Future of Aviation: Multiple Pathways towards Achieving Jet Zero

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Abstract

Nowadays, as climate change keeps progressing, humanity is facing the need for urgent changes to our lifestyles. And this affects not only how we live, but also how we transport. One of the most sustainable ways to travel over long distances is aviation, however it is far from being totally eco-friendly. In this paper we will discuss proposed future aviation concepts, which will reduce carbon dioxide (CO2) emission to nearly non-existent. In the foreseeable future, introduction of these concepts will become inevitable, so brainstorming is needed already to finalise them.

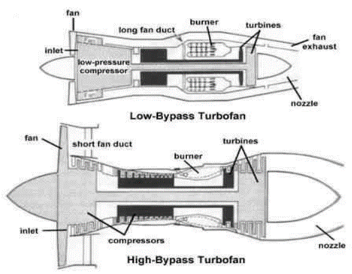
Keywords: Aviation, Carbon Footprint, CO2 Emission, Future of Aviation, Sustainability, Hydrogen Propulsion

1. Important Metrics

When it comes to encouraging customers to buy a plane, one of the most important factors for airlines is fuel burn. The less the fuel burn, the more money the airline can save. And this principle makes the aviation industry way easier to make fully sustainable. So, as in the aircraft production industry everyone wants to reduce the fuel consumption, companies are already going to the goals of green aviation. The main problem is the development of new concepts that will bring aeroplane travelling to zero emissions.

Planes are consuming less and less fuel as the years go by, that's a matter of fact. For example, this could be seen by comparing the old turbofan engines and the current ones. While the new ones are big and wide, the old are narrow and small. That's because they have different bypass ratios.

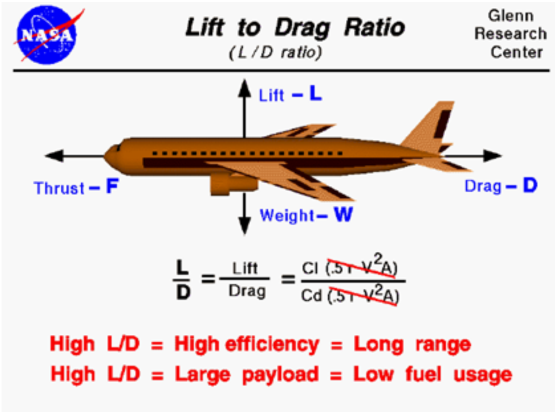
Bypass ratio (BPR) – the ratio between the mass flow rate of the bypass stream to the mass flow rate entering the core.



For instance, the bypass ratio of 5:1 means that for every 5 kg of air passing over the engine core, 1 kg passes through it. This ratio is very important, and as time showed, the higher this ratio is, the less fuel an engine consumes.

Since bypass ratio is only about the aircraft engines, how can we determine an aerodynamic effectiveness of the wing itself? For this need exist two other very important metrics: aspect ratio and lift-to-drag ratio.

Aspect ratio is the ratio of wing span to its mean chord. It is equal to the square of the wingspan divided by the wing area. Lift-to-drag ratio is the lift generated by an aerodynamic body such as an aerofoil or aircraft, divided by the aerodynamic drag caused by moving through air.



They are important because lift-to-drag ratio increases with aspect ratio, improving the fuel economy in engined aircrafts and in the angle of attack of gliders.

As we now know, the main goal of the aviation industry today is to keep the bypass ratio high, while improving how the engine core works, as well as finding a golden spot among the aspect ratio and the drag-to-weight ratio. With this general knowledge about aircraft efficiency, we can now look at the current and the future concepts that are determined to dramatically decrease the carbon footprint caused by aviation.

Different plane makers fight for the wing efficiency in their own ways, some of them are lightening the wing using advanced materials, such as carbon fiber or/and various alloys of the aluminium with, for example, titanium. While some of them are making quite inventive wingtips, which can also help in reducing fuel burn by reducing friction drag and the development of vortexes on the wings' edges.

2. Present implementation

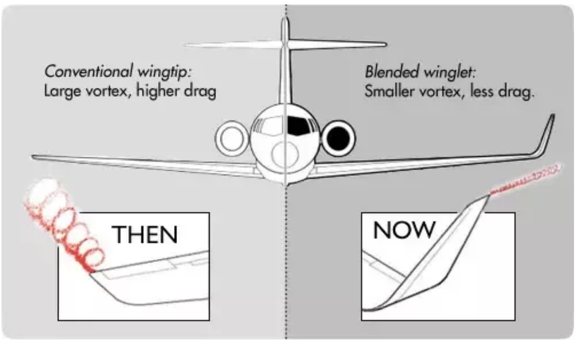
These are the concepts that are already being implemented in the aviation industry. They aren't as major as the proposed concepts, but still they are doing an important job of reducing CO2 emissions. It is still hard to make major changes in the aircrafts' design, because every change needs to be tested for possible cons to the industry and to the safety of the passengers.

Hence, it's very important to be conducting multiple tests at the same time. The simplifying factor here is that there are several competing plane makers, which force each other to consistently improve their designs to earn more customers.

2.1 Aerodynamic improvements

As it was stated earlier in the paper, nowadays the improvements are not going very fast. The aerodynamic changes are being made only with the wings, since the manufacturers don't want to completely rework the whole structure of the aircraft, because this will result in the decades-long tests and certification processes. As a result, nowadays the planes' appearance is being kept the same: there are still two wings, two or rarely four outboard engines, one straight fuselage, two horizontal and one vertical stabiliser.

Therefore, the development of new wing concepts and wingtips designs is essential for the whole aviation industry as of today.



The best winglet in my opinion is the raked wingtip, as it is reducing the development of vortexes and at the same time is increasing the wing area significantly.

With all that said, I can say that one of the most stand out aircrafts, in terms of both innovative wing and airfoil design is the brand new Boeing 777X, which is still being certified. It features the biggest yet seen wing surface area which was made possible with implementation of raked wingtips with the foldable edges. If not they, the plane won't be able to fit into the standard parking space because of its wingspan.

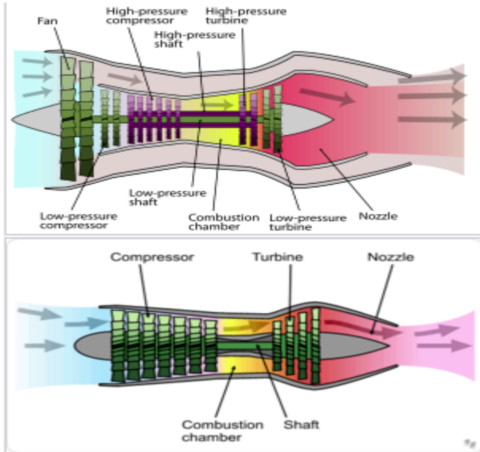
Boeing promises the 777X to be the most effective wide body aircraft there is. That will be achieved not only with the wing improvements, however. Engine efficiency is essential for the best performance.

2.2 Engine innovations

As the years go by, the engines are getting bigger and bigger. And as was explained earlier, that's because their bypass ratio is getting higher, thus making the engine itself more efficient. But how does the bypass ratio improve the airplane's fuel burn? I will try to explain this next in the paper.

There are two ways of achieving the same thrust: one is by accelerating a small mass of flowing air by a large amount (that's what an older airplane engine did), and the second way is to accelerate a large mass of the flowing air just by bit (that's what the current airplane engines are doing). The second way significantly reduces the fuel burn, as the engine core remains at the same size, and the same amount of air is flying through it, as it was before.

Turboprop engines are gaining popularity again, because they are operating in the open air, making their bypass ratio infinitely big. As of now it is considered that turboprops will receive their place in the aviation of the future.



Now, in the aircraft engines production, as well as in the aircraft manufacturing niche, there are few competing companies, such as Pratt & Whitney, General Electric, Reaction engines, and CFM international. They are continuously improving the engine bypass chamber and the fan blades inside the core, to make the engines the most effective, to make the airline want to buy such a product. For that the engine manufacturers need to know how to implement advanced materials, since they will greatly lighten the aircraft and the engine itself, thus making the gas consumption even less.

2.3 Implementation of advanced materials

The last very important aviation sustainability direction is the consistent improvements to the materials from which the aircraft is being made.

The lighter the aircraft, the less fuel it needs to consume in order to fly. As a result of that, the plane makers are also competing with each other in terms of implementation of materials that are both lasting and light at the same time.

When it comes to brainstorming the lightest metal options for building an aircraft, aluminium is the first option to be mentioned. Consequently, most airplanes that were built were made solely of aluminium. Of course, aluminium is light, but also there are few other more progressive options that are needed to be mentioned.

Somewhen at the beginning of 1960s, new types of alloys were starting to emerge. At that time aluminium-titanium ones were only used at the high-stress places in the aircraft's body, but near the end of the 20th century, such alloys were implemented almost everywhere in the airplane

Things have massively changed since those times, and all that happened because of the carbon fiber. Modern airliners, such as Boeing 787, and Airbus a350 XWB are made by half using carbon materials. These are the airliners, which can fly up to 14200 and 15000 km (7667 and 8099 nmi) respectively.

Currently, the main goal is to increase the amount of carbon materials in the aircraft bodies to somewhere around 90%, to make planes more lasting and light. That is the process that will make future innovations even easier to implement, since the airplanes will already be as light as possible, thus requiring not as much thrust as now.

3. Future implementation

These are the sustainability concepts that are planned to be implemented in the foreseeable future (by the most part until 2050). They include a hydrogen propulsion, as well as some major aerodynamic body changes.

Hopefully, these ideas will total the CO2 emissions to zero and make aviation fully safe for the environment in the near future. As the first of those aircraft to take to the skies in 2035 will be the turboprop one, Airbus still have time to finalise the Blended-Wing body aircraft concept until the 2050, when it's due to.

So let's do the thinking process together with Airbus and see how the aerodynamic model of the future aircraft will look like from today's perspective.

3.1 Hydrogen Propulsion

Currently, all aviation engines are using gas to heat up the air inside the core, but it is planned to transition to hydrogen fuel by 2050. That transition would mean the switch to fully sustainable aviation, which will make long-distance travelling completely emission-free.

Let's see the difference in how the hydrogen-powered airplane works. Such an airplane utilises hydrogen as its energy source. Hydrogen can be combusted in an engine or used in a fuel cell to produce electricity for an electric propulsor. Unlike traditional fuel, hydrogen cannot be stored in a wet wing and needs specialised storage in the fuselage or supported by the wing.

Airbus is currently planning to develop three hydrogen-powered aircraft concepts by 2050, such as:

1. Emission-free turboprop aircraft, which will fly at mach 0.5 (612 KPH / 380 MPH) and seat up to 100 passengers

2. Emission-free turbofan airliner, with the cruise speed of mach 0.78 (828 KPH / 511 MPH) and space for up to 200 passengers

3. Emission-free turbofan Blended-Wing body airliner, which will be able to fly at the speed of 0.78 (828 KPH / 511 MPH) and seat up to 200 passengers

Still, it is important to point out that there is still no concept of an airplane which can seat more than 200 passengers. It's unknown whether Airbus won't do such an aircraft because it will be ineffective, or they just can't make hydrogen turbofan engines more powerful for now.

Thus, it is important to start the tests as soon as possible to determine how the blended-wing body could be improved to fit well into the aviation industry.

3.2 Future Aerodynamics

In the near future, it is inevitable that the current shape of the aircraft will outlive itself, making further innovations on it impossible, since everything that was possible to improve was already improved. Competing companies will and are already searching for the advanced fuselage shapes, wing forms and engine mounting options that will become a new norm in the aircraft industry.

Nowadays, one of the most discussed future aerodynamics concepts is making planes with the blended-wing body to make them less susceptible to the friction induced drag. Blended-wing body is an aircraft having no clear dividing line between the wings and the main body of the craft. It has few major advantages and several comparably small disadvantages.

Advantages are that such design can propose more effective distribution of both the freight and passengers, lower noise levels and decreased fuel burn by up to 11% compared to the conventional airplanes.

There are also multiple disadvantages that still, however, don't impact the CO2 emission levels of this airplane. Starting from the fact that passengers from such aircraft would be hard to evacuate in case of crash landing, (because of the plane's main deck area), ending with that this aircraft most certainly won't fit into the airport infrastructure. Moreover, the blended-wing body may not be even able to fly to the destination airport because of its poor handling at a low speed. It is called Overture. The plane itself visually has the design similar to the Concorde, but with the shortened and improved fuselage, as well as hydrogen propulsion.

The company already started working on the project, while building the testing facilities. Boom promised their aircraft to be cruising at the speed of mach 1.7 and to fit in 60-80 passengers (depending on the seat configuration). For now there are three customers which have placed orders for up to 55 airliners. Overture is set to be introduced in 2029, and until then, the whole aviation industry will be observing Boom's progress with cautious enthusiasm.

There is another very promising aircraft concept that was once implemented by Boeing in the 20th century, but was way ahead of its time. It was an airplane that was built only in one copy and was called the Boeing 2707. Made using US government funding to compete against the British and French-made Concorde and Soviet-made TU-144, it turned out to be even more ambitious than both of them. Boeing 2707's main feature was the ability to change the shape of its wing while in flight, both for achieving less drag during his cruise at the speed of mach 3.0 and gaining more control at the low speed during an approach and landing. The project failed because it was impossibly hard to implement the swing wing configuration mechanism in the late 1960s.

But with the technologies from the 21th century, such as hydrogen propulsion, it will potentially be possible to redesign this plane, now with the full-carbon body and hydrogen-powered engines to perhaps reopen the era of supersonic travel.

Speaking of the new supersonic era. Now, when the plane makers started to seriously consider implementing hydrogen to power their engines, there appeared the company called Boom, which is determined to create a new type of supersonic passenger airliner that will be powered by hydrogen.

4. Future of Aviation

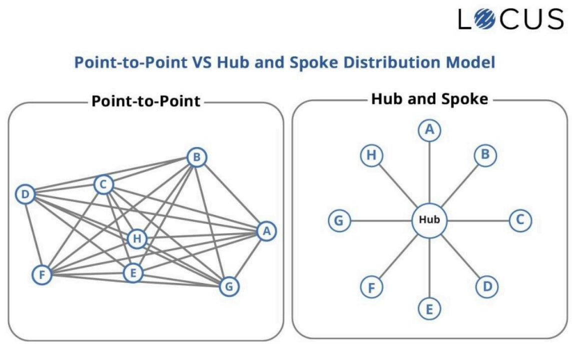
Aviation is not only about technologies, however. With the change of airplane designs, will come the changes to the pilot training and Standard Operating Procedures (STOPs), as well as to many other factors. Also, with the changes to airport infrastructure will come the changes to the passenger flow. We don't need to forget about the possible side effects which will be brought by the new aviation concepts. So let's briefly discuss all that.

4.1 Passenger Flow Changes

While the STOPs and pilot training will be changing, passenger behaviour and route opportunities will be doing so as well.

At first, airlines were flying from the small cities to big ones and vice versa. Such travelling is like a bus: it goes to the point from which almost everyone would continue on their own journey via the connection flight. This way of flight distribution is called the hub-and-spoke system.

Nowadays however, the aviation industry is transitioning to flying from the small to small cities on smaller airplanes with a longer range. Such a system is now called point-to-point. It is convenient in a way that there is a flight that can get the passenger to his destination right away, without any connection flights.



In the future, when there will be more and more planes with long range, the flight distribution will be done in a way, resulting in the lowered airport workload. Almost everyone will be flying from point to point. There will still be an option for connection flights, but it will be present only for the cost efficiency reasons.

The road that the aviation industry is currently going is set for the point-to-point system, thus making changes to the airlines' demands. Consequently, there are no plans to make airliners with the biggest passenger and cargo capacity possible. On the contrary, airlines want smaller jets with the best fuel efficiency to transport small amounts of passengers and cargo to the small places they are needed to be.

Anyway, for now this is a sole proposed concept for the future of aviation. It will definitely be reworked in some ways and finalised. Hopefully, more companies will soon share their vision of the future aviation infrastructure, which will make sustainable travelling safe and emission-free.

4.2 Changes to STOPs and Pilot Training

When the hydrogen engines will be out, the new standard operating procedures will be out as well. The main changes will be due to the innovations to the aircraft's propulsion system and in some cases due to the wing shape change.

Few of the most important features in the future checklists will be safety precautions for the new types of fuel preservation. For a few planes there will be an item in the checklist for unfolding the winglet before takeoff and folding it back after the landing, as well as one more non-normal checklist for the instance of detaching of the wingtip while in flight.

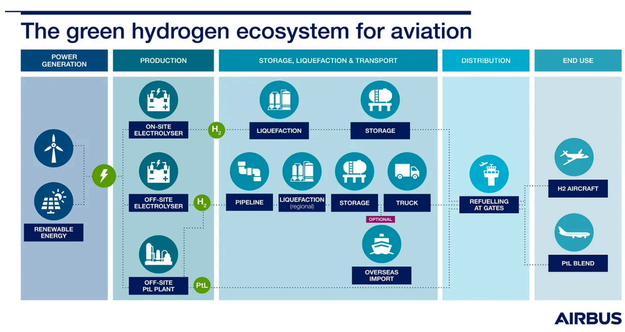
Pilots will be learned to handle new extended dimensions of their airliners, as well as new automated aircraft systems that will probably emerge to reduce their workload. Airport handling and infrastructure will be adjusted to keep all the airplanes constantly moving either to their departure runways or to their arrival gates to ensure the minimal fuel loss due to the delays.

4.3 Future infrastructure concepts and problems

As the plans for sustainable aviation are made only by 2050, it is good to set up plans for further development, as well as to consider the possible risks and costs of new technologies.

The main problem of the implementation of hydrogen engines is the hardness and expensiveness of producing enough fuel to power most of the airplanes that will be flying in future. In massive amounts, hydrogen could be produced through the electrolysis of water, still, it's expensive and quite tricky.

Airbus developed a whole concept for the future aviation infrastructure that uses on-site and off-site electrolysers as well as Power-to-Liquid synthetic fuel facilities. On-site electrolysers will be used during the high-demand times at the airports to generate fuel in close proximity to the airplanes. The gas is proposed to be transported to airports via pipelines and liquefied on site, where, in a liquid way, it will be fueled into the aircraft.



There are still few questions and problems with this plan. For example, it is unknown whether it will be possible to perform electrolysis using only renewable energy. Considering that wind- and solar- power aren't very big energy providers, possible usage of atomic energy could also be a good option.

Another question is from where would the off-site electrolysers take needed amounts of water. If the airport is far from the suitable water reservoir it could be quite tricky. Water quality in this case also plays a drastic role.

5. Conclusion

Whether it will be good or bad, eco-friendly or environmentally-harmful, the future of aviation is constantly getting closer. It is the task of humanity to preserve our planet while keeping on with the constant development. Although aviation contributes only around 2.5% of the global CO_2 emission, it is hard and expensive to make it fully green.

Plane makers will continue making air travelling more effective for people and better for the environment, however. So will be the article writers, who are and will be helping to explain some tendencies and concepts for people far from the industry. Writing this paper helped me understand the future of aviation better, and I hope it did so for you. Thank you for reading and caring about our planet!

Acknowledgements

This research paper was authored by Stanislav Cherniavskii on an open-source and free basis. Research was carried out individually based on the sources from the internet, which are listed below.

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