cost per ton/mile of trucking, which is far better than normal air freight and about two orders of magnitude cheaper than helicopter transport.

#### Trucks

There's no future where airships replace trucks entirely but there are certain roles where they would work at least as well. For last-mile logistics, trucks are hard to beat. There'd be no such thing as a cargo airship that carries as much as a truck as cheaply as a truck (say from a dockyard or train yard to your co-op's loading dock). An airship needs to be carrying dozens of times more than that to make economic sense. This is also why you don't see tiny oceangoing cargo ships carrying a handful of shipping containers, but rather gigantic ones carrying tens of thousands at a time — it's cheaper and much more efficient that way.

The main role where airships can compete with trucks is in cross-country cargo hauling (say from one postal service distribution warehouse to another). With enough cargo, the largest airships can compete with trucks in terms of cargo cost per ton/mile, and are considerably faster.

That's in addition to their capability to carry things too bulky and/or too heavy for a truck/road, such as wind turbine blades, heavy or outsized mining equipment, finished manufactured pieces of infrastructure like prefab buildings or radio antennas, reusable rocket segments, etc. Many visions of a solarpunk future heavily de-prioritize car infrastructure in favor of trains, but trucks, especially large cargo trucks like 18-wheelers need a higher quality of road than your average hatchback. And roads fail quite quickly without expensive, ongoing maintenance.

Speaking of roads, airships can operate without roads entirely. This might give them the edge when intermittently crossing large bodies of water, or rough terrain - for example, the Canadian government is looking at airships as an answer to the loss of seasonal ice roads with climate change.

#### Trains

The solarpunk favorite and for good reason. Trains are vastly more economical for carrying heavy, cheap goods like liquids, raw ore, unprocessed material inputs, etc.

But for passengers, compared to a train, an airship would actually have a slight edge most of the time, since passengers-as-cargo is right in the high-volume, low-weight, high-value zone which is most economical for airships.

Trains are limited by volume for carrying passengers, not weight. You can only stuff so many people into a metal tube less than 10 feet wide and about 600 feet long. Most passenger trains carry anywhere between 200-1,000 people, which could be easily matched by a midsized-to-large commuter airship with similar ticket costs, as they can carry about 10 passengers per ton of payload capacity in a day configuration (which drops to 1.6 passengers/ton for overnight ships with private cabins, showers, lounges, etc).

Also, though the fastest maglev trains in the world are faster than the fastest practical airships, high-speed rail average speeds are comparable to or somewhat slower than the optimal cruising speed for an airship over short distances, since they slow considerably for turns, tunnels, and more frequent stops, etc. “High speed rail” entails an average of at least 93 mph, and “very high speed rail” is at least 124 mph. Amtrak, meanwhile, averages at 45 mph.

Over intercontinental distances, a neutrally buoyant rigid airship with a 100-ton payload has a most productive cruising speed of about 72 mph, which saves on fuel weight over the long journey and allows it to carry more payload. Over short distances of a few hundred miles, however, that optimal cruising speed rises to 167 mph—slightly faster than the average running speed of the fastest Shinkansen bullet train line in Japan.

The real kicker is that high-speed rail is fairly rare, even over land, and doesn’t have anything even remotely similar in terms of speed or cost when it comes to travel over large bodies of water. So despite flying like a plane and being buoyant like a ship, an airship is actually more similar in characteristics to a bullet train than either of those two, just without the rails.

Thus even in a solarpunk utopia crisscrossed by High Speed Rail, you might see passenger airships being used to cover regions which don't currently have train service, for any of a number of reasons.

## Modern Airship Designs and Examples

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, and is not suitable for long-distance rapid or heavy freight transport. 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.

The tradeoff is that 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.

It can carry cargo such as shipping containers or purpose-built structures (like portable hospitals) inside the cargo hold which runs the length of its keel, or dangle oversized loads like wind turbine blades, transmission towers, radio towers, prefab buildings underneath.

### Passenger Liners / Cargo

#### The Pathfinder 1

This airship is a 2/3 scale prototype and training/laboratory ship that doesn't carry passengers yet, only its crew, but it can be seen flying around San Francisco lately. While not technically a Zeppelin product, it's a geodesic, electric modernization of the classic Zeppelin shape, with parts sourced from the Zeppelin Company, such as the fins and gondola. They collaborated heavily on the ship's design.

The actual full-scale production version can be used for passenger and/or cargo purposes, and comes in two sizes that we know of so far: one 3/2 the size of Pathfinder 1 carrying 20 tons, and one 5/2 the size of Pathfinder 1 carrying 200 tons. They'd have roughly 3,500 and 30,000 square feet of cabin space, respectively. The Hindenburg, for context, had a bit over 5,800 square feet of deck space.

### Military

#### The Airlander 10

This is a Hybrid Airship originally built for the United States Army's Long Endurance Multi-intelligence Vehicle (LEMV) program. It has several stubby wings and avoids the typical cylindrical/cigar shape of other ariships for a sort of wide, flat shape that looks like two sleek airships merged side by side. This shape helps provide aerodynamic lift while the airship is in forward motion. The hull is a skin made of triple-layered combination of composite materials which keeps in the lift gas, and provides rigidity so the craft retains its shape when inflated. The four engines, fins and the flight deck are attached directly to it. It only has diaphragms and ballonets as internal framework - weight from the payload module is distributed across every frame via cables running across and into the hull as well

The Army canceled the LEMV project in 2013. The LEMV program was intended to demonstrate a medium-altitude, long-endurance unmanned aerial vehicle capable of providing Intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) support for ground troops. Requirements included the capability to operate at six kilometres (20,000 ft) above mean sea level, a 3,000-kilometre (1,900 mi) radius of action, and a 21-day on-station availability, provide up to 16 kilowatts of electrical power for payload, be runway independent and carry several different sensors at the same time. Operationally, the LEMV was intended to be typically flown autonomously or as a remotely operated aircraft but it can also be flown by onboard operators. According to Northrop's projections, one LEMV could provide the equivalent work of 15 fixed-wing medium-altitude aircraft.

### Survey work

**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

### Cargo

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.

### Passenger Transportation

### Coast Guard Patrol / Search and Rescue

The United States Coast Guard has been complaining since the '80s that they'd really like an airship for coastal patrols, since the Navy's prior experience with their highly successful blimp program showed that they can consolidate many of the roles and tasks of a helicopter and a cutter at a fraction of the cost, but their relatively shoestring budget has never been able to support a brand-new aircraft development program. Per the Coast Guard, upon trialing an advertising blimp for the role: The airship cost 15 percent less to operate than the HU-25 Falcon medium range search aircraft, half of what it cost to operate 378-foot cutters and the C-130 long-range search aircraft, and 70 percent less than the H-3 medium range helicopter. It found that airships could perform long-endurance missions beyond the capabilities of helicopters and some vessels. An airship could interact with surface units more directly than fixed-wing aircraft. These missions were within the abilities of the larger vessels but with an airship, could be done in half the time and use one sixth the fuel.

Blimps rescued hundreds of stranded sailors and airmen in World War II. Modern trials have demonstrated their ability to launch and recover rigid-hulled inflatable boats, and they’re even capable of towing disabled vessels weighing up to several hundred tons in a pinch, albeit slowly.

#### Research

## Relevant Technological Advancements

#### Structure

Unlike blimps and historical zeppelins, which dangled the bridge, engines, cargo/passenger space, etc in gondolas underneath the gas bag/envelope, at least some modern rigid airships (like the LCT-60A) have these spaces built inside the bottom part of the envelope. This improves the aerodynamics of the craft and, by placing these compartments inside the frame, reduces the risk of them becoming detached, as happened to the USS Shenandoah (ZR-1) when the structurally insufficient airship broke in half while attempting to navigate a violent thunderstorm over Ohio, losing its under-slung control and engine cars with the crewmen aboard each.

Others, like the Pathfinder I, still use gondolas but have them securely attached to the frame rather than hanging below it.

#### 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.

#### Electrification

Airships have a lot of surface area, much of which could be covered in solar panels. This study analyzed whether an airship could be self sufficient, powering itself with the electricity it generates from its solar panels. The study was aggressively conservative with its assumptions, basically assuming no improvements over the Hindenburg's ancient design and engineering, but even despite that, they found it was possible to do transatlantic flights in reasonable time on solar power.

The Pathfinder 1 is intended to have solar panels installed eventually, too.

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.

#### Hydrogen Fuel

Suffice it to say that the advantages and disadvantages of hydrogen as a fuel mesh up very poorly with airplanes, but dovetail perfectly with airships, covering a number of their problems and weaknesses while enhancing their strengths. Fuel cells are extremely lightweight, efficient, and produce free heat (lift) and ballast (water), among other things. Fuel cells are still under development, with a handful of flying prototypes, but they're very close to being ready for larger deployment.

#### 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.

There are ways to make hydrogen far safer, on a purely passive level. For example, after the SS Sansinena and TWA Flight 800 exploded, fuel tankers and airliners started inerting their potentially explosive fuel vapors with inert gases. This has proven highly effective. Similarly, an airship can have a double hull of inert gas like helium, nitrogen, and/or carbon dioxide to prevent fires or explosions, in addition to active safety measures. Alternatively, a direct mix of isobutylene and carbon dioxide can render hydrogen fires self-extinguishing and non-explosive across hydrogen's entire ignition range, but this mixture has somewhat less lift than helium, thus probably isn't as desirable as a double hull.

Most people working in the airship space agree—whether quietly or publicly—that hydrogen is just too spectacularly useful as a fuel and/or lift gas for airships to completely forgo using. As a fuel, you can reduce the fuel load by roughly two-thirds, saving tens of tons for payload. It generates its own clean water for ballast or passenger use. It's widely available. It can be generated via solar panels on the ship or ground. It can even be released from fuel tanks to provide extra lift, or be vented or put back into fuel tanks if lift needs to be sequestered. There is no more powerful lift gas. The principal disadvantage of hydrogen in other applications is its bulk, but an airship has literally millions of cubic feet of empty space in the hull to just put it wherever, so that disadvantage is totally moot for airships.

Handling hydrogen safely for large airships used to be a matter of three things: purity, ventilation, and electrical conductivity. Zeppelins acted like giant faraday cages for lightning strikes and static electricity, keeping them surprisingly safe unless there was a major leak at an inopportune time (which is how the Hindenburg, whose skin was not fully electrically conductive under certain atmospheric conditions, ended up being the first and last fatal accident for the Germans' civilian Zeppelin airline after nearly 40 years of operations, during a time when a plane fatally crashed after only a few hundred hours of operation on average). Ventilation between the gas cells and outer hull ensured that no dangerous concentration of hydrogen and oxygen could build up over time from gradual effusion. And, of course, pure hydrogen doesn't burn, which is why Zeppelins were able to terrorize Britain in the first few years of World War One with near-impunity before the incendiary bullet was invented.

In the modern day, though, we have higher standards for safety, and thus airliners and fuel-carrying ships both use inert gases like nitrogen or carbon dioxide to prevent explosive fuel-air mixtures from forming. An airship could do the same, using a balloon-within-a-balloon method, or by sealing the outer hull of a rigid airship and filling it with with nitrogen instead of just trusting to ventilation systems instead.

Interestingly, we do know that this would work in a practical sense for hydrogen, because of experiments conducted by the British in World War I. Prior to late 1916, it was initially thought (before the discovery of helium on earth!) that the Germans had discovered a nonflammable lift gas, since simply shooting Zeppelins didn't catch them on fire, and it took sustained artillery and flak barrages from ground batteries or teams of warships to actually sink the small handful of Zeppelins that they did manage to bring down. Others thought that the Zeppelins were using an inert gas to surround the hydrogen cells, and thus “armor” them against flame, possibly using exhaust gases.

To test this, the Brits fired the experimental Very's and Pomeroy incendiary bullets they were developing into a double-layered balloon of hydrogen and a nonflammable gas mixture. The Very's and Pomeroy bullets were fired through the top where the hydrogen would escape, and burned all the way through the bottom of the balloon, which itself was flammable, and it still didn't catch the hydrogen on fire. It was, in their words, “completely protected” against ignition.

As it would later develop, the Germans were not in fact using inert gases in this way, instead trusting to hydrogen purity and ventilation, but the record still stands. Now imagine if the balloon itself was fire-retardant, like coated synthetic fibers, which would just melt rather than combust if subjected to a hot flame. Imagine if there were sensors to detect hydrogen leaks, and if the ship was constructed from all-conductive materials. They'd be essentially as safe as helium airships, which themselves proved to be much less prone to fatal accidents even during the rigors of World War II than ubiquitous modern helicopters like the Robinson R44 (fatal accident rate of 1.3 per 100,000 flight hours vs. 1.6). In the modern day, the Zeppelin NT semirigid airships currently used by Goodyear and sightseeing companies haven't had a single fatal accident since they started operations in the 1990s.

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.

## 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. The Lockheed-Martin P-791 and Z1 airships have hovercraft landing pads that can reverse and suck down the ship while it’s disgorging passengers or cargo. Even on unimproved ground, without any external support equipment, the grip’s been tested 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. Unfortunately (because they had incredible style) “high masts” were already on the outs by the time the Hindenburg disaster ended airship travel.

Modern “Low masts,” the kind that are mounted on a truck or semi trailer, are much more practical, and still in use today. Not all airship designs need them, but some still do—including the Pathfinder series of airships. The advantage of low masts is that the airship is kept much safer when it’s affixed securely to the ground and allowed to pivot and weathervane into the wind, such that you don’t need a skeleton crew on board to “fly” it while it’s still on the mast. It also makes getting things on and off the airship immensely easier than when it’s hundreds or thousands of feet in the sky.

It also means you can avoid incidents like when the USS Los Angeles famously did a headstand because it was moored to a high mast without the stern being secured to a ride-out car.

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.

### Lived Experience Stuff

What might riding in an airship be like? How many crew?

**Number of crew:**

In the 1930s, 'airship' really was a pretty accurate title as they operated much more like oceangoing ships than like other aircraft, even in their day. They had large crews with postings all around the vessel (including teams of riggers and sailmakers to live inside the hull and take care of the envelope, lines, and gas cells), they were controlled with ship-like speaking tubes and engine telegraphs to relay orders to the engineers to adjust engine settings, and were literally steered with spoked wooden ship’s helms. They’re essentially a submarine in a different fluid medium. The size of the crew varied based on the size of the airship, available technology, and the responsibilities of the vessel. The comparatively small LZ 120 Bodensee had a crew of 12 and could take up to 27 passengers (as long as six people were fine sitting on wicker chairs in the gangway between the compartments) while the LZ 129 Hindenburg had a crew compliment of 40 and could take on 72 passengers after upgrades.

By comparison, the USS Akron had a crew of 76, though it was a military vessel with a built-in airplane hangar and trapeze system, so there were more responsibilities to fulfill than on a passenger liner or cargo airship.

Thanks to advances in technology, modern airships have vastly reduced crews and are built much more along the lines of aircraft, for better or worse:

- Most sources I've seen for the proposed LCA60T Flying Whale mentions at least two crew, one pilot and one payload master responsible for the cargo.
- The Hybrid Air Vehicles Airlander 10 is a prototype funded by the US military and intended for Anti-Submarine Warfare (ASW) and Intelligence, Surveillance, and Reconnaissance (ISR) mission scenarios, so it's proposed crew is somewhat larger. According to a proposal from the Naval Postgraduate School: For flights lasting 72–120 hours, the recommended configuration involves three crews onboard, totaling 18 crew members, with a minimum of three required. In contrast, for flights under 18 hours, two crews onboard Airlander 10 would comprise 12 mission crew members and two pilots.

#### Interiors

The interiors on historical passenger airships took heavy inspiration from seagoing ocean liners, with promenades, double grand staircases, writing rooms, piano lounges, bars, even smoking rooms. The cabins were much closer to those on a sleeper train, though, to save weight.

Modern airships might still look like this in some circumstances, perhaps if your setting is far enough along on the rebuilding-to-utopia spectrum and can support especially long-distance passenger liners, or something akin to cruse ships.

In the nearer term, short-distance passenger airships may look more like a ferry boat inside. Not particularly glamorous but with a fair bit of space. Expected passenger density for a ferry airship (130 passengers in 2,100 square feet) still puts them at about 16 square feet per passenger, which is 3 times as much space as you get in an economy airline cabin. It's also worth remembering that unlike airplanes, airships aren't pressurized or high-altitude aircraft, so they don't have the same problems with dry, circulated air and strange-tasting food. Small, modern sightseeing airships like the Zeppelin NT has passengers enter and leave a few at a time through a single door, so it’s fairly slow to get in and out, even though it only carries a dozen or so people. An actual “ferry” airship would probably be 10-20% heavier than air to facilitate easier, faster ground handling, and have rapid turnaround times by having an embarkation and debarkation model more similar to a train, rather than a plane. For example, by having an exit door on one side of the cabin unloading at the same time as an entry door on the opposite side is boarding, which also helps for maintaining weight and balance.

In a much nearer future, or something where society is still on the mend, or in response to natural disasters, the sorts of airships that would be best suited to transport hundreds or thousands of people over short-ish distances of a few hundred miles at 100-150 knots would be, by necessity, hastily converted cargo airships, not something purpose-built for passengers alone. The airship industry is simply too tiny as yet to support a dedicated passenger design, as opposed to a passenger/cargo or combination design like the original 747. They’d likely try to pretty it up as best they could and make it wheelchair-accessible, but they'd likely use converted cargo spaces for transport and whatever Roll On/Roll Off cargo ramps were already on the basic design for boarding. Unglamorous, for sure, but effective at loading and unloading large amounts of people in an emergency.

#### The Ride

Historical Zeppelins were famed for being eerily smooth and totally unlike an ocean liner of the time (which often made their passengers horrendously seasick). Due to the Square-Cube Law (discussed below), a larger airship will experience proportionally less drag and be less buffeted by wind and turbulence than a smaller airship, so a large passenger or cargo airship should be fairly comfortable even in fairly high winds.

Once all the passengers or cargo are loaded, takeoff is very quick. Airships don’t need to get to high cruising altitudes, and they can ascend very quickly.

As for noise, The Zeppelin NT uses piston engines mounted on the sides and tail, and it has a cabin noise level of about 65 decibels. That’s similar to or slightly better than the quietest jet airliner, the gigantic Airbus A380, which is famed for its comfort. The Pathfinder I, by comparison, uses the same exact gondola as the smaller NT, with more widely-spaced electric motors, which are naturally much quieter than piston engines. This should improve things even further.

#### Funding / The route to airships in the modern day/near future

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. Because airships have to be big to be useful, it's hard to fund the kind of iterative development process when each prototype is an expensive megaproject which might not justify itself with an immediate profit or some kind of military use. Thanks to cheap oil and an entrenched aviation industry and regulatory environment, 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.

In the world today, there are two main sources of investment in airships: The military and billionaires. The military has a sort of on-again-off-again history of funding research towards airships for intelligence gathering roles, and full size rigid airships could make for a flying yacht the size of a mansion.

This isn't great but it's not all bad. Much of what we know about modern airships comes from military and government service. Governments often subsidize new industries when they're necessary for the public good or to meet state objectives, and getting rich people to pay more for something while it's still a rare luxury is a tried and true model for covering up front development costs in consumer products.

It doesn't have to be done this way, but it's worth considering that the industry/field of lighter than air aircraft could be derived from these early design goals, if that fits your story.

Alternatively, a society transitioning towards solarpunk might consider pricing in the negative externalities of flying quickly (with private jets and the like, which have exploded in popularity recently) and use that to subsidize ultra-low-carbon transit like airships (whether that's additional research and development, or just mass production to improve availability). Speed is a luxury and allowing the people who are willing and able to pay a high premium for speed to offset costs for everyone else who just needs to travel might make sense in some settings.

#### Battle(?) Damage

The average solarpunk story may not need to describe airship battles or any sort of combat, but there are plenty of circumstances worth writing about which could damage an airship, so this section collects various examples of documented damage to real life airships to provide some context for their potential capabilities.

Historically, rigid airships proved to be comparatively resilient, even given their relatively crude design, construction, and materials.

For much of WWI, even direct hits to the envelope by machine guns couldn't bring down airships - normal bullets just put holes in them that would leak down too slowly to really be effective. Until the invention of the incendiary round in WW1 to counter hydrogen airships late in 1916, planes only scored one win against Zeppelins by bombing them.

And even larger-payload high explosive bombs didn’t do more than moderate damage against World War One Zeppelins. The LZ-39 survived repeated bombings by airplane. It caught four 20-lb high explosive bombs the hard way and kept flying, landed safely, was repaired, and returned to service. In a separate attack it sustained so much damage that the crew abandoned the bridge - which later actually fell off - and they still managed to limp it home.

Prior to late 1916, it was initially thought (before the discovery of helium on earth!) that the Germans had discovered a nonflammable lift gas, since simply shooting Zeppelins didn’t catch them on fire, and it took sustained artillery and flak barrages from ground batteries or teams of warships to actually sink the small handful of Zeppelins that they did manage to bring down. Others thought that the Zeppelins were using an inert gas to surround the hydrogen cells, and thus “armor” them against flame, possibly using exhaust gases.

To test this, the Brits fired the experimental Very’s and Pomeroy incendiary bullets they were developing into a double-layered balloon of hydrogen and a nonflammable gas mixture. The Very’s and Pomeroy bullets were fired through the top where the hydrogen would escape, and burned all the way through the bottom of the balloon, which itself was flammable, and it still didn’t catch the hydrogen on fire. It was, in their words, “completely protected” against ignition.

As it would later develop, the Germans were not in fact using inert gases in this way, instead trusting to hydrogen purity and ventilation of the spaces between the lift gas cells to prevent the necessary mix of hydrogen and oxygen, but the record still stands. Now imagine if the balloon itself was fire-retardant, like coated synthetic fibers, which would just melt rather than combust if subjected to a hot flame. Imagine if there were sensors to detect hydrogen leaks, and if the ship was constructed from all-conductive materials. They’d be essentially as safe as helium airships, which themselves proved to be much less prone to fatal accidents even during the rigors of World War II than ubiquitous modern helicopters like the Robinson R44 (fatal accident rate of 1.3 per 100,000 flight hours vs. 1.6).

The fact that Zeppelins would harass and annoy surface warships and survive direct hits from their main guns, with only one airship getting destroyed, is telling. Redundancy and sheer size did more for their durability than any amount of magically lightweight armor ever could.

More recent military tests done twenty years ago showed that it took about 1.4 hours for a Stinger missile to sink a small helium blimp, and a modern rigid airship would have 13 or more gas cells, each much larger than that little blimp. Also, since a blimp is under pressure and a rigid airship isn’t, it takes about five times longer for the helium to leak out of a hole the same size in either.

### 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.