PIAGGIO P107

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Graduation project
Lahti Institute of Design
Spring 2019

PIAGGIO P107
Puoliautonominen lentovene
Lahden ammattikorkeakoulu
Muotoiluinstituutti
Muotoilun koulutusohjelma
Ajoneuvomuotoilu
Opinnäytetyö AMK
Kevät 2019
Janne Mustonen

PIAGGIO P107
Semi-autonomous flying boat
Lahti University of Applied sciences
Institute of Design
Design programme
Vehicle Design
Graduation project
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ABSTRACT

As a graduation project I researched the near future of aviation and created a flying boat concept. This project does not reshape the aviation infrastructure but helps to understand it and it's challenges. A result is a realistic concept that offers private transportation to remote locations in and outside of the infrastructure.

Opinnäytetyössäni tutkin ilmailun lähitulevaisuutta ja sen asettamia haasteita. Projektissa en pyri vaikuttamaan infrastruktuurin muutokseen vaan luomaan kulkuneuvon joka soveltuu tähän käyttöympäristöön. Lopputuloksena on yksityislentovene, joka toimii osittain infrastruktuurin osana ja paikoin sen ulkopuolella.

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INTRODUCTION

The goal of this project was to test my skills as a designer and to design an aircraft. I wanted it to differ from most aircraft concepts that are usually either engineering projects or unrealistic concept art. The plan was to do a design process that had it's main focus on visual style and user experience, but solid technical studies to support all design decisions.

Part of my brief was to research the future of aviation, but this project is not supposed to propose a solution for future transportation issues. The product I'm designing does not revolutionize air travel, but tries to make a small part of it better.
I believe it was beneficial for my development as a designer to get out of my comfort zone and do a solid project that balances design and engineering, idealism and utopia.
I wanted to create a good looking vehicle based on well researched and argumented decisions.

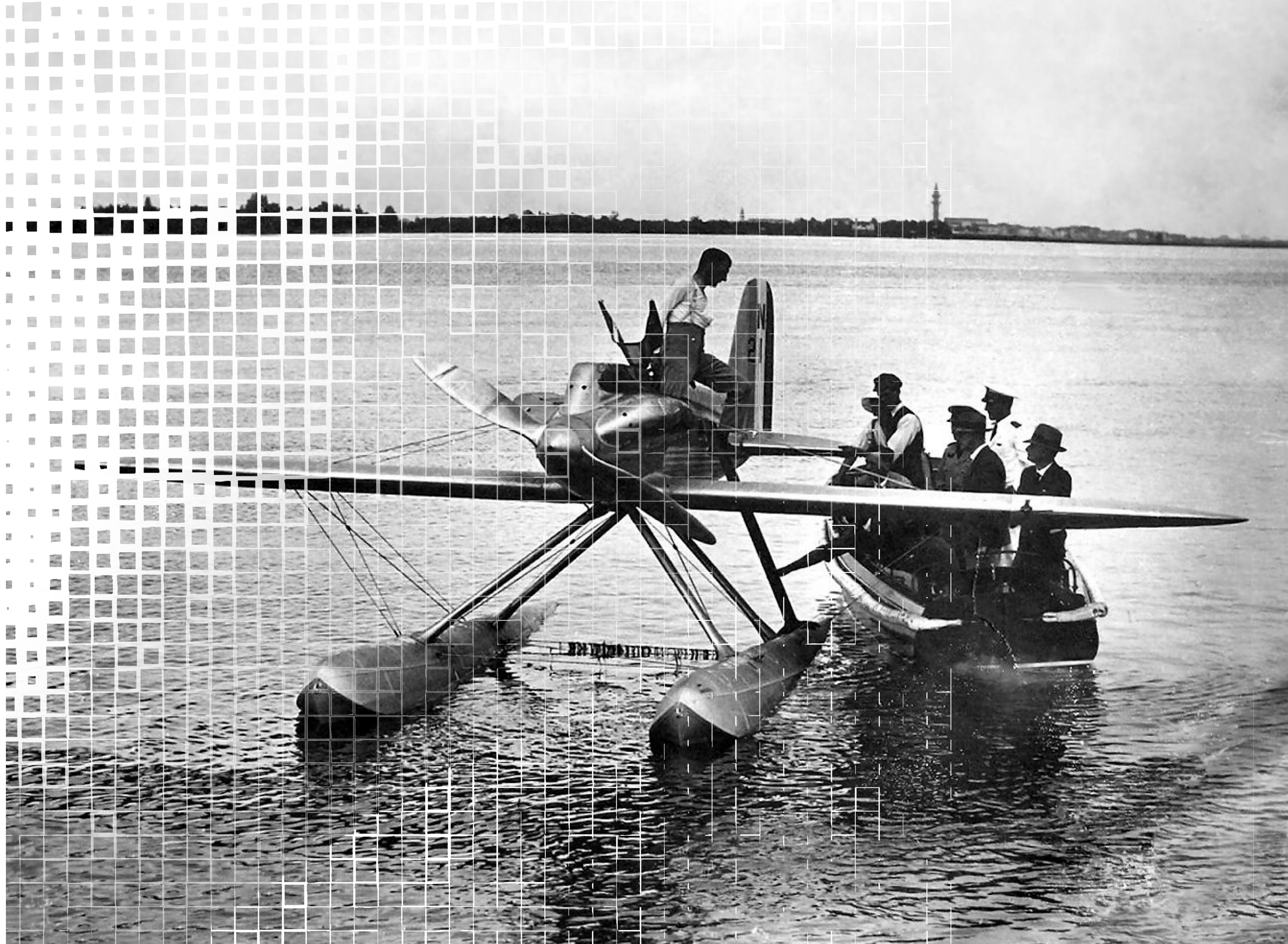
REALISM

To be believable, an aircraft concept requires extensive engineering. As this project focuses on styling and user experience I limited my technical and aerodynamical research only on solutions that directly affect the packaging. The overall performance of an aircraft depends on countless tiny details, so it will be impossible to tell how well this aircraft would fly in reality, but in theory it will fly.

2 HISTORY

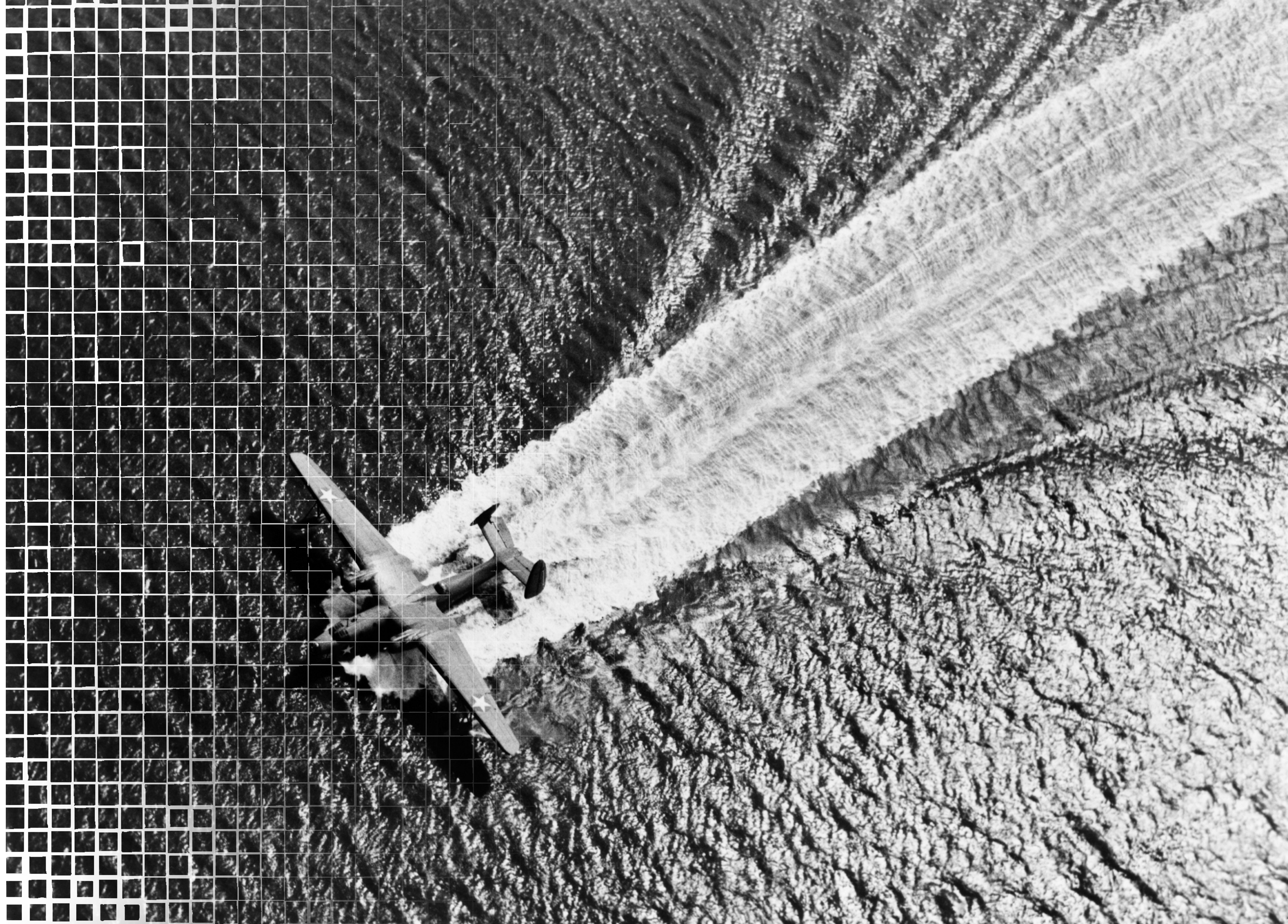
2.1 Seaplanes, floatplanes and flying boats

The story of a floatplane began in 1910 when a French aviator Henri Fabre took off with his Hydravion, a monoplane equipped with wooden floats. In the early years of aviation most seaplanes were wooden biplanes that had their wheels swapped for single or twin floats. Development led by Italians gave birth to a flying boat, a seaplane with hull designed to provide sufficient buoyancy to enable safe operation from water. This configuration had certain advantages over a floatplane. The main difference is the reduced weight and aerodynamic drag due to lack of separate flotation devices. This is the major disadvantage of all kinds of seaplanes, and a flying boat is still aerodynamically inferior compared to a landplane.



Seaplane's main strength, the ability to take off and land without an airfield or any supporting ground structure made it the dominant type of aircraft until the second world war, and 1920's and -30's are retrospectively known as the golden era of flying boats. In an era when flying was but a marginal form of transportation, and unreliable machines had a short range, the ability to use 71 per cent of earth surface as a runway was a huge advantage, and made transoceanic flight possible. This was a major step of evolution from a marginal sport to a world wide airline service.

Eventually the second world war led to the death of seaplane airlines. Seaplane's fundamental disadvantages meant that it was unsuitable for warfare, so small airfields were built on a tight schedule by every nation at war. After the war, the world was filled with tiny airstrips and surplus aircraft, so there was simply no need for airplanes operating outside the infrastructure.



2.2 Present day

Currently both floatplanes and flying boats are used all around the globe by private and civilian aviation. In areas with low infrastructure, like Alaska they are an important form of transport. Being safer and cheaper to operate than helicopters, they provide transport to locations that are not covered by rail and airport network. In areas with high infrastructure but large waterways, like Finland, they are mostly used for leisure aviation. The difference to a pre-war era is that today a majority of users are private pilots, and floatplanes have surpassed flying boat in popularity. The reason behind this is the fact that most small aircraft can be converted to a floatplane just by installing floats, whereas a flying boat has to be designed around the boat hull.

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3 FUTURE OF AERIAL INFRASTRUCTURE

3.1 Asian airport boom

With it's rapidly expanding middle class, the most populated country in the world is building roughly eight new airports every year, and India and rest of Asian countries are likely to follow (Charlton, 2018). In China it is usual to work and live in different cities, so strong shuttle services between cities are vital to the country's economy. That leads to a dense airport network with small aircraft filling the airspace. That puts a lot of pressure on flight control and ground services. It seems likely that technical development of aircraft is no longer the main factor limiting the evolution of aerial transport. Past fifty years the development of aviation has focused on increasing speed, capacity and range of airplanes. That is becoming less and less essential, as people flow to, from and inside the airports are the limit for air service growth.

Airports will shape business location and urban development in the 21st century as much as highways did in the 20th century, railroads in the 19th and seaports in the 18th.
(Kasarda 2018)

3.2 Aerotropolis

Another trend in airport development is their movement towards the city. Unlike harbors and railway stations, which have always been the centre of city planning, the airport has to be located far outside the downtown. The reasons behind this are mostly the safety hazard and sound pollution produced by aircraft, but also high value of the building ground. This means that in cities with large suburban areas the airport may be located tens, even a hundred kilometers from the city centre, and it puts a lot of pressure on airport transportation. With air travel getting safer and quieter, and in the future possibly AI-controlled and emission less, it possible to include airport as a part of urban landscape.

John Kasarda (2018) uses a term Aerotropolis to describe this kind of development and the type of future city it will lead to. Aerotropolis means basically a city built around an airport, with the main emphasis on providing services to support the functions of the airport. These cities have no history, but a smooth and efficient infrastructure.

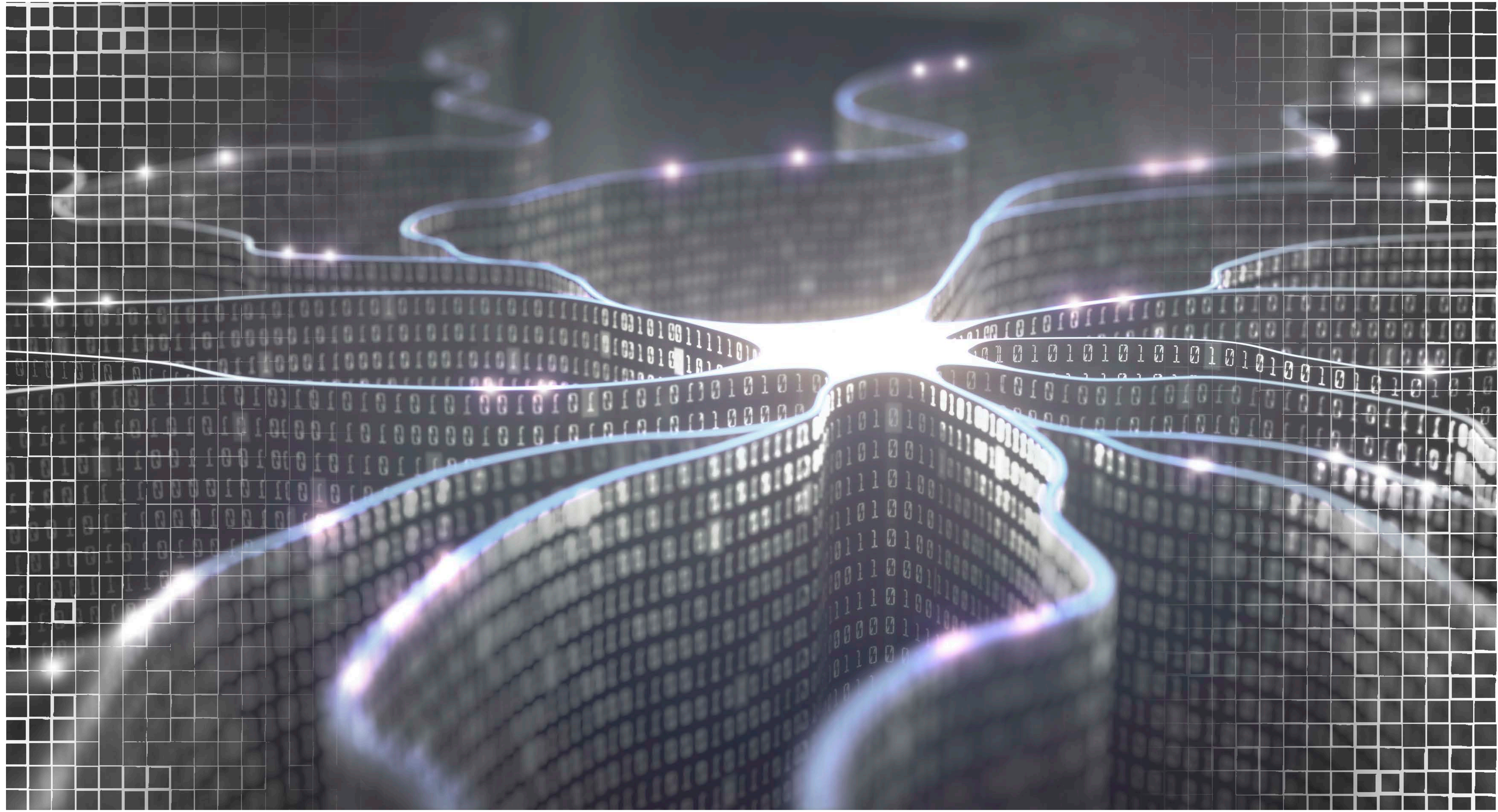
3.3 *Technological trends*

What will shape the flying machines of the future? Two great opportunities are offered by alternative power sources and artificial intelligence. Currently battery technology is under heavy development, but also hydrogen fuel cells are a potential solution for the upcoming energy crisis. Regardless of the power source used, both battery and fuel cell systems are user-wise almost identical. They produce no tailpipe emissions, so running the vehicle doesn't contribute to climate change directly. All of the emissions come from electricity production.

Both run on a clean and silent electric motor, so they can be used near population centers. Electric motor also provides some major technical advantages that will be processed in depth in later chapters.

Electric power is perfect for short distance shuttle services, as well as for increasingly popular narrow routes, which means long distance flights with smaller passenger volumes. Hauling fewer people with more units means increased flexibility and customization, but fills the airspace with larger quantity of aircraft. The downside of flexibility is the need for more controlled air and ground handling.

A mega trend that will surely answer to this need, and also reshape the whole way of living as we know it is artificial intelligence. In Canada, air traffic control is already streamlined by using direct communication between aircraft (Suokas 2019). This system utilizes a basic computing software, with some simple AI. For efficient and safe air traffic control many different factors contribute to the final decision, and these factors have to be constantly analyzed and ranked, and used to create alternative plans for action. Then again these plans need to be analyzed and ranked, and they affect and are affected by the preliminary factors, creating a complicated and constantly changing collection of options. Simple algorithms can be used for analyzing and ranking, but decision making requires a highly sophisticated AI. (Spencer 1989)



3.4 Swarm intelligence

Swarm intelligence is predicted to be one of the greatest trends in autonomous and semi-autonomous transport, and it is already used to streamline airline services. It means individual units acting independently, but for benefit of a single colony. When applied to aviation, this means essentially that instead of one large airliner hauling hundreds of people at once, smaller units can share a common route, but with customized schedule and destinations. While this may seem irrational at first, when applied to a larger scale the benefits are clear.

3.5 Downsizing

Airports have become one of the largest hotspots of modern transport infrastructure. There is usually only one airport per city, and some major airports serve multiple smaller cities. This leads to a situation where people flying from different parts of the world are gathered in the same point, where they are transported by road or rail to their separate destinations around the area. This makes the airport a bottleneck of passenger flow. While modern airports are relatively effective, it would be so much more effective if every passenger could be flown as close to their destination as possible. Quite paradoxically though, our current model creates a need for itself; large passenger volumes need big planes, and these in turn require long runways and lots of space and ground facilities to operate. Due to cost and space limitations, it is impossible to build multiple large airports for one area, not to mention locating them close or in downtown.

Building a whole aerial infrastructure solely on swarm model would mean disassembling the current aerial transport network and replacing it with small airplanes operating on a network of small, strategically placed airports. That won't likely happen any time soon, if ever, but the agile swarm model can be used to support and partly replace the effective mass model. It seems that we are looking at a future with a flexible but totally controlled infrastucture; An AI-controlled system where every flight is planned to meet their exact requirements. A system that uses small local transports, compact intercity shuttles and large intercontinental airliners. This is a future that would be flexible yet effective, and most importantly, completely possible. (Dagli, 2012)

3.6 *Civil aviation*

If we're looking at an age of agile, flexible and people-oriented aerial transportation, what will be the role of private civilian aviation? Sports and leisure flying is probably going to remain quite unchanged, but does precise computer-controlled system have room for truly customized, spontaneous traveling? And is it even needed anymore? In the past ages flying has been sort of a premium form of traveling. It offered speed and distance unmatched by cheaper road and rail transport. In modern globalized world speed and distance are no more considered a luxury. They are a standard. Flying is exhausting and expensive, but necessary evil for ever-growing middle class. People who can afford private charter flights or private aircraft are not paying for speed but comfort and flexibility. But if future air transport offers flexibility as a standard, why fly privately?

3.7 Tranquility

Comfort is one thing, but what's really worth investing is time. In hectic world of business and communication we have less and less time to stop and relax, and public flying certainly can't be considered relaxing. Even first class flying involves interaction with strangers, and on some level you must paint a presentable picture of yourself. Even private flying requires a hired professional pilot, a person who most likely isn't your family or one of closest friends. Only by flying yourself can you have a truly private vehicle, but flying is exhaustive and so removes the relaxing aspect. Fully autonomous aircraft, however would offer an undisturbed safe space, something completely private and peaceful.

Autonomy doesn't need to mean taking all control from user, because most people find driving a car relaxing and therapeutical, and same certainly applies to flying. AI would take care of safety by preventing crashes and collisions, and deal with air traffic control. Only when user wants to experience the true joy of flying, could (s)he take control, thus transforming the private space into a sports aircraft. AI could adapt to user's flying skills, so a pilot with only the very basic knowledge would be essentially just pointing the direction and giving instructions, more like a commander of the plane instead of pilot. Seasoned pilot with real skills would have a complete control over their vehicle, and AI would act as a failsafe mechanism and communicate with other traffic.

3.8 *Aerial exoskeleton*

A vehicle with user working seamlessly with AI puts a lot more pressure on user experience design than one which is just an autonomous transport capsule. To be agile and fun to fly, it needs to be as small as possible, so it won't have the luxury of making passenger compartment a separate space. Instead, the same, very limited space needs to act both as a living room and a cockpit. Luckily it doesn't have to act as both at the same time, but instead transform between two modes, a flight mode and a passenger mode. In passenger mode it needs to have as little feeling of control as possible, and vice versa. Most of the controls and instruments need to blend in the interior, and those that don't can be hidden when not needed. In flight mode these same instruments have to stand out and the controls will provide a seamless connection to the vehicle.

It doesn't have to be a physical transformation between modes, but a mental one. The vehicle can give a sense of flight mode for example by altering the lighting and transparency of windows, illuminating instruments and turning the pilot's seat.

3.9 SWOT ANALYSIS

Strengths

The main advantage of an electric flying boat is the ability to land on the surface of water, so the rising sea level is about to turn majority of earth's surface area into a runway. Electric motor not only provides emission-free movement, but has a thrust curve very different from a combustion based system. The huge amount of static thrust greatly improves water and ground handling, and gives greater control in take off and landing. Advantages of batteries over fuel is the absence of flammable liquid and the weight of the battery remains unchanged, so they can be located far from the center of gravity, or even asymmetrically.

Weaknesses

In order to take off from water the hull needs to be shaped to provide enough buoyancy and stability. It also has to be structurally strong to withstand waves and rougher landings. All the panel lines and openings such as landing gear doors have to be watertight. All of this adds to weight and drag of the hull, and though a lot can be done to reduce these disadvantages, designing a flying boat will always be a matter of compromise between good water handling and aerodynamic performance, and so it can never be a direct rival to a landplane. Being constantly in contact with water, especially saltwater, corrodes the components quickly, so they need to be protected from moisture and serviced frequently.

Opportunities

The water hull is by default wider, and that can be used as an advantage in interior design. Electric power system allows an easy installation of an auxiliary motor, for example water propulsion or bow thrusters. From a design perspective sea as an environment creates whole new opportunities. A journey on an airliner is a holistic experience that involves interacting with multiple different spaces, such as airport terminals, cafes, lounges, trains, buses and taxis. In order to make this journey pleasing and easy, all these spaces, including the airliner, have a similar atmosphere; they have a certain sense of movement, a public space designed for temporary stay. Users of these spaces are supposed to feel comfortable and safe, but never at home. The aesthetics of a boat, or a flying boat, however may include nature and nautical motifs that would feel completely out of place in middle of hectic transportation infrastructure. In the middle of the sea, with not a soul nearby a feeling of serenity is a default, and the vehicle can amplify this feeling.

Threats

Operating outside the infrastructure is obviously risky. In event of an accident getting help is difficult and slow, and the quiet calmness of the sea can turn into a deadly hazard in matter of minutes. As September 11 attacks and Malaysia Airlines Flight MH-17 prove, war, terrorism and other forms of hostile activity can present a threat to even safe and controlled large scale aviation. Compared to these acts of mass murder, hijacking or destroying a vulnerable private aircraft in a remote location is extremely easy. Since installing defensive armament in civil aircraft is clearly neither an answer nor an opportunity, the only way to protect such an aircraft is to provide it with certain level of invisibility. This means sharing the data of it's type, destination and passengers only with trustworthy parties such as air traffic control. Also a possibility of cloaking it from illegal and unlicensed tracking systems has to be researched. Some unintended accidents, like a collision with a dam or an offshore oil rig might lead to a large scale catastrophe, but these should be averted with the aforementioned AI-failsafe mechanism. A grim topic of intentional accidents, such as terrorism and murder-suicides lead to a difficult but fundamental question of autonomous vehicles. How much authority are we willing to give the AI? In a situation where the decision must be made between sacrificing the passengers and risking bystanders, what will the decision be, what will it be based on and most importantly, who makes it? Are we ready to give computer more power than to a human?

4 DESIGN PROCESS

4.1 Design vs technology

One of the goals of this process is to research how modern technology and design can affect such an engineering-led area as aeronautics. An argument widely used is that present-day aircraft is already perfect as it is. The argument usually refers to modern airliners, and from the traditional engineering point of view it is true; there are neither certain faults in the design, or any layout or shape that would be clearly better. The truth is, however, that humanity has yet to perfect any of it's inventions and the modern airliner, based on a design from 1960 is certainly one of them. Aircraft design hasn't always been a fully engineering-first process, and neither is it today. It will reach that point only when we can design the ultimate form, the ideal aircraft. And even then there's room for design. Humans are, and will always be imperfect, and as long as a human is involved, nothing designed solely to meet the technical requirements can be truly perfect.

4.2 Emotions

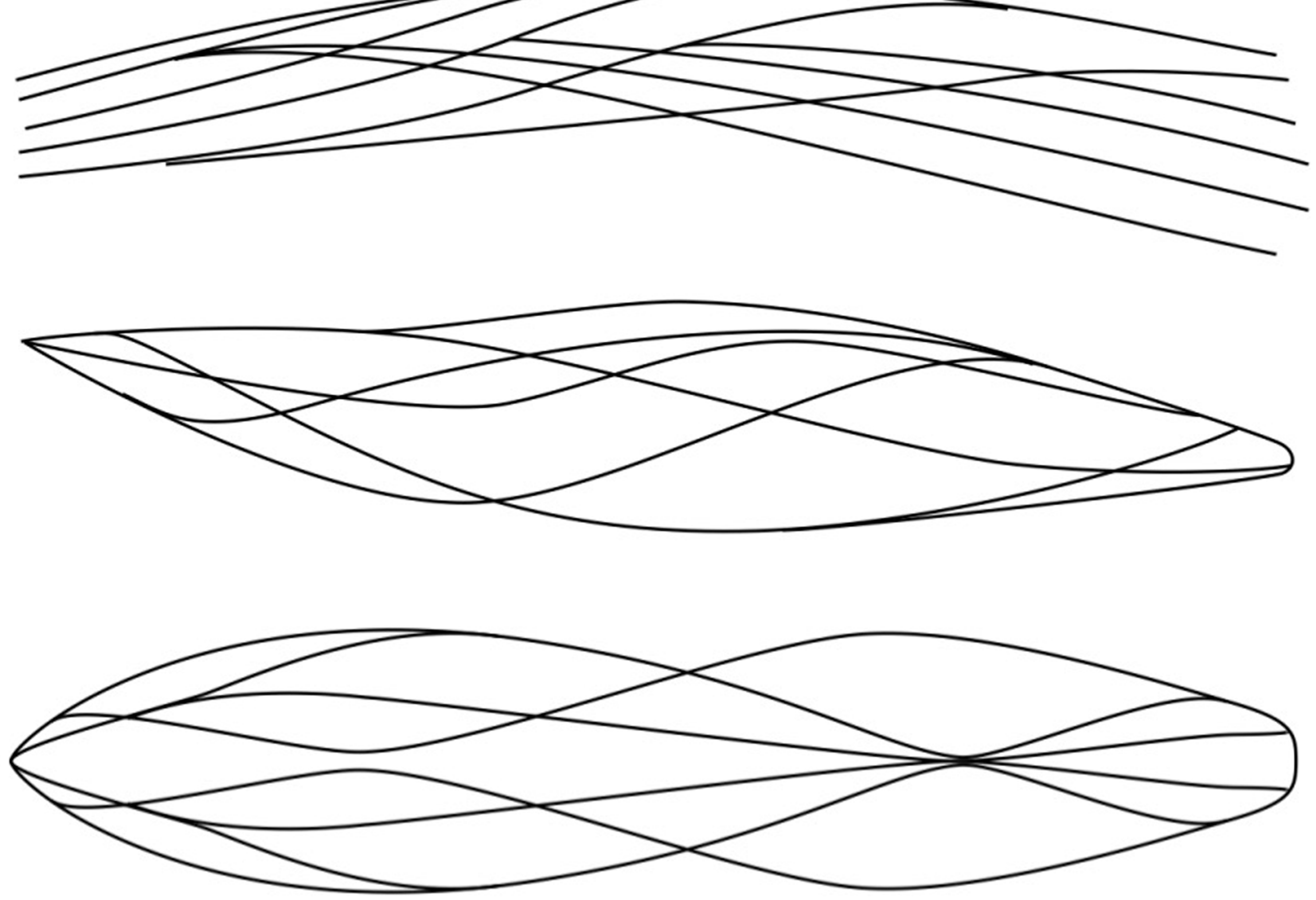
Human beliefs and emotions have always shaped the overall evolution of aviation. All the major components, like wings, tail and engine are designed according to their technical requirements because these parts can be researched, analyzed and ranked precisely, but how about the rest? How to attach wings to the body? What shape should doors take? And most importantly: how to make sure the user, whether pilot or passenger gets a maximum benefit from the plane?

History of aviation is full of examples that show that sometimes simply the image of some aircraft can lead to it's success or ultimate failure. The best known example is the crash of airship Hindenburg that led to almost complete disappearance of airships even though they are completely safe. Or one of war history's most romanticized events, the Battle of Britain where brilliantly designed Hawker Hurricane was surpassed by Supermarine Spitfire's sweeping shapes and awe-inspiring lines (Laurier, 2016, 38). An event that led aerial transport to the jet age took place in 1955, when test pilot Alvin "Tex" Johnston performed a barrel roll with a Boeing 707. Importance of the stunt has since been underrated, but years preceding it Boeing had failed to sell any of it's jetliners, and almost immediately after it became one of the biggest commercial successes in the history of aviation. (Lacitis 2015)

4.3 Algorithms as designers

Anything can be done as well as absolutely possible, but that doesn't happen by accident. In order to do so, one must consider every aspect from every angle, and understand how every single decision affects every other decision. When pursuing something truly perfect, the design process can't be a linear one. A vehicle, like any other product can't be designed from inside out, or from front end to rear. The whole process should be sort of a non-chronological one, and the design of every part should begin at the same time as project starts, and be finished when project ends. Every part, aesthetics, engineering, economy and manufacturability should be viewed as equal, supporting aspects, instead of separate, conflicting issues.

Algorithms are sure to reshape the design process, and they are already being used in different parts of vehicle design. An open algorithm written by Rafael Matsunaga (2019) creates random cars and compares and improves their properties in different enviroments, leading to the best possible solution. This algorithm focuses only on a very narrow part of car design, but in the near future these kinds of algorithms could be combined into a massive one that takes every part of the design into account. Despite the huge potential it offers, I still believe there will be room for human emotions and traditions. It will take decades before absolutely everything can be calculated. In this project I am not going to use algorithms, but mimic the appearance of an aircraft that could have used algorithms as a part of structural design.



4.4 Marketing

The Piaggio P107 aims at the same market share of lower end private jets, but electric flying boat won't be able to beat them in speed, so other aspects need to be emphasized. Being so different from traditional business jets, it would be unwise to try and take over their segment. Instead it's special characteristics can be utilized to create a whole new segment. Despite offering first class comfort, it has the soul of an undeveloped area air service, an aircraft commonly known as a bush plane.

Although it isn't uncommon to upgrade a bush plane with a luxury interior, these type of aircraft are always designed and marketed as functional workhorses. The P107 is not designed as a thoroughbred bushplane since it still needs a paved runway for land operation, but the ability to land in water gives it a certain adventurous off-road stance.

Business jets and bush planes very rarely share a common user group, but two new groups can be formed from these users. One is people who absolutely need regular transport to remote locations, but want comfort and tranquility not offered by a common bush plane. This group will benefit from a lounge-style interior and a high level of autonomy. The other consists of people who expect a luxurious and stress-free travel, but enjoy the thrill and freedom of sport aircraft, speedboats and sportcars. Serving this need requires sporty appearance and great handling characteristics.

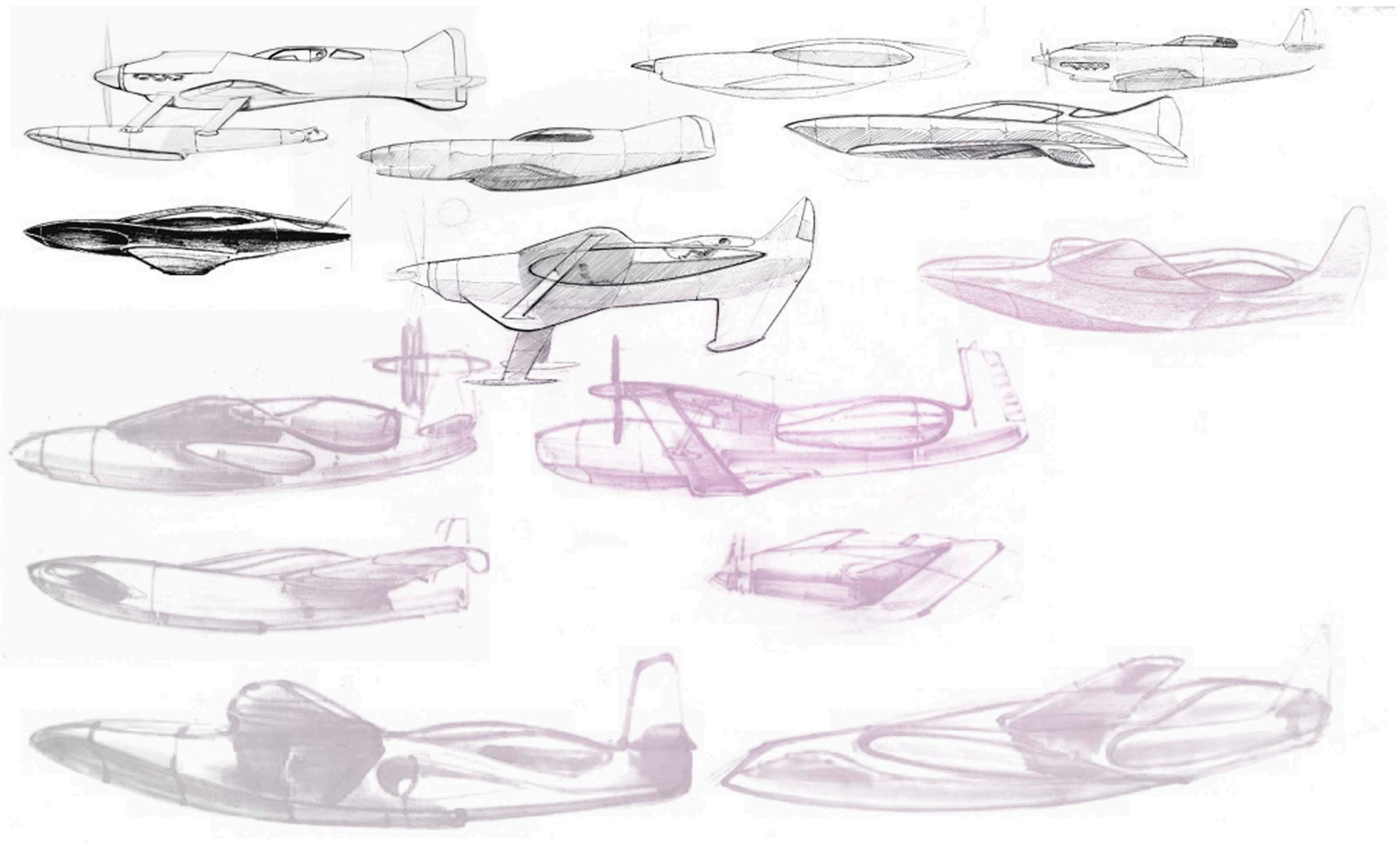
The former group of people wealthy people who need access to remote locations is very small, so this project will focus mostly on the latter. That group does not require transportation to remote locations, but will greatly benefit from the ability to operate outside the infrastructure. They can save huge amounts of time by entering a city from harbor instead of an airport. A survey conducted by Business Jet Insider states that the most important reasons to fly privately are time savings and the ability to use airports not served by airlines (Gollan, 2018). Other important factors are the ability to use the aircraft as a flying office, both for working and holding business meetings en route, but also as a refreshing space to relax and spend time with family or alone.

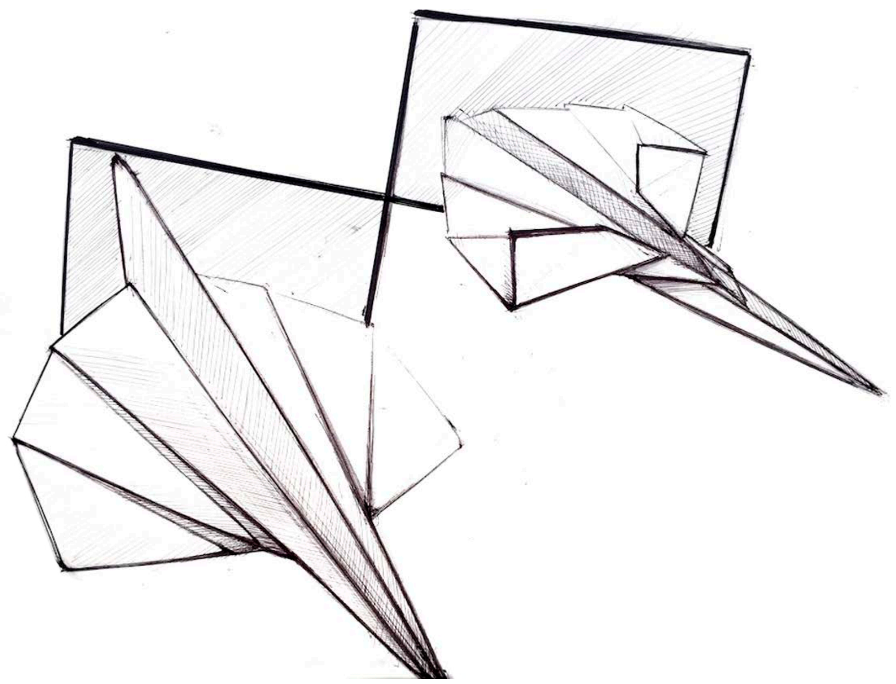
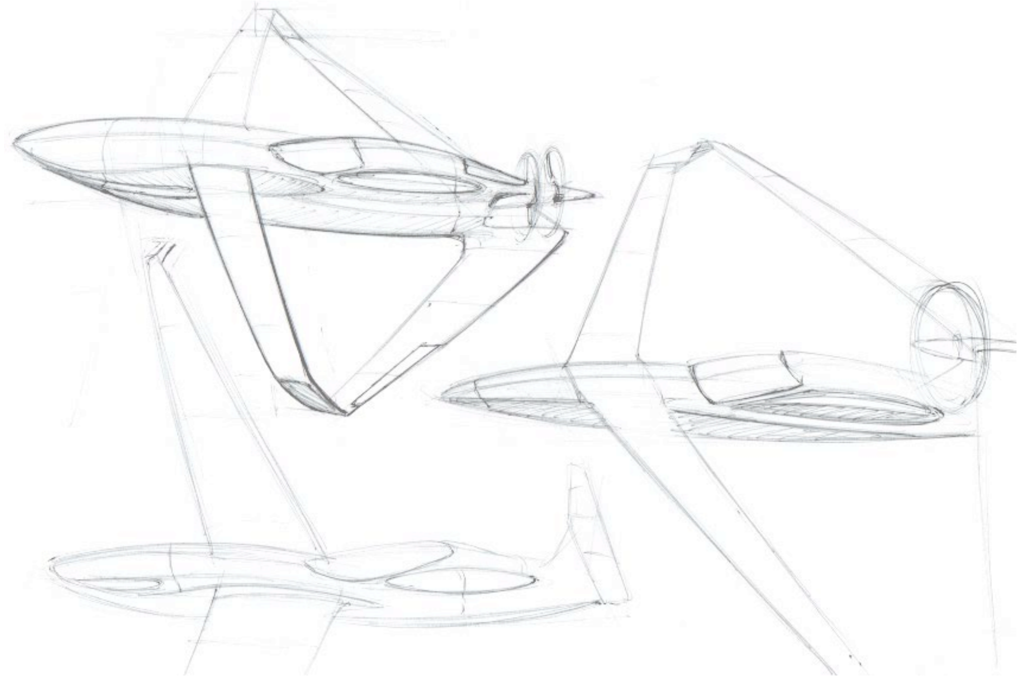
4.5 Final brief

The design process started by defining the design criteria. I used post-it notes to find out every requirement for any type of aircraft and ranked them according to what I believed were the most important. These were comfort, speed and long range, with less value given to cheap price, compact size and versatility. Rest of the year was spent benchmarking and doing research about the future of commercial aviation. This process led to final brief of electric luxury flying boat with focus on design, and how the same innovations that are shaping automotive industry will affect aviation.

4.6 Benchmarking

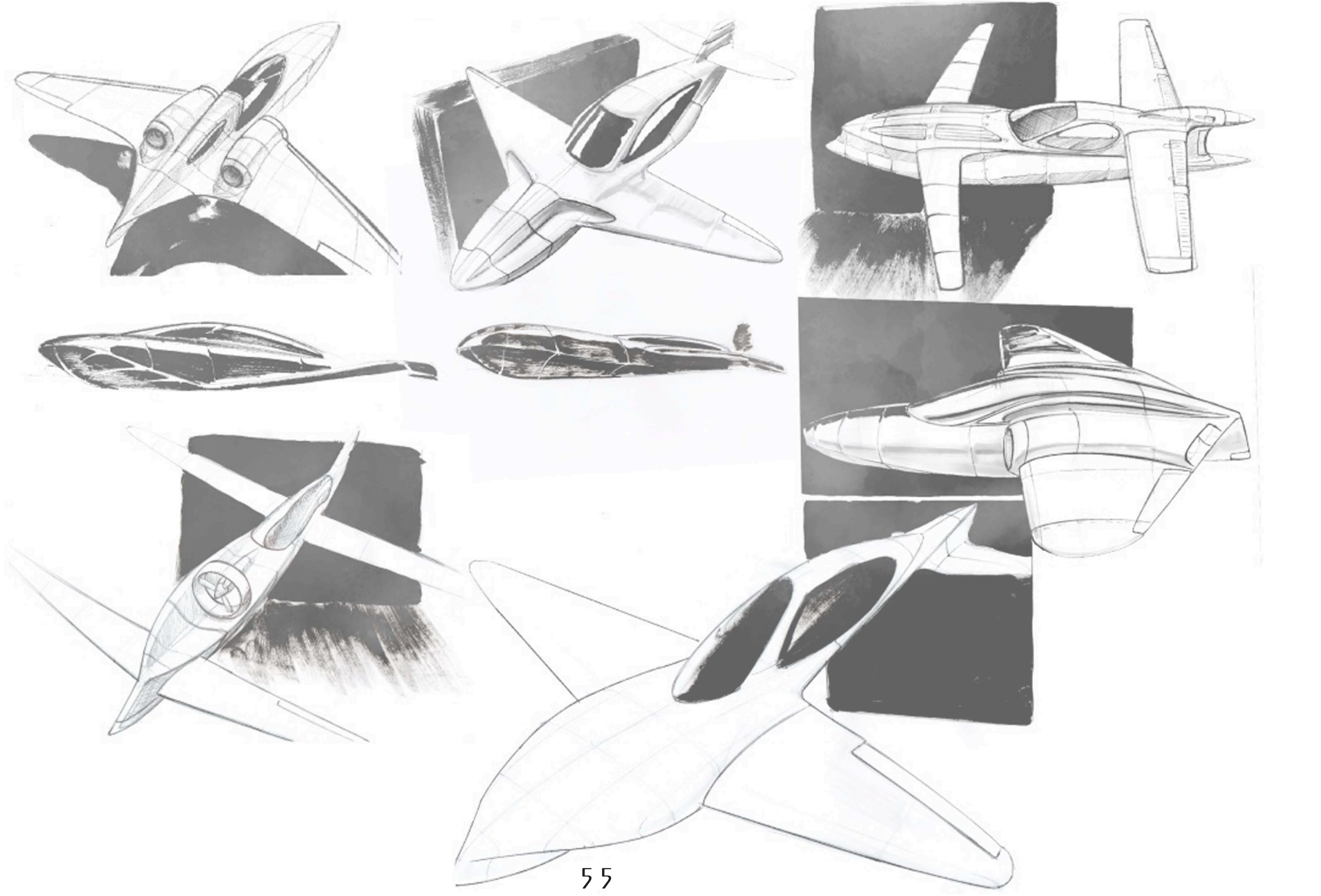
In benchmarking I focused on past and present vehicles, that share common characteristics and user groups as this project. An important part of my brief was some historical inventions that could be resurrected with modern technology.



4.7 Layout & Package

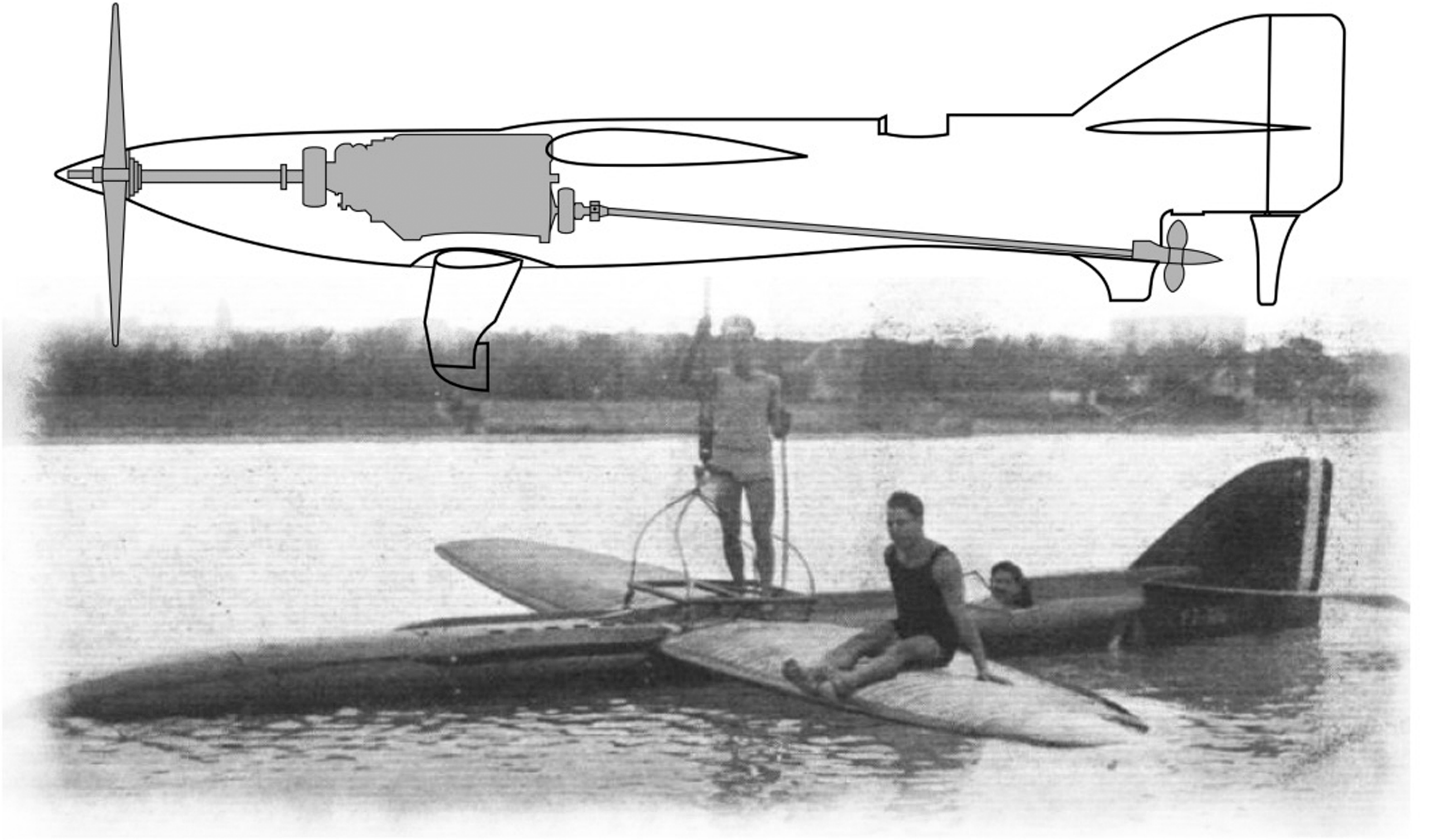
I started the sketching process by experimenting with different interior and exterior layouts. At this stage I used the research from earlier stages as guidelines, but didn't let them limit my creativity. Although I was pretty confident about the feasibility of an electric flying boat, I also thought about different types of aircraft, such as landplanes, jets and flying wings. The only demand I had at this stage for my proposals was that they had to be believable and attractive.



4.8 The Brand

Piaggio Aerospace is a sub-brand of Piaggio C. & SpA. Though Piaggio is best known from it's scooters, before WWII it manufactured mainly aircraft and aero engines. Even the legendary Vespa scooter is designed by famous aeronautical engineer Corradino D'Ascanio (Piaggio Group, 2019). Piaggio Aerospace is an ideal brand for an elegant private flying boat, since it is one of the only still fuctional aircraft manufacturers with roots deep in the golden era of floatplanes. Italian racing heritage has long been part of company's brand image, an image further intensified by former front man Piero Ferrari. For benchmarks I chose three particularly interesting products from Piaggio; one of them is a highly innovative concept, the other an amphibious bush plane and the third an elegant private turboprop.

Piaggio-Pegna P.c.7 was a racing seaplane designed in 1929 for Schneider Trophy race. Although never flown, it was an innovative take on floatplane design, and one of the first attempts to reduce the aerodynamic drag created by floats or water hull. Instead of conventional floats it utilized two hydrofoils, and a complicated system of both air and marine propeller driven with a single engine via twin clutch assembly. The project was cancelled due to reliability problems with clutches and structural weakness of the hydrofoils, but the idea of hydrofoil as a part of seaplane design is revisited occasionally. (Aircraft Enthusiasts' Group, 2019)



Piaggio P 136 is an twin-engine amphibian designed in 1949 an an utility aircraft. Though robust hull design and short take off and landing capabilities make it an ideal transport for remote locations, most of them are nowadays used as aerial yachts, comfortable leisure aircrafts with spacious interior and a long range. (Cook, 2016)

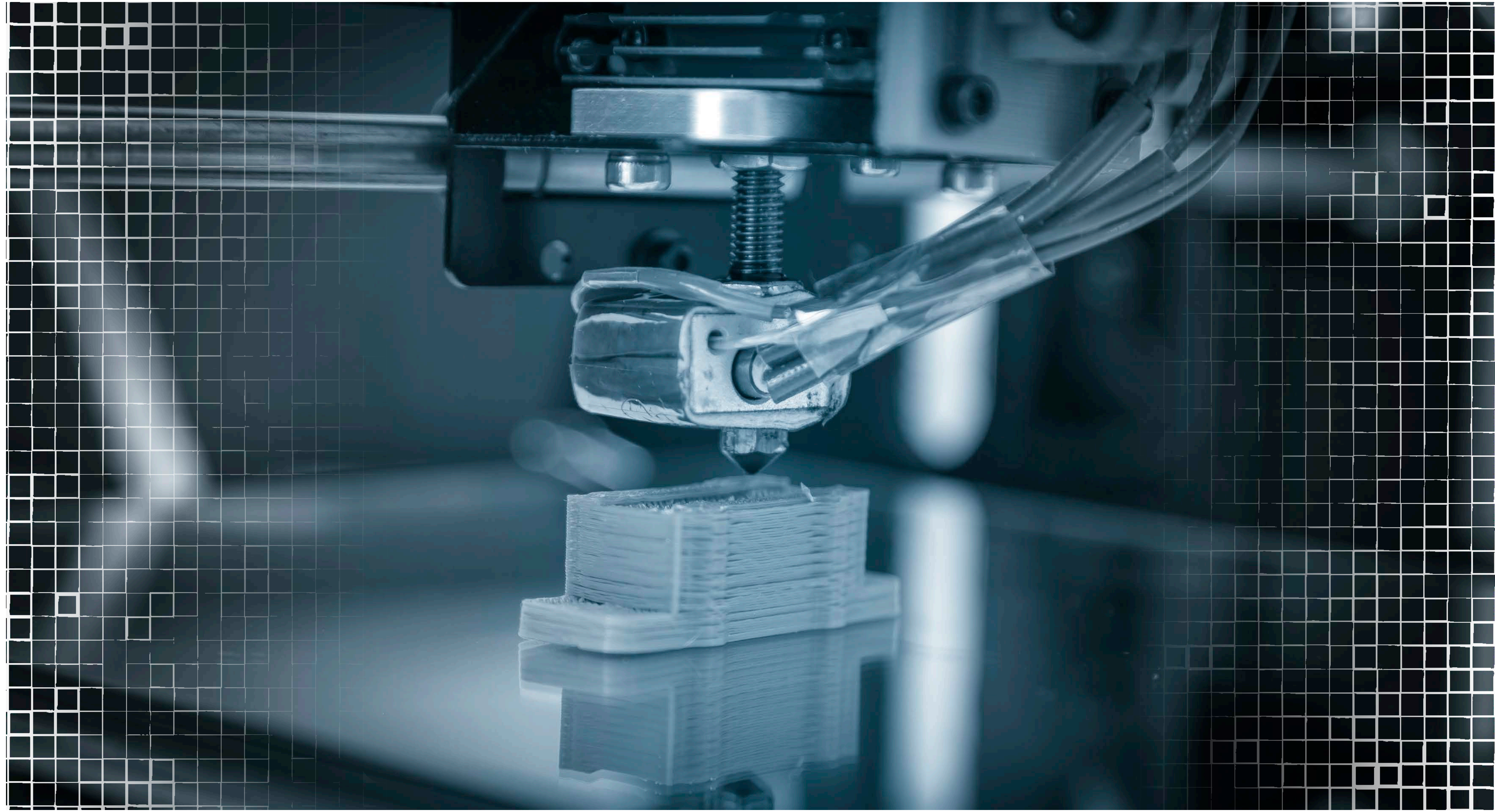
Piaggio P180 Avanti is a turboprop business aircraft with three lifting surfaces. The unique canard-and-tailplane configuration aims for laminar airflow and reduced drag, but Avanti is an airplane that truly distinguishes itself with awe-inspiring lines. Avanti's interior atmosphere and the front windows give the aircraft an unique expression.

Piaggio Aerospace uses a relatively irrational naming policy, and there is little information to be found of prototypes that never entered production. As P.180 is the only current production model, the name of the new flying boat should share some similarities with it. It would be risky to name it P190 as Piaggio Aerospace is currently developing a business jet with a project name P1XX, and that may become P190 when it enters production. I decided to go backwards with naming to paint an image of a much lighter aircraft that draws some of it's aesthetics from the past. I settled upon P107, as it homages the P.c.7, but sounds closely related to the 180.

5 TECHNOLOGY

5.1 Additive manufacturing, addictive design

The best known form of additive manufacturing is 3D-printing, but essentially it means all sorts of fabrication processes where material is added precisely to build up the final shape of the object. Traditional manufacturing processes are based on standard mass-produced parts, that are cut, bent and joined to form the final shape. This obviously limits the design opportunities as every object is limited by the availability and quality of these parts. Current aircraft design is seen as a multi-volume process, where one volume, such as wings, body or tail is designed at a time, and these volumes are then joined together. The most effective way of working would be to handle the object as a single volume, a shape that bends and stretches to form an ultimate shape, an ideal aerodynamic form that serves its purpose as well as possible. I tried to used this kind of process, but the goal of this project was not to create an ideal aerodynamical form. I used the possibilities of additive manufacturing to sculpt a single volume that forms both the interior and exterior. At some separate parts, like rear wing, motor pod and vertical stabiliser the traditional multi-volume processes still proved to be the most effective way of working.



5.2 Framework

Framework is a fundamental part of any aircraft design, and the two major types used are a truss and a monocoque hull. Former means a frame welded together from steel or aluminium tubes, with the sole aim of providing enough structural strength with minimum weight. Bodywork and interior are then installed on top of this frame as separate components. Truss is clearly lighter, but it can not be seen as very effective, since from structural point of view the outer body is just dead weight, serving only cosmetic and aerodynamic purpose. The latter and nowadays more popular type means that body panels carry all the weight and stress, making an internal frame obsolete, and freeing interior space for passengers and components. It’s effective since structure, aerodynamics and cosmetics are provided by a single component, and even the interior can be molded as a part of the hull. The main disadvantage of this type of construction is that due to manufacturing process structural support is added also to places where it is not needed, making the hull heavier. A popular compromise is called semi-monocoque, that is essentially a lighter monocoque with added structural struts.

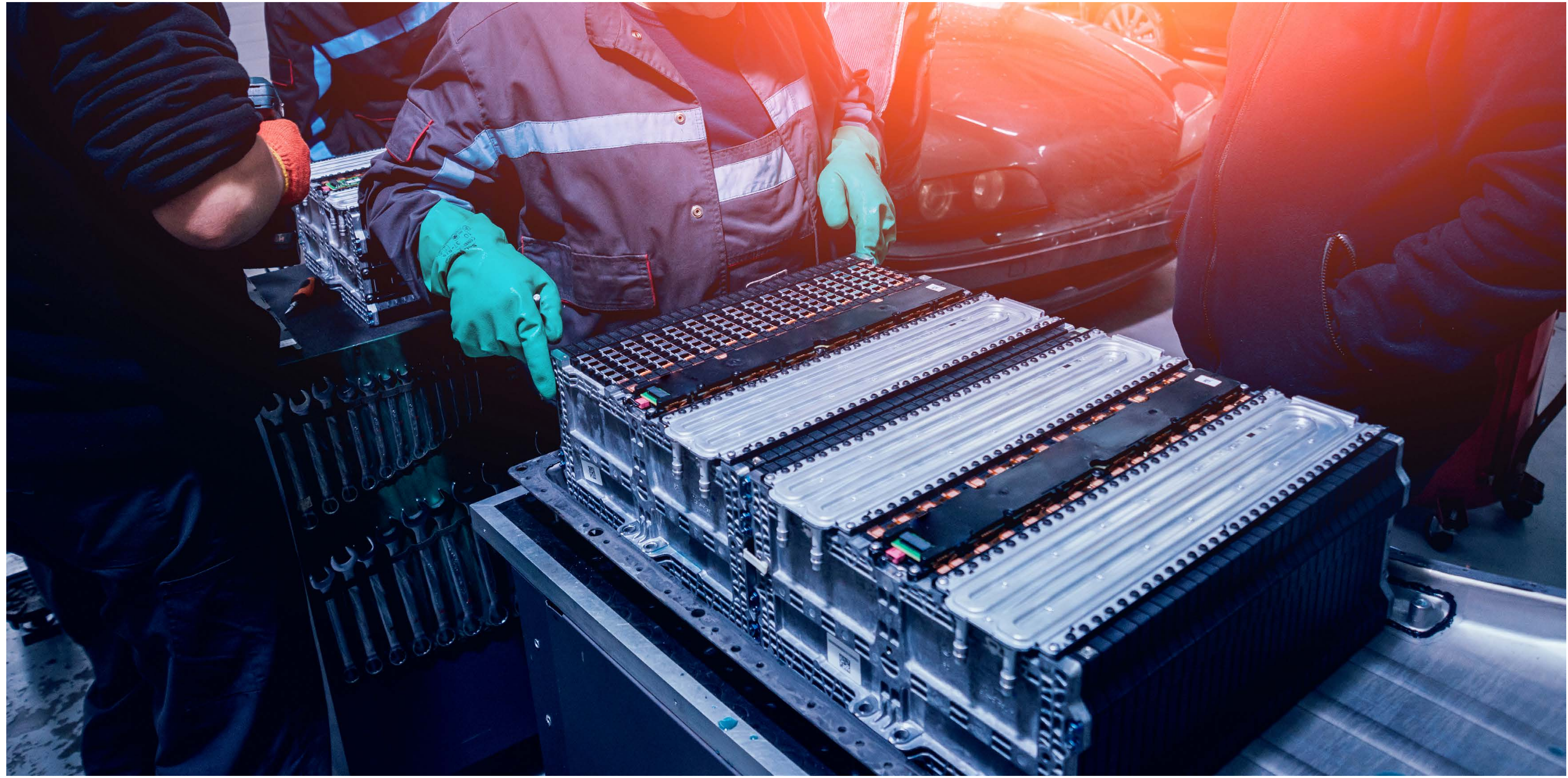
For this project I had an idea of kind of an external truss structure, a carbon fiber structure build with the same technique as a monocoque, but engineered to provide structural strength only where needed. The structure would form the shape of the body, but rely on external panels to form the final skin. This way it would have the lightness of a truss fuselage, but the effectivity of a monocoque. A similar construction known as unibody is widely used in automotive industry, but an aeronautical application would differ from it greatly, mostly due to different proportions and structural requirements of these vehicles.

It's been known for centuries that the most rigid structural form is a triangle, but with carbon fiber these triangles can be modified and styled without sacrificing strength. Different properties can also be achieved by variating triangle size and shape, so the whole frame can be designed to have optimum rigidity or flexibility in right locations. The wing root or tail plane assembly, for example, need to be rigid in order to provide sharp control, whereas wings and water hull benefit from some level of flexibility to withstand aero- and hydrodynamic impacts. The design of such an optimal frame can greatly benefit from use of an advanced algorithm and simulation.

5.3 *Battery technology*

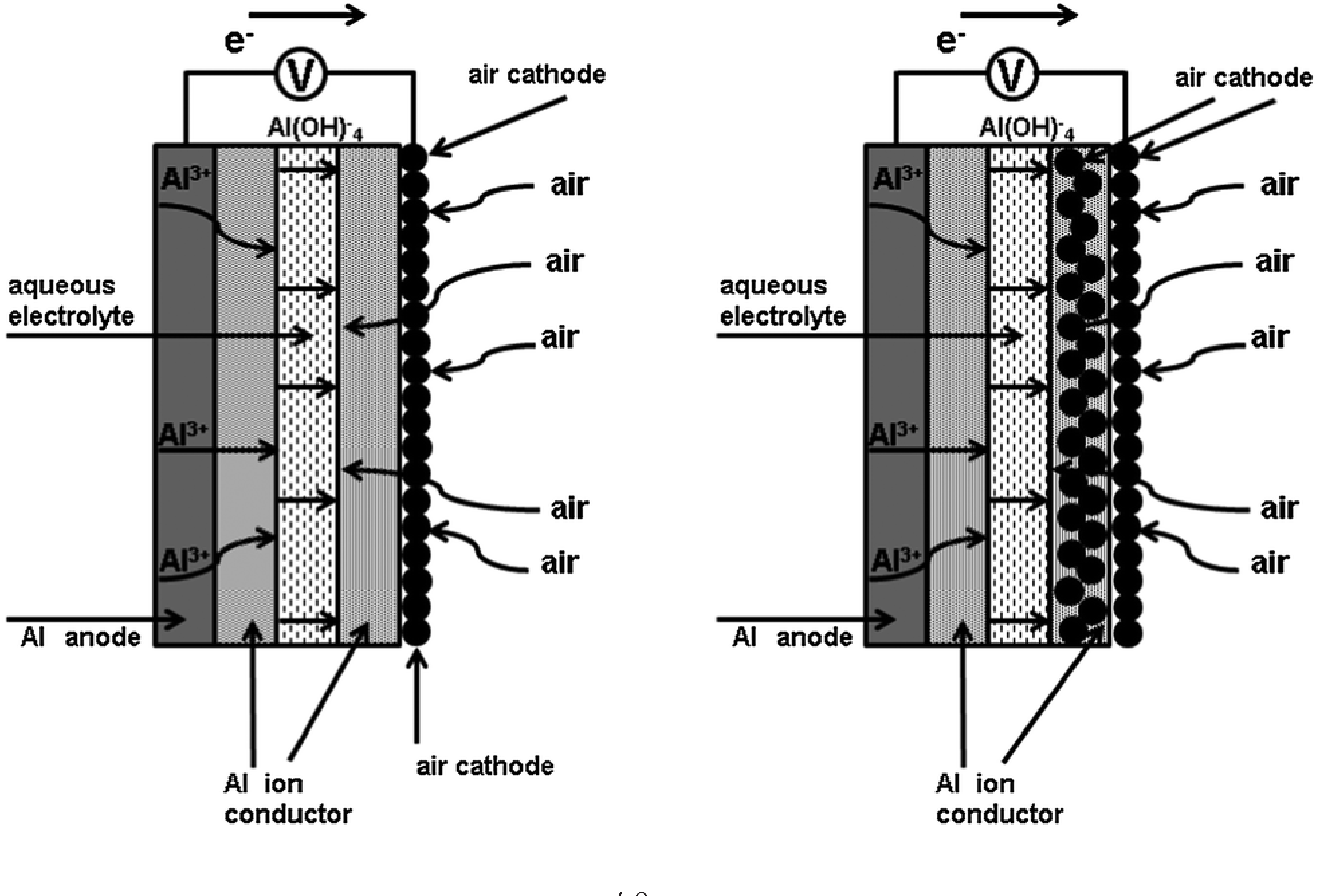
Battery technology is bound to advance, but it's yet too early to state which type of battery will be best suited for this type of vehicle, or will nitrogen fuel cell replace battery as a dominant power source for an electric vehicle. Battery chemistry is irrelevant for this project, but different battery architecture can affect the design directly. Vast majority of present day electric vehicles rely on non-removable packs that are filled by charging.

However, there are different battery types that show a great promise to future EV's in general, and three of them are particularly interesting from this project's point of view. One is a conventional chargeable pack, that is removed from the vehicle for charging. So instead of charging the vehicle, the empty battery can just be swapped for a full one. The downside of this system is that it requires a standardization of batteries, as well as a high infrastructure for swapping and charging them.



Another new battery type is an aluminium-air battery, that benefits from using air as a cathode, giving them a superior theoretical energy density of 13000 Wh/kg compared to current lithium-ion batteries (100-200 Wh/kg). Although they take a lot of space, light weight makes them ideal for aeronautical applications. A huge issue with the type is the fact that they are not rechargeable, so aluminium anodes need to be replaced and hazardous byproducts recycled. (Liu, Sun, Li, Adair, Li, Sun, 2017) Aluminium is relatively common and recycleable material, so it is possible to create an efficient and ecological process to supply new anodes, but it will only work if this type of battery becomes widely used. The aluminium-air battery seems like a potential candidate to power a flying boat of future.

It is also possible to use carbon fiber both as an anode and a cathode, in a manner that the hull of a vehicle can double as a battery. An issue with this so called structural battery is that strong carbon fiber currently used in aircraft industry has too weak electrochemical properties to work as a battery. Weak but well conducting carbon fiber is still a bit harder than steel, so structural batteries will undoubtedly be a great benefit to future EV industry. (Szymkowski, 2018)



(a) (b)

Royal Society of Chemistry, 2014

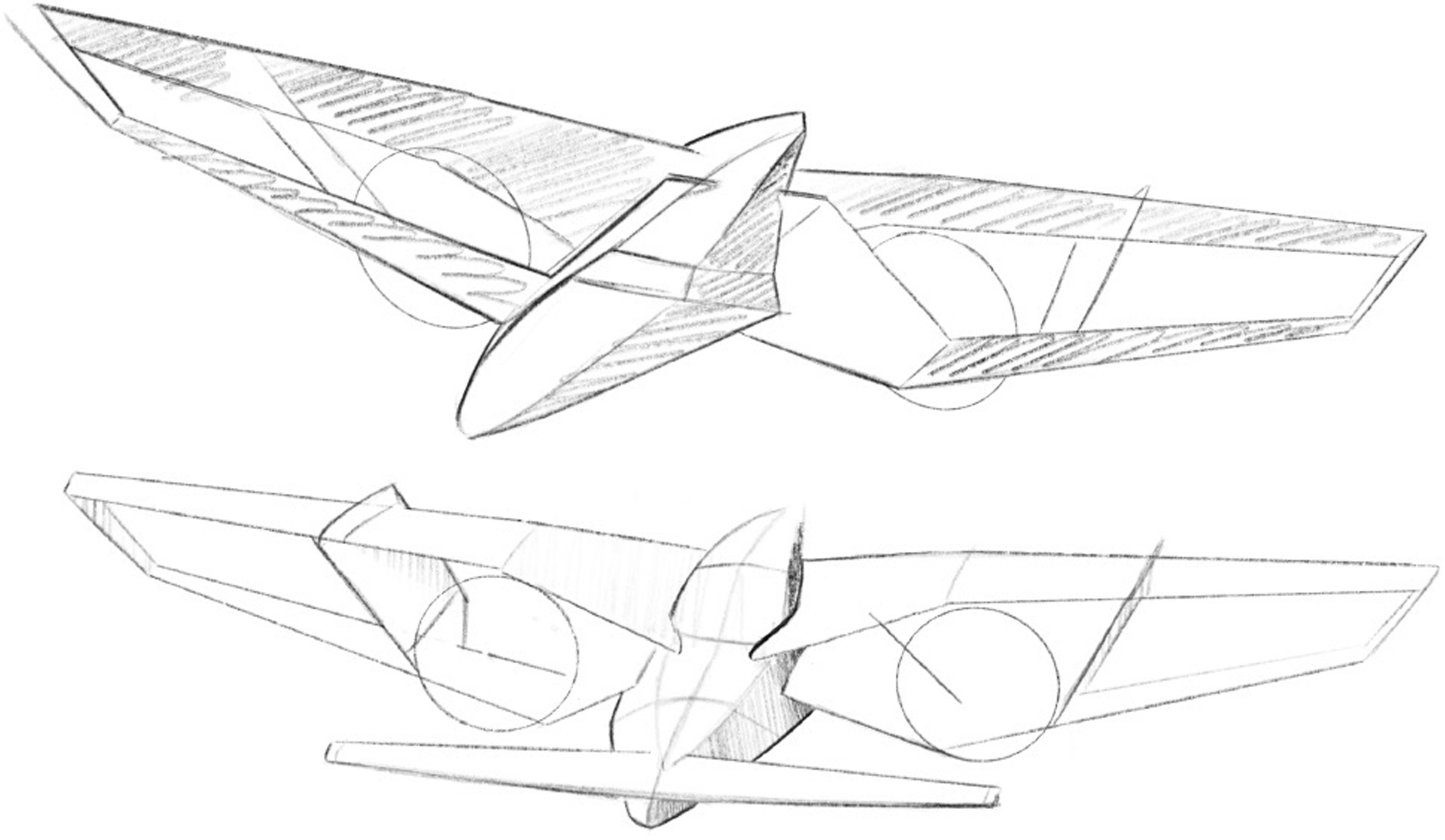
5.4 Hydrofoil

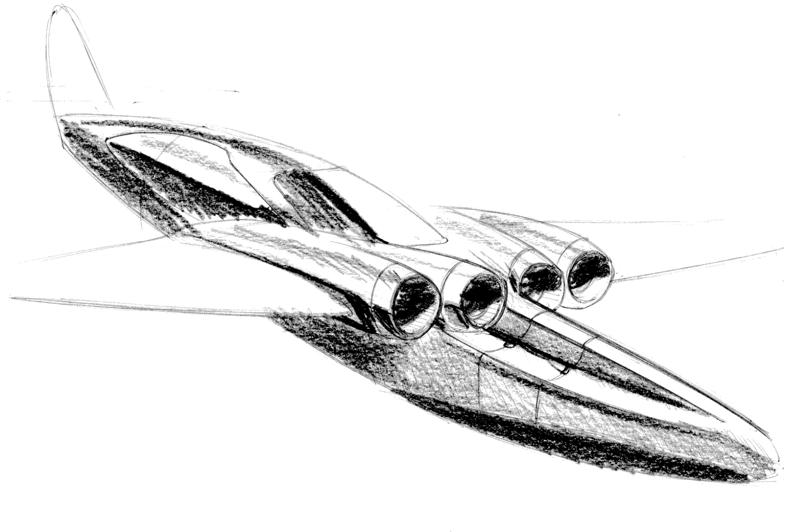
One of the earliest parts of my brief was to research some past innovations of aviation industry and to find out if they could be beneficial for the future. The history of aviation is full of concepts that were excellent at solving some problems but had to be abandoned due to technical or economical reasons. Some of them could be resurrected with modern technology and I strongly believed that hydrofoil could be one of them. It was used in Piaggio P7 to solve the aerodynamical problems created by floats, and these problems still need solving ninety years later. P7 failed mostly due to problems with clutches, but that wouldn't be a problem with electric power. With hydrofoils, the hull could be shaped according to aerodynamical guidelines and remove the weakest point of a seaplane. Hydrofoils are relatively small and flat, so they could be retracted in hull in a similar manner as landing gear. A French company LISA Airplanes uses hydrofoils in their seaplane Akoya, and the boat industry sees hydrofoils as a strong opportunity for future transportation. Hydrofoils offer low drag and smooth ride as they work beneath the waves.

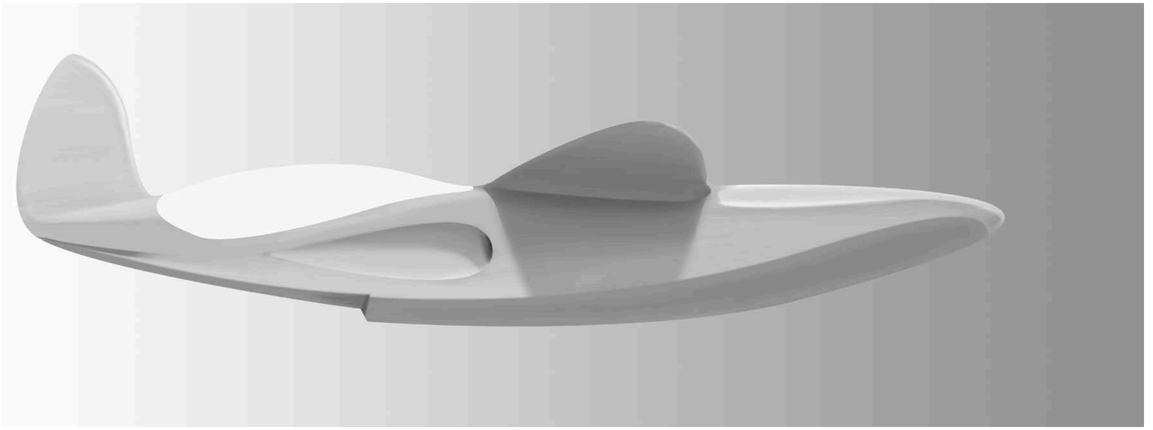
I abandoned the idea of hydrofoils after an interview with M.Sc. Aki Suokas. Mr Suokas stated that hydrofoils are an idea that surfaces on regular basis, but rarely get into production due to structural limitations and high impact forces directed to them. He also verified my assumption that the angle of attack is critical to hydrofoil. Too high angle may lead to forces that may break the airframe, and too low to aircraft diving. (Suokas, 2019)

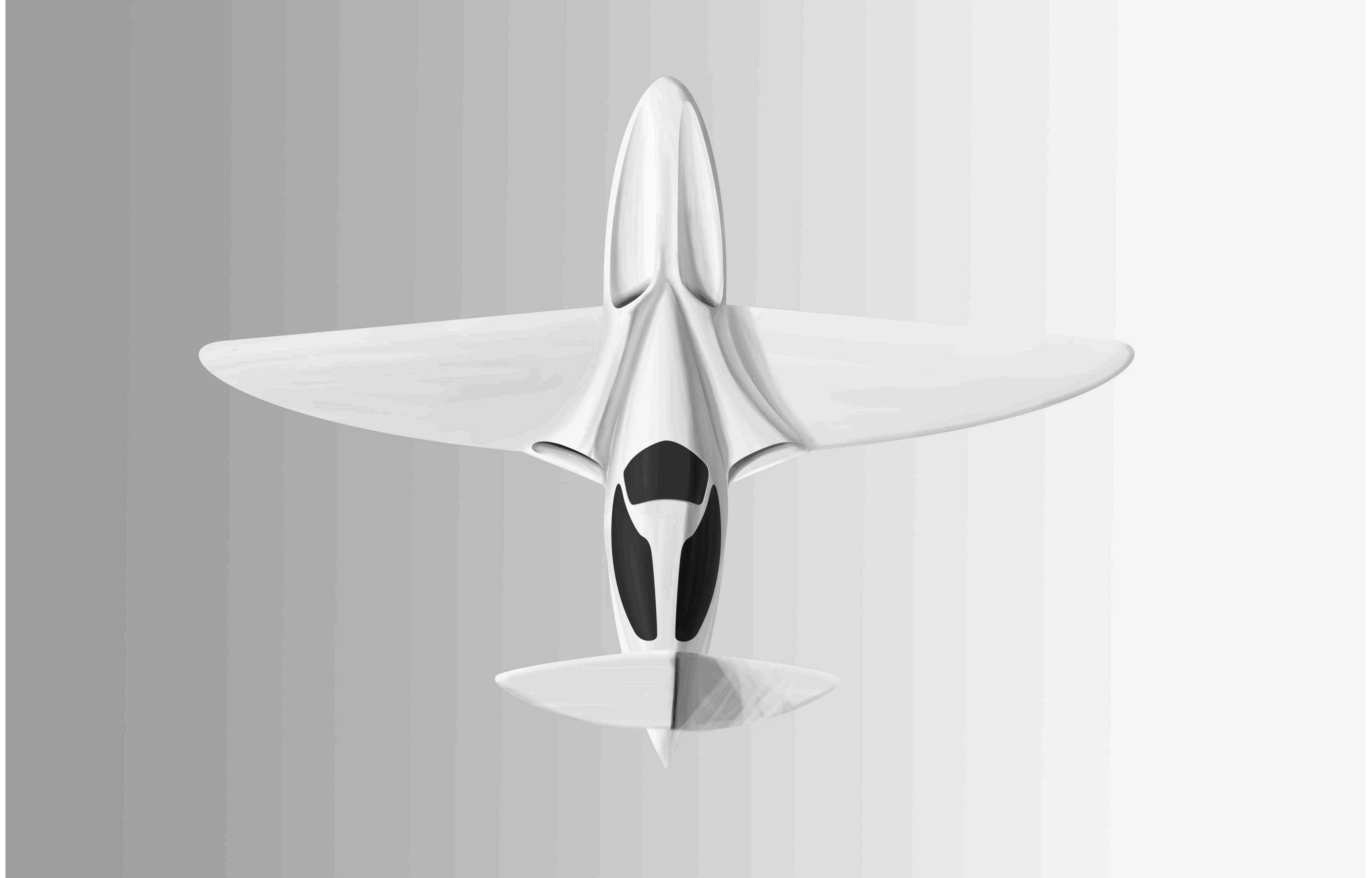
5.5 Wings

I started the wing design with a traditional layout, a monoplane wing in the middle, and stabilizers in rear. As requirements for power source and flight characteristics cleared I started moving towards more unorthodox constructions. A promising one was a sesquiplane with canard wings: a biplane with wings at rear end and horizontal stabilizers in front (pictured). Lower wing would have had a surface area less than half of upper wing, and two electric fans were to be installed in between of the wings. This layout would have resulted in high static thrust with agile handling and unobstructed view to front. Though biplane as a default offers good short take off and landing characteristics, canard wing is not ideal for slow flying due to the instability it creates, and biplane creates high amounts of drag, reducing cruising speed dramatically.









Another layout that affected the final form had turbojets or electric fans embedded in the wing and air intakes in the gap between wing and the hull (pictured). This was completely different from the previous model, as streamlined forms would have been effective on high speeds and altitudes, but small turbojets are extremely ineffective in low speeds and low static thrust would have made water handling tricky. The most important part of this design, the one that lived on on subsequent models was the blending of wings and body, and the frontal area of the water hull that was shaped to act as a lifting surface.

The layout that can be seen as the basis of current form, is one with tandem wings and a tractor propeller in front. Tandem wing has the same lift characteristics as a biplane, but with much less parasite drag. On the downside, because of longitudinal distance between wings, induced drag may be higher, resulting in inferior slow flight characteristics. However, looking at the uses of this aircraft, these are less essential.

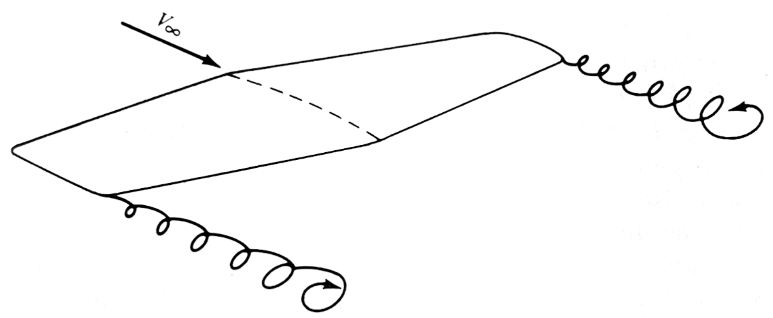
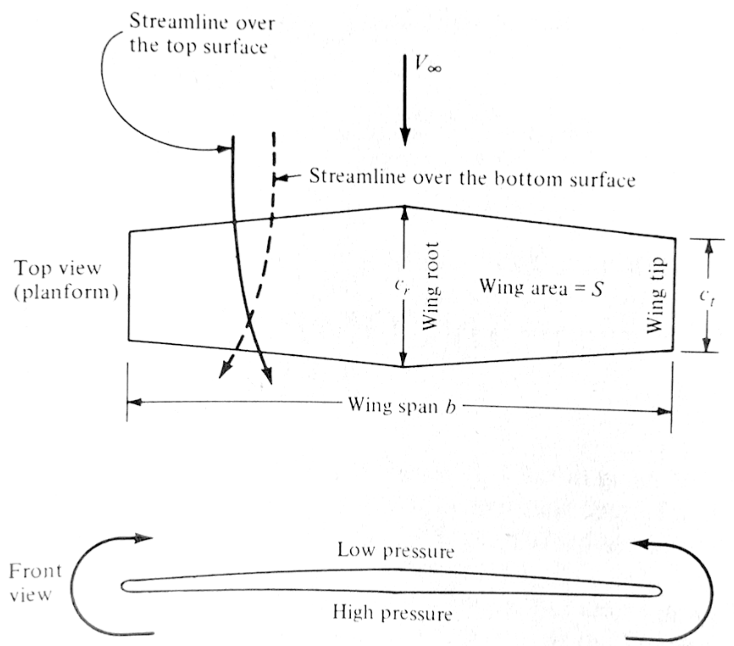


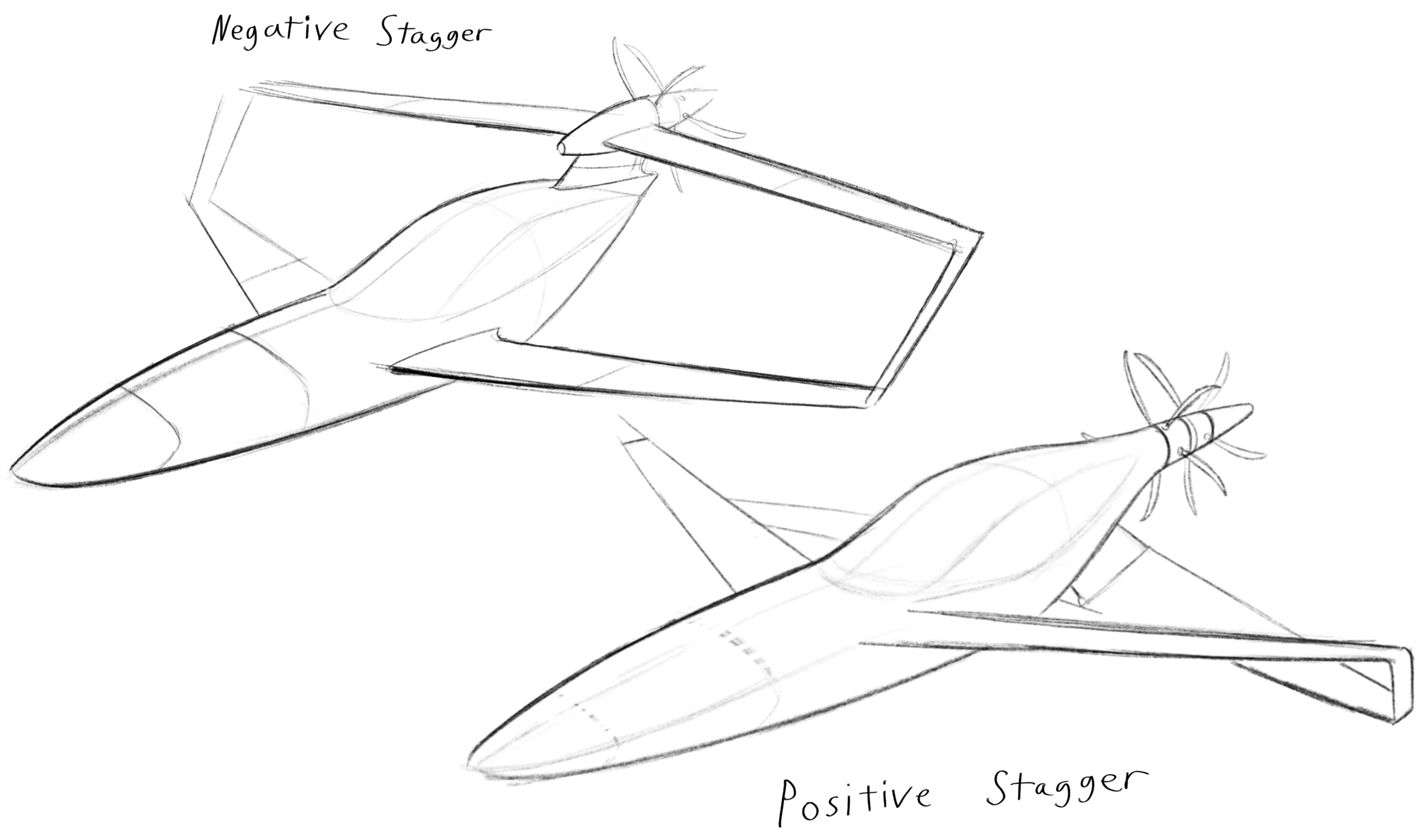
FIGURE 5.2
Schematic of wing-tip vortices.



Wingtip vortices form at the tip of the wing when high pressure and low pressure zones collide, and the high pressure zone under the wing spirals over the onto the upper surface, increasing pressure and reducing lift. In addition to increased drag this may lead wingtip stalling and whole plane entering a spin with possibly catastrophic consequences. Winglets are a device designed to reduce the effect of wingtip vortices, as they are extensions of wingtip that physically block this transition between the pressure zones. Another, smaller vortex forms at the tip of winglet, and one solution to remove this altogether is a spiroid winglet. Even a circular wing has been tested, but the solution I chose was to connect the wingtips, turning a tandem aircraft into a sort of circular-winged biplane. this also increases vertical stability, decreasing the required size of vertical stabilizer and reducing induced drag with a positive effect on cruising speed.

Stagger means a biplane layout with upper wing forward of the lower, and the opposite is called negative stagger. I modeled a mock-up of these configurations and researched their advantages and disadvantages.

One clear advantage of positive stagger is the opportunity to install a motor on top of the rear wing, in a way that the wing will protect the propeller from splashes. The rear wing could also be used as a step to make access to the cabin effortless. Problem with this layout is that due to water hull, the lower wings can't be flush with the bottom of the fuselage that would otherwise be the best solution. So in order to work, this layout would need either hydrofoils to lift the rear wing from water for take off, or the front wing could be on a separate support pylon in front of the cabin. The latter would increase drag and limit forward visibility, and as I was considering about abandoning hydrofoils, negative stagger seemed more suitable. From aerodynamical point of view I had to rely on estimations. A rule of thumb is that with positive stagger the wings' centers of pressure are farther from each other, resulting in more horizontal stability, and with both layouts the front wing contributes to more lift than the rear one. This has a direct effect on handling as I wanted the center of gravity to be as close to the pilot as possible, and the pilot is located close to the front wing. If designed right, negative stagger can provide good recovery from stall and almost completely prevent the aircraft from entering a spin (Foster, 1943). While this would be a great advantage on a plane not aimed for professional pilot, stall characteristics are defined by many other features as well.

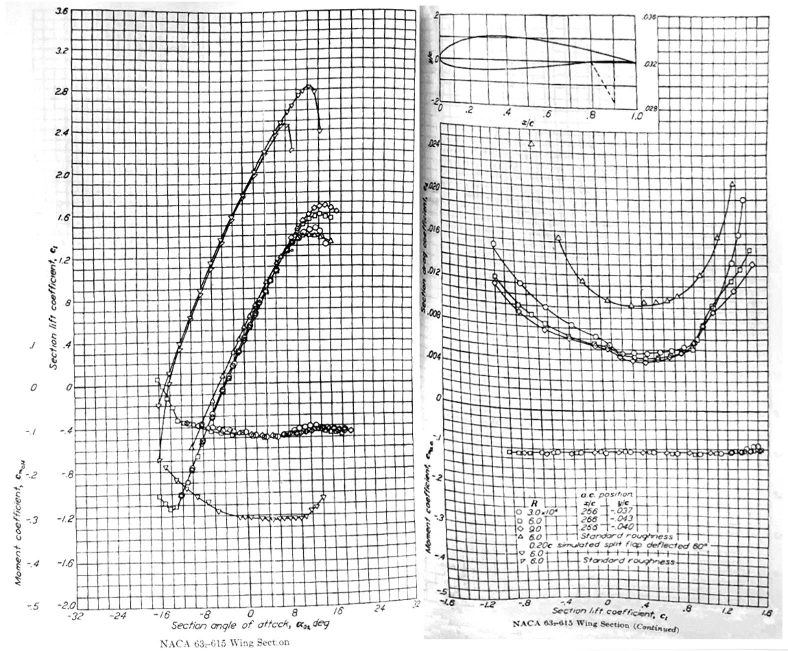


As a final step after package and aerodynamical decisions I froze the layout by judging both proposals from aesthetic point of view. My opponent and other people I showed the layouts preferred negative stagger, so that was the one I kept on developing.

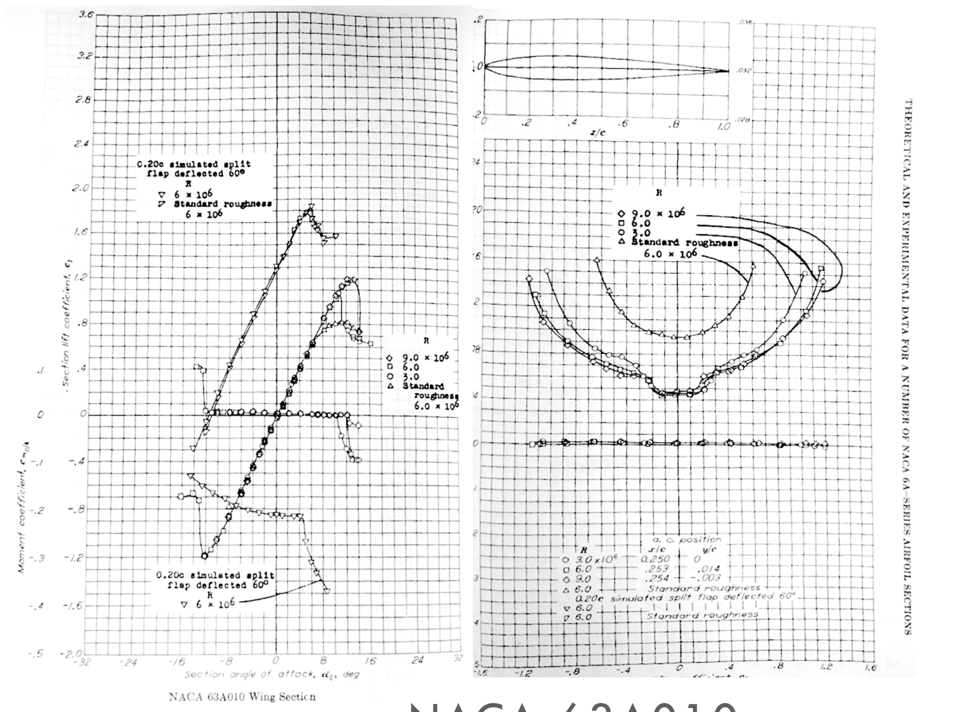
The next step was to define wing profiles and location of control surfaces and high-lift devices. Though it is neither possible nor reasonable to decide the exact wing profiles on a design project like this, I was able to define certain requirements for the lifting surfaces and relied on data collected by National Advisory Committee of Aeronautics to get a rough idea of shapes of different profiles (Abbott, I., Doenhoff, A., 1949).

The root of the front wing is the spot under most stress and so it needs to be relatively thick. Thick and asymmetrical profile provides steady lift on different angles of attack, but to prevent tip stall it needs to be one that stalls on lower angle of attack than the profile at the tip. To minimize the amount of washout needed the profile in the wingtip should have a high stall angle and a low stall speed. An ideal would be an almost symmetrical one so it could blend seamlessly with the winglet and tip of the rear wing.

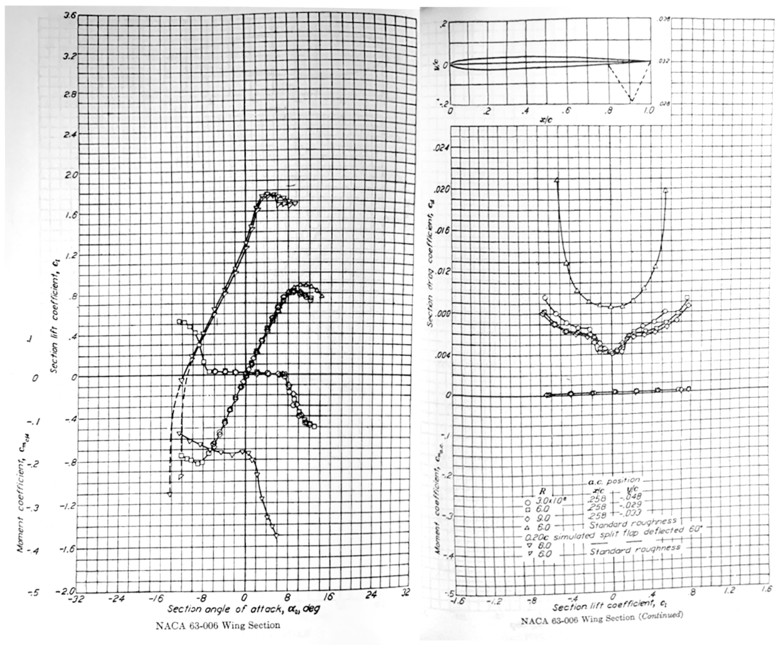
The rear wing acts as a horizontal stabilizer, so to ensure crisp handling the lift it produces should be closely related to angle of attack. Otherwise choosing such a profile would be easy but if the rear wing stalls before the front one, the nose of the aircraft will rise, resulting in a loss of airspeed and even a spin.



NACA 63-615
Front wing root



NACA 63A010
Rear wing root



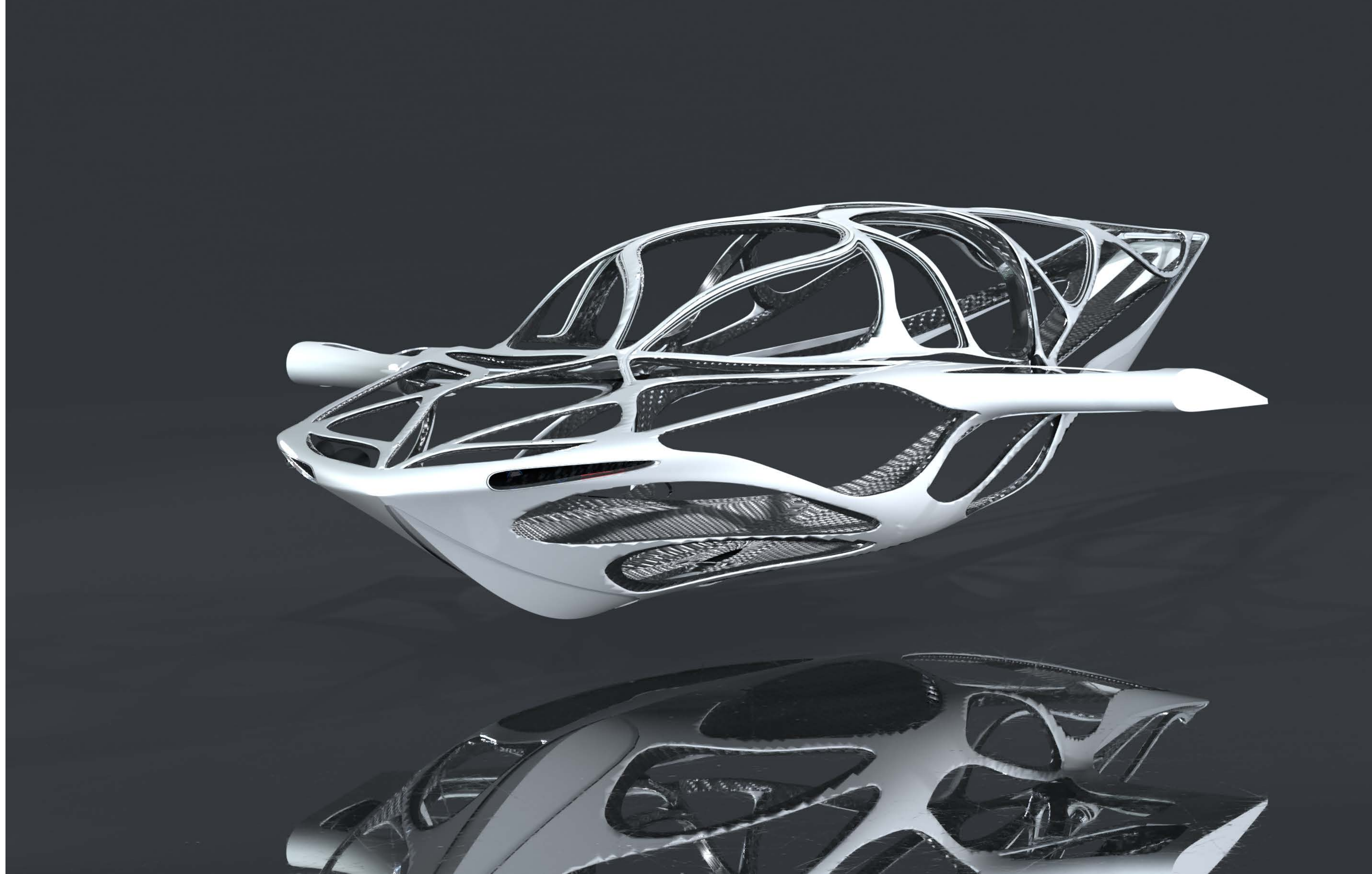
NACA 63-006
Wingtips

Promising wing profiles

5.6 Hull

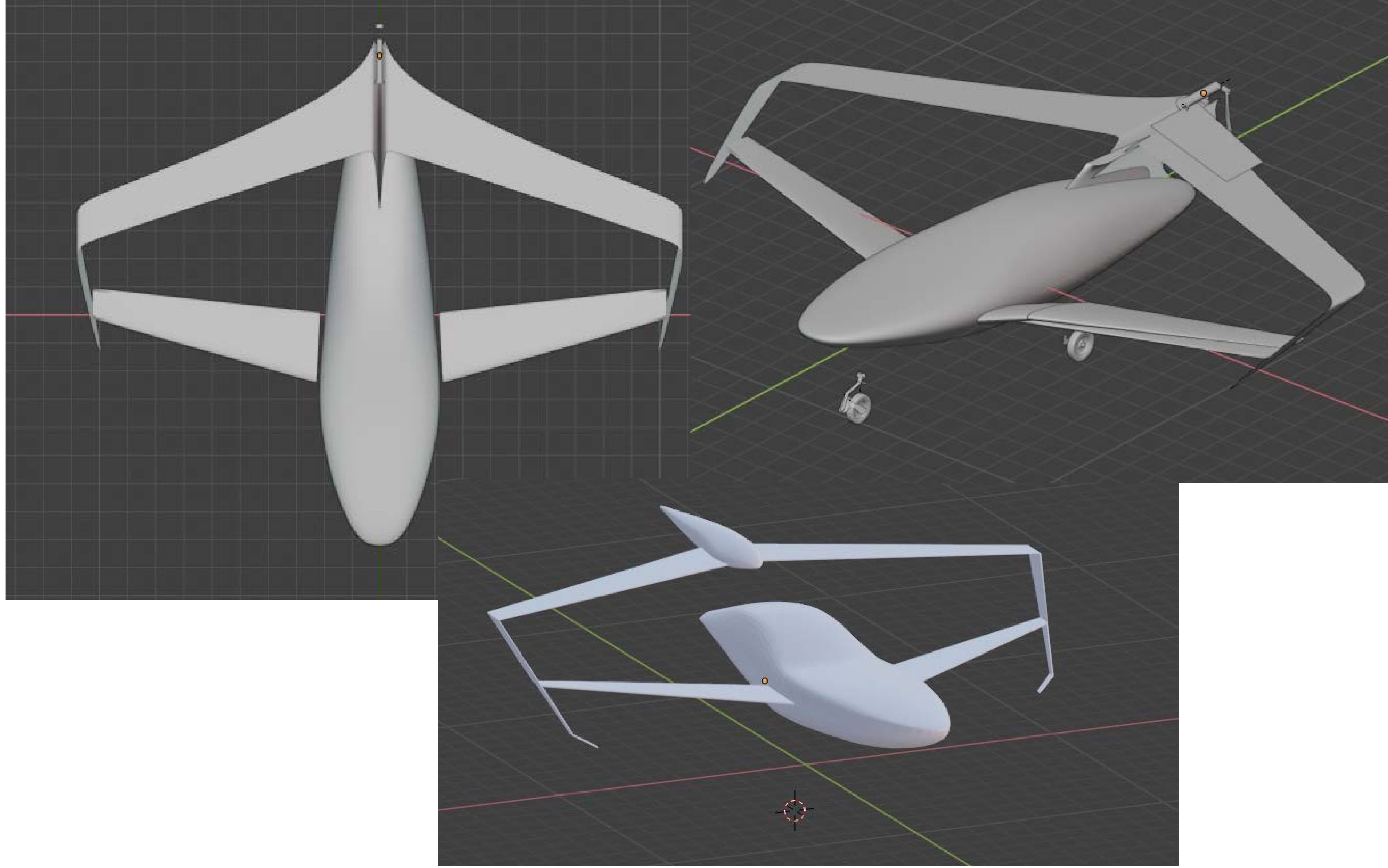
To be buoyant and stable, the hull needs to be wide. To compensate the drag created by such a hull, I tried to make it as low as possible. In order to achieve this I decided to differ from the usual packaging solution of installing batteries, landing gear, cargo and other utilities under the cabin floor, and instead extended the hull to have space for them. This lowers the height of the aircraft drastically, as the overall height of the hull can be only a bit more than sitting height in the cabin. Length is not an issue, since surface friction drag is by far smaller that cross area drag. I tried two different layouts, one with cabin behind utilities, and one with cabin in front of them. The main advantage of latter is great forward visibility, but I settled with former. It put's the center of gravity closer to the pilot's position and gives better access to utilities as there are no lifting surfaces in front. Servicing or switching the battery, for example can be done by fully automatic service station: a small facility that covers only the front end of the aircraft, leaving wings and tail exposed.

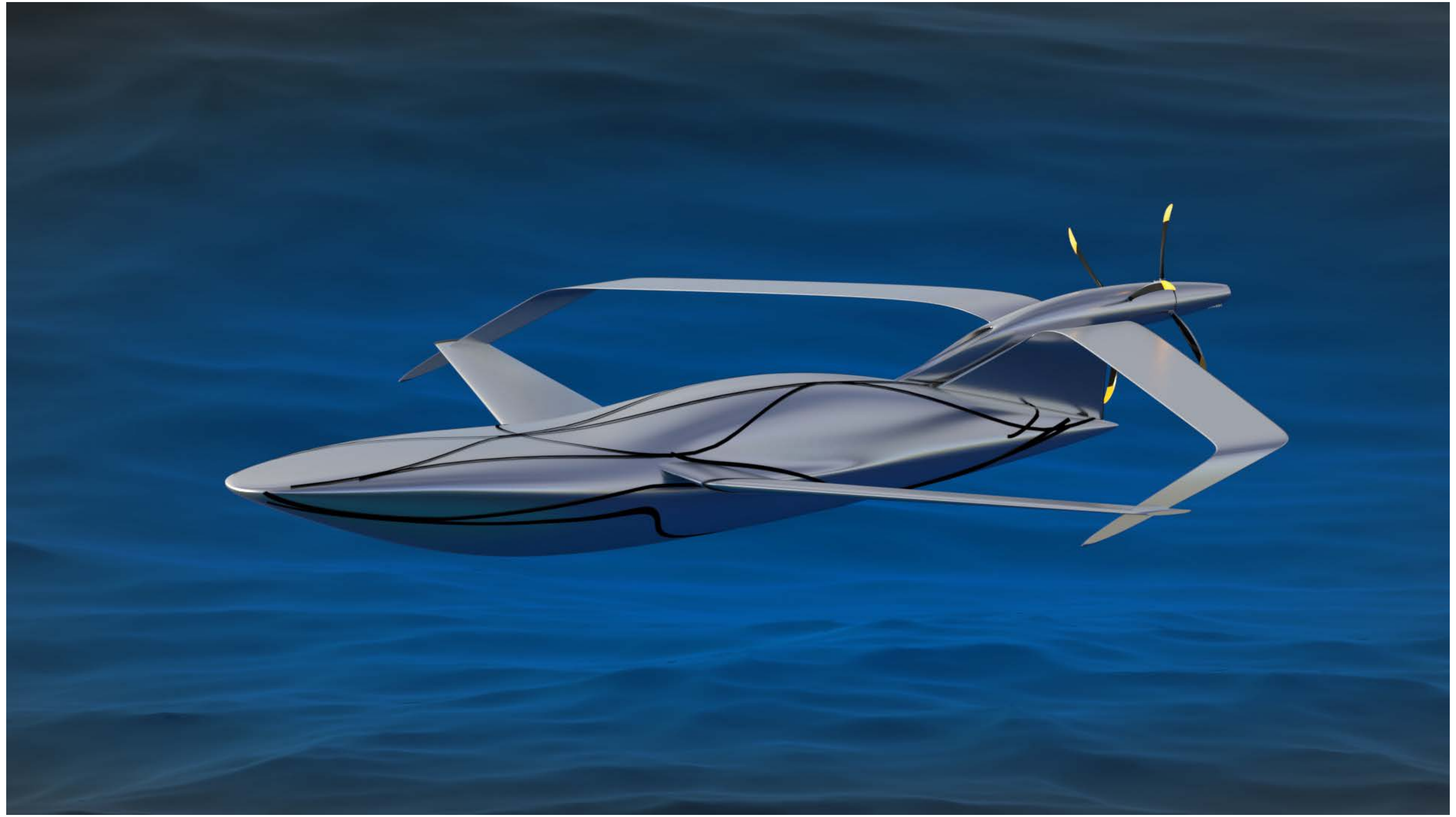
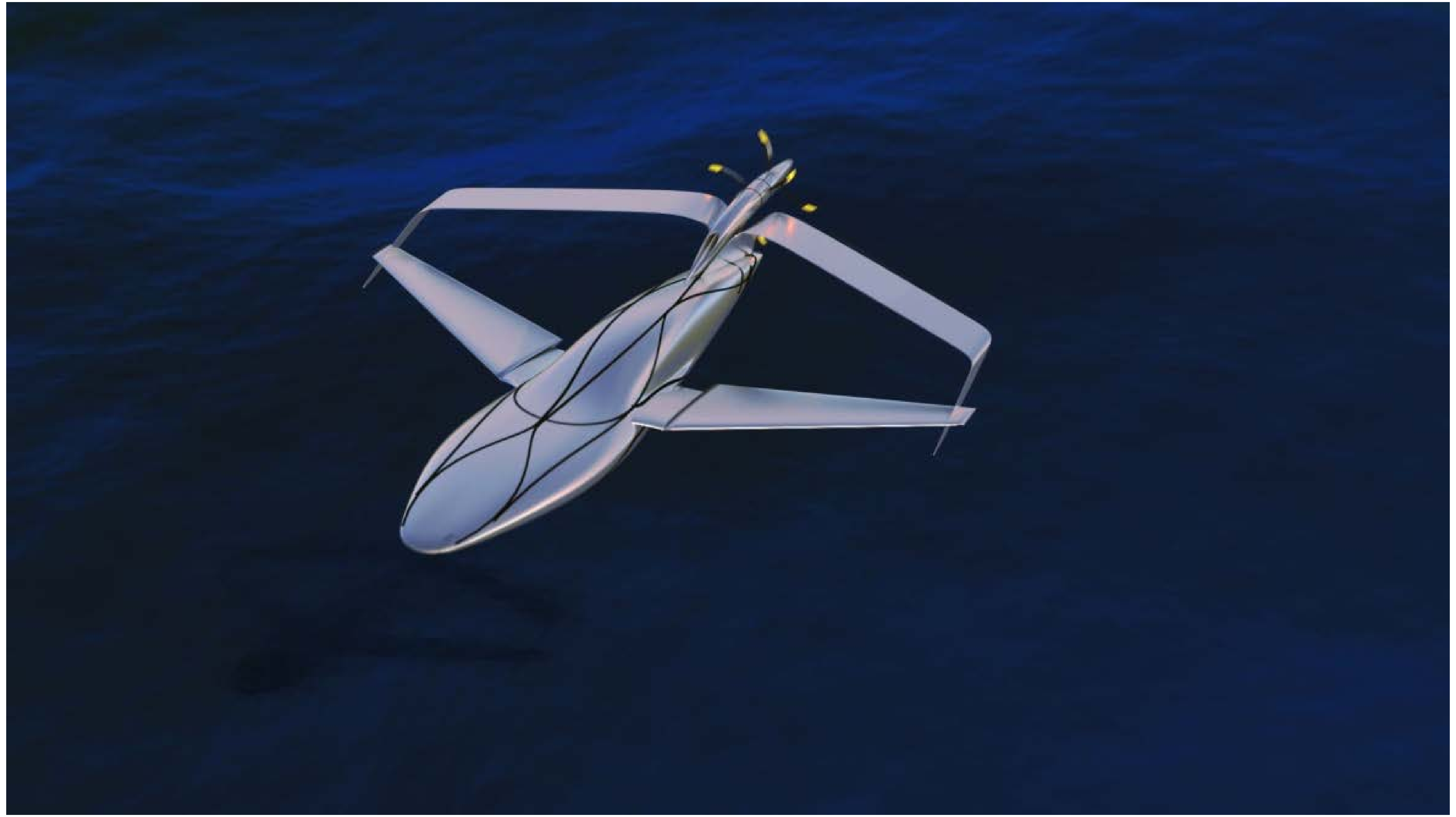
These kind of proportions create by default a strong grand tourer stance, and the visual goal of the hull design was to emphasize this. I tried to bring out the front bulge by giving it shapes usually seen in speedboats and yachts, while trying to maintain a



One of the most challenging parts of the hull design was to maintain a good forward visibility without ruining the lines. One of the less aesthetically pleasing solutions would have been to merge the greenhouse into hull, in a way that windscreen would have extended all the way to the nose. This puts a lot of pressure on materials, as the windscreen glass would have to be light but sustain pressure difference caused by cabin pressurization. While being aerodynamic, the low angle of glass creates an optical problem, because below a certain angle of attack glass reflects all the light, making it impossible to see through. In addition to total internal reflection, a multi-layered plexiglass commonly used in pressurized aircraft distorts the view more than a thinner material. In Aérospatiale-BAC Concorde, these problems were solved with an external, retractable visor outside of the pressure hull. In a plane as slow as Piaggio P.107 added weight from such a system would outweigh aerodynamic advantages achieved with it, so

I returned to a compromise. The windscreen angle is high enough to provide headroom and undistorted view, but low enough to minimize the disturbances in airflow, as my untested hypothesis is that the biggest aerodynamical fault of the hull design is a high pressure zone formed in front of the windscreen. In the interior this angle can be seen as an extension of dashboard, as the lower edge of windscreen is about one meter in front of the instrument panel. This creates some pressurized cabin space that is far too low for passengers, so I used this space to house a cargo hold, flight computer and storage for groceries. Cargo hold can also be accessed from outside in order to load larger items, but as it doubles as a wardrobe, it is important to access it mid flight.



5.7 HVAC and Pressurization

In the upper levels of atmosphere the air gets thinner. As thin air equals to lower air resistance, it is beneficial to fly as high as possible, but low pressure creates also problems. One of them is the loss of intake air in modern air-breathing combustion engines, as these devices produce thrust by combusting mixture of air and fuel. That loss of intake air can be combated with superchargers and higher airspeeds, but electric motor is superior to combustion engine as it does not rely on intake air. With electric motor the only factor limiting the service ceiling is the loss of lift that reduces effectiveness of wings and propellers.

An important aspect of electric power is the high static thrust that makes it possible to reshape flight trajectories completely. Thrust from a combustion engine is directly related to airspeed, as higher airspeed feeds more air to engine so to gain altitude the airspeed

must be high enough to maintain enough thrust. This is particularly true with a jet engine, that excels at high speeds but is fairly ineffective at low. Electric motor is completely different in this sense, as thrust is not affected by airspeed so maximum thrust can be achieved even with zero airspeed. In theory this means that an electric powered aircraft can climb with a much higher angle, this angle limited only by effectiveness of wings. That's why an electric aircraft benefits from a wing profile with high stall angle, but the total lift is formed from lift created by wings and motor's thrust against gravity. The higher the angle, the more the latter of these contribute to the total amount of lift, so with motor powerful enough an aircraft could climb vertically.

These high angle trajectories have two major benefits. One is increased efficiency, as cruising altitude can be achieved more quickly so larger part of the flight can be flown on maximum cruising speed. As cruising speed in high altitudes is a lot higher and less energy consuming, this means a decrease in both duration of flight and costs of it. If an aircraft spends shorter time at low altitudes, the noise pollution and disturbance to caused to people nearby is reduced. As electric motor is by default quieter, this could really help to move airports closer to city centers, and benefit the future of downsized airports and aerotropolises.

User-wise the more important aspect is the fact that human body can't survive high altitudes so the cabin must be pressurized. This is where electric power system is clearly inferior compared to combustion engine. In a gas turbine powered aircraft, the high pressure air is bled from main engines and as it is already hot can be used also to heat the cabin. With electric motor, there is no bleed air, so a separate compressor is needed to supply compressed air (Derber, 2018). Most airliner cabins are pressurized to 1000 meters to reduce the pressure difference between cabin and atmosphere. Some new generation private jets offer a sea level pressurization as that is much

more comfortable, but that is unlikely to become mainstream due to increased weight. (Aviation Stack Exchange, 2015)

From passenger comfort point of view even more interesting aspect is the humidity of cabin. Air in the cruising altitude of a jet airliner is -40 degrees celsius and extremely dry, so it must be humidified before pumping it into the cabin. Cabin moisture in most airliners is around seven per cents, so it still creates discomfort on flights. (Aviation Stack Exchange, 2015) The reason behind this is that the water needed for humidification is heavy, but more importantly it may cause corrosion to parts made of metal. With an fully composite aircraft like Piaggio P.107 this is not an issue, so cabin climate can be nice and humid. On the exterior pressurization can be seen mostly as rounded window corners.

5.8 Planing

After getting rid of hydrofoils I faced a new challenge. Water hulls create huge amounts of drag. While not a problem with slow watercraft, like rowing or sailing boats, the take off speed of a seaplane is so high that the enormous drag created by conventional boat hull is usually higher than thrust of the engine or motor, so the craft isn't able to even reach the take off speed. Traditionally this has been solved with a stepped hull, a hull that forms an air pocket under the rear part of it, and reduces drag by reducing the area in contact with water. The downside of this solution is the added aerodynamical drag created by the step. As the goal of this project was to reduce the fundamental problems of seaplane, I started researching other solutions, modern ones.

One of the most interesting is the Air Supported Vessel (ASV) hull technology that uses compressed air to form a layer of air between hull and water surface, effectively raising the majority of the hull from water. In nautical industry the main goal of this is to reduce fuel consumption so a compromise must be made between less power required from the main propulsion, and more power from the air compressor. An effective ASV hull is one with total power consumption less than with a hull without the ASV technology. In an aircraft this is irrelevant, since the air cushion is used only a short time to assist with take off, so it doesn't need to be particularly economic. In this project the power savings and comfort offered by an air cushion are beneficial, as the P.107 may be used as a leisure watercraft.

At this stage the pressurization system is greatly beneficial. The main drawback of an ASV hull is the auxiliary air compressor required. As a pressurized aircraft, the P.107 already has a compressor system, and the biggest advance is that the cabin pressurization is never needed on sea level. When the plane is landed the full power of the compressor can be used to form the air cushion. The one and only issue with this system is that I found no data of it ever being used in a flying boat, so it works only in theory and the proof of concept is just my hypothesis.

With installation of this system I took advance of the frame-and-panels -structure. Between the cabin and landing gear doors there are two panels that can be retracted a few centimeters to create a small step, and air will be pumped into this gap separating the rear hull from water surface. I left a small portion of frame between these panels in contact with the surface to stabilize the hull. The only challenge is the tight package as this system is installed really close to the landing gear, and multiple doors create a challenge to watertightness. If this aircraft was to enter production, it could be reasonable to move landing gear in the root of the wing. With a concept model I prefer the current location, as it keeps wings thin and weight closer to the centerline, improving handling.

5.9 Propulsion

An electric ducted fan is essentially a high-rpm propeller that is similar to a turbofan in appearance and performance. I investigated a possibility of using it as a power source of P.107, but ended up using a traditional propeller due to good low speed performance it offers. One of the downsides of a propeller is that torque and asymmetric blade effect, or p-factor, causes yawing moment that turns the nose of the aircraft and has to be compensated by the pilot. In states with low speed and high angle of attack this effect may even lead to asymmetric stall of the aircraft.

This effect does not affect a twin engine aircraft with counter-rotating propellers, and the only reason why every twin engine aircraft doesn’t use these, is that it requires reversing one of the engines. With traditional combustion engine it can be done either with a gearbox or by building one engine differently than the other. Both of them add to cost, but this is not the case with an electric motor, as it can be reversed by an electronic controller. This is also a great benefit on water taxiing as floatplanes usually need a reverse thrust, since they cannot be maneuvered by another vehicle or a human.

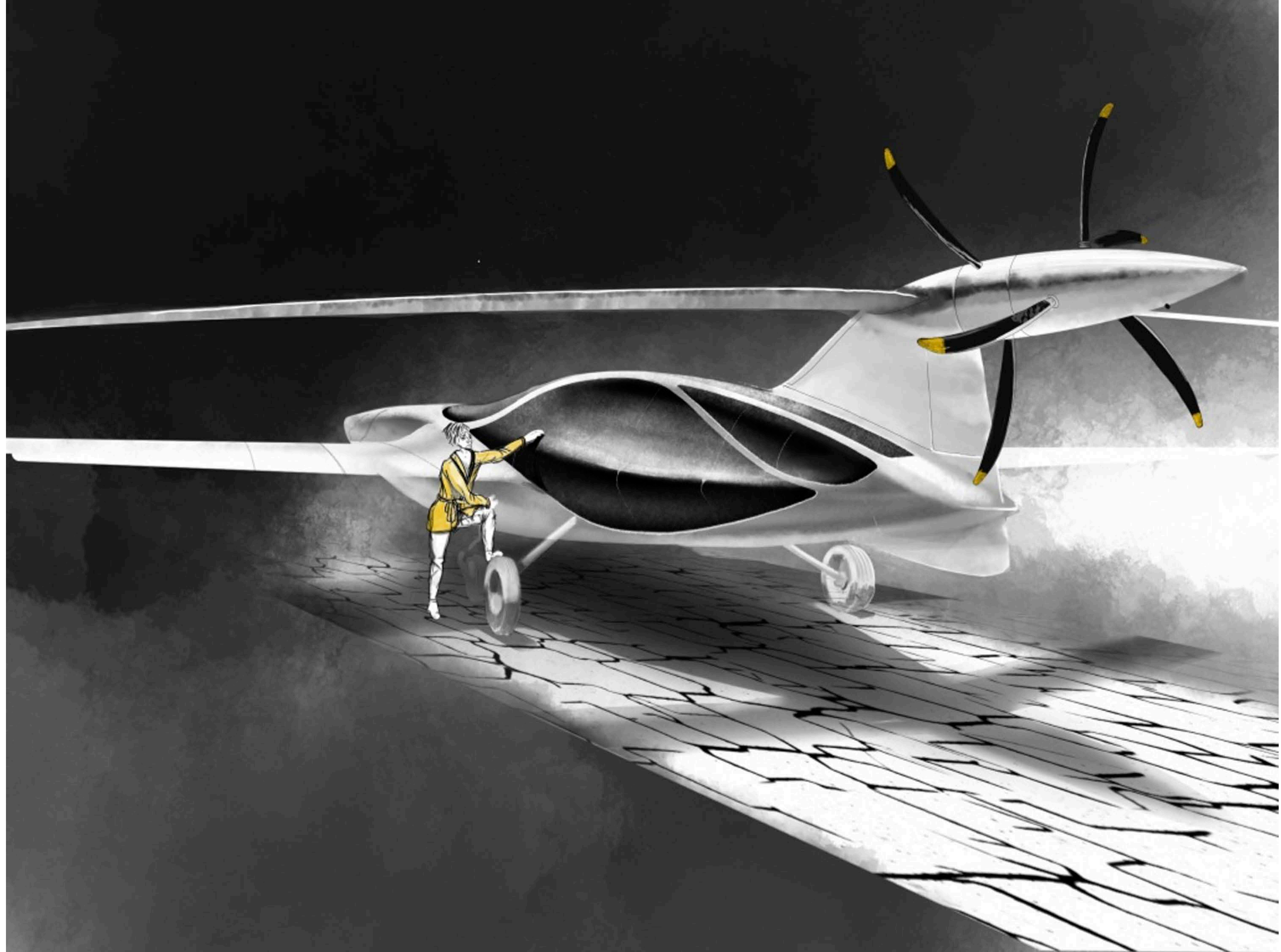
The most effective layout for counter-rotating propellers is contra-rotation: a setup with propellers located directly behind each other that share a common shaft. Drawbacks of contra-rotating propeller are added noise and complexity of the system, as they are usually run by a single engine via a complex and heavy gearbox. Electric outrunner has a potential to remove the latter, so I designed the motors of P.107 with contra-rotating propellers in mind. Stators are installed around a hollow, large diameter carbon fiber shaft, and a rotor with magnets is fitted with ball bearings to the shaft. Both the shaft and rotor can be build using carbon fiber, reducing the overall weight of the motor unit radically. Stators are cooled by ducting air through the shaft, as this creates less drag than blowing it directly to the outer casing of the motor.

This is still primarily a design process, and even though I'm proud of my motor design, and genuinely believe it is in many ways superior to current models, I found no real life examples of such configuration and I got no scientific data to support it's plausibility. It is a concept worth developing but not the main novelty of this project.

6 USER EXPERIENCE

6.1 Pilot Experience

Aircraft design starts by defining technical requirements and fulfilling them. These requirements are defined by different factors, and in this project the most defining one was user experience, and especially the contrast between flight and lounge mode. To provide most intuitive handling, I wanted the center of gravity to be as close to pilot's H-point as possible. I started with a traditional layout of single cantilever middle wing with pilot seat close to the leading edge. I also tried a configuration with a separate, fighter-style canopy protruding from the upper surface of the hull, and passenger compartment directly below that, a similar construction as in the first airliners back in 1920's. This seemed ideal at first, since it truly provides user with two completely different mindsets and an easy transition between these two. The interior would essentially be an elegant living room with pilot seat in centre, and this seat can be raised half a meter and pilot's environment would chance from elegant living room to a cockpit of a fighter jet. Finally I reached a conclusion that flying a fighter jet is not the kind of action this flying boat is supposed to offer. These types of aircraft offer loads of power and raw masculinity like a high end hypercar, but a comfortable business plane could never offer such adrenaline-fueled action.



And it's not supposed to. It should have a strong sense of sport, but not an extreme sport where you push yourself to the limit. Sports that it should represent are the relaxing, old, noble and pure ones, such as riding or alpine skiing. After all, the P107 is not supposed to replace aerobatic and stunt planes, or even mimic them. It should rather bring back some feeling of the great air races of the 1930's; the era when aircraft symbolized progression and dreams, and elegant, streamlined machines soared through the sky, as a last manifestation of hot-blooded thoroughbreds.

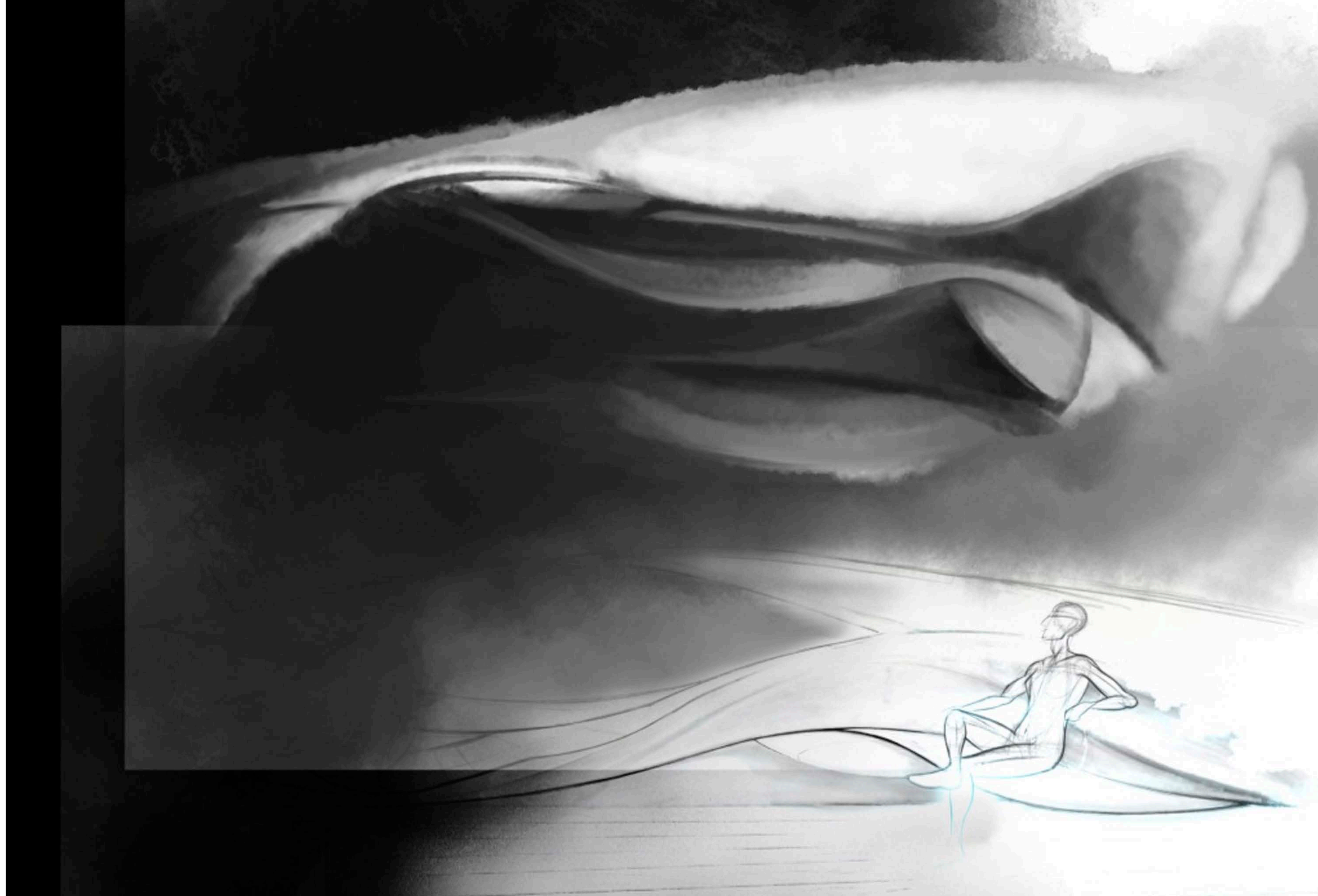
Elements associated with these gentleman sports are not something to hide. They are things to put on display, something beautiful to lay your eyes on, even to represent your lifestyle. In general, putting a picture of a racing horse or a glamorous sports car on display shows primarily your visual preferences and personal conducts, but displaying pictures of football players or rally cars suggest that you are interested in rally or football. In the same way, having a fully equipped fighter or stunt plane cockpit as a part of your business aircraft interior tells that you try to get your kicks from a vehicle thats not primarily built for that.

That is the reason why having a separate, transforming cockpit seemed pointless. I rather wanted it to be a fundamental part of the interior, to stand out and show it's function, but blend in the overall visual style of the interior. I wanted the interior to tell a story, so that different parts of it showed their uses, while forming a uniform entirety.

6.2 Interior

Interior design started as a minimalistic white space with cubical shapes and architectural surfaces, but it gradually started to blend into the frame. As with the exterior, I wanted the framework to be the defining element of interior forms, and so clean industrial lines had to make way to organic waveforms. As stated in part 4.3, the interior of a private offshore watercraft may be complicated and organic as it does not need to blend into urban landscape or transportation infrastructure. As the interior will be exposed to moisture, salt water, dirt and sand I had to get rid of all the light and soft materials I had become so used to. Designing a dark, complex luxury interior was a thrilling escapade deep to an area far from my comfort zone, but I didn't have to abandon clean lined minimalism completely.

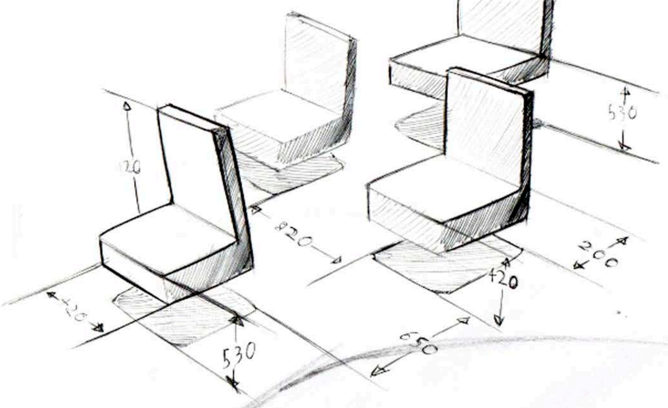
After the research I formed a brief for my interior design, a one based on ideas presented in part 6.7. I tried and created an interior that was asymmetrical, alternating but uniform. The process started by studying different possible layouts, as the dimensions of P107 was so different from many aeronautical and automotive benchmarks I wasn't able to use any pre-existing one. One of the biggest challenges was the shape of the hull. Most aircraft have a hull with almost cylindrical cross section, so they offer length and height but very limited horizontal space. I pursued low drag with a low hull instead of a narrow one, so it became clear early on that the P107 would not offer standing height, or even an upright sitting position. As a result, most of my benchmarks were found in the automotive industry instead of aviation.

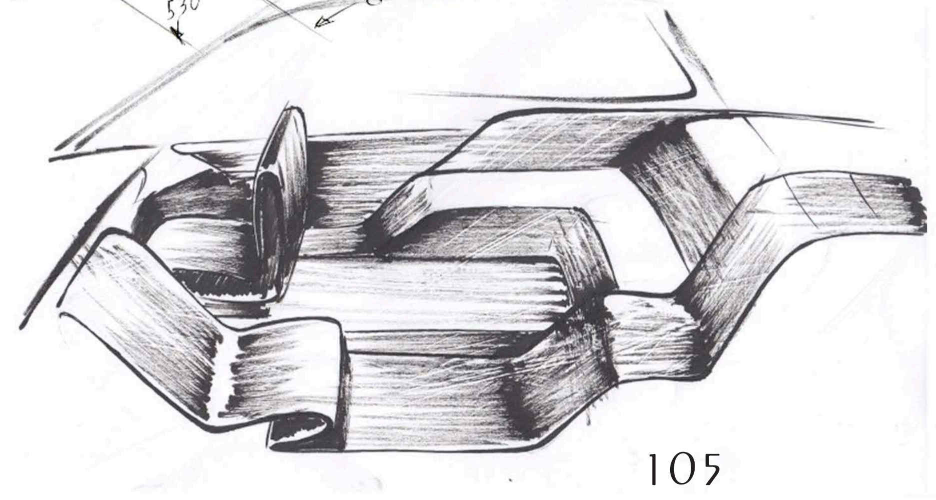


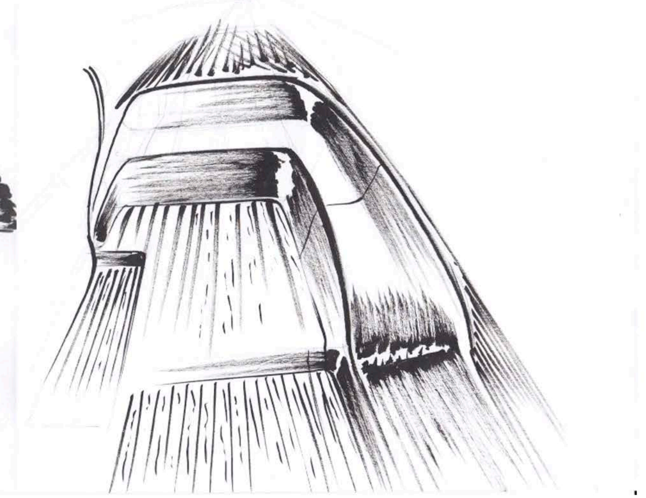
My first sketches show a very traditional approach to a vehicle interior, an interior based on separate seats, but that was not in line with the idea of a flying lounge, a vehicle as a living room. In a vehicle like this, traditional seats are not effective in terms of weight or space, but their advance is good support and adjustability. That's why I chose to install only one separate seat in P107, the pilot's seat.

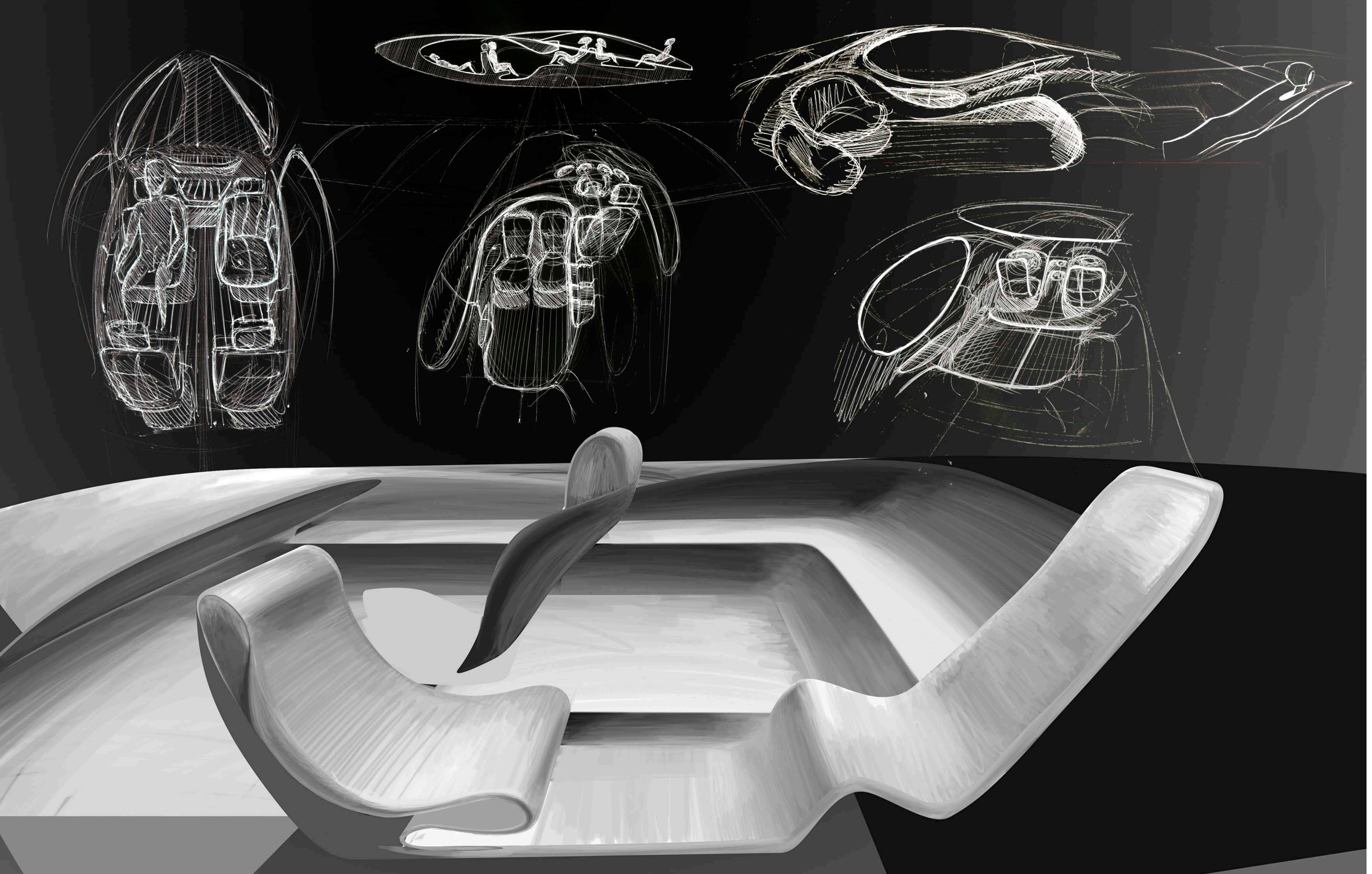
Design for rest of the seats was driven by organic shapes of the exterior, and my first sketches of these show flowing sofas, thick, soft and heavy structures similar to Verner Panton's lounge studies from 1970. At this stage, I was too deeply immersed into the idea of flying lounge, and a far larger interior space than necessary. It offered extreme comfort for five passengers, but the large size would have sacrificed performance and good flight characteristics that were half of my initial brief.

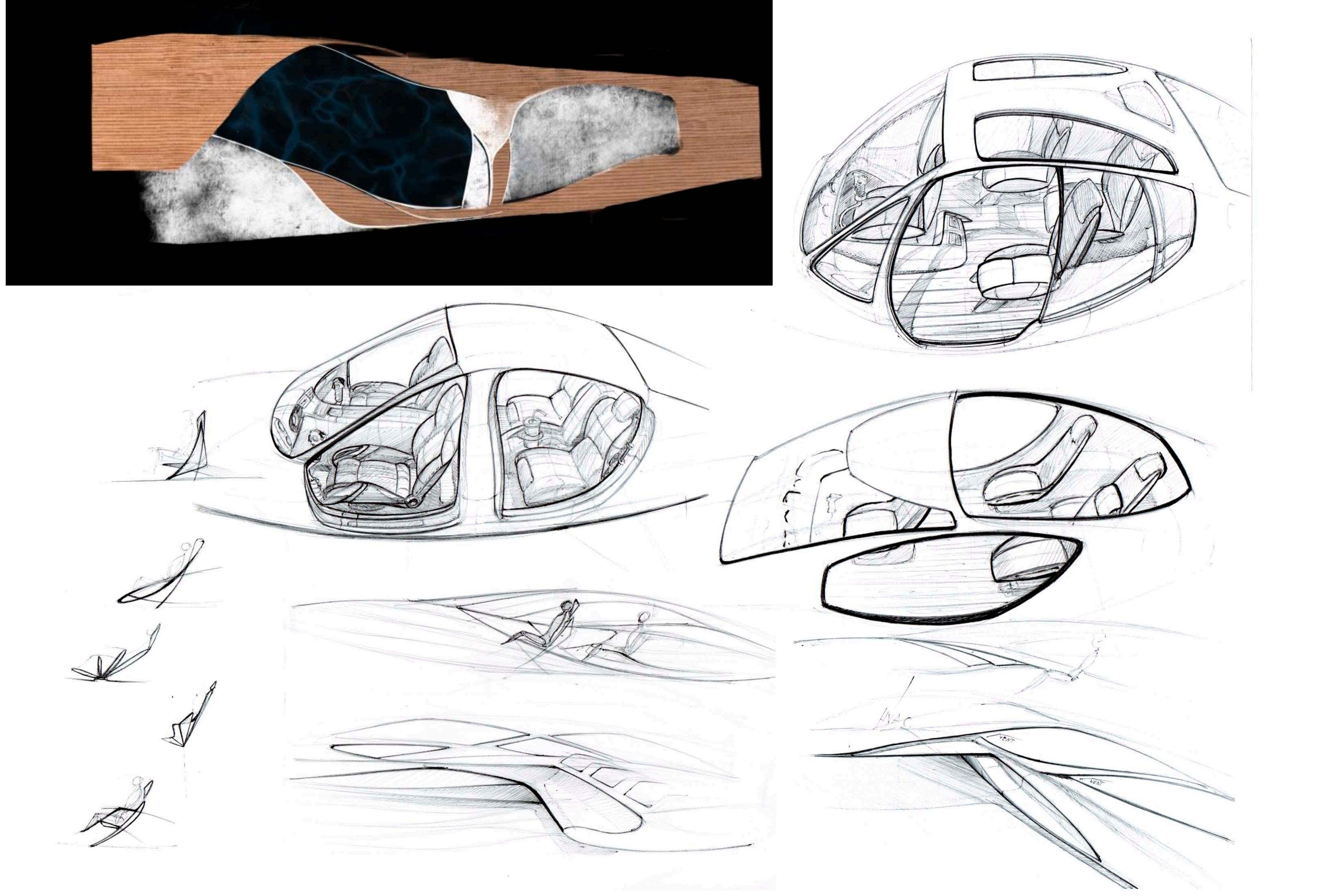
Couple of necessities required in a long distance flight were a bathroom and a sleeping compartment. Finding room for a bed was easy, as the tail cone after cabin offered two and a half meters of empty space too low for seating, but perfect for a small bedroom. A toilet was surprisingly difficult, as it had to be a completely separate space from cabin. During the interior design process I had built mockups from office chairs and cardboard and tested them with people representing different percentiles. Particularly useful were roof mounted dust cleaners found in a workshop as they shared almost the same curvature with the roof of P107. At this stage I used these mockups to define the minimum space required for a toilet and different ways to access it. Finally I managed to fit the toilet inside the dashboard. This allowed me to shape the dashboard as a large architectural block with lots of similarities with my first interior sketches. This solution was not ideal but it was a good, visually pleasing compromise.

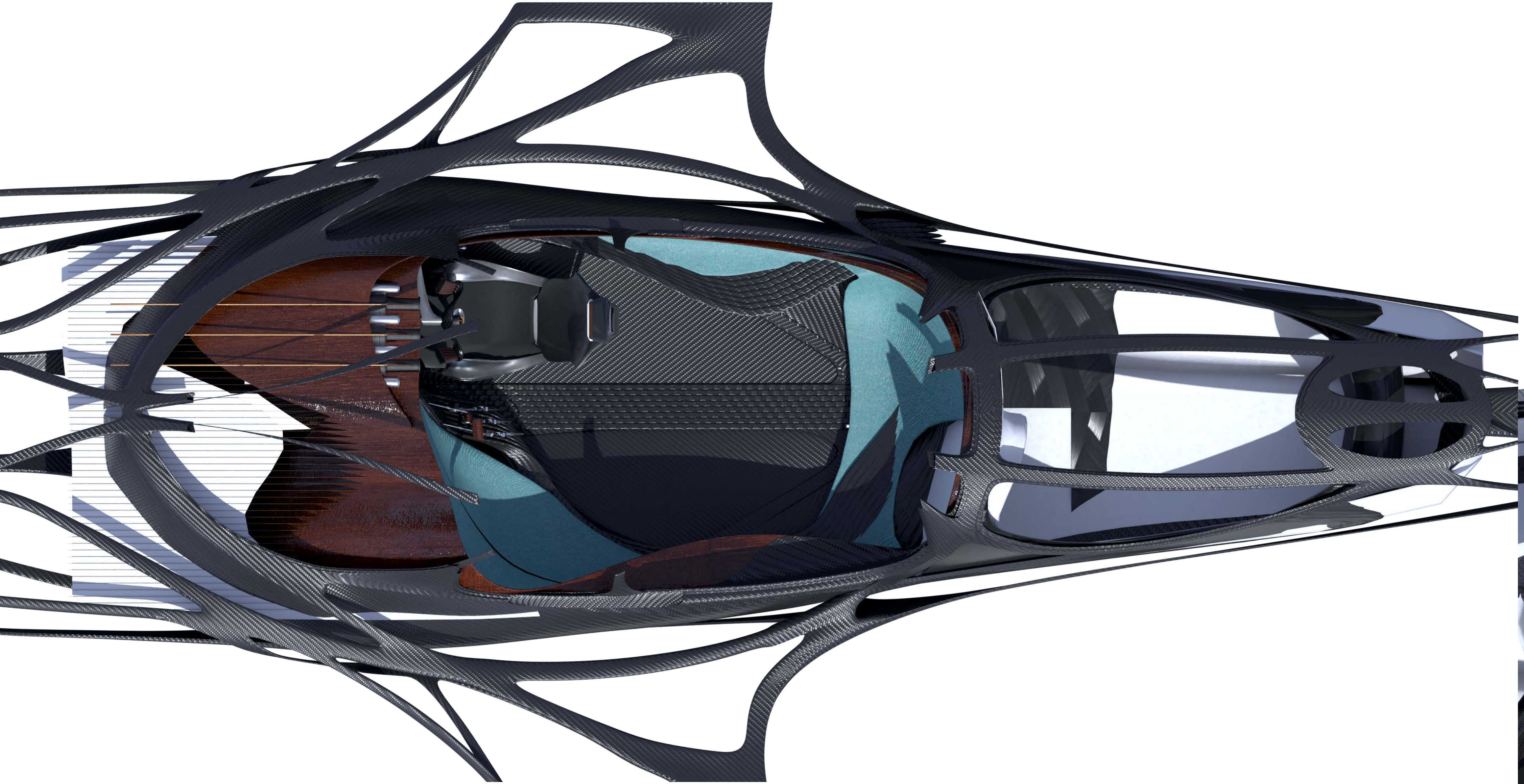













6.3 Panels

I decided to use the panels as a key point of visual interest, as their shape is defined by the framework, so instead of being just excess ornaments they bring out the structure of the vehicle. Basically the P107 follows a constructivist form language, but that is not apparent by the first glance, as the carbon fiber framework is really flamboyant and organic. I tried to balance between futuristic forms and classic elegance, and chose fine wood for a deck material, as seen in mahogany speed boats of past days. The front deck overall is supposed to remind a bow of a wooden speedboat, so I'm probably going to add some nautical details on it. The rest of the aircraft has close to nothing to do with boats, so it relies on aeronautical and automotive styling. The wings and motor pod are to remain light, minimalistic and bird-like, and the rear part of the hull resembles streamlined cars of the 1930's. Nevertheless, I wanted to avoid retro styling, so they are not to mimic the old age aestheticetics, but simply to resemble them.

Windows are an other part of the aircraft that brings out the framework, but to to keep focus on these two areas I didn't bring out the panels more than as panel lines. They are barely noticeable, but act as a reminder of the frame underneath.

6.4 Landing gear

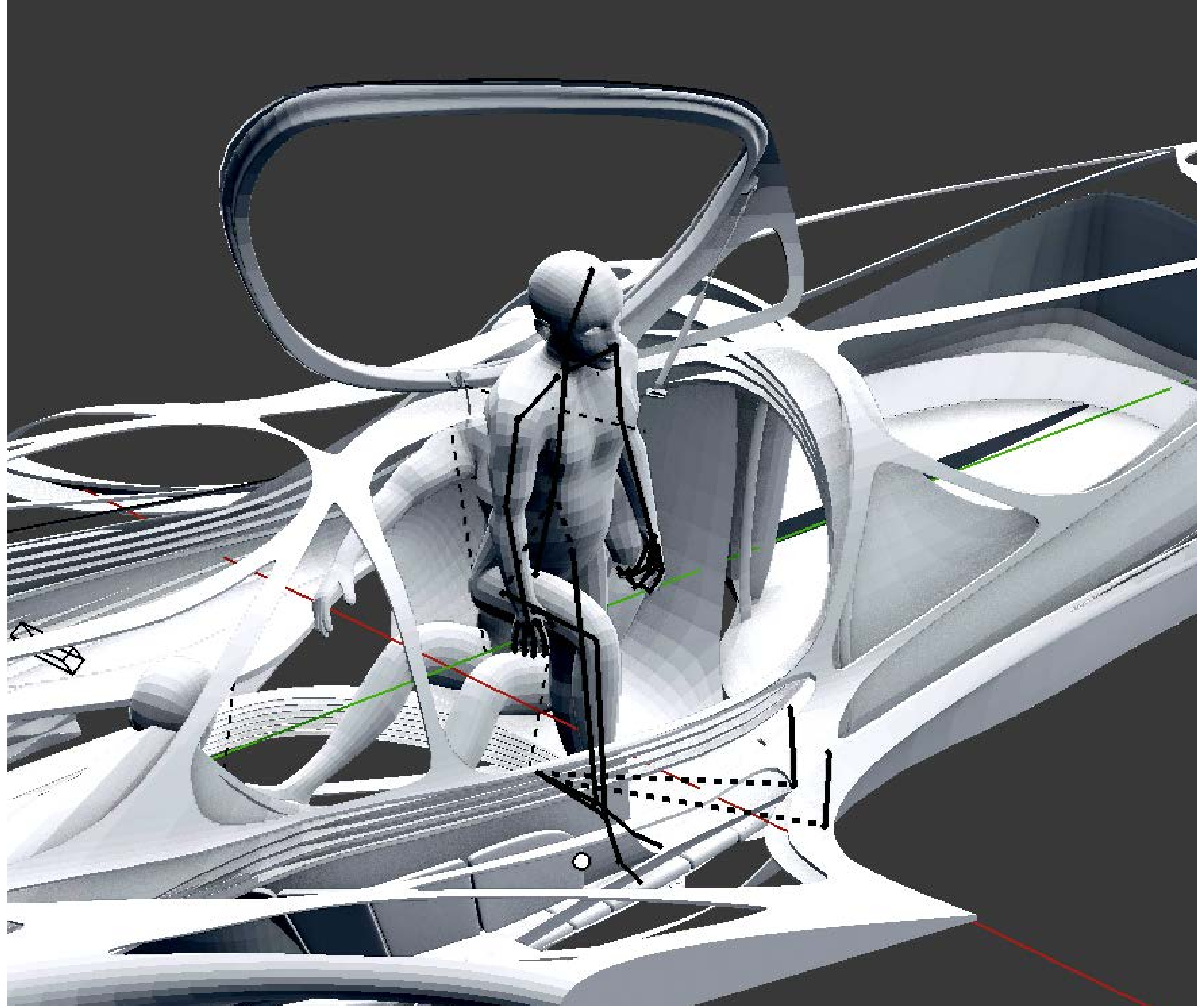
A seaplane with a retractable landing gear is called an amphibian. Landing gear adds weight and in difficult to design but for this type of an aircraft it is a necessity, because every city does not have a waterway access. With landing gear it is also easier to raise the aircraft on land for maintenance.

An ideal place of installation would be above waterline, but P107's hull shapes and narrow wing don't allow that. Instead I took advantage of the rear landing gear location and decided to use it as a step to assist climbing into the cabin.

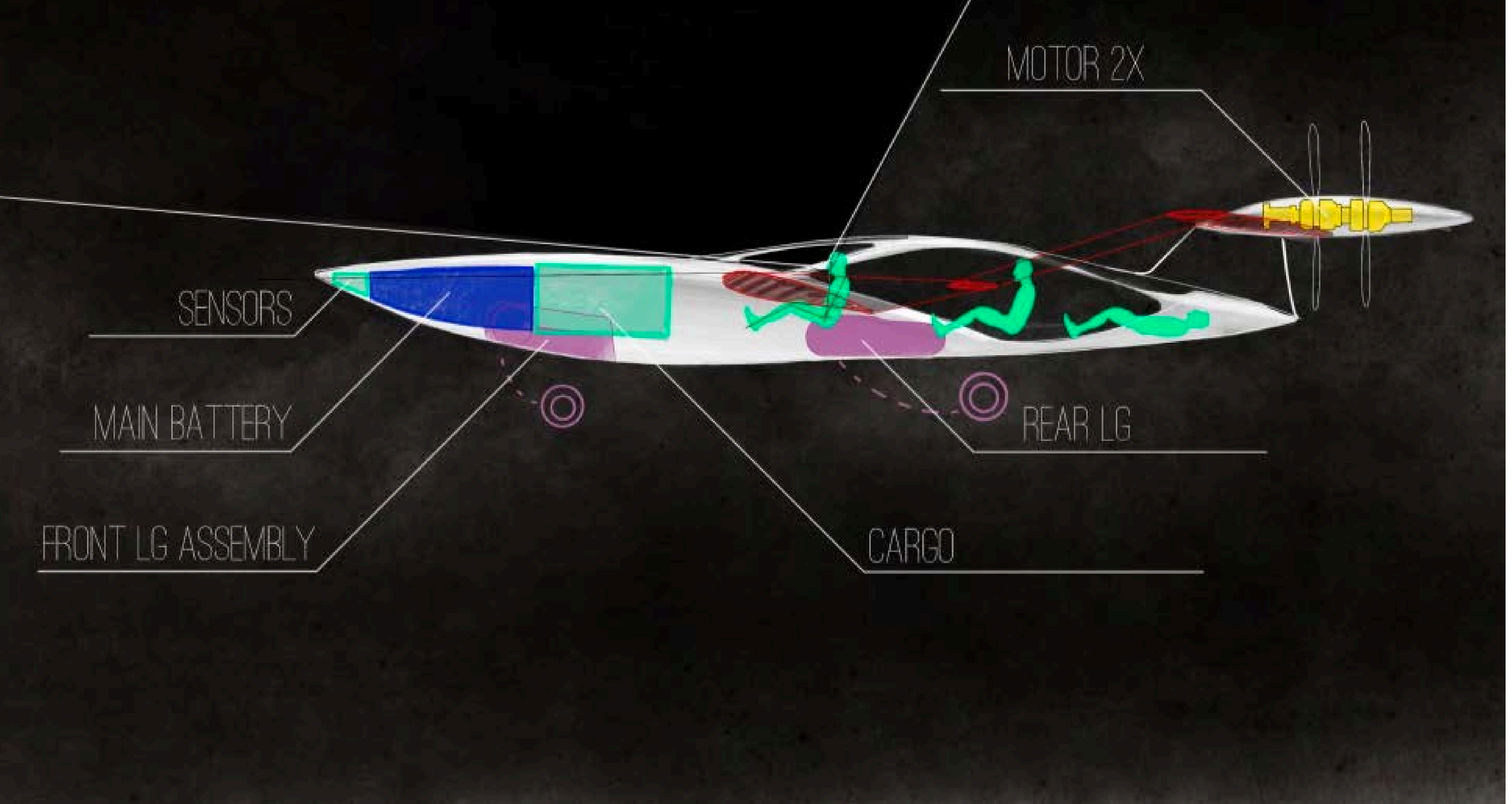
6.5 Doors

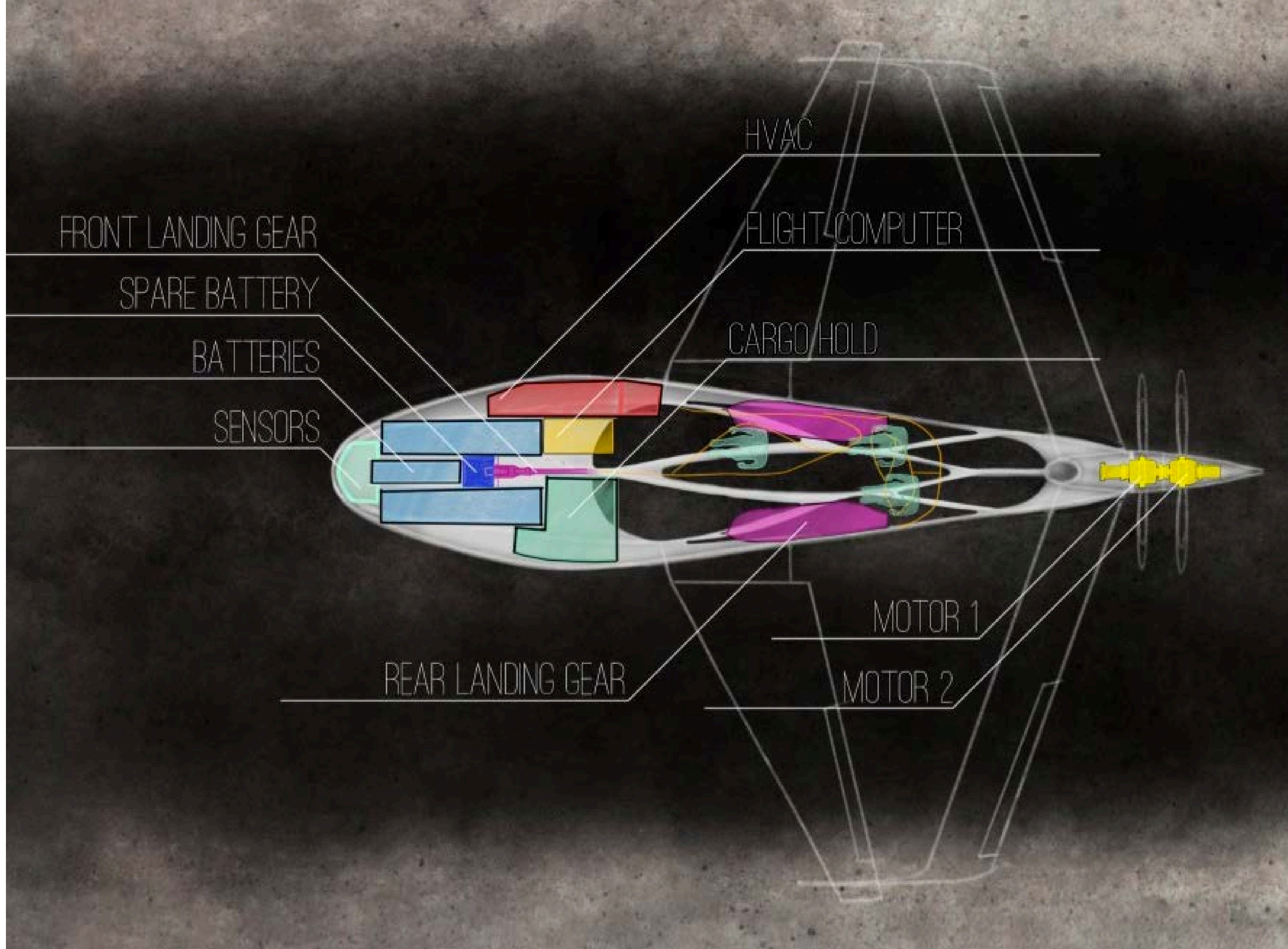
The doors presented a surprising challenge, because they had to provide easy access to the interior without compromising strength of the pressure hull. Also the low but wide hull created some special requirements. A classic solution is either a traditional turning door, or a door that opens downwards and doubles as stepladder. The advantage of this type of door is that it provides standing height and easy access. I had to abandon this type of door because as it has to extend below waterline, it would be inoperable in water. My favorite solution was a complete sliding canopy, that could be used to turn the whole passenger compartment into a sundeck. The whole middle part of the greenhouse would slide backwards when the aircraft is floating, and really adventurous passengers could even open it mid air. The marketing department could use this ability to sell the only convertible business plane in the world. This kind of solution would greatly compromise the structural integrity of the hull, require a heavy mechanism and be difficult to pressurize.

For a while I studied an idea I got from my opponent, doors that open downwards and extend sundeck. Many luxury yachts use similar system, but eventually the shape of my hull would have made this kind of extension ineffective. I decided to use the foredeck as a sundeck, and shaped the roots of the wings to blend into deck and provide easy access from door. The best solution was a traditional gullwing doors that starts far above the waterline but extends all the way to the roof.



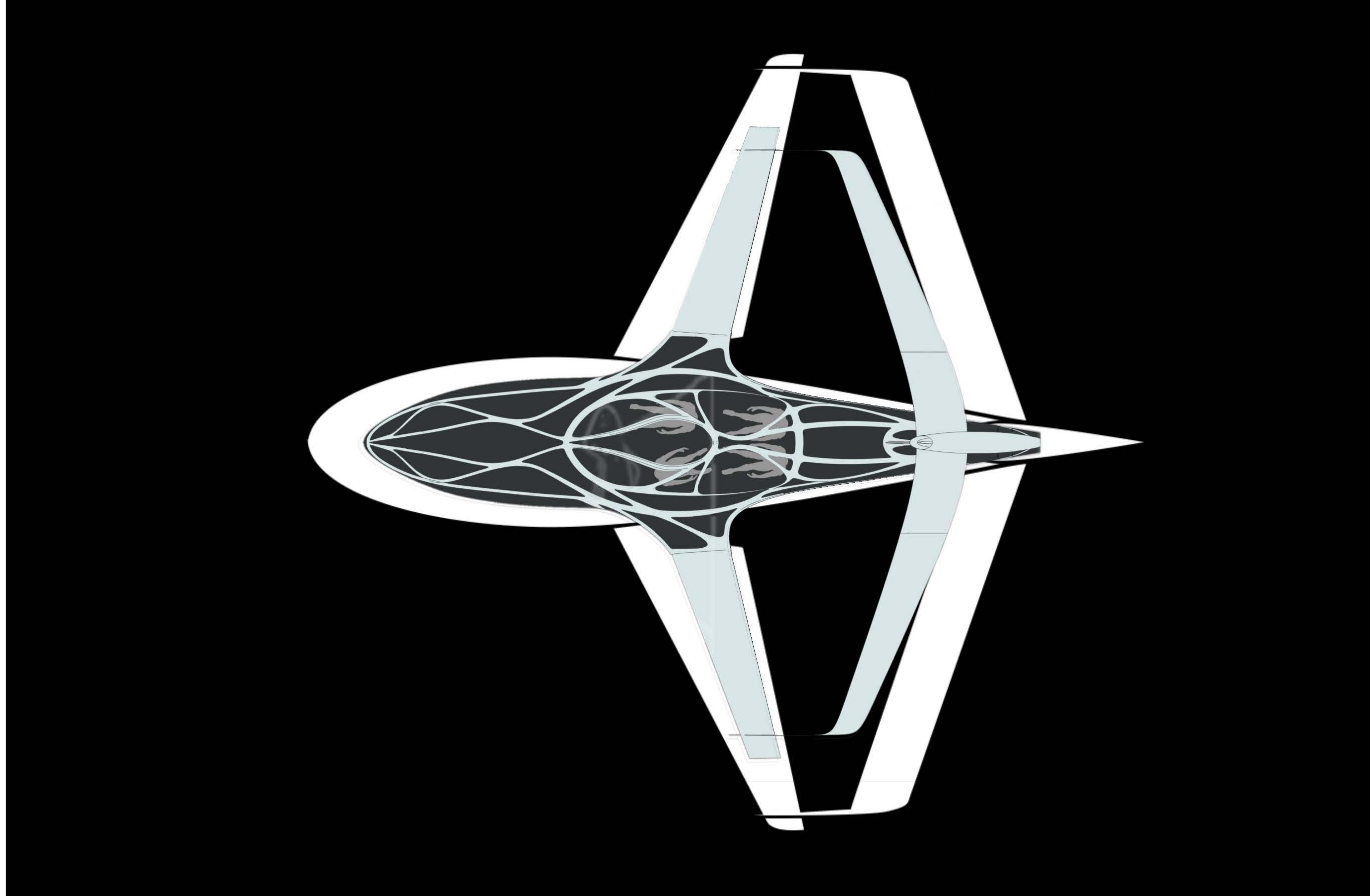
Package of the P107 before the last transformation. The cabin location, visibility problems and an awkward motor position are clearly visible





6.5 Evolution

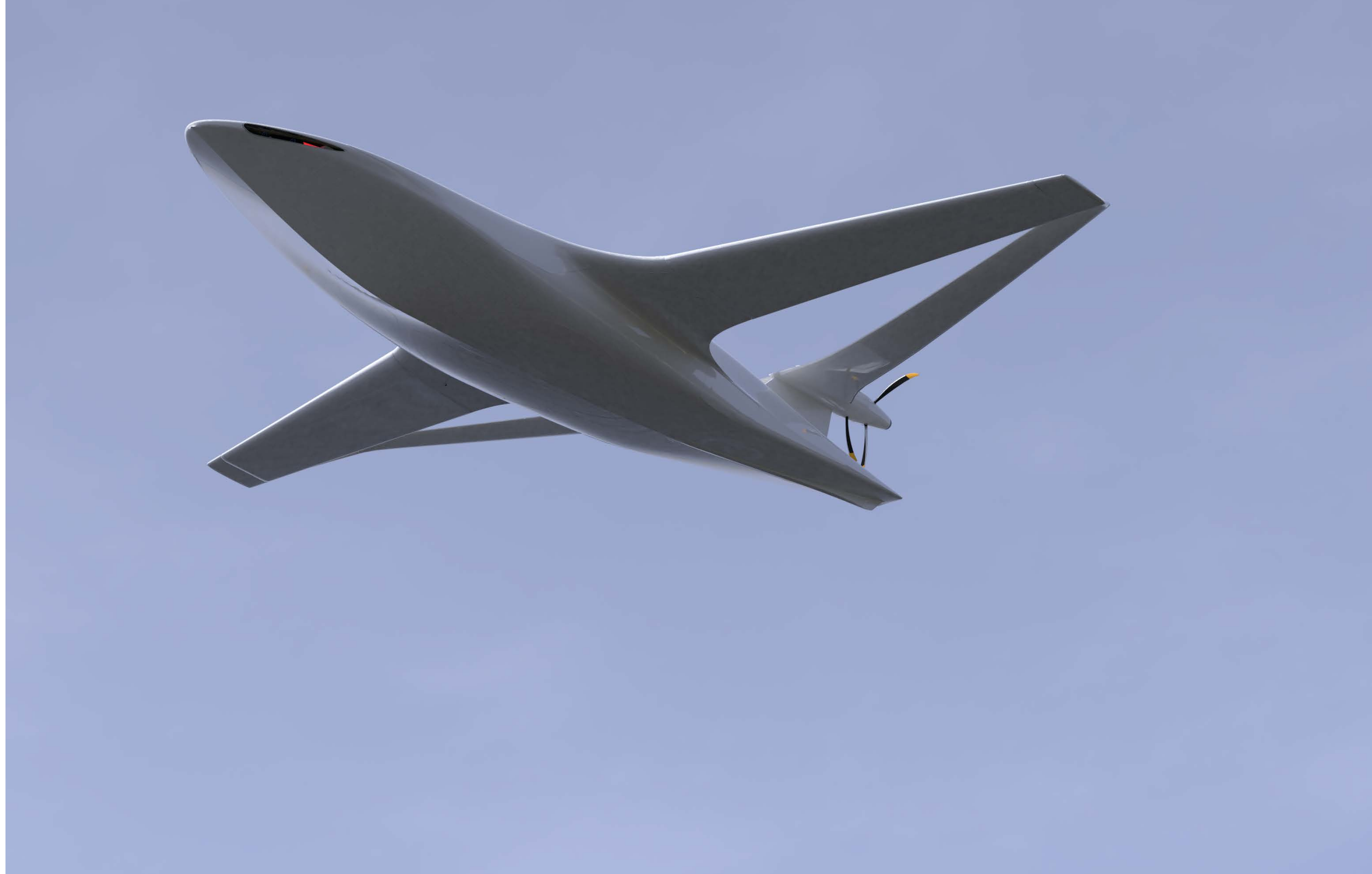
The concept went through it’s last massive transformation after I met with the grand old man of Finnish aviation, Aki Suokas. Mr Suokas pointed out some major issues with my concept, the biggest of them being the overall size of P107. After his feedback I realized that even though every individual component were right sized compared to each other, it is ultimately the user that defines the scale of these components. It was interesting to notice that when designing a completely new package from scratch, every single decision affects every other. Adding some legroom or interior space in general led to bigger hull, bigger wings and bigger batteries. A result was an almost twenty meters long five-seater, and even though Suokas agreed that the size didn’t make the concept unrealistic, he helped me to understand there was no real need for it to be that big.



While maintaining passenger volume and the package, I started downsizing the craft. The results were astonishing. Just by moving occupants a bit closer together and reshaping the greenhouse, I managed to ultimately reduce the size dramatically. Cabin space is not significantly smaller, but now it takes roughly 70 per cents of the hull volume. This makes a huge difference compared to earlier 50 per cents. I had to get rid of the toilet, but managed to actually increase the size of the sleeping compartment. Tighter packaging actually made finishing the interior design easier, as there was no excess space to fill but form, or at least layout, could truly follow the function.

Mr Suokas had doubts about the water stability of P107, especially in the rear part of the hull. In my first model the motor pod was located behind the hull instead of above it. As a result there was no hull to protect the propeller from water splashes. The rear part of the hull was also too small to provide enough buoyancy to prevent the tail from sinking. I consulted my classmate, Iiro Laine to estimate the correct size for motor and batteries. After this I did some really basic calculations to estimate the size of the propellers.

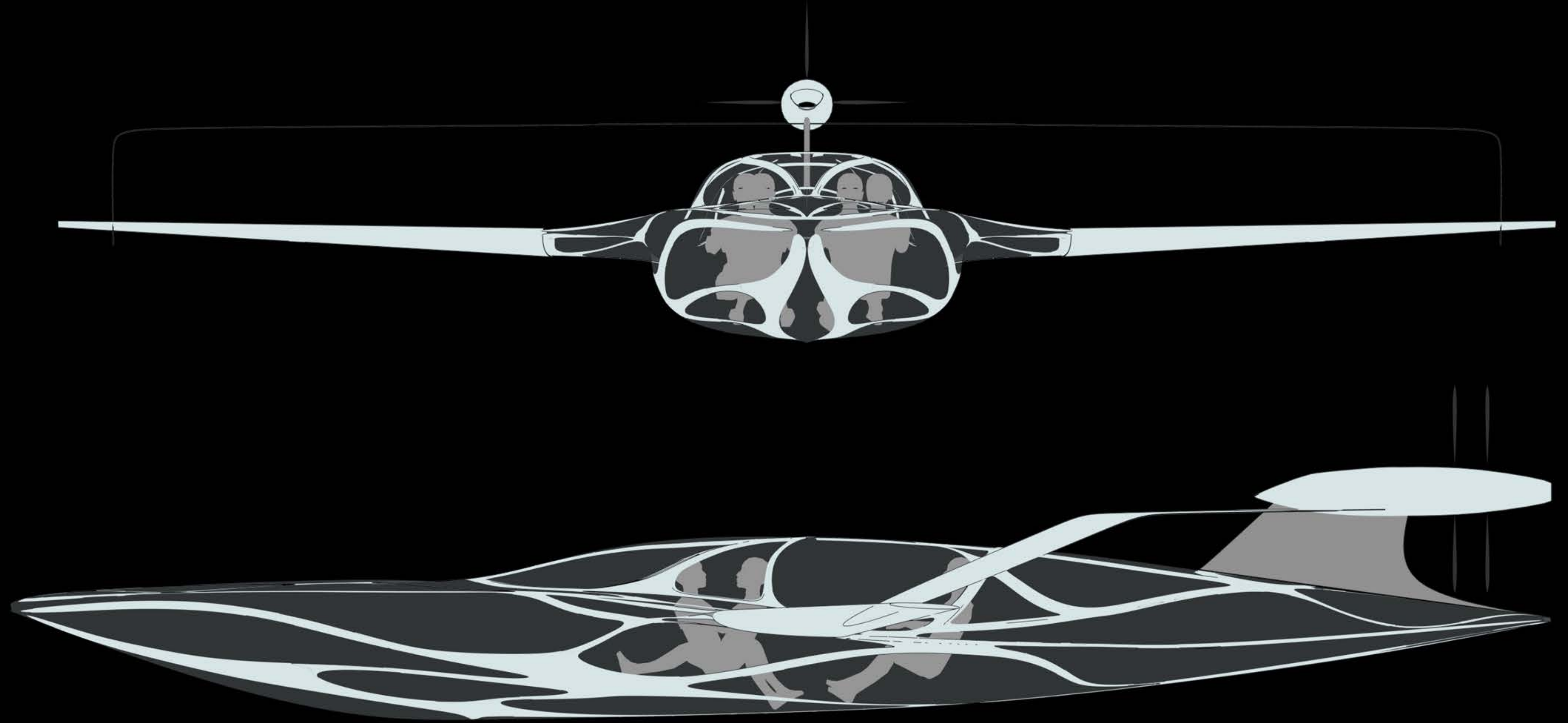
I was insecure about designing the wingtip floats, but Aki Suokas gave me useful guidelines to help with the process. With him I ideated the inflatable floats that blend into wingtips to reduce drag.

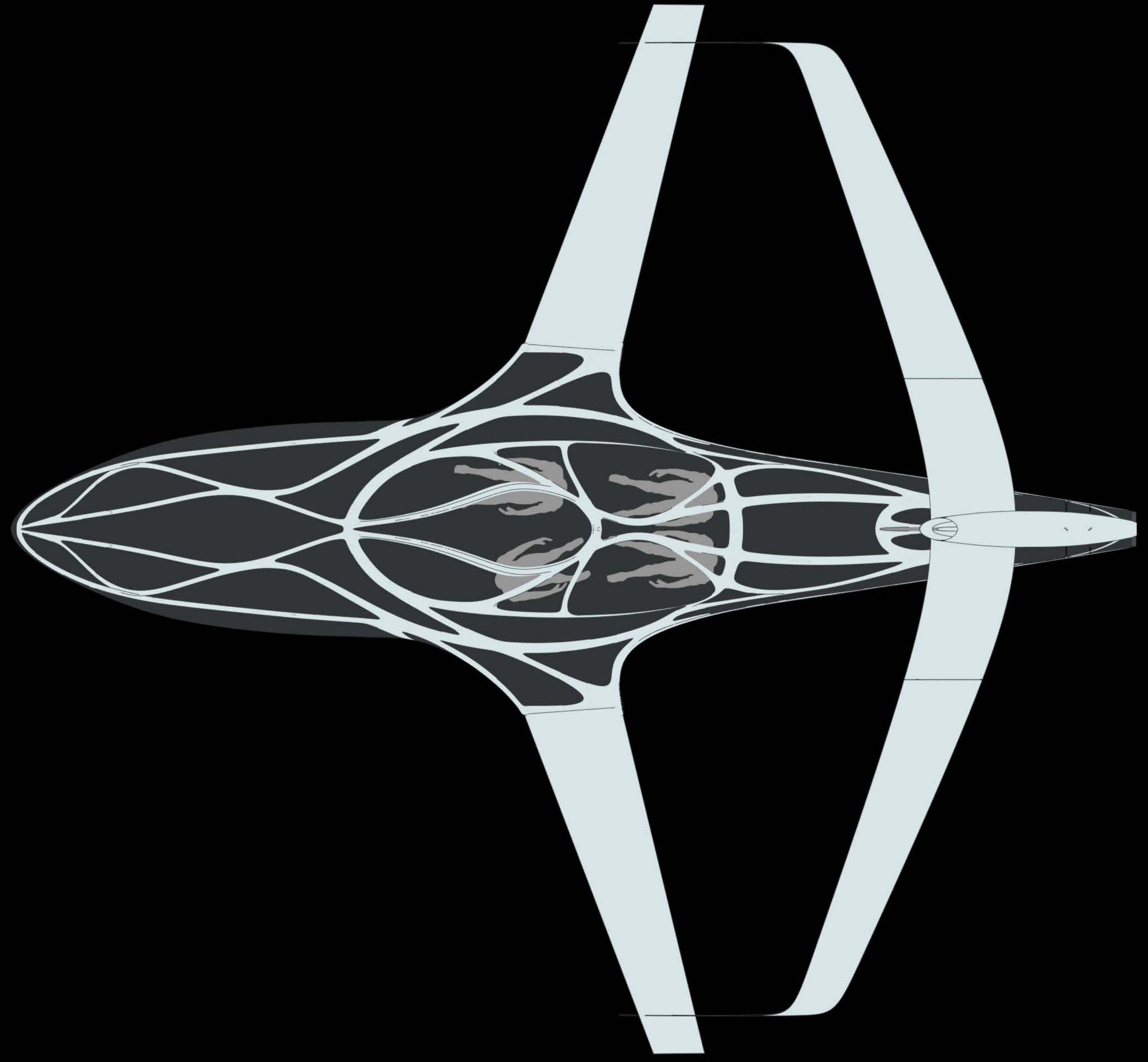


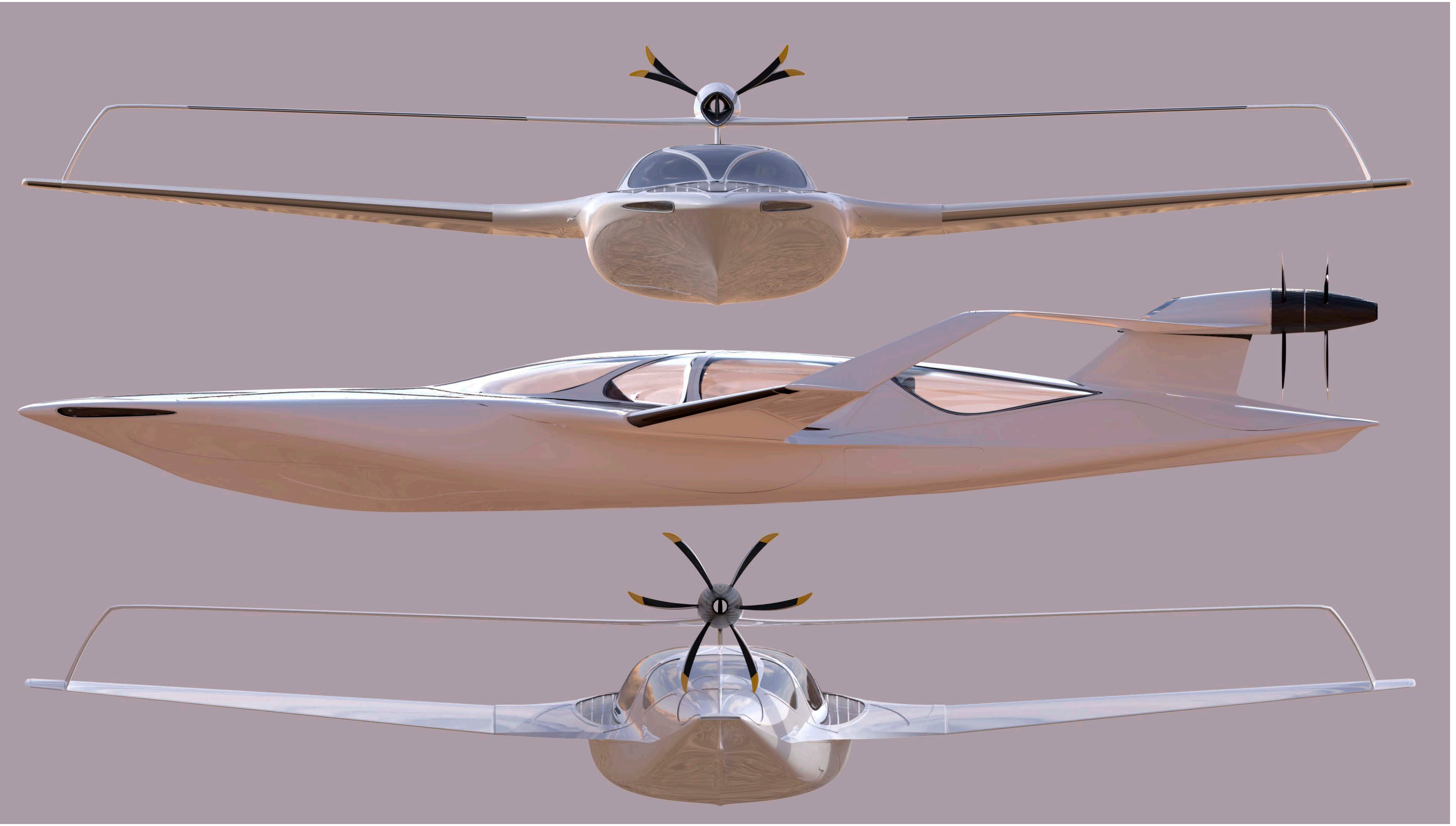
7 CONCEPT

7.1 Piaggio P107

Piaggio P107 is a four-seater electric flying boat. It offers glamour and luxury of bygone days in a compact, sleek and sporty package. Those who can afford it will get a state-of-the-art flying yacht, more versatility, comfort and fun than any speedboat can offer. Exterior is clean without being modest, and sculptural interior brings greatest elegance into the middle of the bare ocean.





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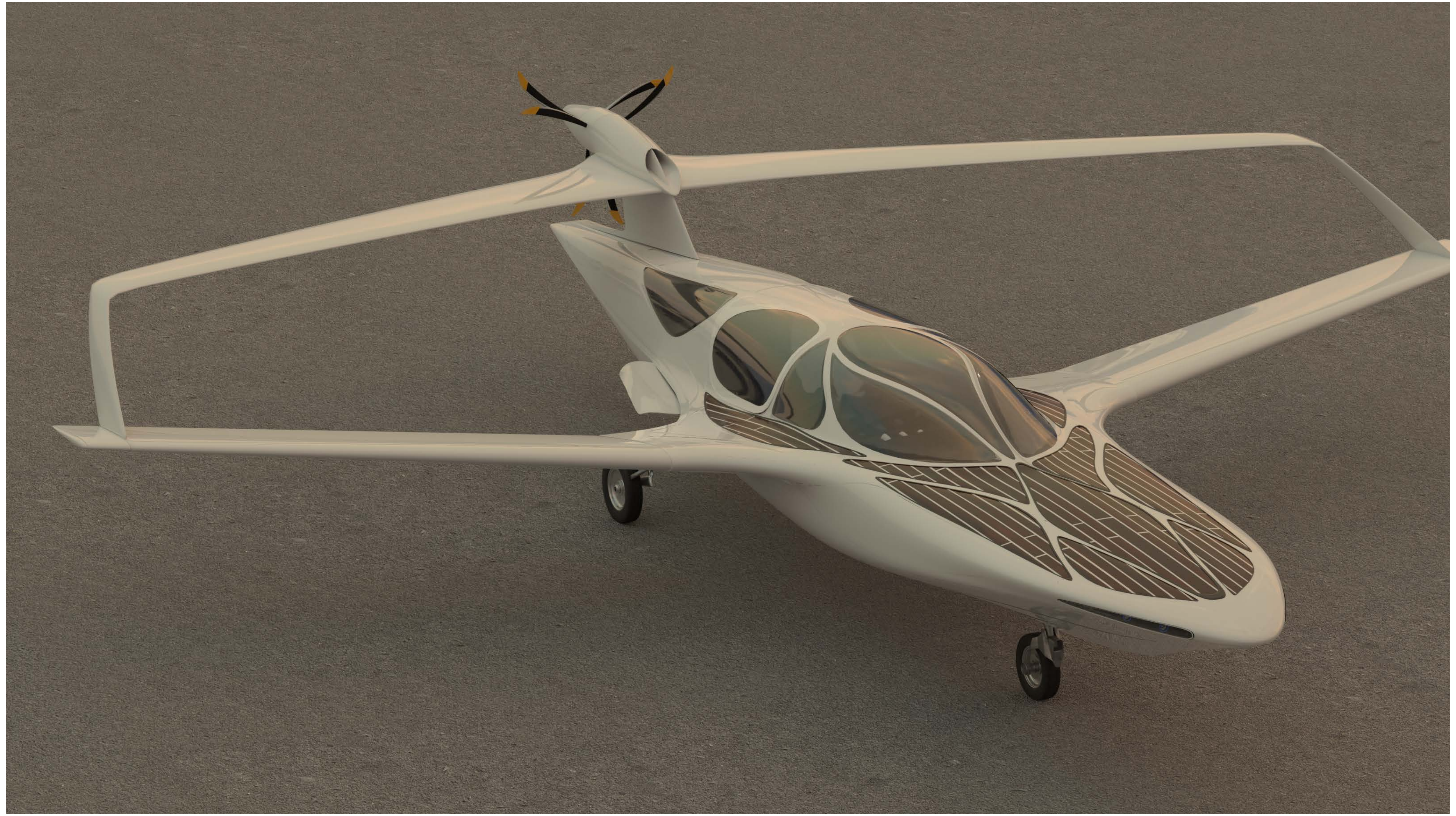

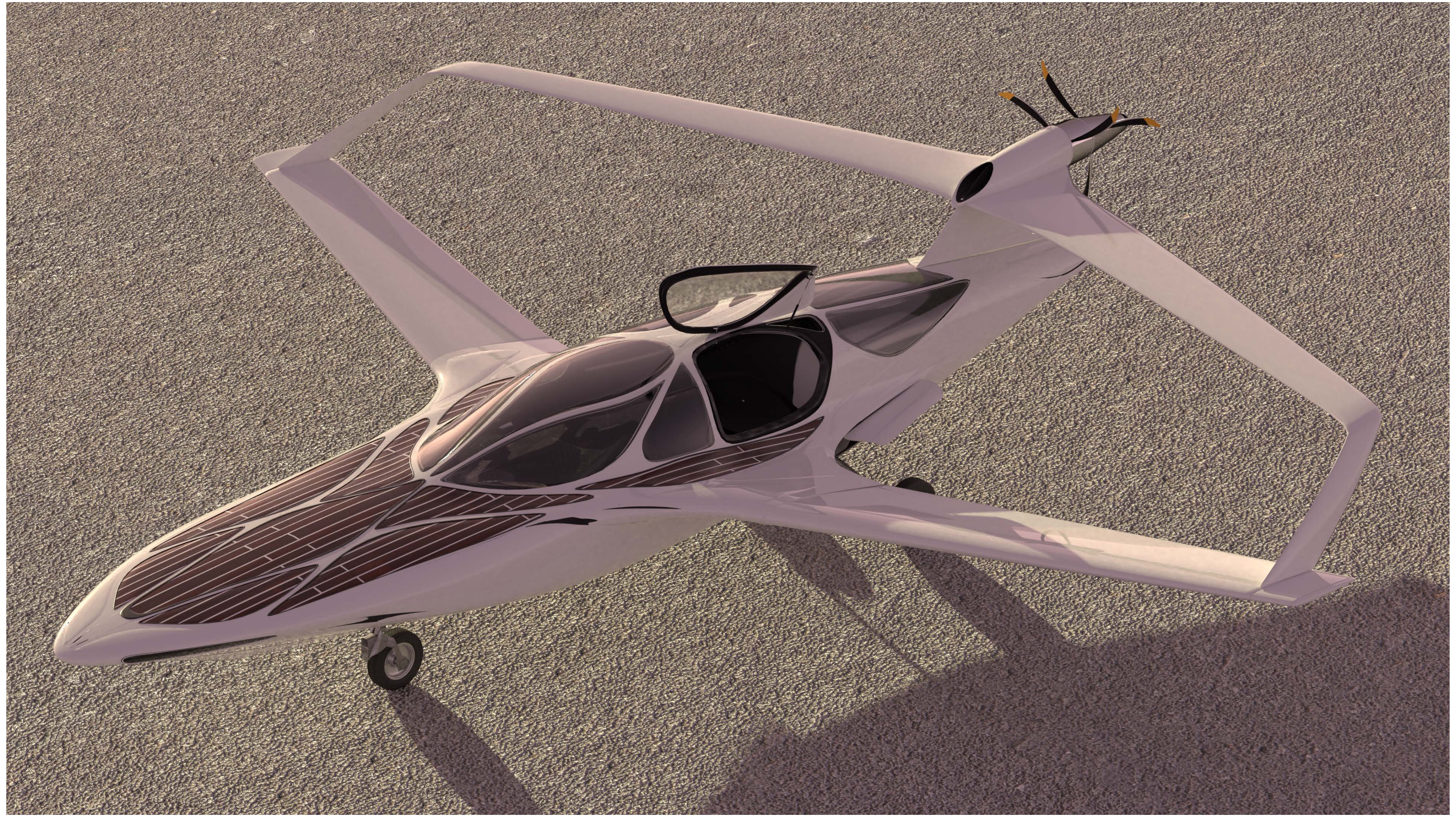

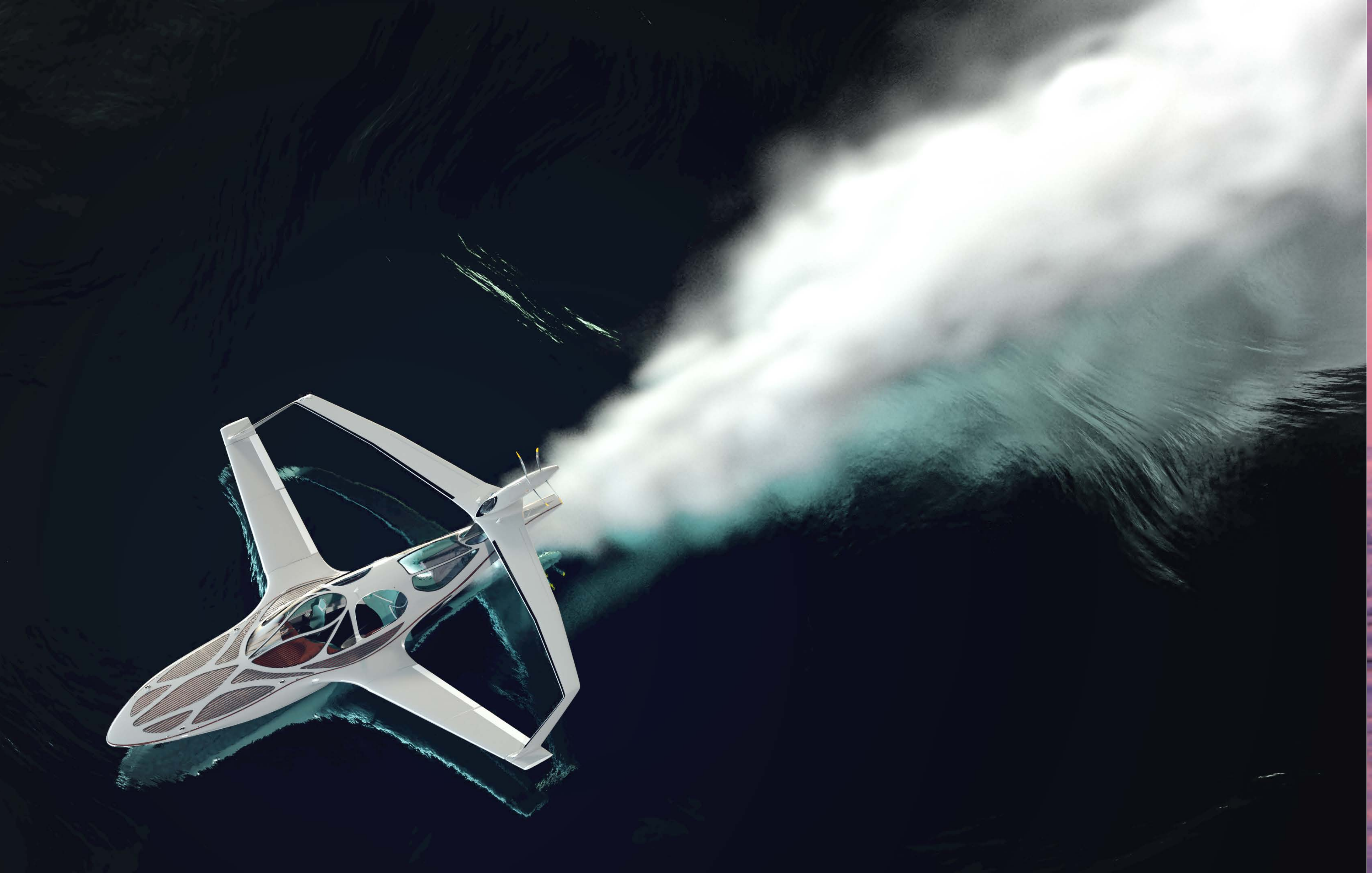



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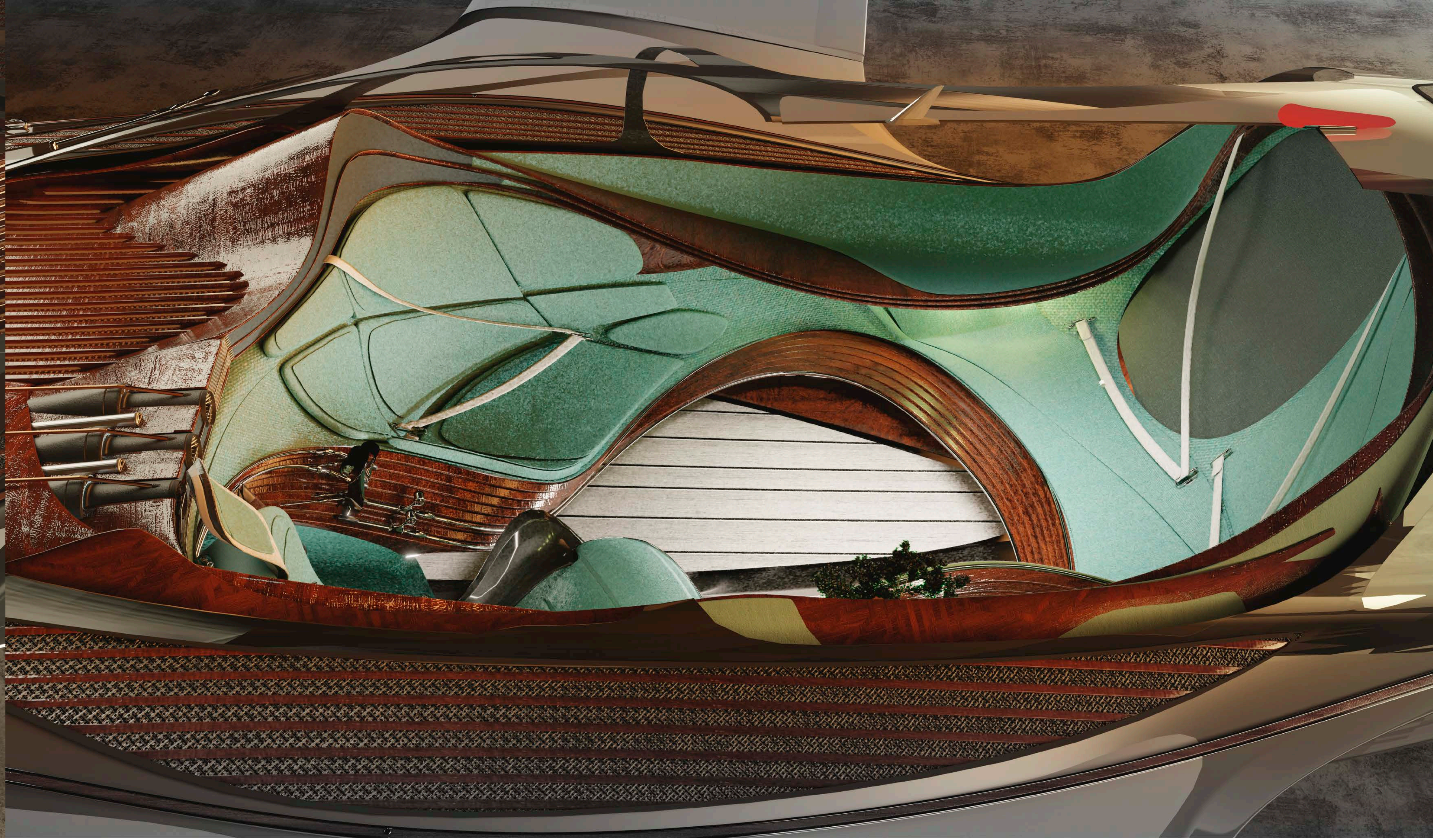



PIAGGIO AEROSPACE


Bianchi

8 EVALUATION

8.1 Process

This process created two products I'm very satisfied with. One is the design itself, a good-looking aircraft that is probably my favorite work so far. There are some parts I'm not completely satisfied with, but any of the design decisions don't really seem wrong or faulty. More important than the vehicle I created was the process itself. I have done styling processes and packaging processes, but this one was the first truly complete design process. If this had been a styling project, I'm sure the result would have looked completely different, maybe an awe-inspiring visual sculpture. As I look at the final model, I see more perfection than in any of my previous projects, because the forms are based on extensive research and requirements.

Despite the strict technical requirements the forms are not dictated by them. During the whole process I tried to keep in mind that this was primarily a design process, and even though I used a lot of technological

innovations, they are only supporting the process, not defining it. Last few months have shaped my design thinking as I have really started to understand my own design process, as well as design in general. As I started, I had no vision of the final product. I tried to give equal value to visual interest, user experience and plausibility, and in the end I feel like I've succeeded. These three weren't always balanced, but they have been behind every decision, and it is impossible to say which one of them contributed most to the final design.

It is important to point out that even though my technical and aerodynamical hypotheses are based on real facts and hard science, they may still be faulty. This is not an engineering project, and the point of the extensive research is to act as a proof of concept. My brief was to make a realistic aircraft concept instead of concept art, and that would not have been possible without technical guidelines. Design is the part that solves the problems created by user and technical requirements, not the other way round. To achieve the best user experience I chose many technical solutions that were not the most efficient, but I did not create engineering problems with purely visual choices. In cases when I had no real data of the differences of some virtually similar aerodynamic solutions I made the choice based on appearance. All the aerodynamics and engineering in this project are explained from the standpoint of this project, and they are not supposed to educate the reader. That is the reason why I haven't explained all the common aerodynamical terms or have explained them roughly.

In terms of realism the P107 is at a level where it could be used as a layout for a real production aircraft. With rough calculations, simulations and interviews I have proved that with right wing profiles and weight it would fly. This would require an intervention of a real aeronautical engineer and many solutions could probably be done much more efficiently. This is my vision of an ideal aircraft for the proposed user group, and a real production aircraft would be much more affected by economical and safety regulations.

Over the course of the next month I'm going to focus on presentation of P107. I'm trying to produce fictional marketing material, at least renders that would appeal to the users. If schedule allows I'm planning to make a scale model and/or an animation. It would also be interesting to test my aerodynamical decisions with simulations and interviews.

I had lots of innovative ideas that eventually had to be abandoned as they did not fit into this project. For the project it was beneficial that I did not choose ideas based on personal preferences, but there were some innovations I liked so much I'm probably going to use them in some other concept or at least in concept art.

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