



SLEEPING ON CLOUDS

ECONOMY CLASS SLEEPING FACILITY



MASTER GRADUATION THESIS

SLEEPING ON CLOUDS

ECONOMY CLASS SLEEPING FACILITY

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EXECUTIVE SUMMARY

Overview of this Master Thesis Project

This Graduation product concerning a Master Thesis for the faculty of Industrial Design Engineering explores and develops an Economy Class Sleeping Facility meant for the Flying V concept plane developed by the Delft University of Technology. Sleeping and relaxing are the highest performed activities inside an airplane during cruise flight, however this is scored lowest on comfort. To increase passenger comfort on long-haul flights a better sleeping facility has to be provided by airlines. An extensive literature research along with gathering of relevant information resulted in a list of requirements the Economy Class Sleeping Facility had to fulfill. These requirements together with the knowledge from gathered information were taken into account during the ideation phase. Out of these ideas 2 ideas proved to be possible to turn into a viable product meeting all requirements. These ideas were subsequently turned into concepts by evaluating measurements to check if they were indeed as promising as expected from the ideation phase. A life size prototype was built to make it possible to test both concepts with potential users. This user test performed with 10 participants generated several insights which led to changes to the concepts. Subsequently, concepts were compared and evaluated by using a Harris-Profile to see if they met all requirements formulated from the analysis phase. From this evaluation 1 concept turned out to have the most potential and was chosen to be developed into a full design. The final design consists of the Economy Class Sleeping Facility, but also took into account the whole economy class interior it should be placed in. A final evaluation was performed to evaluate the design and form recommendations. This final evaluation is done by an online questionnaire filled in by 204 participants, with 184 relevant responses.

This all resulted in the final design of the Economy Class Sleeping Facility. This Economy Class Sleeping Facility is unique because it offers beds that transform into seats which need to be used during taxi, take-off and landing. This all without occupying extra space, by applying the proposed lay-out capacity of the Flying V even increases with 3 passengers. The beds have a length of 193cm, which means that the majority of people can lay down fully flat while flying. Inside the cabin passengers have their own control panel controlling airflow, lights and the curtains which create privacy. Next to that each bed is equipped with a personal In-Flight Entertainment system. Out of 184 people who evaluated the design, aged between 17 and 75, 69,57% indicated they would use the bed system as presented to sleep during a long-haul flight. Also, participants rated the expected comfort of the beds with an average of 4,45 out of 7. While experienced comfort of sleeping in economy class seats was rated 2,63 out of 7. This shows a large increase in passenger comfort offered by the Economy Class Sleeping Facility.

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CH. I PREFACE



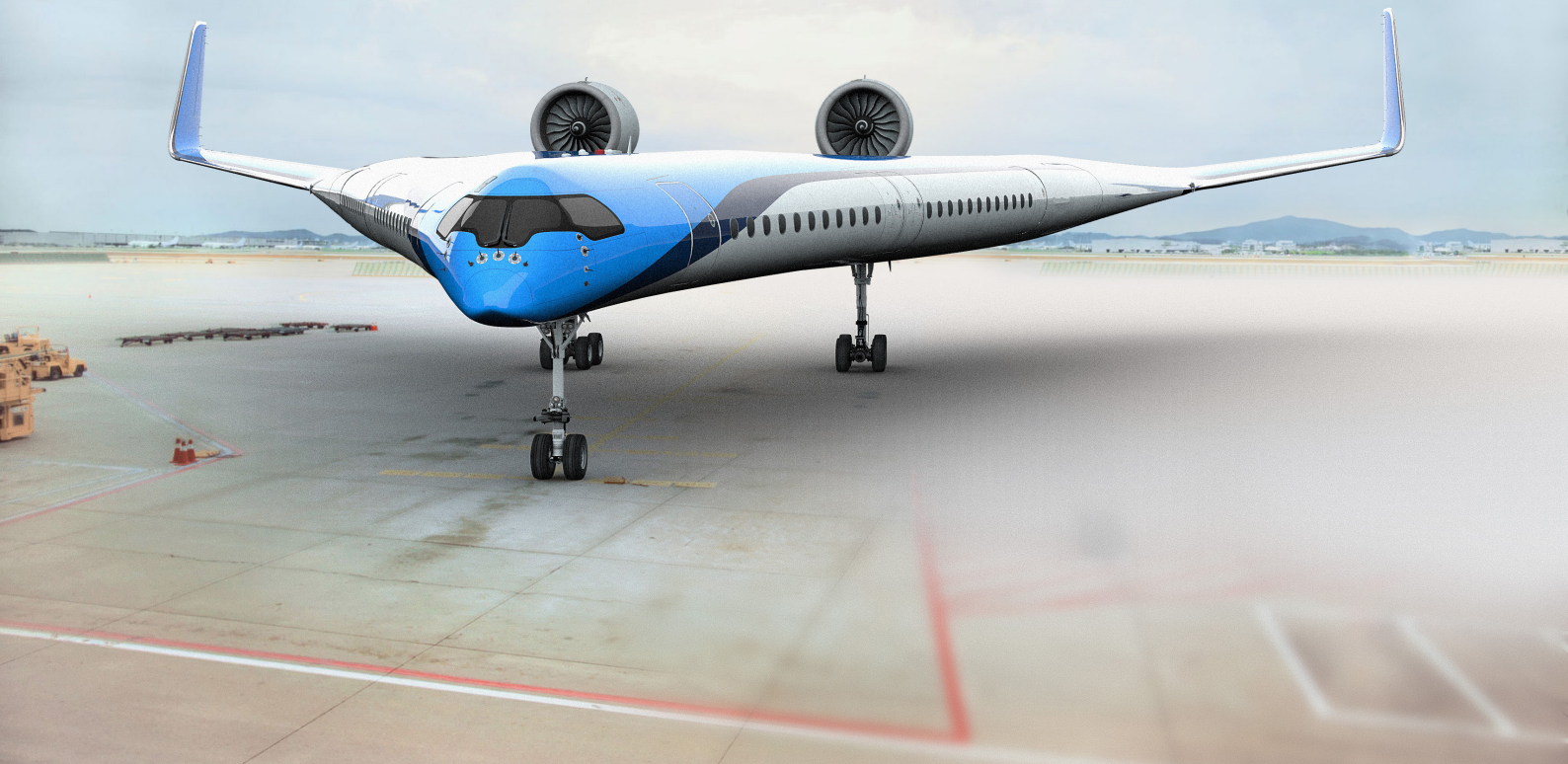


Figure 1: Flying V concept plane

1.1 ABOUT THE GRADUATION ASSIGNMENT

Preface describing the assignment

The graduation assignment to design a part of the interior of the Flying V airplane is an internal thesis project of the Technical University of Delft (TU Delft). The Flying V airplane (figure 1) is a joint project between the faculties of Aerospace Engineering and the faculty of Industrial Design Engineering.

Roelof Vos from Aerospace Engineering is in charge of the project team that is developing the exterior of the airplane, they are making a scaled prototype to demonstrate the working principle of the Flying V. The Flying V is a concept plane meant for long haul flights; the intention is that this Flying V will be in use around 2050. The airplane is basically a flying wing, passengers will be seated inside both wings. This has aerodynamic advantages which means the plane is more economical on its fuel and therefore produces less carbon dioxide emissions compared to current regular airplanes it is meant to replace in the future.

The faculty of Industrial Design Engineering is responsible for the interior of the Flying V, overseen by Peter Vink several students/employees have a part in the design of this interior. As the airplane is really conceptual, the interior being designed for this airplane will be more innovative to explore the possibilities of future air travel. Several aspects of the interior are being developed. In this report, a sleeping arrangement for economy class travellers will be investigated and developed. This sleeping arrangement poses several challenges which will be discussed further on in this report.



1.2 PROBLEM DEFINITION

Explaining the need for sleeping facilities in economy class

As mentioned before, the goal of this graduation project is to create an economy class sleeping facility for the Flying V airplane. The goal for this sleeping facility is to improve comfort of economy class passengers. This increase in comfort in its turn will create a competitive advantage for the airlines implementing it.

Literature states (see page 20, Comfort) that during flight, resting/relaxing is rated as most important activity by passengers, with sleeping rated as the most performed activity. However, this activity also has been scored the lowest on comfort. Anthropometrics of the seat combined with the position assumed by the person is considered as the most important factor determining comfort while sleeping, furthermore prolonged sitting is found to be unhealthy. Airlines have reduced the seat pitch over the years, to create the highest passenger's capacity inside their aircrafts. Next to the reduction in seat pitch, airlines also reduced the reclining angle in economy seats [1]. So, sitting in an upright position during a long-haul flight is uncomfortable, unhealthy and obstructs the most performed activity; sleeping. Therefore, the goal of this graduation project is to increase passenger comfort by providing a sleeping facility for economy class passengers.

This goal creates several challenges which need to be taken into account during development. First of all, passenger safety. There is an enormous number of rules in passenger aviation all concerning the safety of the passenger. The main rule to take into account is the fact that passengers cannot take-off or land while laying down, they have to be in fully upright position. Next to the safety concerns, the capacity of the airplane is an important aspect to take into account as well. The sleeping facility should occupy roughly the same space as the economy seats to prevent a large increase in price. Finally, comfort of the passenger is a very important factor to take into account while designing.

All these challenges will be analysed further on in the report, out of this analysis conclusions regarding the economy class sleeping facility will be drawn.

“The goal of this graduation project is to create an economy class sleeping facility for the Flying V airplane.”





1.3 STAKEHOLDERS

Explaining the need for sleeping facilities in economy class

The aviation industry has to deal with many stakeholders, ATAG (Air Transport Action Group) created a stakeholder's map concerning the global air transport system [2], this illustrates the large number of stakeholders involved in this industry (figure 2).

When looking at this map it can be concluded that not all of these stakeholders are relevant for this project; developing an economy class sleeping facility. Therefore, several relevant stakeholders have been listed with an explanation of the relevance considering this project.

1.3.1 Passengers

Starting with the most important stakeholder, the passengers. This stakeholder will be the one using the product; therefore, it has to meet their expectations. The sleeping facilities will be offered in economy class; therefore, the passengers will expect that a comfortable sleeping position is offered without paying business class rates.

1.3.2 TUDelft

Since the Flying V concept is being developed by the TUDelft this can also be considered as a relevant stakeholder. Their main demands are the fact that the sleeping facilities should be made with the sizes of the Flying V in mind. The number of passengers should not decrease comparing it to a regular airplane lay-out. Finally to meet fuel economy goals the structure should be as light as possible.

1.3.3 Airlines

Airlines are the stakeholders who end up buying the product. The product should meet the safety regulations and offer them a competitive advantage by providing extra service/comfort.

1.3.4 Safety Agencies

Aviation has to meet a lot of safety standards set by safety agencies like the FAA (Federal Aviation Administration). Therefore, it is key that the product meets these regulations.

1.3.5 Cabin crew

Cabin crew has to work inside the aircraft, maintain an overview and serve the passengers drinks, food and so on. Next to that they should offer services to the passengers specific for the sleeping facility, like providing a clean blanket if necessary.

1.3.6 Cleaning staff

Because airlines want to prevent their planes from getting a delay it should be taken into account that the cleaning staff need to do their job as convenient as possible. This means that cleaning staff needs easy access to the surfaces which need to be cleaned. For instance, replacing the blankets or cleaning the mattresses should be a task achievable in a short time.

1.3.7 Manufacturers

Because of the fact that the design of the sleeping facility is to be used in the future, manufacturing options are more diverse. However, production should be taken into account, to ensure the possibility of production.

1.3.8 Maintenance crew

Since airplanes have to endure regular check-ups to ensure safety, it should be possible to replace broken parts.

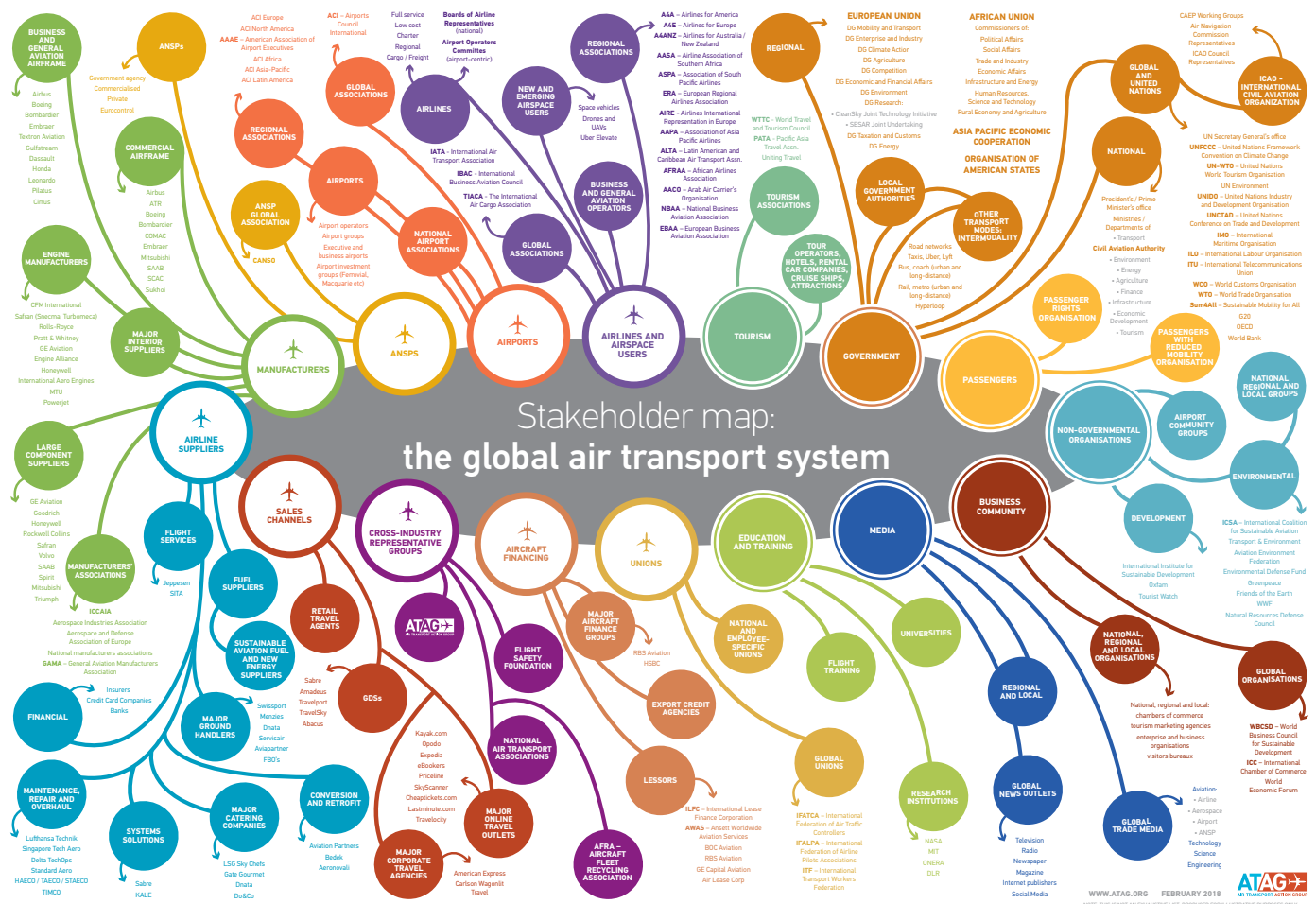


Figure 2: Air Transport Action Group Stakeholder map [2] of the global air transport system

The previous page has listed several stakeholders which should be taken into account while developing the design of the sleeping facilities. Nonetheless, many other stakeholders will have a stake in this product. These stakeholders exceed the scope of this project, were the main focus is on the product itself, and therefore will not be taken into account.

Along the most obvious remaining stakeholders which are not taken into account are the airports. There needs to be extra storage space to place replacement parts and so on, which is ofcourse also relevant for the Airlines using the product. Next to that, suppliers who intend to sell this product also are not taken into account. Costs in general will not be investigated, as the design is meant for an airplane hitting the market in 2050. Therefore production costs are difficult to estimate considering new technological developments.

CONCLUSION

Stakeholders were analyzed in this section to create more insight in which factors have influence on the product. Stakeholders relevant for this project will be taken into account while developing the product. Since the result of this project is quite contextual, not all stakeholders will be explored extensively. Production for instance will not be looked into in a lot of detail. It is listed to be aware of it during designing, meaning that it should be possible to be produced. Analysis of several subject related to the stakeholders will be performed further on in the report, which generates new insights and requirements which can be used to evaluate ideas and, in the end, the selected concepts.

Only the most relevant information which has influence on the product and can be verified will be turned into requirements, other factors that have influence on the product will be turned into wish-es.

ANALYSIS

CH. 2

INTRODUCTION

The following chapter will explore the context of this graduation assignment. By looking into literature and relevant information conclusions can be drawn which affect the design of the economy class sleeping facility. This analysis chapter consists of several sub chapters all exploring a different subject/context. After this chapter all conclusions of the context exploration together with the assignment description are listed in a program of demands. This program of demands will benefit the ideation and conceptualization phase, it will result in a more complete design and help make substantiated decisions.





2.1 AVIATION INDUSTRY

Illustrating the relevance of the development of the Flying V

In this first-sub chapter of the analysis phase the aviation industry will be investigated. Growth, pollution and environmental goals of the industry will be discussed to portray the relevance of development of new airplanes. After this chapter the Flying V, which is briefly discussed earlier on in this report, will be investigated more meticulous.

The Aviation Industry is one of the largest industries worldwide. In 2017 global commercial airlines generated a revenue of 755 billion dollar [3] To illustrate the sheer size of this industry, with their total generated revenue in 2017 they would rank as 20th largest country in the world in terms of gross domestic product (GDP) [4].

Alexandre de Juniac, International Air Transport Association (IATA) Director General and CEO stated that flying has never been more accessible. In 2000, the average citizen flew just once every 43 months. In 2017, the figure was once every 22 months[5]. This statement

depicts the growth the aviation industry has made, and it doesn't show signs of stopping growing. In 2017, around 4.1 billion passengers were carried by the world's airlines. The IATA expects passenger number to nearly double and grow to 7.8 billion in 2036 [6]. Accountable for the huge growth of this demand will be the emerging markets in the Asia-Pacific region [7]. It is expected that this region will be the source of more than half the new passengers over the next two decades.



Reducing the environmental impact [4]

In 2008 the aviation industry agreed to three sector specific climate change targets.

1. Between 2009 and 2020, Aviation will improve its fleet fuel efficiency by an average of 1,5% per year.
2. From 2020, net carbon emissions from aviation will be capped through carbon neutral growth.
3. By 2050, net aviation carbon emissions will be half of what they were in 2005.

The largest Dutch airport, Amsterdam Airport Schiphol has reached the limit of growth in 2018 of 500.000 flights a year, this limitation was set for 2020 [8]. Currently there is a lot of discussion going on about the growth of Schiphol after 2020. Most arguments against the growth of the airport regard nuisance because of the noise, air quality because of the emissions, safety and nature which has to give way for expansion of the airport [9]. The environmental impact of air travel is the main counter argument against a growth of the Amsterdam Airport Schiphol at the moment. Currently the climate agreement by the United Nations of Paris 2015 is a major discussion point in Dutch politics[10].

The fact is that flying is a big contributor to the carbon dioxide pollution. In 2017 flights produced 859 million tons of carbon dioxide [3]. Comparing that to the 40 billion tons of carbon dioxide produced by humans globally in 2017 it can be concluded that over 2 percent of human induced carbon fiber is produced by the aviation industry [4]. With the growth of the aviation industry the carbon dioxide pollution by the industry grows with it. In 2013 the pollution by the aviation industry consisted of 710 tons of carbon dioxide, in 2017 that grew to 859 tons in 2017 [3] . Therefore, the huge expected grow of the aviation industry due to the emerging markets [5-6] will also create an immense growth in Carbon Dioxide pollution.

To reduce the carbon dioxide emissions of the aviation industry to half of the value emitted in 2005 a lot has to change. According to the

ATAG, companies across the sector are collaborating to reduce emissions using a four-pillar strategy. This strategy consists of new technology, efficient operations, improved infrastructure and market-based measures to ensure the emissions will reduce to the stated goal in 2050 [11].

The aviation industry adopted the world's first global carbon mechanism for any industrial sector: the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [12]. As of October 2018, 73 nations signed up to the initial voluntary phases of this agreement, which means that around 80% of the post-2020 growth of international aviation will be offset. To help achieve the goal of a carbon-neutral growth, the agreement becomes mandatory from 2027. However, to achieve the long-term goal of the industry set for 2050, cutting overall emissions to half of the 2005 value, the aviation industry will need constant technological innovation. At the moment, civil aerospace invests 15 billion dollars a year on efficiency related research and development.

CONCLUSION

The aviation industry is one of the largest industries worldwide and keeps on growing. To meet the environmental goals of the aviation industry set for 2050 a lot of improvement is necessary. Therefore, the development of the Flying V is of importance in trying to achieve this environmental goal.





2.2 FLYING V

About the concept plane being developed by the TUDelft

This part of the analysis phase features an in depth analysis of the Flying V concept plane. The Flying V is a concept plane meant for long haul flights, it is more fuel efficient than current airplanes and the intention is to replace these airplanes with the Flying V around 2050.

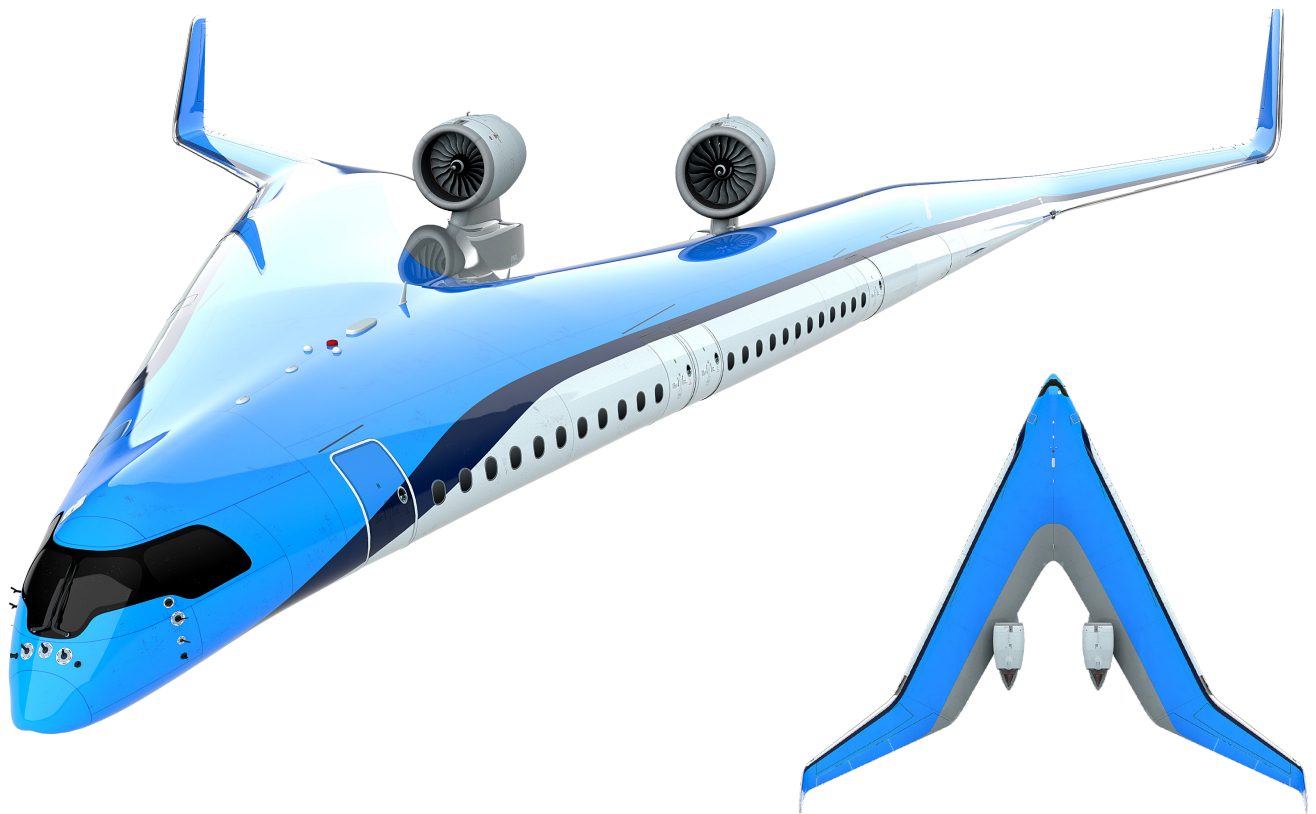


Figure 3: Flying V airplane.

As mentioned in the previous section, the aviation industry has to reduce their carbon dioxide emissions. One of the ways to accomplish this is by developing new airplanes which are more fuel efficient, this is the reason the Flying V concept is being developed. The Flying V is basically a flying wing, it is a V-shaped aircraft (figure 3) without a hull in the middle as can be seen in regular airplanes. The cabin of the Flying V is localized inside the wing, this has several benefits compared to a regular airplane. A flying wing has remarkable aerodynamic and structural advantages because of the low wetted area and interference drag and beneficial spanwise distribution.

Next to that, because the engines are mounted at the top back of the aircraft the noise produced is shielded by the wing, so less noise disturbance on the ground. Instead of having a cylindrical hull, the Flying V has a cross section shaped in the form of an ellipse (figure 6&7). This means the volume of the wing can be used in an efficient way without a large structural setback due to the cylindrical nature of the cabin. (Faggiano et al. 2017)



The Flying V is originally a project from the Airbus Future Project Office, they handed it over to the faculty of Aerospace Engineering at the TUDelft to further develop. At the moment of writing, Roelof Vos from the department of Aerospace Engineering is leading the developments of this aircraft and they are working on a functional scaled prototype. The interior is being designed by the faculty of Industrial Design Engineering, who are creating a more conceptual future interior instead of a regular 10 a breast seating configuration.

As mentioned before, the faculty of Industrial Design is working on a more conceptual, innovative lay-out for the Flying V interior. Part of this innovative interior is the sleeping arrangement in economy class developed in this graduation report. However, because capacity of an airplane is of major importance for the airlines who will use the airplanes, it should be taken into account that the capacity should stay the same in the most ideal situation. Figure 4 depicts a general, more conservative floorplan of the Flying V. In this floorplan the economy class consists of 266 seats, they are placed 10 abreast with a seat pitch (figure 5) of 32 inches (81,28 cm).

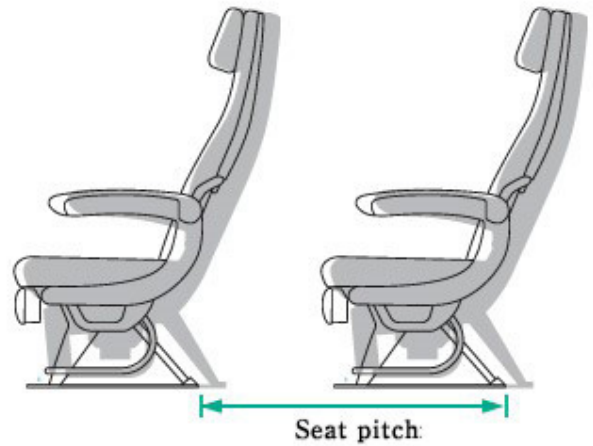


Figure 5: Seat pitch.

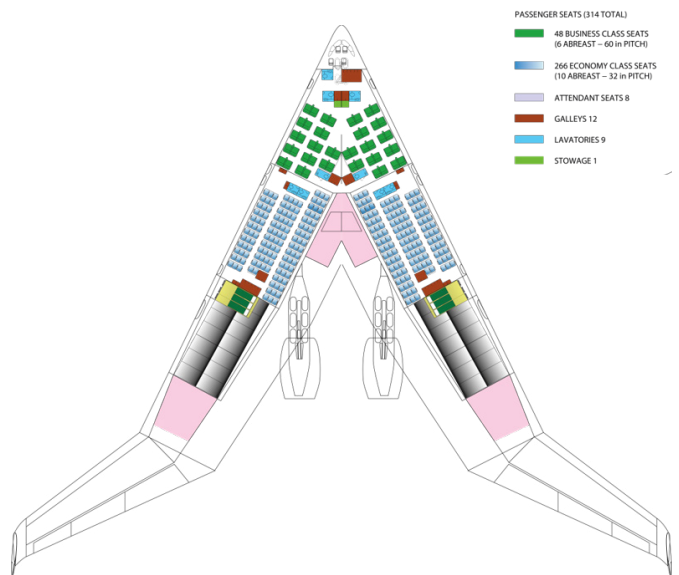


Figure 4: Flying V conservative floorplan.

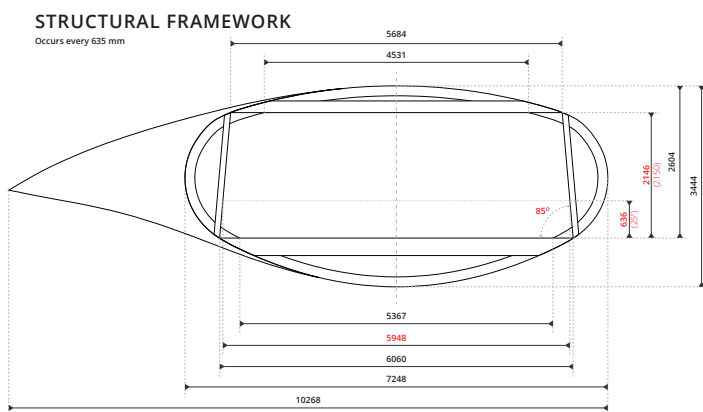


Figure 6: Cross Section of part of the Flying V.

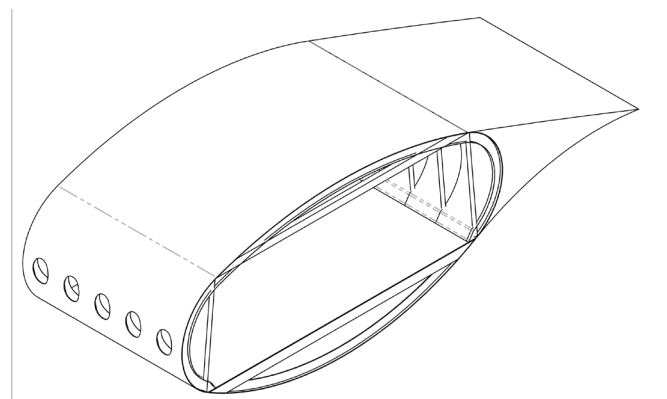
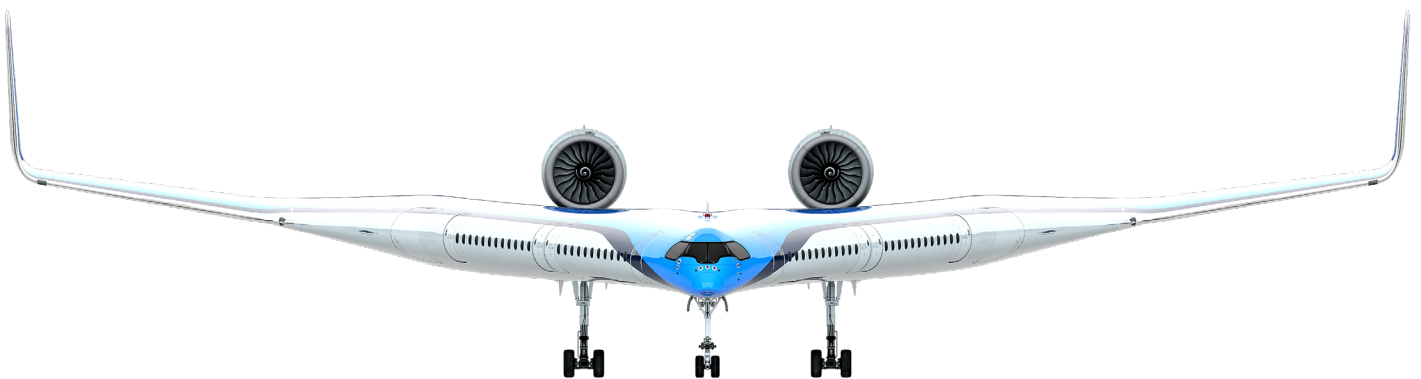


Figure 7: Part of Flying V hull.



CONCLUSION

To make sure that the airplane is as economical as possible the interior should be as light weight as possible. Next to that it is important that innovative interior doesn't affect the passenger capacity of the airplane, because in that case more airplanes need to fly which in its turn is not beneficial for the pollution by the aviation industry. Since the goal of this project is a conceptual design of a Sleeping Facility for Economy Class the weight of the design will not be calculated, it will be taken into account by using as little parts as possible.



2.3 COMFORT

Investigating passenger comfort in airplanes and the need for a sleeping facility

Comfort of the passenger is very important. In the end, they will be the ones using the product. Results of relevant literature considering passenger comfort in airplanes is listed below, from this conclusions are drawn which influences the economy class sleeping facilities.

Research indicates that comfort is an important factor for passengers in the decision to book another flight with the same airline (Vink et al. 2011). Comfort is established by the following six factors: anthropometry, climate, sound, vibrations, light and smell (Bubb, H et al. 2015). Research regarding these six comfort factors while sleeping in aircraft interior shows the order of importance rated by passengers. Anthropometrics of the seat is considered as the most important factor determining comfort while sleeping (Bouwens et al. 2018).

When looking at a study which investigated the passenger satisfaction based on their inflight activities, passengers rated resting/relaxing as most important activity. The second highest rated activity was using the bathroom, followed by sleeping. Both resting/relaxing and sleeping received low satisfaction scores by passengers, sleeping was the lowest scored activity out of the 23 possibilities (Torkashvand et al. 2019).

Bouwens, et. all (Bouwens et al. 2017) executed a research to identify whether there are differences in passenger's comfort experiences during different phases of a flight. This resulted in the fact that storing hand luggage and cruising were scored as the lowest phases of the flight considering comfort. Subsequently looking at activities performed by passengers during cruise flight it can be perceived that sleeping is done by the majority of the respondents and rated as most executed activity.

While sleeping was rated as the most performed activity, it also has been scored the lowest on comfort. Sleeping and being bored were

rated significantly lower than the other activities considering comfort during flight. Where sleeping on long haul flights is logically being rated even lower than short flights.

It can be concluded from conducted studies described above that sleeping is a frequent activity executed by a majority of passengers. However, all researches indicate a low comfort score given to the sleeping activity. Therefore, an opportunity is present in increasing passenger satisfaction by increasing comfort during sleeping. Because comfort attracts passengers (Vink et al. 2011) this increase of comfort will be an opportunity for airlines to gain an advantage over their competitors.

Further more, research indicates that In Flight Entertainment can distract from a situation with low discomfort (Bouwens et al. 2017). This means that an In Flight Entertainment system is used to cover up discomfort and increase the experienced comfort of passengers.

CONCLUSION

Sleeping is rated as the most performed activity inside airplanes, and scored the lowest on comfort. This means an Economy Class Bed can improve passenger comfort a lot. Passenger comfort is the most important aspect of this project, therefore the project can only be marked as successful if the Economy Class Sleeping Solution to be designed is rated higher on (expected) comfort.



2.4 SLEEPING

How people sleep and what stimuli influence sleep

To create a sleeping facility, it is necessary to first understand how people sleep and what factors influence their sleep. This analysis will generate relevant insights which can be used developing the sleeping facility meant for economy class.

2.4.1 Stimuli

While sleeping, sudden loud noises can be disturbing. Stimuli like sound, light or touch can end your sleep. This is a sort of instinctive safety system because these stimuli can indicate a dangerous situation. Not only hard stimuli can end sleep, but also suspicious low intensity stimuli are capable to do so. For instance, the smell of something burning is perceived as a threatening stimulus and can result in the termination of your sleep. During sleep, an evaluation mechanism unconsciously analyses all stimuli. If these stimuli are judged to be important the sleep is ceased. This mechanism is of vital importance for humans, and the conscious level during sleep is the difference between sleeping or being in a coma. Normal sounds like a ticking clock don't disturb us in our sleep, unless they annoy you while falling asleep. A sudden stop of a sound perceived as normal can also evoke a waking up reaction by the evaluation mechanism (Coenen, 2006)

2.4.2 Posture

The bed is a large factor which improves sleeping quality. Laying down requires the least amount of energy, connected to the largest relaxation of muscles. The pressure on our vertebral column and joints is the lowest and the heart has the least amount of trouble pumping blood through our veins. Therefore, sleeping in a bed, so while laying down, is the most comfortable position for humans to be in. It is recommended that the bed is 20 centimeters longer than the person sleeping in it. To provide enough freedom of movement, the width of a bed is recommended to be 80 to 90 centimeters (Coenen, 2006).

During sleeping many different postures are assumed (figure 8) [13]. People do have a favorite sleeping posture which occurs most during sleep (Coenen, 2006), however between 20 and 40 posture changes take place during the night (Coenen, 2006; Verhaert, 2011). Movement during sleep is beneficial to relieve local pressure and shear loads acting on the skin. Blood flow and oxygenation might be affected when maintaining a posture for too long. Posture change is caused by local tissue ischemia which generates metabolic substances that stimulate nerve extremities (Verhaert, 2011). If no posture changes occur during sleeping people will wake up with sore and stiff muscles and joints. As mentioned before, there are many sleeping postures people take while laying down (figure 8), the basic sleep postures consist of supine, lateral and prone (Verhaert, 2011). Where supine means sleeping on your back, lateral on your side and prone with your belly facing down. Lateral is the favorite position for people to sleep in, this is also the best posture for your body to be in (Coenen, 2006).

An observational study where 12 persons were monitored during their sleep for 2 nights showed that during the first night of observation 73,2 percent of the sleeping time was spent in the side (lateral) position. The second night barely showed a difference in results; with 73,1% of the sleeping time spent in lateral position. Next to that 10 out of the 12 respondents indicated that they sleep on their side on a usual night (Gorden et. al. 2004).



Figure 8: Several different sleeping postures

CONCLUSION

During sleeping our posture often changes, therefore the measurements of the sleeping facility should be taking these movements into account. This means that it should be possible to sleep on your back, side and front. The recommended length of a bed to be 20cm longer than the length of the person seems unreachable because of the limited space available in airplanes. The same accounts for the recommended width of 80-90cm. These measurements make sense in a bed you would sleep everyday in, since this would take up way too much space inside the airplane measurements will be analysed more extensive further on in this analysis phase. Finally, while sleeping several stimuli must be avoided to prevent waking-up. One of these stimuli is light for instance, it should be possible to create a dark environment inside the sleeping cabin.



2.5 Regulations and Safety

What regulations influence the design and need to be taken into account

Passenger safety is keen in the aviation industry. Several agencies worldwide cooperate to create and administer rules. This section will discuss relevant safety regulations and how they affect the economy class sleeping facility.

2.5.1 Agencies

The aviation industry has to deal with many regulations considering safety of passengers and crew. In 1944 the International Civil Aviation Organization (ICAO) was founded, this agency of the United Nations concerns themselves with reaching consensus together with the 193 Member States and industry groups on international civil aviation Standards and Recommended Practices (SARPs). Furthermore, they also create policies in order to have a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. National agencies subsequently make sure these regulations are met in their area to maintain a global safety aviation norm [14]. These local agencies are for instance the Federal Aviation Administration (FAA) in the United States and the European Aviation Safety Agency (EASA).

2.4.2 Force

Aircraft interior has changed tremendously over the years to improve comfort and more important safety of passengers to increase the chance of survival after a crash. Looking at passenger seats from 1929 in figure 9 it is hard to imagine these seats will keep occupants safe during crash. Currently all airplane seats are required to withstand a dynamic force of 16G forwards and a force of 14G downwards. Two separate dynamic tests were selected to simulate accident scenarios.

The first test (figure 10) simulates ground impact following a quick vertical descent in order to test vertical loading on the passenger. The seat is to require a force of 14G in the vertical direction to reduce spinal injury. The second test (Figure 11) regards the force of 16G forwards which the seat has to withstand. This test simulates a horizontal impact with a ground-level obstruction, which provides an assessment of the occupant restraint system and seat structural performance[14-15].

2.4.3 Upright & Evacuation

All seats should be in upright position during taxi, take-off and Landing (TTOL) to assure the degree of safety intended during emergency evacuation. This upright position is obligatory to prevent hinder of tilted seats while evacuating and makes sure airplanes suffice to the rule that an airplane should be evacuated in 90 seconds. The only exception to the upright position is to accommodate persons who are unable to sit upright for medical reasons, providing that the seatback doesn't obstruct access to the aisle or emergency exit for any other passenger. [16-18] Next to that it is also stated that when a seat isn't reclined it is easier for a passenger to assume the brace position. [19]



Figure 9: Wicker passenger seats on a 1929 Hamilton Metalplane [15]

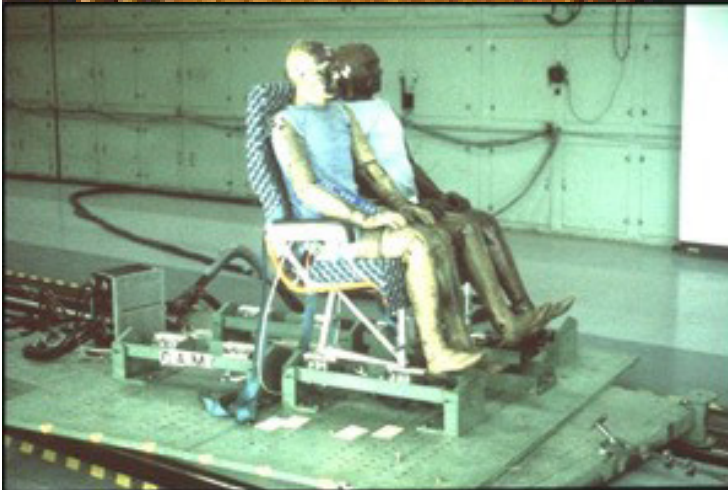


Figure 10: 14G test

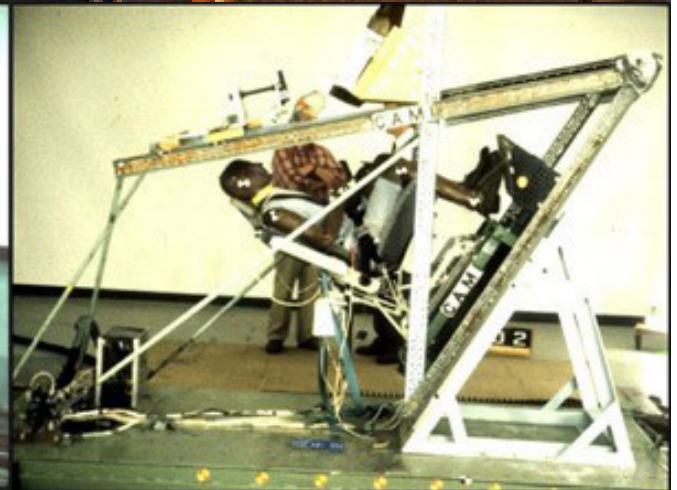
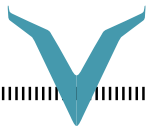


Figure 11: 16G test

CONCLUSION

The most important regulation to be taken into account is the fact that you have to be seated, in upright position, while taxi, take-off and Landing (TTOL). This poses a challenge which has to be solved to make the design into a feasible product. Next to that, an airplane has to be fully evacuated within 90 seconds. This however is fairly difficult to test within this project, nonetheless it should be taken into account.



2.6 Current Sleeping Facilities

Sleeping facilities present in airplanes at the moment

Exploring the alternatives being offered by the airline industry which will compete against the design pro-posed in this report.

2.5.1 Business/First Class

Premium-class cabins like first and business are of vital importance for airline finances. Combining January and February of 2018, the premium cabin accounted for 5.4% of total international origin-destination passenger traffic. This 5.4% generated 30% of the revenues in those 2 months. [21]

Airlines offer business class seats which can be reclined fully, creating a flat bed to sleep on (figure 12). Next to that there are also several airlines who offer first class suites, these suites (figure 13) provide a private room inside the airplane.

When comparing Economy Class with Business Class a huge price difference can be perceived. Below figure 14 illustrates the enormous price difference present if you book Economy or Business on the same flight. If you book a return flight to New York JFK airport an Economy Class ticket will cost you 706 euro's excluding the 10 euros booking fare, a Business Class ticket on that same flight to New York will set you back 8354 euro's excluding 10 booking fare. That is a price difference of 7648 euros for the exact same flight, so why do people travel business class? (both prices retrieved from the KLM website at the 29th of May 2019, both at the same time)



Figure 12: KLM business class

Amsterdam → New York, 1 volwassene, Economy Class										Wijzig
Heenvlucht - donderdag 20 juni 2019										
13:20	AMS	8h15	Rechtstreeks	JFK	15:35	1 Vluchtgegevens	KLM	4.5 ★★★★★	47 beoordelingen	EUR 541
Terugvlucht - donderdag 27 juni 2019										
17:35	JFK	7h20	Rechtstreeks	AMS	06:55	1 Vluchtgegevens	KLM	4.2 ★★★★★	30 beoordelingen	+ EUR 165
Amsterdam → New York, 1 volwassene, Business Class										Wijzig
Heenvlucht - donderdag 20 juni 2019										
13:20	AMS	8h15	Rechtstreeks	JFK	15:35	1 Vluchtgegevens	KLM	4.5 ★★★★★	47 beoordelingen	EUR 5.473
Terugvlucht - donderdag 27 juni 2019										
17:35	JFK	7h20	Rechtstreeks	AMS	06:55	1 Vluchtgegevens	KLM	4.2 ★★★★★	30 beoordelingen	+ EUR 2.881

Figure 14: Comparison between economy and business prices

According to Neil Patel, an entrepreneur who has spent over 180.000 dollars on business class tickets, flying business class is a really good way to network and meet new people. Next to that he states that one of the great things about business class is the fact that you can sleep in a bed.

"I'm used to getting eight or more hours of sleep a night, so keeping up with my sleep on an airplane is important for me. When I arrive at my destination, I'm usually rested and ready to go." [21]



Figure 13: Business lounge



British Airways was the first airline to offer fully flat beds in their business class in the early 2000's. They managed to fit the 180-degree flatbeds by applying their innovative ying-yang layout (figure 15). This lay-out meant passengers would sit side by side but face different directions, one forwards and the other backwards with more space at the wider part of the body and less space at the narrow body parts.

The combination of reducing aisle space and the ying-yang configuration even meant that their business class increased in capacity, from 7 seats to 8 seats a row. These flat beds had a length of 6 foot, almost 183 cm, in fully reclined position. [22-23]

Current KLM Business Class seats measure a length of 80 inch (203,2cm) and a width of 20 inch (50,8 cm) [24]

Of course, flying Business Class is not viable for the majority of people because of the huge costs attached. However, providing a sleeping arrangement in economy class could result in an increase in comfort for passengers. Therefore, it is worthwhile to investigate if there is an opportunity to offer more comfortable sleeping arrangements in economy class, compared to the regular economy seats.



Figure 15: Ying-Yang business class beds

2.5.2 Cabin Crew

On flights which take longer than 10,5 hours it is demanded by law that the crew should get some rest. Therefore, there are several beds inside the long-haul aircrafts, which are called the overhead crew rest (OCR) (figure 16). These beds are located above the cabin or below the floor. Cabin crew take turns resting to ensure the safety on board. The bed is 195 cm in length and 70 cm wide, and is equipped with a seatbelt.

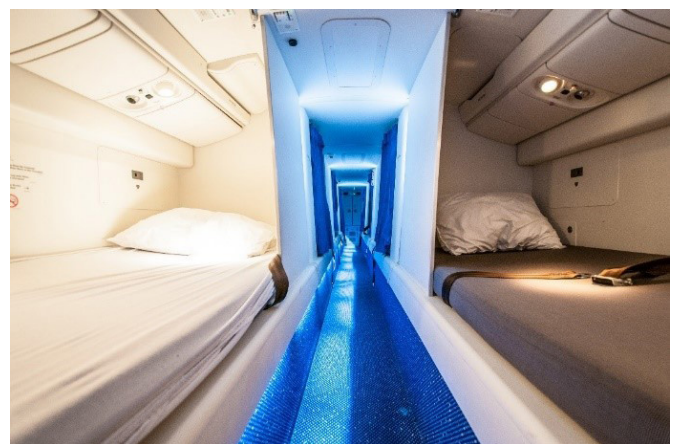


Figure 16: Crew Rest



2.5.3 Economy Class

Currently several airlines offer an option to lay down stretched in economy class on a long-haul flight. This option turns a row of seats into a flat couch/bed where passengers can relax and sleep on.

1. Piuma Sofa (figure 17)

Air France and South African Airlines offer the Piuma Sofa produced by company Geven. By taking of the headrests and placing them in the gap your legs supposed to be a flat surface is created. [25-27]

2. Sleeper Seat (figure 18)

Thomas Cook Airlines recently started with providing the option of having a stretched bed in economy class. A row of three economy seats is converted into a bed by placing a mattress over the row of seats. Passengers will be seated during take-off, after the seatbelt sign is switched off cabin crew will make up the bed. The bed includes a mattress with sheet, headrest, pillow and blanket. The seatbelt comes with a special extension so it can be used while laying down. These sleeper seats will be available on long haul routes from 13 May 2019. Because the sleeper seat is the length of one row of three seats not many people are able to lay down fully stretched. [28]

3. Economy SkyCouch (figure 19)

Air New Zealand offers a row of 3 seats which can be converted into their SkyCouch by footrests which move up, filling the gap between the seat and the row in front. The length of the Skycouch is 155 cm and 74cm wide, so most people will not be able to lay down fully stretched. [29-30]

2.5.4 Stretcher

Of course, not the most pleasant situation to be in, but it is possible to book a stretcher on a commercial airliner for medical reasons. If you had an accident on vacation for instance or if you are not able to sit upright during flight. This stretcher is however very expensive to book and it occupies 9 economy seats in the aircraft. [31-32]



Figure 17: Piuma Sofa

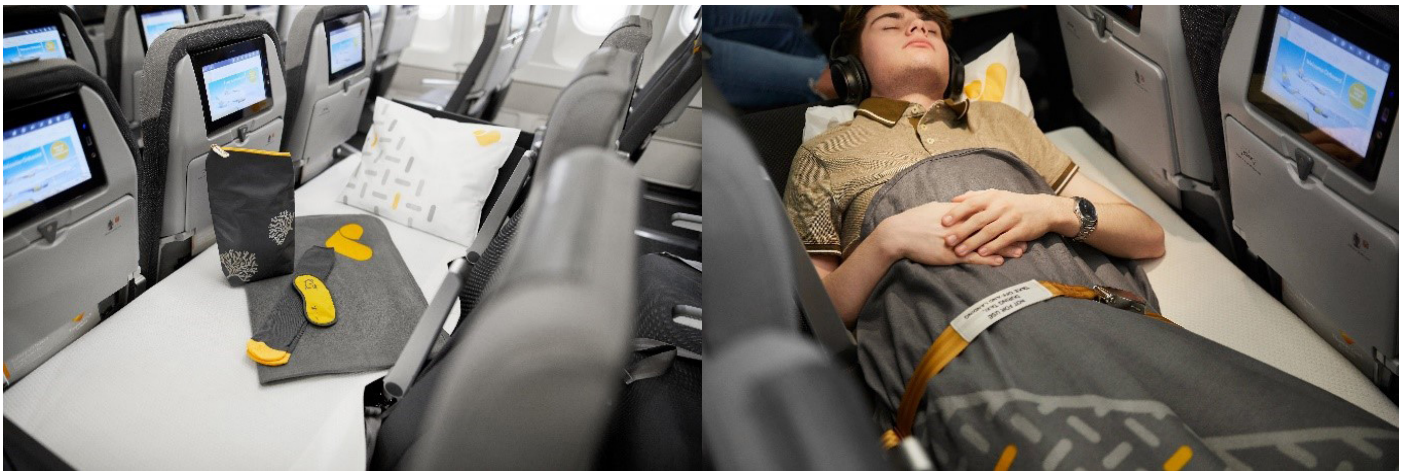


Figure 18: Sleeper Seat



Figure 19: Economy SkyCouch



2.7 Laying position

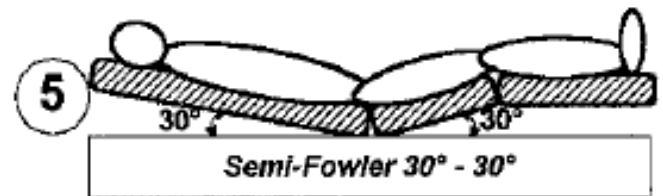
Exploring the options to reduce the space occupied by the sleeping facility

Because of the fact that replacing economy seats with flatbeds shouldn't compromise the passenger capacity of the airplane, measurements of the sleeping solution are considered to be very important. Therefore, it should be investigated what sleeping position is comfortable enough for air travel. Offering a bed which is not completely flat but partly reclined might save space and is therefore valuable to look into.

2.7.1 Semi-Fowler

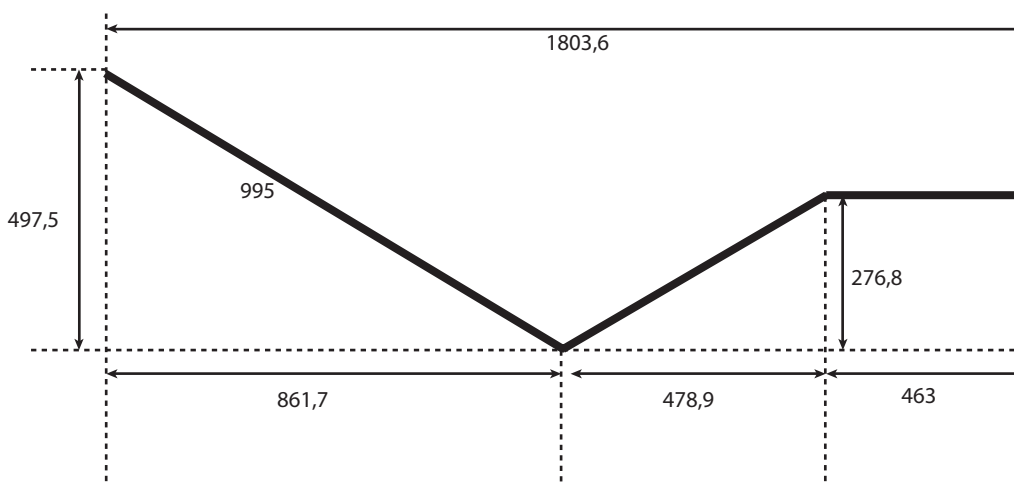
Research which investigated several lying positions to determine pressure on the skin found that a 30° semi-Fowler position and the prone position resulted in the lowest pressures on the skin (Defloor, 2000). If a person would remain in a same position for more than 2 hours, a 30° semi-Fowler position is preferred.

To examine the amount of space saved by applying the Semi-Fowler instead of a normal flatbed several relevant P95 measurements from the DINED-database are used to create the 2 positions. This doesn't mean that these are the most ideal measurements, but this is to ensure both are based on the same data.



CONCLUSION

Applying a Semi-Fowler position instead of a flat position only results in 113,4 mm length reduction. Next to the fact that headroom is way less compared to a flat position while stacking 3 above each other, and the fact that the majority of people sleep on their side (Coenen, 2006; Gordon et. al. 2004) which is not possible on a Semi-Fowler layout. Therefore a flat surface to sleep on is the best option.



P95 stature equals to 1917 mm, therefore a semi fowler position saves 113,4mm



2.7 Measurements

Important measurements that influence the design

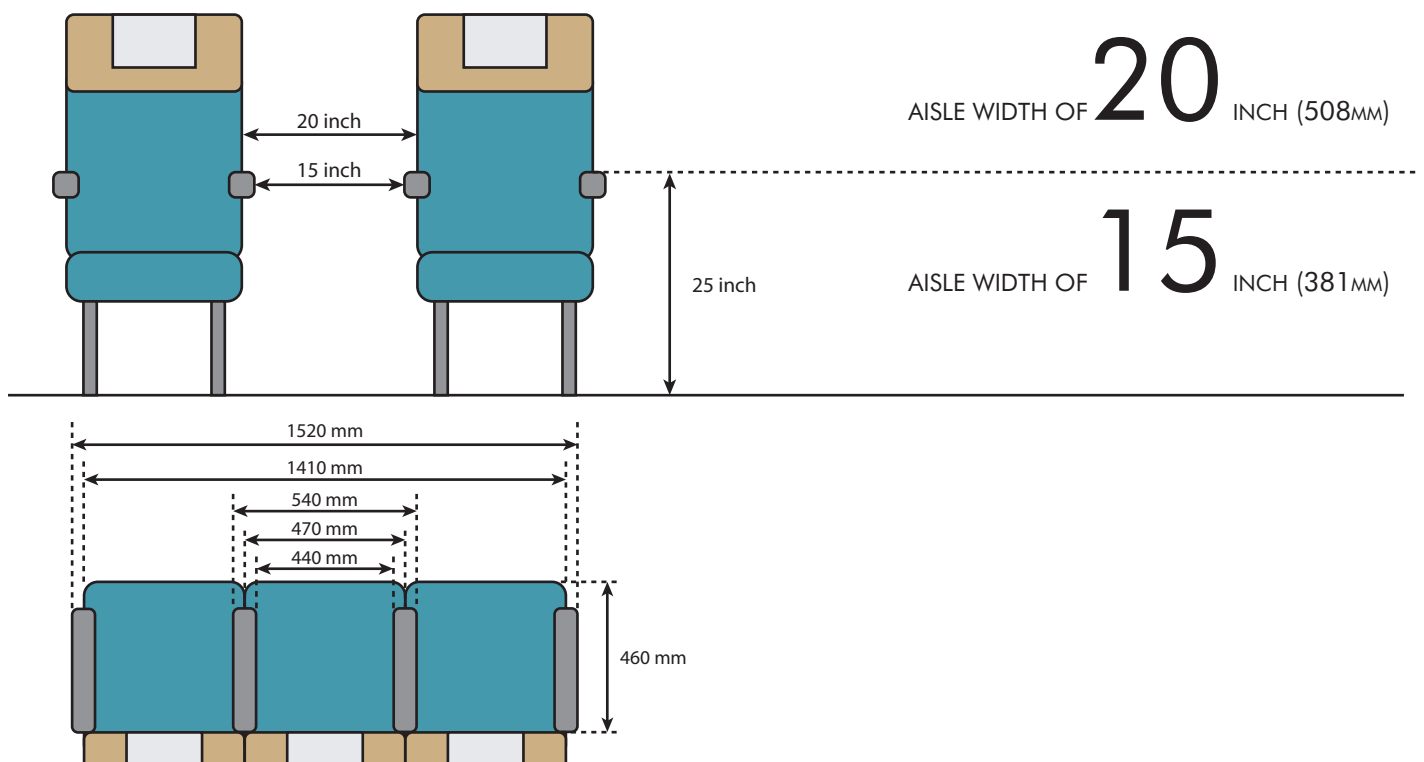
Inside an airplane there is a limited space for everything. Measurements are important because seat antropometrics and seat pitch influence the comfort of the passengers. Next to that measurements are also taken for the airlines, since they want their planes to be filled with as much passengers as possible. Finally, safety concerns and luggage space are among the key factors why taking measurements into account are so vital for airplane interior. This chapter lists the most important measurements to take into account while designing the sleeping cabin.

2.7.1 Aisle width

Aisle width is an important measurement to take into account considering safety of passengers. Regulations (CS 25.815) state that the aisle of passenger aircrafts needs to comply to the measurements given in figure below.

Since the Flying V will offer seats to far more than 20 passengers the width of the aisle needs to be 15 inches (381 mm) less than 25 inches (635 mm) from the floor, and 20 inches (508mm) 25 inch and more from the floor.

Passenger seating capacity	
20 OR MORE	
Minimum passenger aisle width	
Less than 25 inches from floor	25 inches and more from floor
15 INCH (381mm)	20 INCH (508mm)





2.7.2 Current Economy Seats

By replacing several economy seats with a sleeping cabin it is first necessary to know the dimensions of economy seats. Ofcourse economy seats differ in size, they vary between 17 inch and 18,5 inch in width. At the faculty of Industrial Design Engineering there is a row of economy class seats in the Applied Labs, measuring it resulted in the measurements displayed in the illustration at the bottom of the page

Out of these measurements it can be concluded that these seats located in the Lab have a width of 18,5 inch. Next to that the arm rests of the seats have a width of around 50mm.

When calculating the width of a row of 3 economy seats, all 18,5 inch wide, it can be perceived that it is 1cm shorter.

Calculated lenght of a row of 3 economy seats

$$(18,5 * 3 * 2,54) + 10 = 150,97 \text{ cm} = 150,97 \text{ cm}$$

18,5-inch: Seat width

3: number of seats in the row

2,54 cm: 1 inch

10 cm: width of the arm rest on the left and right of the row

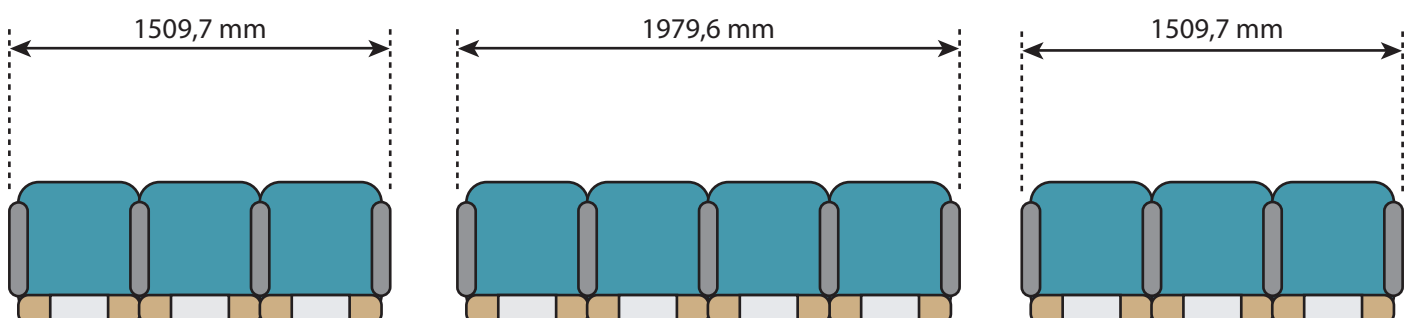
Because it is more convenient to calculate the width of other chair sizes in a row, the calculated length will be used. The calculations are done as following: (number of seats * seat width (inch) * 2,54 cm) + 10. Also this 1cm surplus which was measured is not a reall big deal, since these chairs where quite old. It can

be assumed that this 1cm can be solved by changing dimensions of the armrest a little. Since airlines always will try to fit in as much passengers as possible, and the fact that the Flying V is intended for 2050 it can be concluded that this 1cm can be left out with more modern economy seats.

When fitting the Flying V with a regular airplane interior, there is 5948 mm of space to fit 10 chairs plus 2 aisles. 18,5-inch seats are the maximum size seats which can be fitted inside the Flying V while complying to the aisle regulation norm.

Calculated lenght of rows of economy seats

Seat Width (inch)	Length row of 3 seats (mm)	Length row of 4 seats (mm)
17	1395,4	1827,2
17,5	1433,5	1878
18	1471,6	1928,8
18,5	1509,7	1979,6





2.7.3 Antropometrics

To provide as much comfort as possible to the future user of the sleeping facilities, several relevant antropometric data is collected. This data will help form requirements regarding the dimensions of the future sleeping cabin. Because the sleeping cabins can not fullfull the recommended sizes of a regular bed, stated in chapter 2.4 Sleeping, the minimum sizes will be determined by the antropometric data.

The data used in this chapter is retrieved from the DINED database. This data concerns Dutch adults between 20 and 60 years old, both male and female. Although only Dutch data is used, it can be concluded that the majority of people worldwide will be able to fit, since the Dutch are the tallest people on earth [33].

Starting with the length of the bed. By looking at other bed lengths of for instance crew-rests, business seats and concepts of sleeping cabins it was concluded that a total bed length of 200cm, which is normal for a regular bed, is not applied often. The main reason for this of course being the limited space available inside an airplane. To be able to offer a bed in which the majority of the world's population can lie down in fully flat the P95 stature (1917mm), or body length, has been chosen to be the minimum length of the bed.

Next dimension is the width of the bed. And again, it is not possible to use the recommended regular bed size. Therefore, the widest point of the human body is used to determine the minimum value. Thus, P95 breath over the elbows (554mm), with an additional 75mm of movement space. This equals to 629mm. This ensures that passengers can lay down in their favorite sleeping position, because the size is specified taking the basic sleep-ing position into account which takes up

the most space (supine and prone). The 75mm extra is added to ensure posture change during sleeping/laying done is possible.

The last important dimension is the height of the facility. Again, to offer passengers enough space to change posture the P95 breath over the elbows has been selected, which is the widest measurement available. Instead of an additional 75mm to move, 50 mm has been added. The reason for this 25mm reduction is that while laying on your side the measurement does not equal the 554mm which was measured while standing. Having a minimum height of 604mm also ensures that passengers can enter the cabin.

Minimal length

1917_{MM}

Minimal width (mm)

629_{MM}

Minimal height (mm)

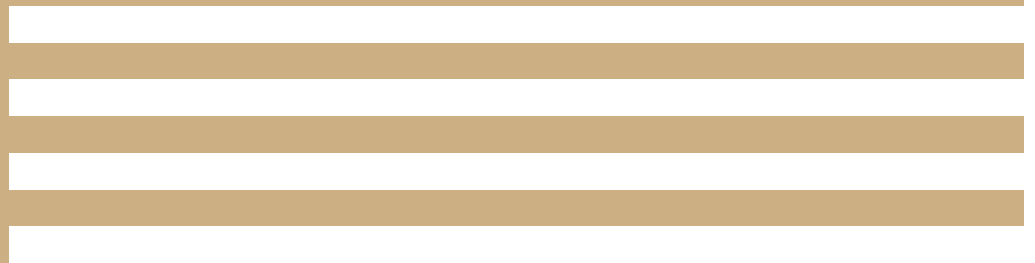
604_{MM}

REQUIREMENTS

CH. 3

INTRODUCTION

This chapter shows the requirements derived from the analysis phase and why they have been turned into a requirement. These requirements will help the ideation, conceptualization and decision phase further on in the design process.







3.1 LIST OF REQUIREMENTS

Requirements vital for the feasibility of the final design

R1. The sleeping cabins should be designed to fit inside the Flying V concept plane; therefore, the measurements have to comply with the technical drawings of the inside of the plane.

Since the sleeping cabins are designed to be placed into the Flying V it is logical that the measurements of the Flying V are leading. Which also means taking into account placement of other furniture, aisles and so on.

R2. The sleeping cabins should comply with set aviation regulations and therefore offer an upright sitting position for passengers during take-off and landing.

International regulations state that everybody should be in upright position during take-off and landing. This has to do with the fact that an airplane should be completely evacuated within 90 seconds. Next to that seats have to withstand a specific amount of force during crashes, this has been tested on seats in upright position.

R3. Economy class passenger capacity should stay the same or be increased by applying the sleeping facilities to the interior. This means the plane should offer a place to 266 economy class passengers.

Because of the fact that passenger capacity of an airplane is extremely important for airlines, this requirement is listed high as well. Next to the airlines who want to fit as much people as possible inside, the requirement also has an influence on the credibility of the Flying V. The Flying V is being designed because it is more fuel efficient than current airplanes, so it makes sense the airplane should transport the same number of passengers as the current airplane it is designed to replace. Decreasing passenger capacity will result in more flights and will therefore the validity of the plane would decrease.

R4. The regular economy seat size placed besides the sleeping cabins should be 18-inch-wide and should have a seat pitch of 32 inch.

Since designing a completely new interior for the Flying V is not achievable in the time period of this graduation project, and the fact that the main focus of this project are the sleeping facilities. The remaining space of the airplane will be filled with regular economy seats. To ensure comfort of passengers travelling inside these regular economy seats the seats should have at least the dimensions stated in this requirement.

R5. The minimal width of the sleeping cabin bed should be equal to the P95 breath over the elbows (554mm), with an additional 75mm of movement space. This equals to 629mm.

To ensure that passengers can lay down in their favorite sleeping position, the width of the bed is specified taking the basic sleeping position into account which takes up the most space (supine and prone). Because of the amount of posture changes during a normal night sleep 75 mm is added to the minimum width to ensure posture changes can be achieved.

R6. The minimal height of the sleeping cabin bed should be equal to the P95 breath over the elbows (554mm), with an additional 50mm of movement space. This equals to 604mm.

Again, to offer passengers enough space to change posture the P95 breath over the elbows has been selected, which is the widest measurement available. Instead of an additional 75mm to move, 50 mm has been added. The reason for this 25mm reduction is that while laying on your side the measurement does not equal the 554mm which was measured while standing. Having a minimum height of 604mm also ensures that passengers can enter the cabin.



R7. The length of the bed should be at least be equal to the P95 stature (1917mm).

Although most regular beds people have in their bedroom are 200cm or even 210cm this doesn't mean this should be the length inside the airplane. Due to the many restrictions inside the airplane considering capacity it has been concluded the bed should be smaller than regular beds. To be able to offer a bed in which the majority of the world's population can lie down in fully flat the P95 stature, or body length, has been chosen to be the minimum length of the bed. Although only Dutch people were selected in the data-base it can be concluded that the majority of people worldwide will be able to fit, since the Dutch are the tallest people on earth [33].

R8. While sitting in upright position, the seat pitch should be equal or larger than the P95 buttock-knee dept while sitting, which equals to 686 mm.

In order to offer passengers a comfortable sitting area during take-off, landing and while consuming their in-flight meal the seat pitch offered should at least be equal to the P95 buttock knee dept while sitting. Although these parts of the flight take less time than cruise flight, it is still an important factor to take into account. According to the peak-end rule (Kahneman, D. (2000)) people remember 2 main things about an experience. The peak or low of the experience and the end. Therefore, it is important that during landing sufficient seat pitch is offered to have a more positive effect on passengers considering their experience of the flight.

R9. There should be space available for 1 piece of carry-on luggage per passenger. The dimensions of this luggage should be complying with the general dimensions of economy class carry-on luggage utilized by KLM. This equals to 550 x 350 x 250 mm.

It is always a hassle with carry-on luggage. By providing the passengers who booked a sleeping cabin with space for carry-on luggage boarding will be smoother and faster.

R10. The sleeping cabins should offer a form of privacy by giving the option to exclude the passenger from the sight of the other passengers.

Besides blocking stimuli that influence sleep, like light, privacy is a factor to take into account. During a user test (page 53) several participants asked if there would be some sort of curtain to create some privacy.

R11. Passengers should be able to watch a form of in-flight entertainment while being inside the sleeping cabins.

IFE distracts people which make them perceive a higher level of comfort.

R12. Oxygen masks and life-vests should be facilitated for every passenger.

Basic emergency necessities



3.2 WISHES

Whises that influence the design

- W1.** The sleeping cabins should be as light weight as possible.
- W2.** It should be as easy as possible to convert the beds into sitting space & vice versa.
- W3.** Passengers should have as much space as possible while laying inside the sleeping cabin.
- W4.** Passengers should have as much space as possible while sitting in upright position.
- W5.** The sleeping cabins should increase passenger comfort.
- W6.** The sleeping cabins should be accessed as easy as possible.
- W7.** Entering and leaving the sleeping cabins should not obstruct or hinder other passengers.
- W8.** Passengers with reduced mobility should be able to use some of the offered sleeping cabins.
- W9.** Passengers should be able to take off their shoes and store them without disturbing others with the location or smell of their shoes.



IDEATION

CH.4

INTRODUCTION

This chapter shows and describes the ideas generated during the ideation phase. The goal is to generate ideas that can be turned into concepts, which will be discussed next chapter.





4.1 Ideation versus Feasibility

Evaluating several ideas on the most important requirements

From the Analysis phase it was concluded that providing a flat-bed is desired to offer passengers an environment to lay-down in their favourite posture and are able to change posture. A flat-bed does occupy a lot of space, therefore the overall lay-out of the plane should be investigated to check several placement ideas of the flat-bed. This is done in order to ensure that the overall passenger capacity of the plane doesn't decrease. Next to that several other insights are noted which have an influence on the feasibility of the idea.

Because passenger capacity of the airplane and being in an upright position while taxi, take-off and Landing (TTOL) are the major issues which have to be overcome, these 2 requirements are the main benchmarks during the first ideation phase. Ofcourse the other requirements are being looked at as well, and discussed if it will pose a problem. The ideas are formed by retrieving inspiration from the analysis performed, next to several How To's which can be seen in Appendix B.

Main requirements ideas have to fulfill

R2. The sleeping cabins should comply with set aviation regulations and therefore offer an upright sitting position for passengers during take-off and landing.

R3. Economy class passenger capacity should stay the same or be increased by applying the sleeping facilities to the interior. This means the plane should offer a place to 266 economy class passengers.



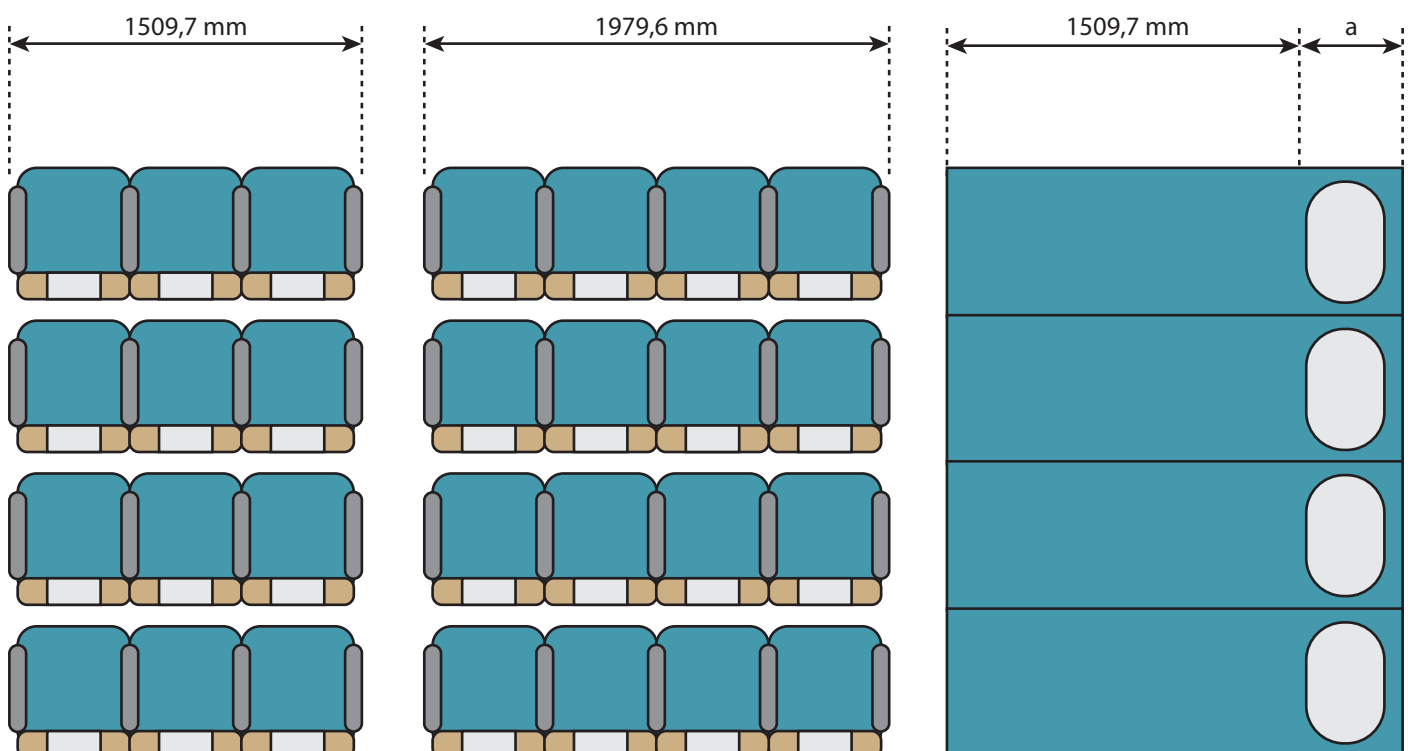
4.1.1 Idea 1

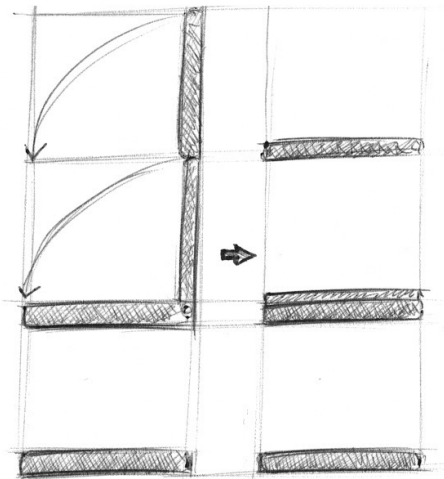
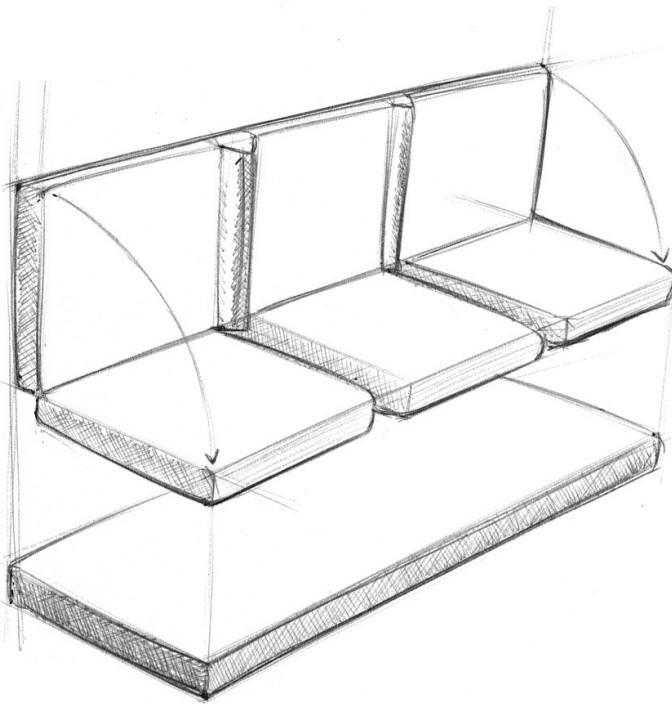
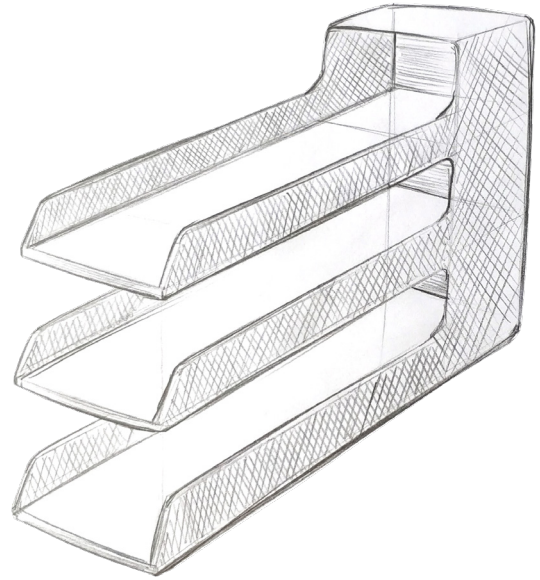
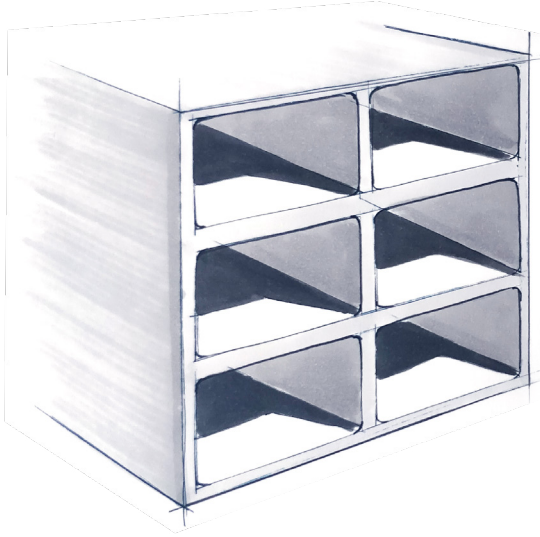
The first idea to look into is based on the Japanese hotels who offer sleeping pods. You enter the bunk-bed from the front, with your head first. You have to go head first because going feet first in the middle bed will require quite some physical fitness, so designing it for that will exclude a lot of potential users. Next to that because the top bed is against the ceiling it is almost impossible to climb in the top bed with your feet first.

By placing the beds in the direction shown in the image on the left it means the empty space on the side of the flying V can be utilized to create extra room and attain the 1900 bed length as desired. This can be achieved by placing the lowest bed not on the floor, but higher. There is 650mm of unutilized space at the widest point, so this should be possible.

However, a problem which occurs with this idea is the fact that there are support beams located every 700mm. These support beams have a diameter of 70mm, which means there is 630 mm left for the width of the bed. Which is quite tight when being in a pod like this with walls almost all around you. This can be fixed partially by only covering the head area fully, and make the remaining walls semi-open.

Another problem created by the support beams is the fact that the beds have to fold, or be removed in another way (will be treated later on in this report), to create seating space for passengers to sit in upright position during take-off. Because of the beams being 700mm apart seating pitch will decrease from 812,5 mm to 700 mm. This decrease in seat pitch does not seem that big of a problem, as some airlines offer a 28 inch seat pitch; which is 71,12 cm.

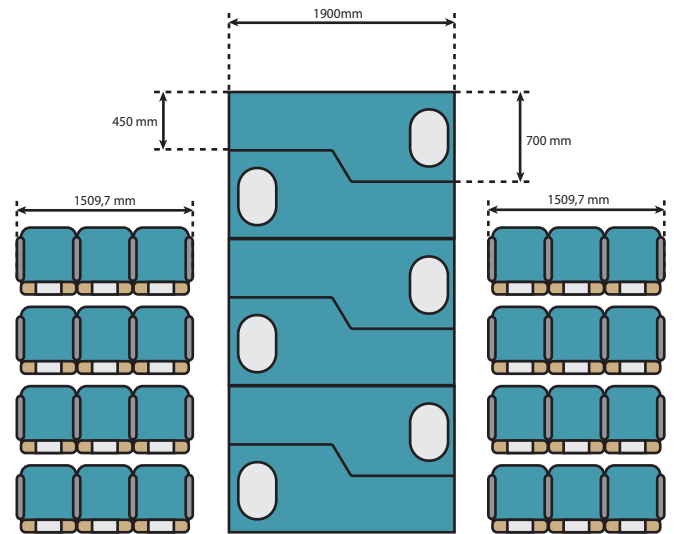






4.1.2 Idea 2

Replacing the middle row of 4 seats with beds, which you enter at the front just like idea 1. A ying-yang pattern was needed to make sure no capacity was lost. Replacing 11 rows of 4 seats means 44 passengers should be able to lay down. By applying the pattern from this idea 45 people will be able to lay down, so an increase of 1 passenger. However, a massive downside is that the folding systems to create seats for take-off and landing can't be applied in this idea



4.1.3 Idea 3

Another possibility for the bed placement to take into consideration is below the middle row of 4 seats. One person sitting on this row booked the sleeping cabin, which they can use after taking-off. By creating a variable width, so wider at the shoulders and narrower at the legs it is possible to fit more of these next to each other, instead of 1 per row. However, the problem is that the other passengers have to climb up onto their seats, which again excludes the physically impaired travelers. Next to that, by placing the seat on top of the bed compartment there isn't a lot of headroom left for the sitting passengers. Let's say the height of the bed compartment is 600mm, adding a sitting height of 400mm will mean there is only 115 mm left above the seat. This makes moving into one of the middle seats, or going to the toilet a lot more uncomfortable.

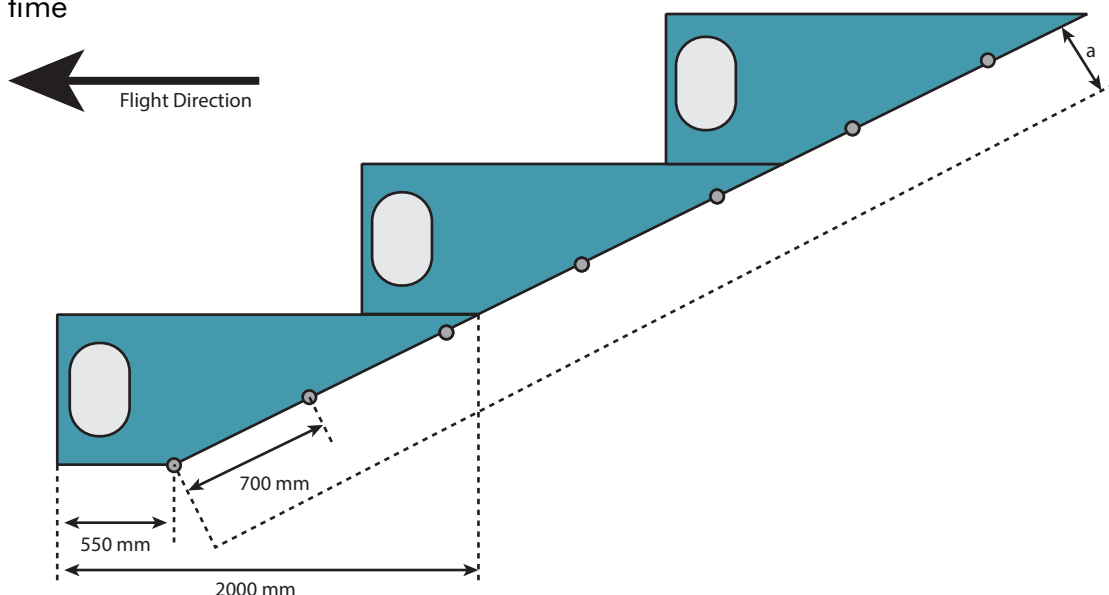
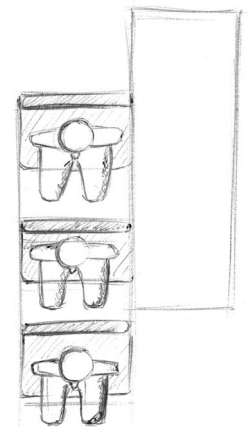
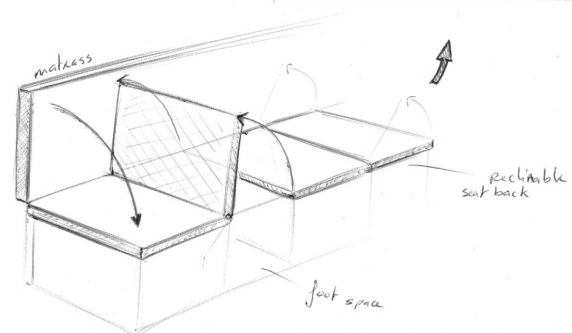
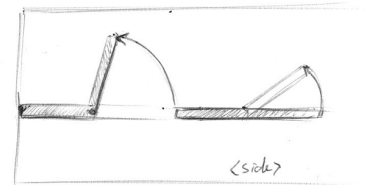
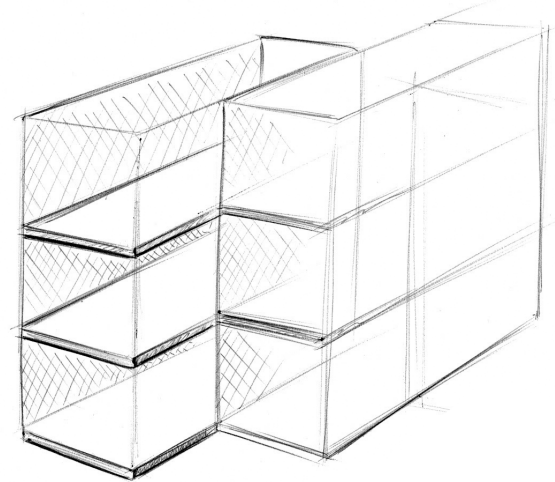




4.1.4 Idea 4

Placing the beds in the flight direction will create a more open look because instead of one, 2 sides are open.

When adjusting the beds to the flight direction triangular beds are created, to compensate that angle the length of the bed is increased to 2000mm. There is an option to put extra legroom in the empty space (a) of the curve on the side, there are 70mm diameter post in the way unfortunately, so to access this space you have to maneuver your legs around these posts. A couple problems arise however by placing the beds in the flight direction. First of all, because of the post it is necessary to enter the beds feet first, this poses problems for the top 2 bunks. Next to that another vital issue is present, which is the seating arrangement while taking off. Sitting next to each other like shown in idea 1 is not possible because of the triangular shape of the bed, neither is sitting behind each other (depicted in the drawing above). So, the only option is to sit on the side of the beds, which means you will be sitting in the aisle, as the regular seats also have to be placed in the flight direction. Next to that creating zig-zag aisles will not be beneficial to the 90 seconds evacuation time

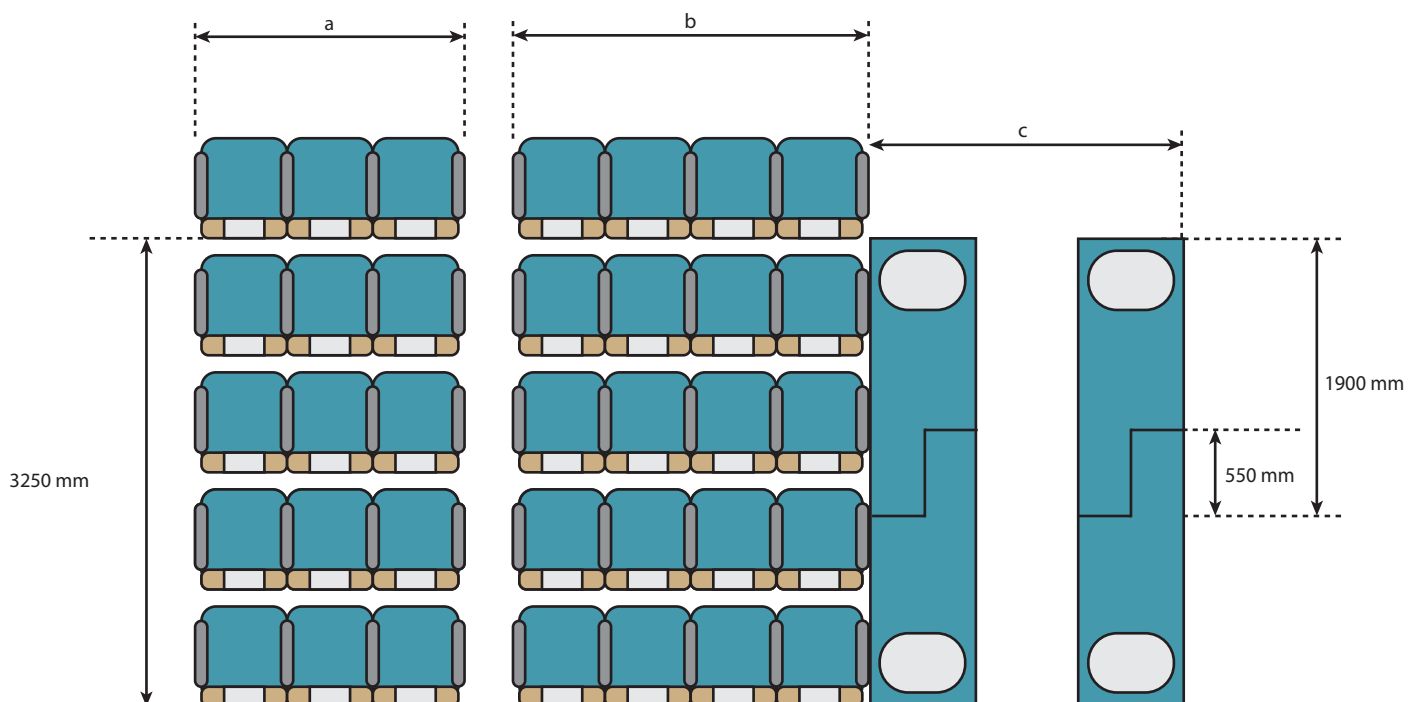
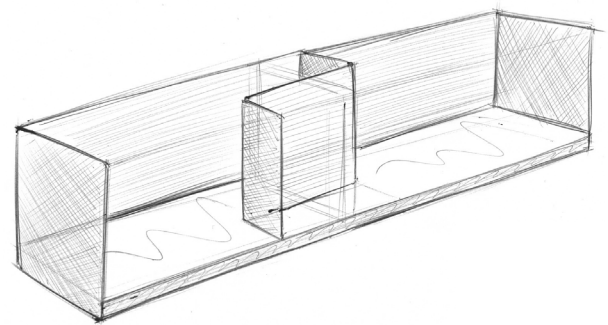
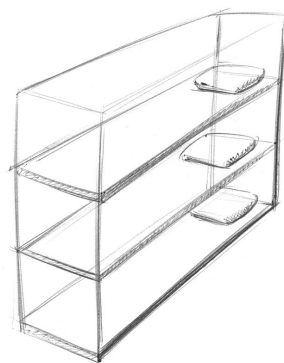
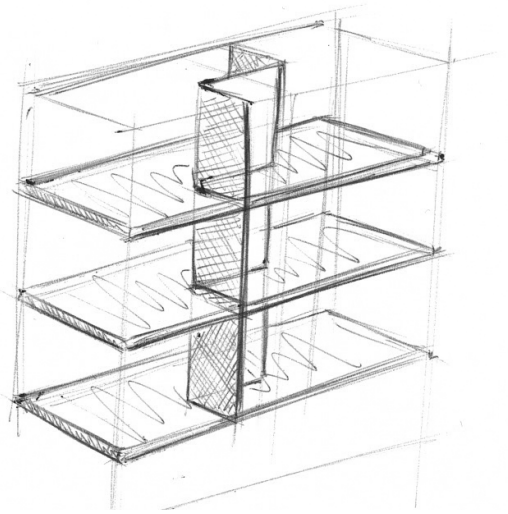




4.1.5 Idea 5

Triple bunkbed with sideway entry, like in a submarine. By entering from the side there is a lot more space to get in the bed, because the whole length of the bed is open. Next to that because of the open side you are less likely to feel trapped inside.

Placing a 1900 mm bed takes up too much space, therefore the legroom is narrower than the rest of the bed. By doing this 2x3 beds linked to each other are 3250mm in length, which is the same length as 4 seat pitches.





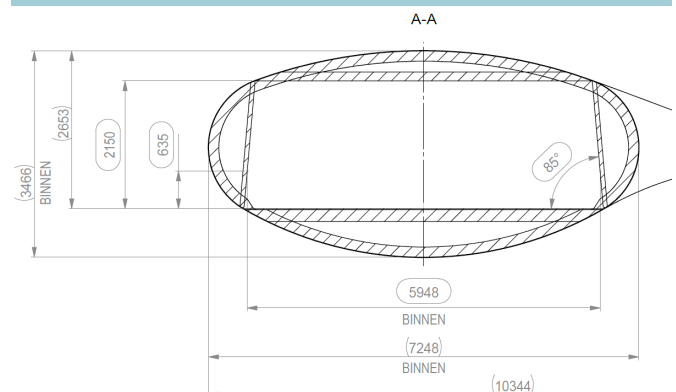
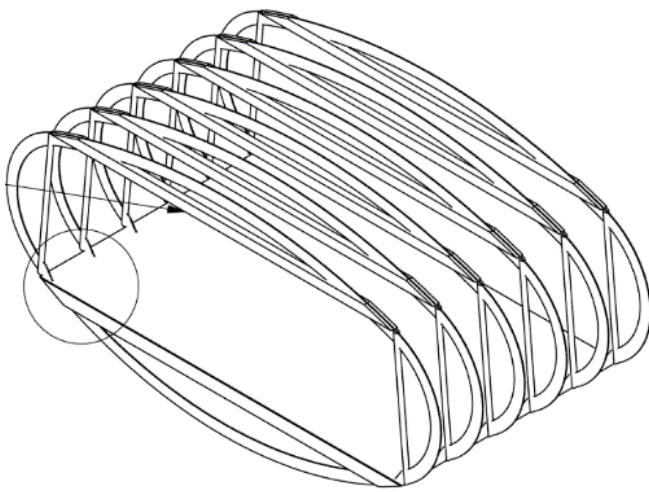
4.1.6 Idea 6

Placing a bed completely in the unused curved zone on the side of the plane. The passenger takes-off and lands while being in their normal seat located next to the bed. During cruise flight they can take place inside the curved area where their bed is located.

When looking at the measurements of the Flying V it can be calculated that the empty space in the curve is 650mm at its widest point $((7248-5948)/2)$. However, ribs are located inside the empty space to make sure the cabin can be pressurized. These ribs are 170 mm wide, which means only 480mm is left for the bed width. Considering the fact that the P95 shoulder breadth is 501 mm and the P95 breath over the elbows is 554 mm this space is not suited for placing a bed in.



The antropometric data used in this chapter is retrieved from the DINED database. This data concerns Dutch adults between 20 and 60 years old, both male and female. Although only Dutch data is used, it can be concluded that the majority of people worldwide will be able to fit, since the Dutch are the tallest people on earth [33].



CONCLUSION

The ideation phase has resulted in 2 feasible ideas. Firstly idea 1; this is a promising idea since it makes optimal use of the curved area besides the structural beams, which is so specific for the Flying V. Next to that because these structure beams are located every 70cm, placing sleeping cabins between these beams means an increase of passengers, since the seats they replace had a 81,25 cm seat pitch. The second feasible idea is idea 5. This idea provides a less enclosed sleeping cabin, thus creates more overview for the flight attendants. Also it is expected entering and leaving this cabin is easier. These ideas will be explored further in the conceptualization phase next chapter.

CONCEPTS

CH. 5

INTRODUCTION

This chapter shows the development of concepts, a user test to help come to new insights and adjustments, and finally a decision-making process with help of a Harris Profile.





5.1 Conceptualization

Turning the selected ideas into concepts

Out of the ideas generated two promised to be feasible and meet the set requirements. These two ideas will be further explored and tested in this chapter. After that both concepts will be discussed, both pros and cons will be addressed and a weighted evaluation will be performed by comparing their ratings considering the Requirements and Wishes. In the end to decide which of these concepts is most suited to develop into a final design.

Although usually 3 Concepts are created to make a decision between, this project only has 2 Concepts. The reason for this is the fact that ideation was done with all requirements in mind already, therefore a lot of ideas were already eliminated. Creating a third concept just because there has to be one was considered to be a waste of time. Therefore the decision was made to only develop 2 concepts.

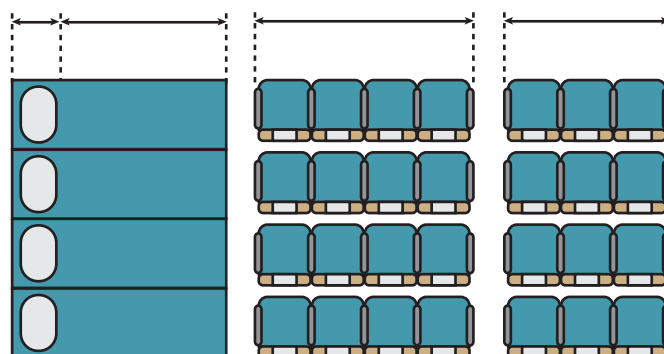
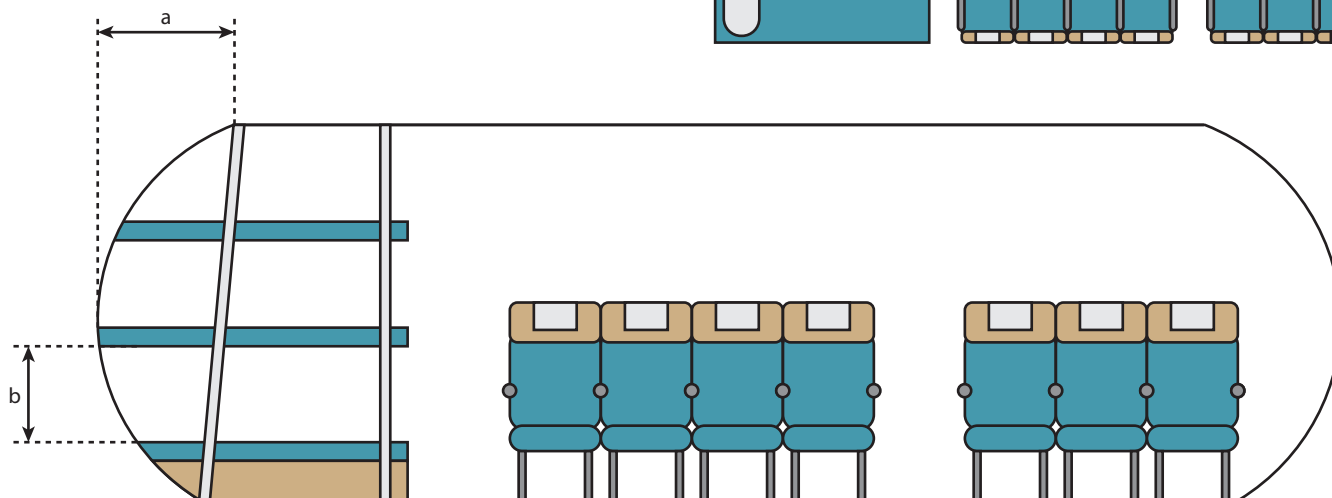


5.1.1 Concept 1

Concept 1 is based on idea 1. The advantage of this idea that it takes advantage of the space inside the curved area in the most efficient way. Next to that passenger capacity even increases with this concept, which is really interesting for airline companies ofcourse. This does come at a cost for the passengers though, considering space offered. To achieve the desired bed length inside the curved area it means it needs to move along the curve, which has the consequence that the height decreases.

5.1.1.1 Placement

The beds will be placed on the side of the plane which does not have any windows. The length of the bed determines the height of the cabins which is shown in the table at the bottom of the page. In this table the height of the cabin is without the thickness of the matrass and structure.



(cm) Bed length	Required length in curved area (a)		Height of cabin (b)	
	18 inch seat	18,5 inch seat	18 inch seat	18,5 inch seat
190	29,36	38,23	643,7	612
191,7	31,04	39,93	638,3	605
195	34,36	432,3	626,7	590,7



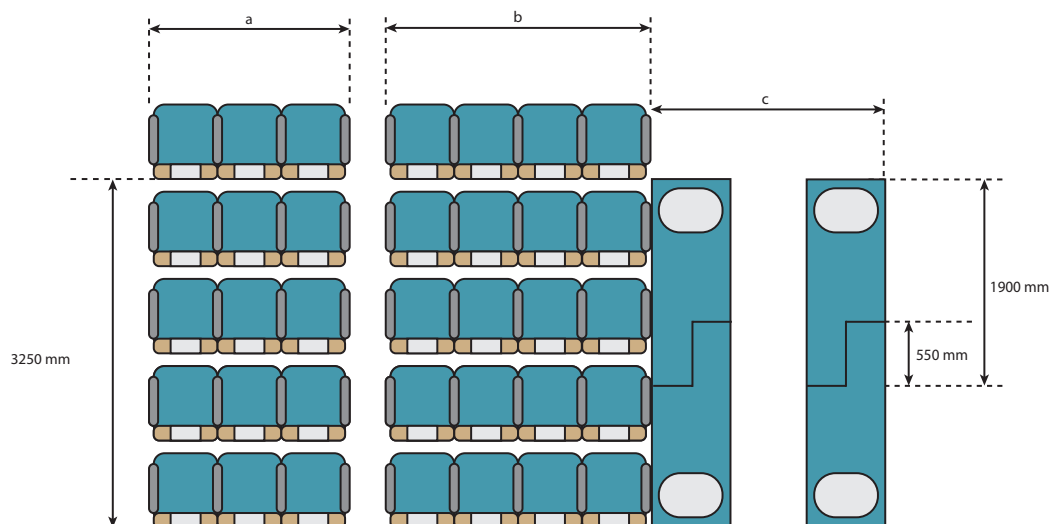
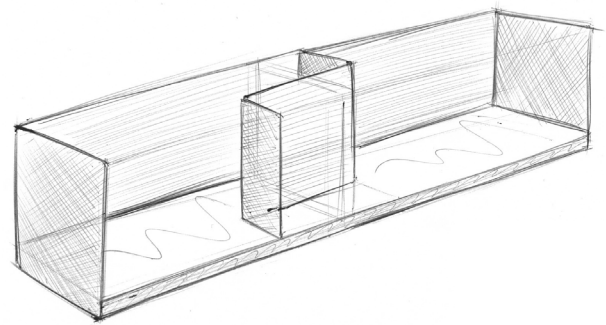
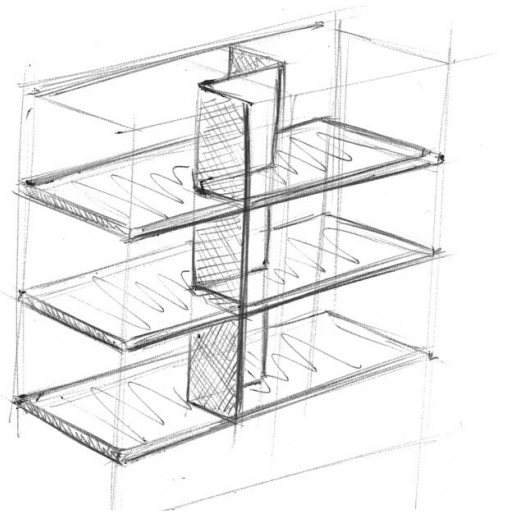
5.1.2 Concept 2

Continuing on one of the most feasible idea considering the factors of entering, capacity and providing sitting space for all passengers while taxi, take-off and landing. Idea 5, the sideways accessible bunkbeds will be analyzed in this section to explore what the best way of placement inside the Flying V is. The beds turn into seats by a folding/retracting system, this system will be developed further after selecting a final concept.

5.1.2.1 Placement option 1

Replacing the row of 3 seats which is not on the window side, including the aisle with a row of beds with their own private aisle. By using reduced space at the foot area, it is possible to fit the beds in the available space. The 12 bunkbeds replace 12 seats, so there is no decrease in passenger capacity.

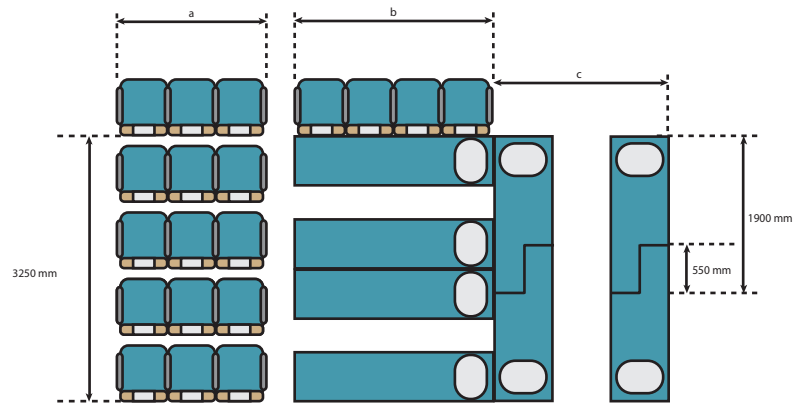
However, replacing the aisle in this way does have the consequence that there is a row of 4 seats next to a wall. This will have consequences for the evacuation time, and might result in not making the mandatory 90 seconds evacuation time. After doing some research not a single plane lay-out was found with 4 seats next to the window side, therefore it is safe to assume this isn't possible.





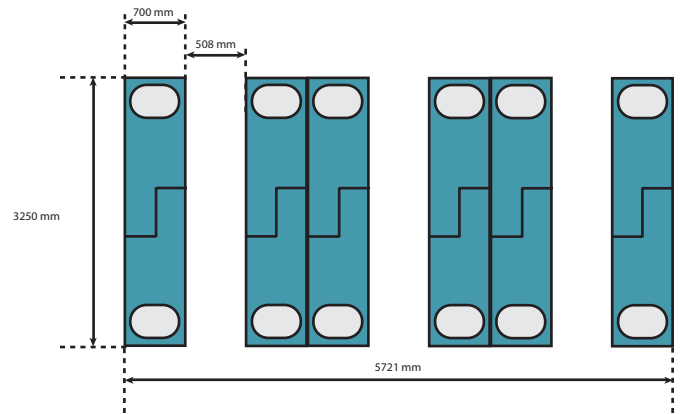
5.1.2.2 Placement option 2

To prevent the case of a row of 4 seats being next to a wall an option is to replace those rows by beds as well. This poses several problems however. First of all, the reduction in capacity, by replacing 4 rows of 4 seats with bunkbeds the capacity will go down by 4. Next to that because of the compulsory aisle size of 508mm leaves 2234 mm for 4 beds ($3250 - (2 \cdot 508)$). This means 558,5 mm space is left for the width of each bed, which is too narrow.



5.1.2.3 Placement option 3

Another option is to replace 4 entire rows of 10 seats with beds. When using beds with the desired 700 mm width and the required 508mm aisles it is possible to place 36 beds, while still having a 227mm margin left ($5948 - 5721$). However, 36 beds means a reduction of capacity.



5.1.2.4 Placement option 4

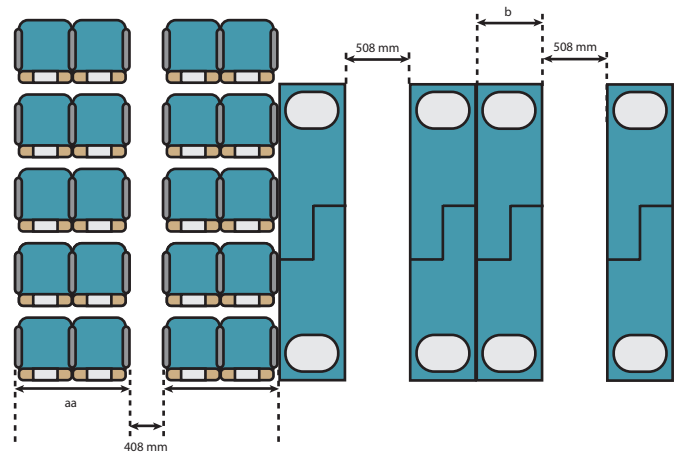
Again, this lay-out has the 12 beds replacing 4 rows of 3 seats, so no capacity is lost. Adding a third aisle will increase the chances of achieving the 90 seconds evacuation rule. To be able to fit the seats have to be 17-inch wide, and the beds should be 649,2mm wide.

$$((508 \cdot 2) + 408) + (4 \cdot b) + (2 \cdot a) = 5948$$

$$a = (2 \cdot 17 \cdot 2,54) + 10 = 96,36 \text{ cm} = 963,6 \text{ mm}$$

$$((508 \cdot 2) + 408) + (4 \cdot b) + (2 \cdot 963,6) = 5948$$

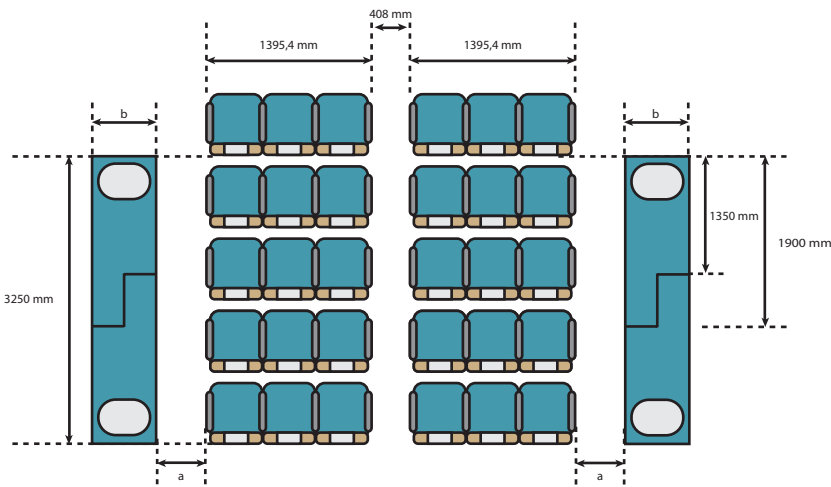
$$b = (5948 - 3351,2) / 4 = 649,2 \text{ mm}$$





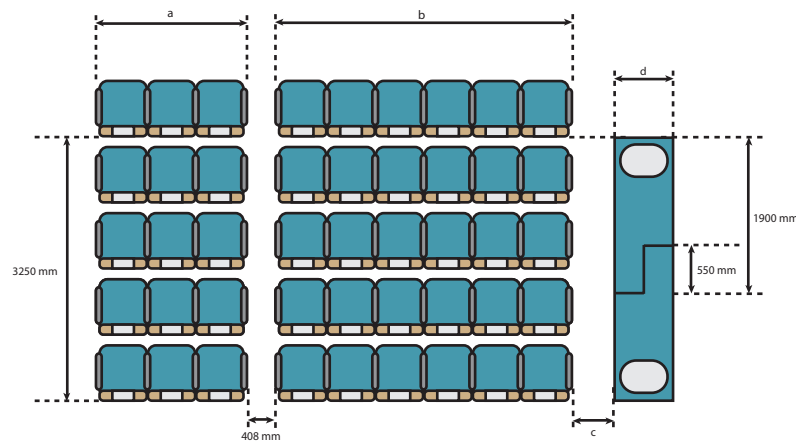
5.1.2.5 Placement option 5

Facilitating beds on both side of the plane will result in plenty of space for the bed and aisle a . When using 17-inch seats in the middle and aisle a set at 508 mm the beds will be 866,6mm wide. An option is to reduce bed size and offer 18 or 18,5-inch seats to increase passenger comfort. However, by placing the beds on both sides, capacity will reduce from 40 to 36. Also, the window side will only be available for the one person who has the bed with the window.



5.1.2.6 Placement option 6

By placing a row of 6 in the middle, with an aisle on each side the evacuation should be manageable within 90 seconds, as every passenger has a maximum of 2 seats between them and an aisle. When looking at the overall measurements, the seats need to be either 17,5-inch or 18-inch wide to provide as much comfort as possible to all passengers. Applying this lay-out will even increase passenger capacity from 40 to 42.



Because sitting on the aisle or window side is being preferred by passengers (Reference to paper) the possibility of placing a separation wall in the middle of the row of 6 should be taken into account. And windows on the ceiling should be looked into.

Because option 6 facilitates the option to place 18 inch economy seats, leaves enough space for a comfortable sleeping facility and the fact that passenger capacity increases slightly this is the most ideal set-up.

Seat Width (inch)	Length a (mm)	Length b (mm)	Length c (mm))	Length d (mm)
17	1395,4	2690,8	458	995,8
17,5	1433,5	2767	458	881,5
18	1471,6	2843,2	458	767,2
18,5	1509,7	2919,4	458	652,9



5.2 User test

Testing the concepts

To complete the concepts and substantiate the final decision a user test is performed. This user test will test several factors of the sleeping facility by letting participants experience the two concepts. By letting participants answer several questions and by observation, multiple insights were found which resulted in adjustments and arguments which will help the decision phase.

The major difference between the 2 concepts is the way of entry and leaving the sleeping cabin. Sleeping cabin 1 is entered from the front, while sleeping cabin 2 is entered from the side. Both of these cabins have their advantages and disadvantages. To provide extra information to help making the decision of which cabin is most suited to develop, a user test is executed. The main purpose of the user test was to evaluate which of the two concepts was most convenient to access, so entering and leaving the sleeping cabin. Next to that several other questions were asked to participants to get more data out of the test to help decision making.

The goal of this user test is to find out several factors which influence the comfort of passengers. First, entering and leaving the cabin was tested. Prior to letting the participants enter and leave the concepts and score that experience, they were asked to score the concepts on expected convenience of entering and exiting. This is done because when booked, the only thing passengers see are pictures of the sleeping facilities. Next to this space inside the cabin was tested as well, by letting participants lay down in their favourite sleeping position to see if this was possible, this also means they have to change position. Next to these 2 most important factors several other questions were posed about the overall idea of sleeping facilities in economy class.



5.2.1 Method

Ten participants were asked to test 2 different sleeping cabins on several comfort aspects and other factors that influence comfort. The goal of this research was to find qualitative data to help evaluate both concepts in order to come to a more substantiated decision.

5.2.2 Participants

Ten participants, 50 percent male and 50 percent female, were asked to test 2 different sleeping cabins. Participants of different body length were selected; they range from 163 to 190 cm. Due to the fact that this research will help evaluate 2 ideas only students from the Delft University of Technology were asked to participate; ranging from 22 to 27 years old.

5.2.3 Pilot

A short pilot with my mentor and chair resulted in several insights to improve the test. First of all, a question considering claustrophobics inside the cabins was replaced by rating the cabin on spaciousness, this was done to prevent suggesting claustrophobia to the participants. Also, females wearing skirts or dresses might be having trouble entering/leaving the cabin. Another insight that surfaced during the pilot was the fact that there wasn't a real airplane environment. To simulate the fact that there was not a lot of space to enter the cabin normal seats were placed to indicate where fellow passengers would sit.

5.2.4 Stimuli

Participants were asked to evaluate 2 sleeping cabins, both were placed at a height of approximately 70 cm, to simulate the fact that there would be a cabin below and above. Therefore, the height of the cabin was 70cm, which was the width as well.

5.2.5 Apparatus

Research was done in person, with a paper evaluation sheet filled in by participants. Remarks of participants were noted in a sketchbook.

5.2.5 Procedure

Participants were asked to rate two sleeping cabins on expectations and on experience. First several general questions were posed considering flying, sleeping and a combination of those. After the general questions participants were asked to judge the first sleeping cabin on perceived comfort and convenience of access. Subsequently the same questions were answered considering the second sleeping cabin. After testing both cabins some concluding questions were asked about the preferences of the participants. By changing the order of cabins which were tested by the participants any learning which might occur during testing was eliminated.

5.2.6 Measure

Questions posed to participants will be answered by filling in a 7 point scale. From these answers the average will be calculated for each concept, these averages will be displayed in a table. Observations made were noted in a notebook and relevant insights will be discussed.



5.2.7 Results

When looking at the average scores of the sleeping cabins it can be perceived that Cabin 1 was rated the highest overall. This doesn't mean directly that cabin 1 is best and the one to be developed further, since both cabins were quite simplified to discover several pros and cons and to see what should be improved. Below, the several points will be discussed and explained with the comments of participants and observations made during testing.

First of all, the expected level of comfort; The reason cabin 1 was rated higher than cabin 2 was the space available. Because Cabin 2 had a smaller area to place the legs people expected it to be less comfortable. Therefore, it can be concluded that they associate space with comfort. While looking at the expected convenience of entry, sleeping cabin 2 was rated highest. The reason for this rating was the fact that the entrance was bigger.

Subsequently looking at the experienced level of entering and leaving the cabin scores were quite similar, with cabin 1 being slightly higher. The reason that cabin 1 scored higher on this point was due to the reduced legroom in cabin 2, some participants struggled with this while entering the cabin. The reduced legroom also was the reason cabin 2 scored lower on spaciousness inside, participants felt restricted by it and some indicated they were being careful to avoid bumping their shins against it while changing sleeping position.

Finally, the participants rated cabin 1 higher on the ability to lay down in their favorite sleeping position as well. This higher score was again due to the fact that cabin 1 offered more leg space, which made maneuvering into a sleeping position easier. All these factors contribute to the overall comfort score of both cabins, which has resulted in cabin 1 being scored as most comfortable. Also 7 out of 10 indicated they preferred cabin 1.

	Concept 1	Concept 2
EXPECTED LEVEL OF COMFORT	4,4	3,6
EXPECTED CONVENIENCE OF ENTERING THE CABIN	3,7	4,4
CONVENIENCE EXPERIENCED ENTERING AND LEAVING THE CABIN	4,5	4,4
SPACEOUSNESS INSIDE THE CABIN	5,4	3,5
OPPORTUNITY TO LAY DOWN IN FAVOURITE SLEEPING POSITION	6,2	4,9



5.2.8 Observations and insights

Several observations were made during testing, insights which might influence the decision process of choosing cabin will be discussed below. First of all, while entering cabin 1 a lot of participants would sit on the bed first, and subsequently curled their back to lay down. This was an unexpected result, as it was expected that participants would dive in with their head first, facing down. Another observation made concerning cabin 1 was that while leaving the cabin, the feet of the participants would stick out quite far. The problem with this is that the feet would hit passengers sitting in their normal economy seats. Next to that it was possible to stick your feet out while being in cabin 1, this means that there are feet hanging in the aisle which obstructs people passing by. Next to that it isn't the nicest view for other passengers, especially if people take off their shoes. Another observation that surfaced, which was already discovered during the pilot, was the fact that some females were wearing dresses or skirts. This was especially troublesome while entering sleeping cabin 1.

The length of 190 cm was not sufficient. This length was chosen as minimum requirement because the concept at Safran had this length according to their employees. This length was found to be comfortable by myself (186cm) and my chair Peter Vink (almost 200cm). However, while preparing cabin 2, with the reduced foot area, I noticed that the 190cm would probably not suffice. Testing this cabin with the longer participants confirmed this assumption. Therefore, the requirement is adjusted, the length should be at least 195 cm, to be able to fit P95 bodyweight.

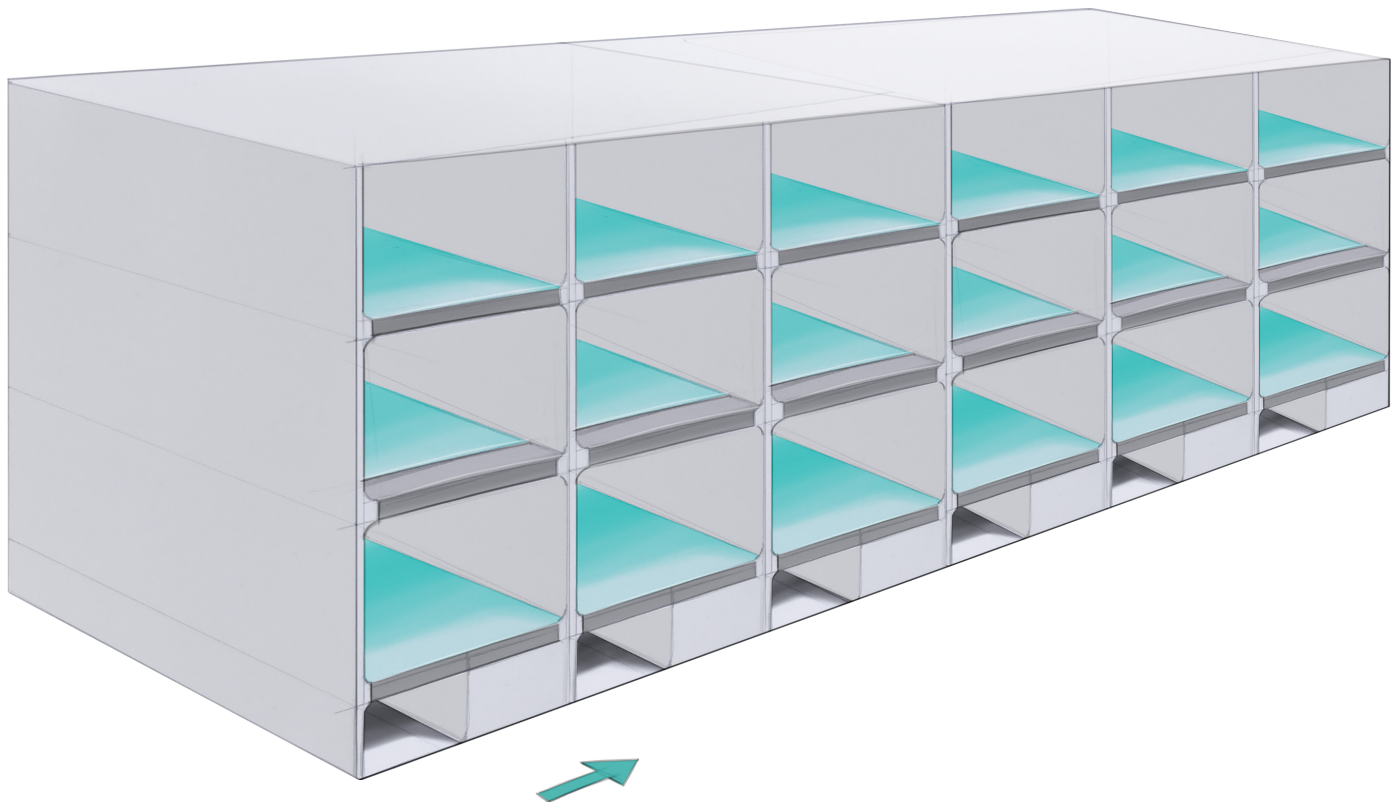
Participants did indicate that they liked the open side of Concept 2, it made them feel less enclosed.

5.2.9 Discussion

Because the sleeping cabins were quite simplified for the research several points can be discussed. First of all, the height of sleeping cabin 1; which was 70 cm in the user test. When looking at the placement of the cabin inside the airplane it is not possible to have the height of the cabin being 70 cm. This is due to the fact that part of the bed should be located inside the curved unused area, since there was more space available entry of the cabin was easier than it would be in the real product.

5.2.10 Conclusion

This user test has provided several insights about the concepts that will help the decision making process. Looking at the results it can be seen that Concept 1 was rated highest on 4 out of 5 questions that evaluated the concept, besides that 7 out of 10 participants rated that they favoured Concept 1. The main reason for this is the smaller space offered at the legs in Concept 2. To improve Concept 2 it needs to be adjusted to offer more space, since the reduced footspace was a major issue considering the experience of the participants. The main issue of concept 1 is entering and leaving the cabin. Although the rating was higher than Concept 2, people expected it to be less comfortable. Next to that, observations showed that participants were sticking their legs out quite far while leaving the cabin. This sticking out of legs would mean they would kick a passenger sitting in the normal economy seat in their face. Since this was the middle cabin, which is the easiest to enter this poses quite a severe problem. These insights will be taken into account in the next section which shows the adjusted concepts and evaluates these concepts.



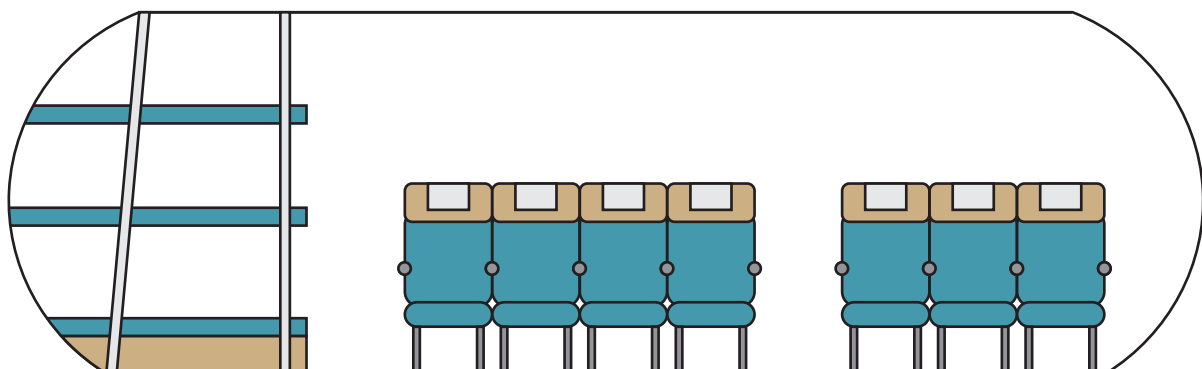
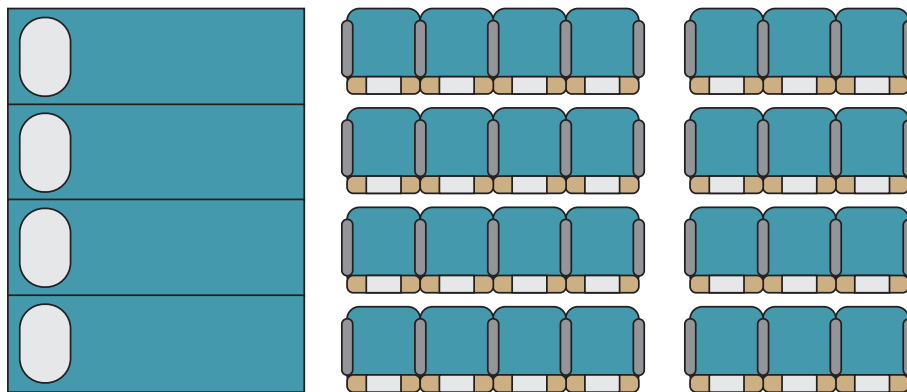
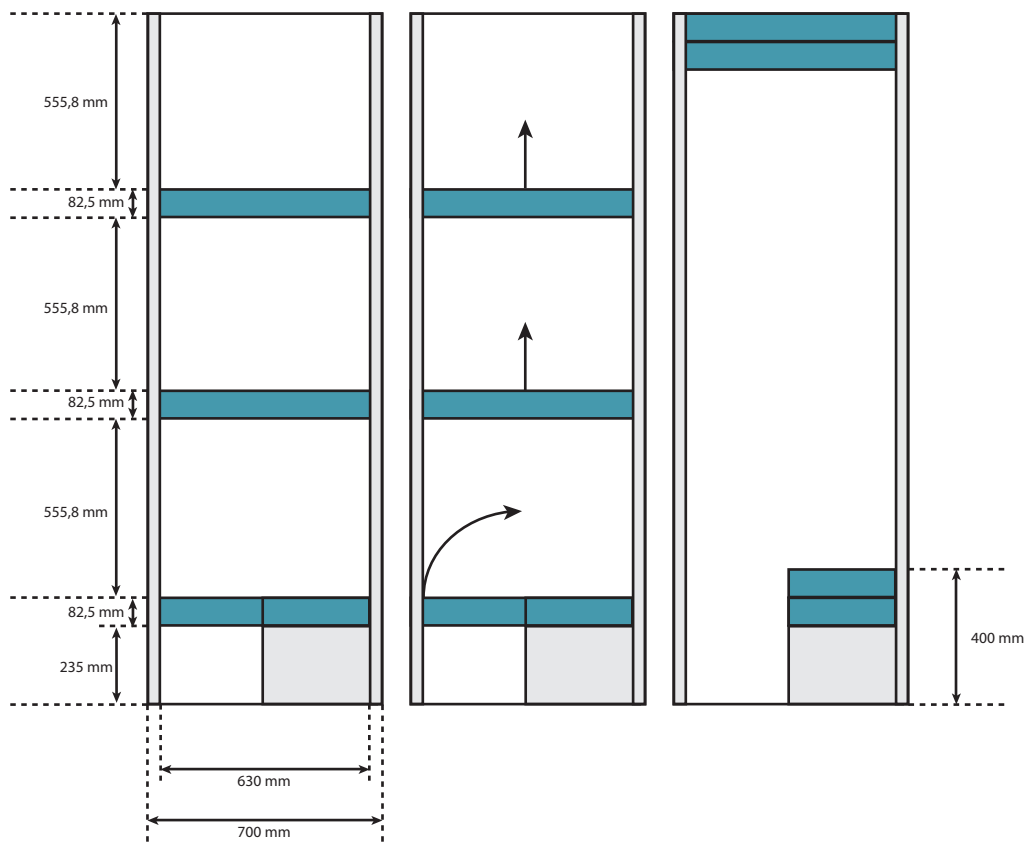
5.3 Concept 1

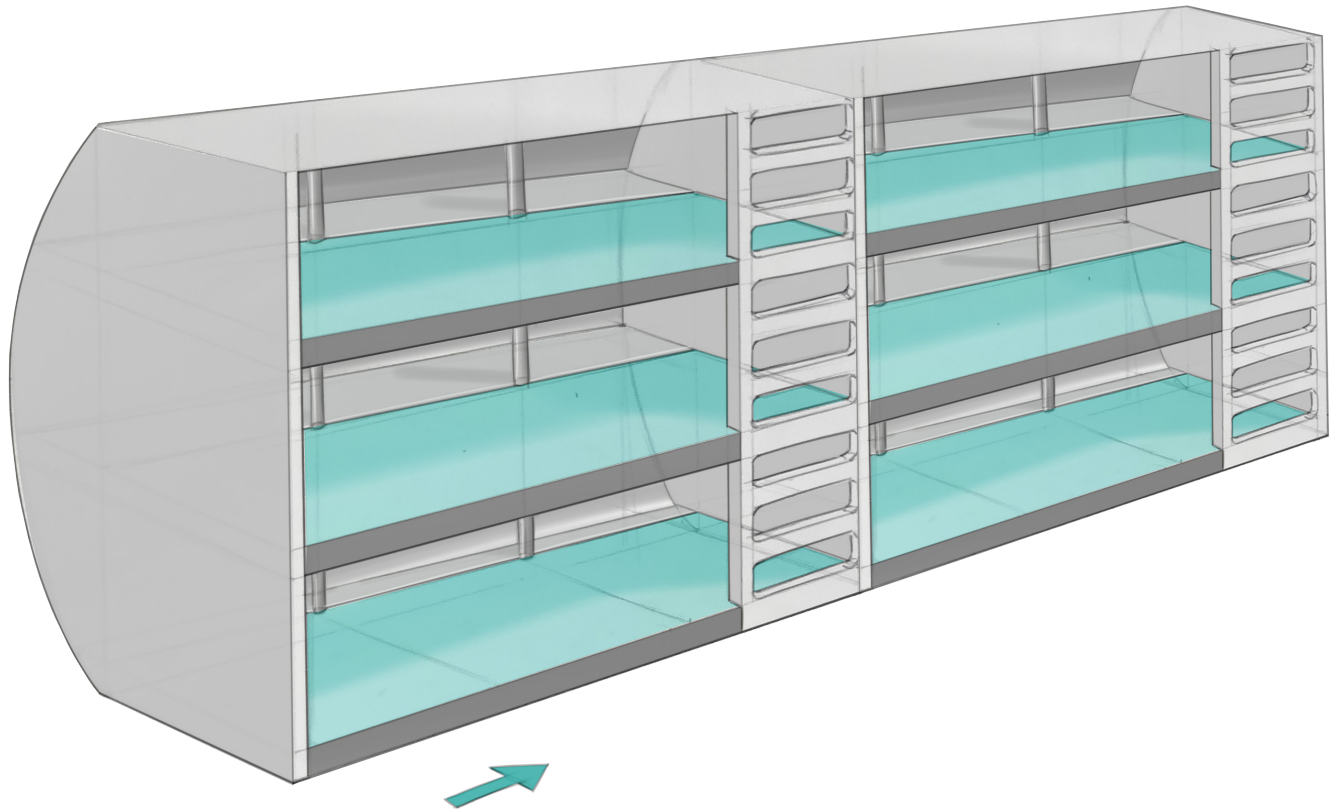
Overview of the concept that will be evaluated

Concept 1 looks similar to a Japanese hotel that offers sleeping pods. This concept makes the most optimal use of the extra space in the curved area, which is a specific trait of the Flying V. The beds are located partly inside this curved area, which means the normal economy lay-out located next to the sleeping facility can offer 18 inch wide seats. Another huge advantage of fitting these beds in the curved area is the capacity increase that comes with it. Because of the support beams located every 70cm the total width of the structure can not exceed that. This means that instead of a row of 3 seats with a 32 inch seat pitch, which occupies 81,28 cm of space, 3 passengers fit within the 70cm of space provided. That means that replacing the 17 rows of seats which are located on the inside of the V shape, can be replaced by 19 rows of sleeping cabins. This means an increase of 6 passengers on each side of the V. So a total passenger increase of 12. This increase of passengers however, does mean a reduction of passenger space.

The support beams located every 700mm are 70mm wide, this means only 630mm of space is left between them. Next to that because of the curve of the plane the bottom bed had to be placed 235mm from the ground to make sure all bed were the required length of 1917m. Therefore the height of the cabins are all 555,8mm, while using a matras and structure thickness of 82,5 mm.

The system of changing the sleeping cabins into passenger seats is fairly simple. The bottom bed folds in half. The surface that is now on top is the seat, the matras is covered. The top 2 beds slide up to be clamped on the ceiling.





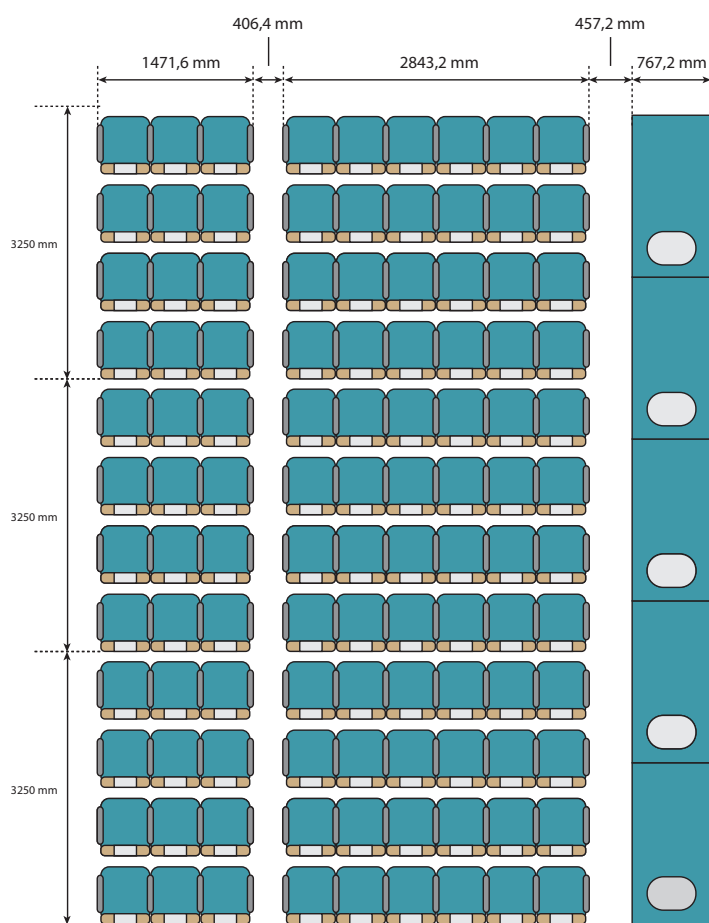
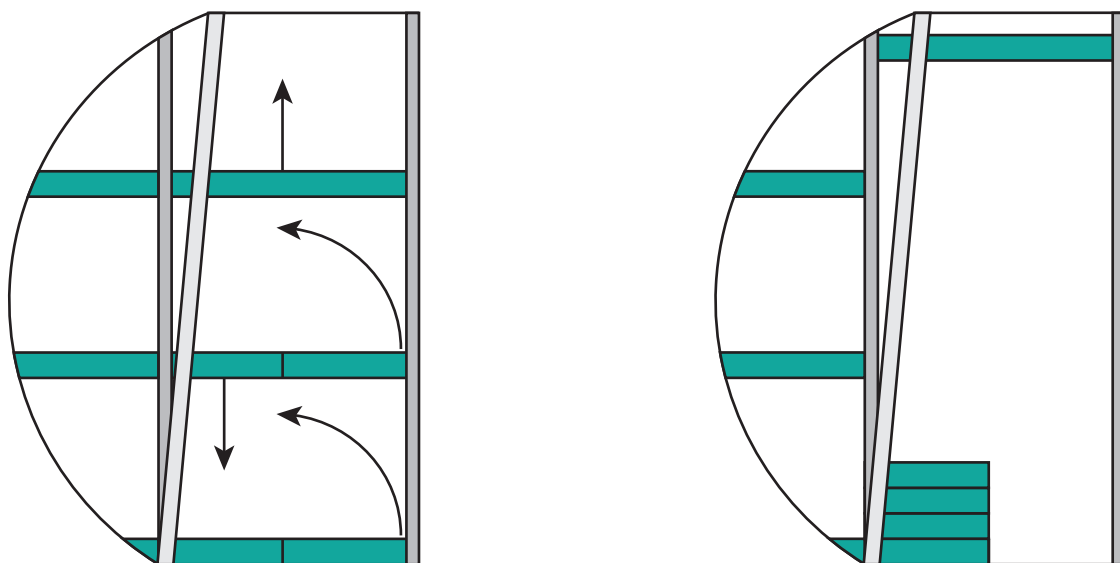
5.3 Concept 2

Overview of the concept that will be evaluated

Concept 2 looks similar to sleeping arrangements inside a submarine. As can be seen in the image the reduced foot area is removed from the concept. Because the user test indicated that this reduced space did not work another solution was found. Since the concept with the reduced foot area increased passenger capacity it was possible to change the layout so that the reduced foot area was not necessary. By placing 5 sleeping facilities next to 12 rows of seats no passenger capacity is lost. The structure of each bed is 195 cm long. A huge advantage of this Concept is the amount of space, this concept is way more spacious than Concept 1. Because the area inside the curved area is added to the facility a lot more room is created, unfortunately the support beams can not be removed. Next to that by placing a bed on ground level, each cabin is higher than the cabins in Concept 1 as well. Providing a full open side also makes it more open and entry won't disturb other passengers as much as Concept 1.

Finally there is space for a ladder to make climbing to the top cabin easier. This does not take away the fact that some extra handlebars should be placed on a couple of locations.

The largest disadvantage of this concept is the large middle row of economy seats. Luckily some space is left to place a separation in the middle of the row of 6. This does mean that skylights should be installed to provide daylight.





5.4 HARRIS PROFILE

Checking the requirements to support decision making

R1. The sleeping cabins should be designed to fit inside the Flying V concept plane; therefore, the measurements have to comply with the technical drawings of the inside of the plane.

Of course, the most important requirement of the design. Since the cabin is meant for the Flying V measurements of the Flying V are one of the most requirements to take into account. Both Concepts comply with this requirement and therefore both concepts get a rating of 2+ in the Harris Profile.

R2. The sleeping cabins should comply with set aviation regulations and therefore offer an upright sitting position for passengers during take-off and landing.

Also, a very important requirement. Measuring up to this requirement is necessary because if this requirement is not met the product will not work. These regulations make or break the product; therefore, it is key to comply to the regulations. Since regulations are this important for the design, they were taken into account during idea-tion so both concepts get a rating of 2+.

R3. Economy class passenger capacity should stay the same or be increased by applying the sleeping facilities to the interior. This means the plane should offer a place to 266 economy class passengers.

Because of the fact that passenger capacity of an airplane is extremely important for airlines, this requirement is listed high as well. Next to the airlines who want to fit as much people as possible inside, the requirement also has an influence on the credibility of the Flying V. The Flying V is being designed because it is more fuel efficient than current airplanes, so it makes sense the airplane should transport the same number of passengers as the current airplane it is designed to replace. Decreasing passenger capacity will result in more flights and will therefore the validity of the plane would decrease. Since Concept 1 increases passenger capacity it is rated higher than Concept 2, which capacity stayed the same.

R4. The regular economy seat size placed besides the sleeping cabins should be 18-inch-wide and should have a seat pitch of 32 inch.

Both concepts work together with this regular lay-out combined. So both get a rating of 2+.

R5. The minimal width of the sleeping cabin bed should be equal to the P95 breath over the elbows (554mm), with an additional 75mm of movement space. This equals to 629mm.

The width of the sleeping cabin has influence on the experienced comfort of the passenger, mostly on the movability. Since Concept 1 has to be fitted between the support beams located every 700mm the separations between cabins cannot be thicker than 35 mm. Because Concept 2 has more space available considering the width of the sleeping cabin it is rated higher than Concept 1.

R6. The minimal height of the sleeping cabin bed should be equal to the P95 breath over the elbows (554mm), with an additional 50mm of movement space. This equals to 604mm.

Since Concept 2 has a height larger than 604mm it is rated 1+, not 2 because it is still quite low. Concept 1 has a height lower than 604 so receives 1 minus in the Harris Profile.

R7. The length of the bed should be at least be equal to the P95 stature (1917mm).

Both of the concept suffice, but even longer would be better. Therefore, both get a score of 1+

R8. While sitting in upright position, the seat pitch should be equal or larger than the P95 buttock-knee dept while sitting, which equals to 686 mm.

Concept 1 does not suffice. Because the support beams which stand 700mm apart, with a thickness of 70mm. It is not able to create the 686mm desired. Concept 2 does offer this space. However because passengers are able to stick their legs stretched in the aisle it only receives 1+.



	CONCEPT 1				CONCEPT 2			
	--	-	+	++	--	-	+	++
R1								
R2								
R3								
R4								
R5								
R6								
R7								
R8								
R9								
R10								

R9. There should be space available for 1 piece of carry-on luggage per passenger. The dimensions of this luggage should be complying with the general dimensions of economy class carry-on luggage utilized by KLM. This equals to 550 x 350 x 250 mm.

Concept 1 does not have any space for this luggage. The space below the first bed is just too small. Making this space fit the luggage will decrease the height of the cabins even more, therefore the concept gets a rating of 2-. Concept 2 has plenty of extra space in the curved area, therefore it gets 2+ as a rating.

R10. The sleeping cabins should offer a form of privacy by giving the option to exclude the passenger from the sight of the other passengers.

Both concepts can be fitted with a curtain of some sort. Closing it is a bit more difficult in Concept 1, but both concepts get a score of 1+. This is because while entering and leaving, ladies with dresses or skirts might not feel this privacy.

CONCLUSION

When looking at the most important requirements it can be concluded that Concept 2 is the better concept and deserves to be worked out into a final design. Although Concept 1 looked very promising, the small space available between the structural beams was simply not sufficient. If these structural beams would be 32 inch apart from each other, just like the regular economy seat-pitch, Concept 1 would have been a very strong contender.

DESIGN

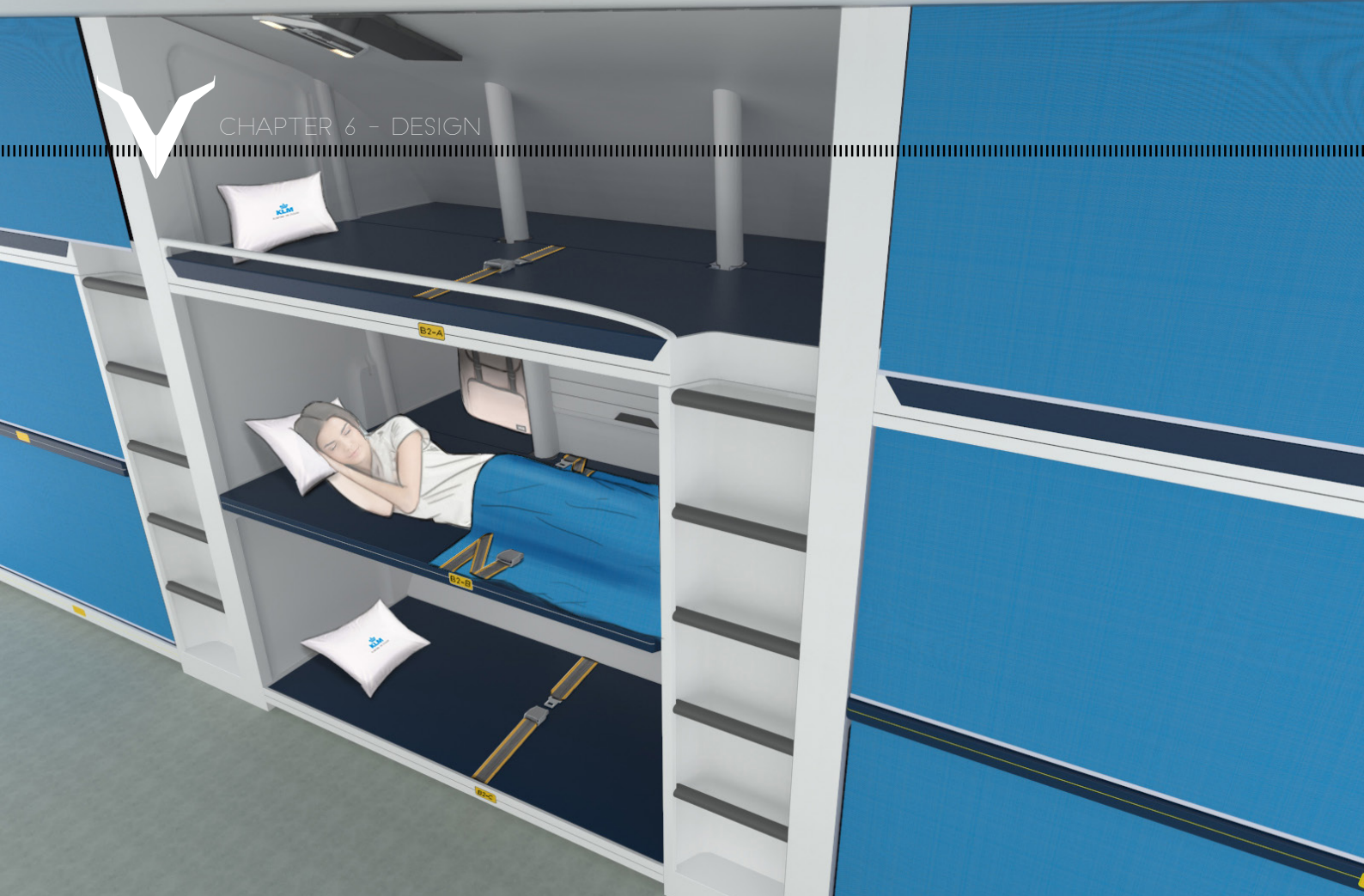
CH. 6

INTRODUCTION

Showing the design, how it works, how it it placed inside the airplane and finally the validation with a user test and the recommendations and conclusions that resulted from the test.



CHAPTER 6 - DESIGN





6.1 Design Summary

Showing the main features and Unique Selling Points

This summary shows all features the Economy Class Sleeping Facility offers and describes the unique selling points this design offers.

- 1:** 3 Full Flat-beds in economy class with a length of 193cm.
- 2:** Personal In-Flight Entertainment.
- 3:** Personal control-panel which controls airflow, lights, curtains and calls a flight attendant. Also displays fasten your seatbelt sign.
- 4:** Luggage compartment which fits 3 pieces of carry-on luggage.
- 5:** Curtains for privacy.
- 6:** Seatbelts for turbulence.
- 7:** Extra space for a back-pack, or to place your book/smartphone and so on.
- 8:** Emergency oxygen masks above the seats and inside the beds
- 9:** Three separate folding seats transformed out of the middle bed meant for taxi, take-off and landing.





Unique Selling Points

“Economy class flat-beds that offer a seat during taxi, take off and landing without occupying extra space. ”

“Capacity increase of 3 passengers in Economy Class.”

“Making sleeping in a bed possible for Economy Class Passengers.”





6.2 Final Design Story Board

Illustrating the Final Design and features of the Design

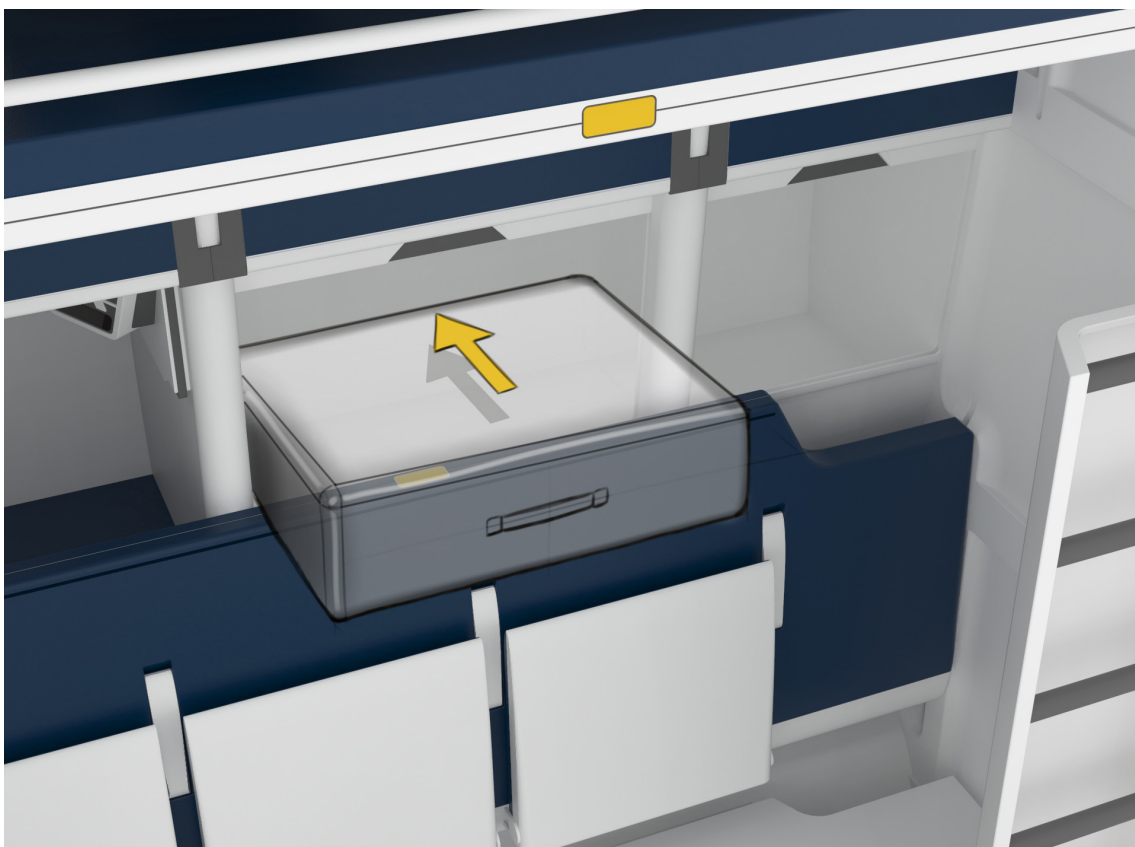
To demonstrate the final design this chapter shows several images which depict how the design works and how it is fitted inside the Flying V airplane. Each image is supported by a short explanation to ensure it is clear what happens in the image and why.



Starting at the Airport, in this case Schiphol International Airport. The Flying V is ready for boarding. You have booked one of the available Economy Class Beds.



While boarding all beds are in the sitting position, to ensure fast boarding. Therefore, it is important that in this sitting position the luggage compartments are accessible. This is the reason all carry on luggage is stored in the middle bed cabin. There is space available for 3 pieces of carry-on luggage, giving the fact that it not exceeds the 550 x 350 x 250 mm listed in the list of requirements for each piece of carry on luggage. There is some space left for backpacks inside the luggage compartments, otherwise they can fit below the folding seats.





After closing the luggage compartments by sliding the divider down, passengers can fold down their seats and armrest and take a seat. The dimensions of the seats are described in more detail further on in this report, but the space available is similar to normal economy seats. However, because it is possible to stretch your legs into the aisle there is more leg-room available. Of course, the seats are equipped with safety belts.

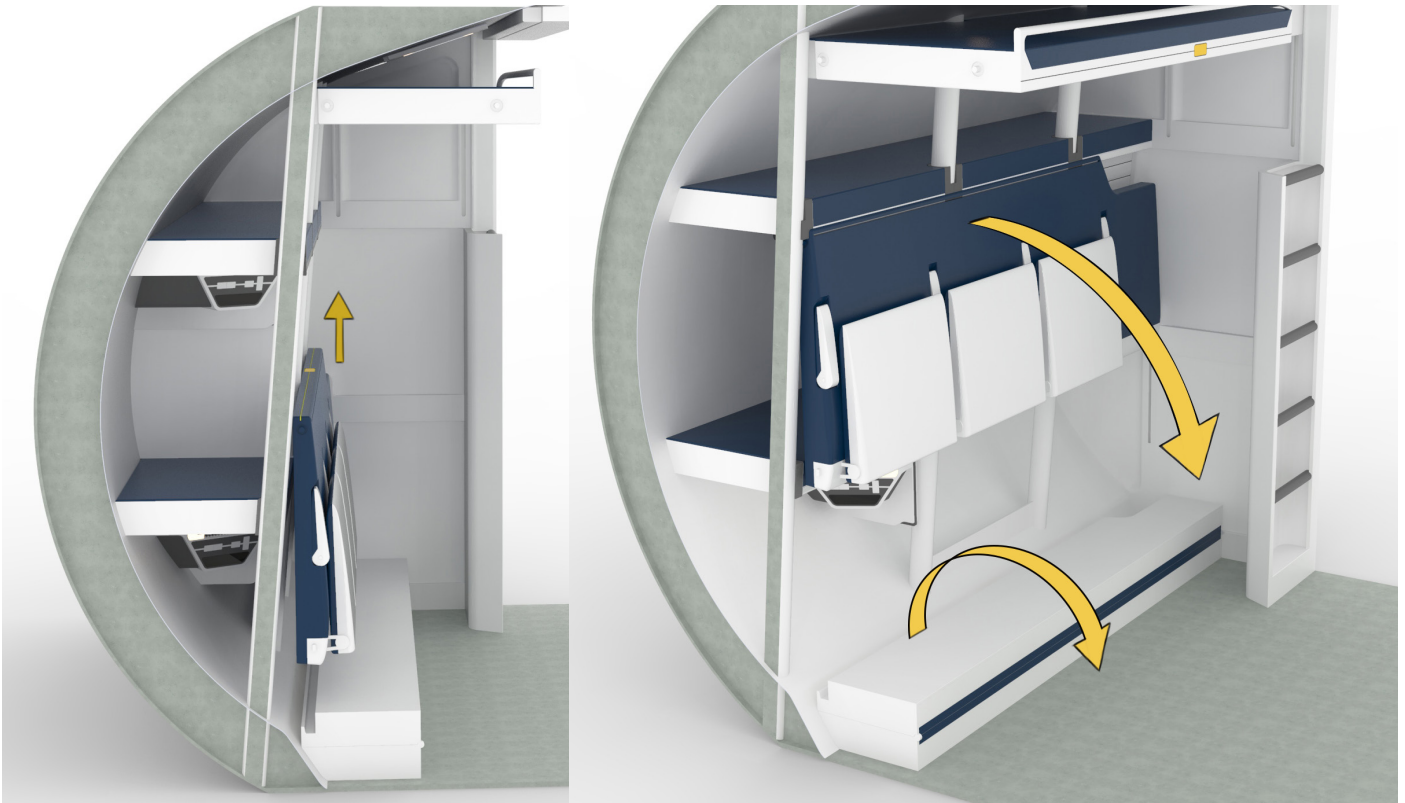




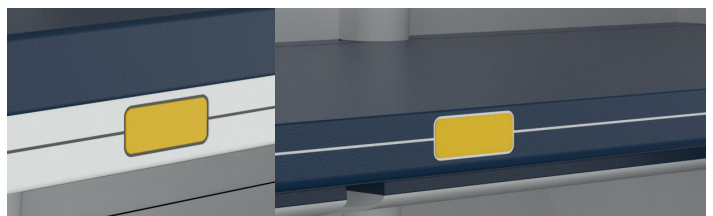
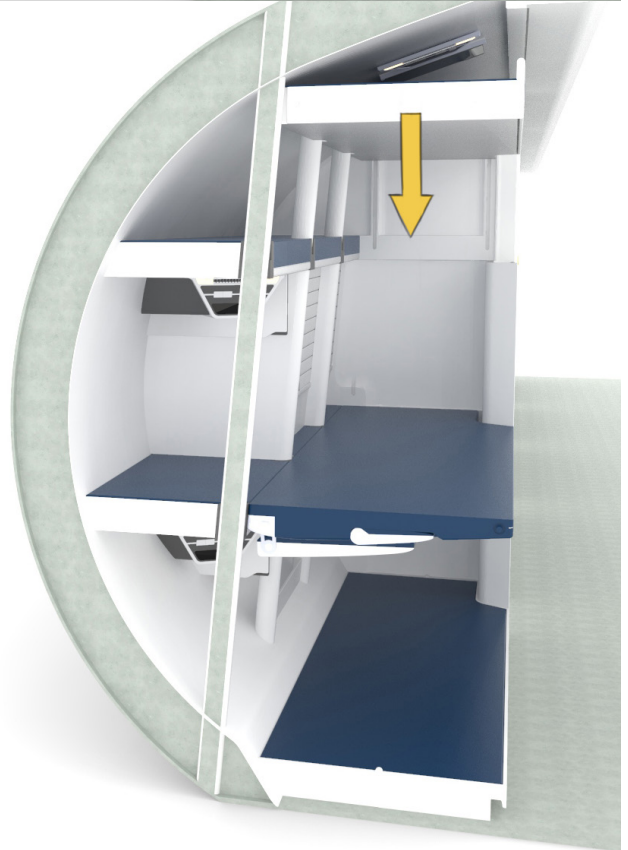
Since the view towards the cabin crew is obstructed during the safety demonstration from the bed seats, a screen is located in the overhead bins facing the bed seats. On this screen the safety demonstration is displayed by video, there is also a fasten your seatbelt indicator to make sure the seatbelts are used on the required moments. Also visible are the digital windows to give passengers a less enclosed feeling and create a horizon people can look at to determine in what position they are flying.

Above the seats there are oxygen masks available for all three folding seats, in case of loss of cabin pressure or another emergency. Below the seats there are life-vest available as obliged.



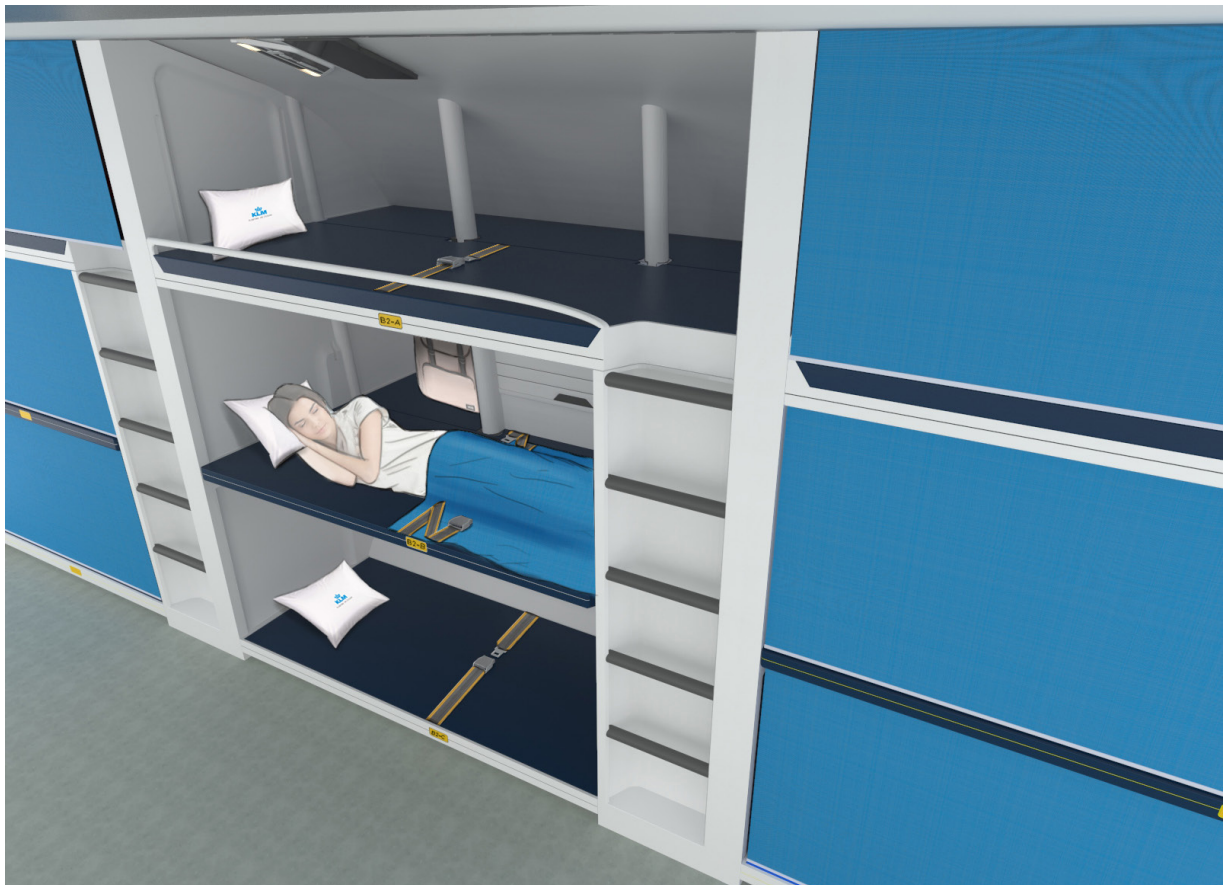


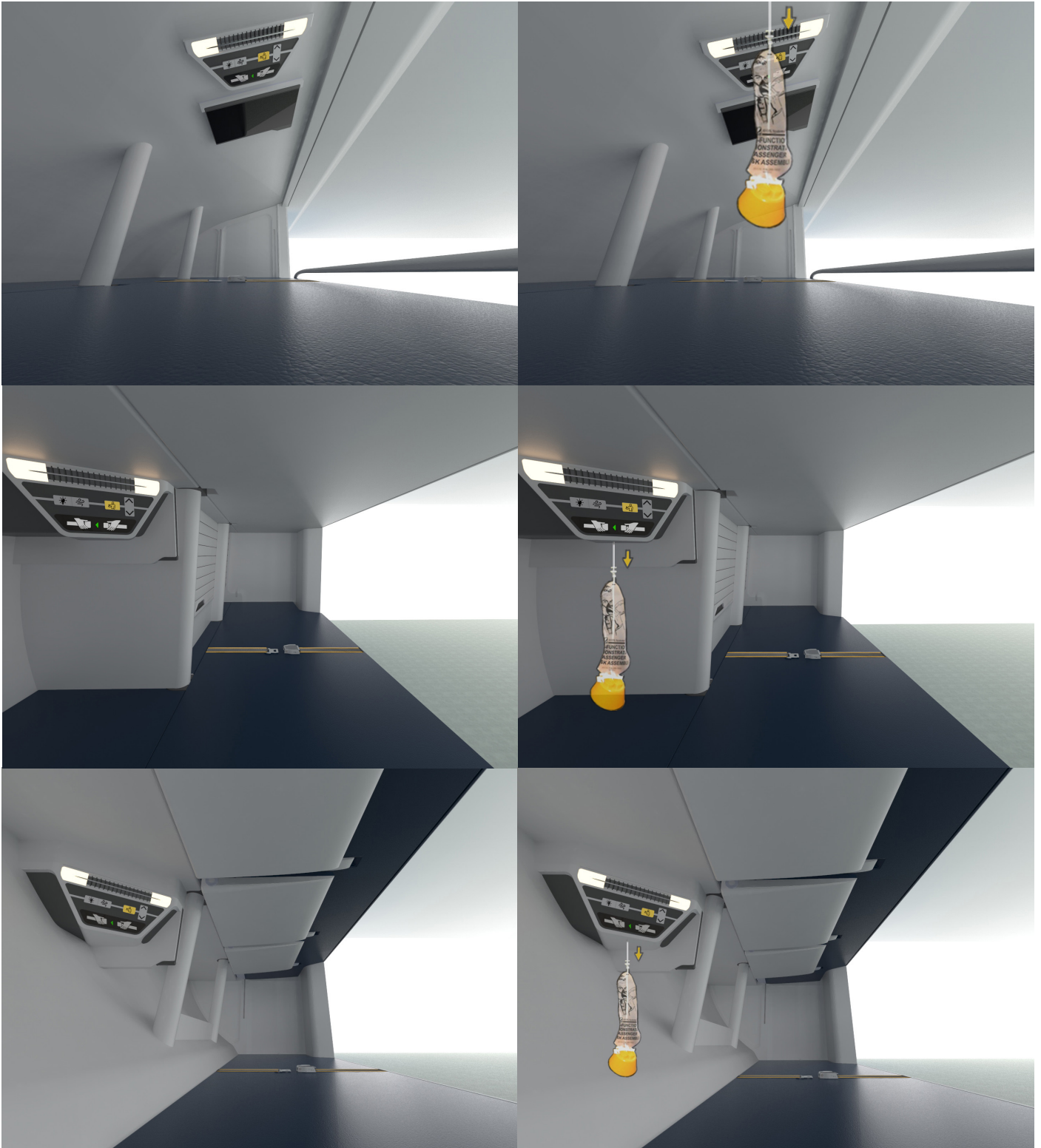
After take-off, when the airplane reached cruise flight and the fasten your seatbelt signs are turned off, it is time to transform the seats into beds. First all three passengers should leave their seats and fold back the armrests, the seats will fold back automatically. Pushing the orange button releases the pins that clamp the bed in their position. First the middle bed, which is the backrest of the seats at the moment, should be lifted. When lifted to the maximum height it can be turned to create a flat surface, which is the middle bed. Finally, the middle bed should be pushed slightly towards the curved wall to click the system in the fixed position. After this sequence, the bottom bed can be folded open. It was folded to make sure that while the seats are being occupied the bottom bed does not get dirty. Finally, the top bed can be moved down, again by using the orange button on the side. The top bed was lifted to create easier access to the seats which should prevent boarding from taking longer. Next to that because of this elevated top bed a larger standing height is created, which makes turning the middle seats into a bed easier.





During cruise flight passengers can sleep or relax in their personal Economy Class Bed

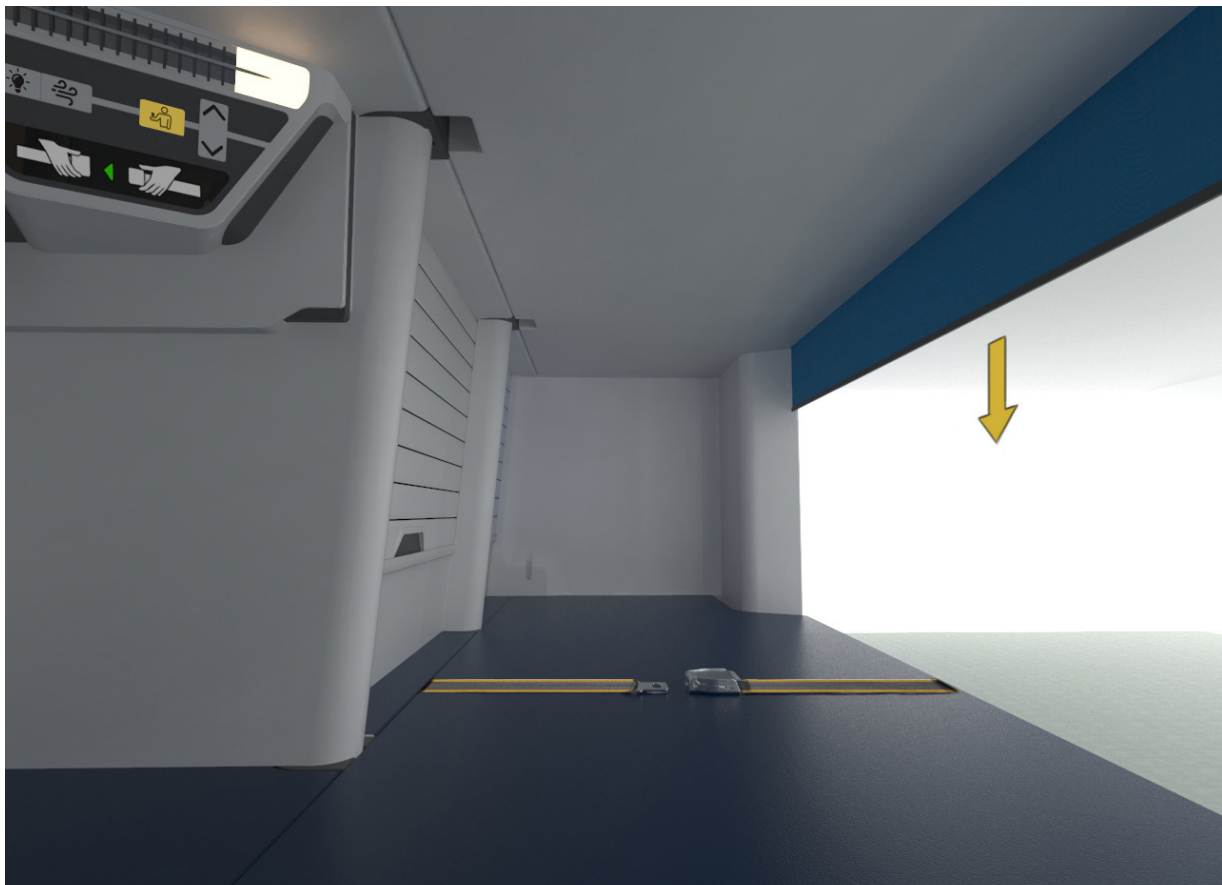


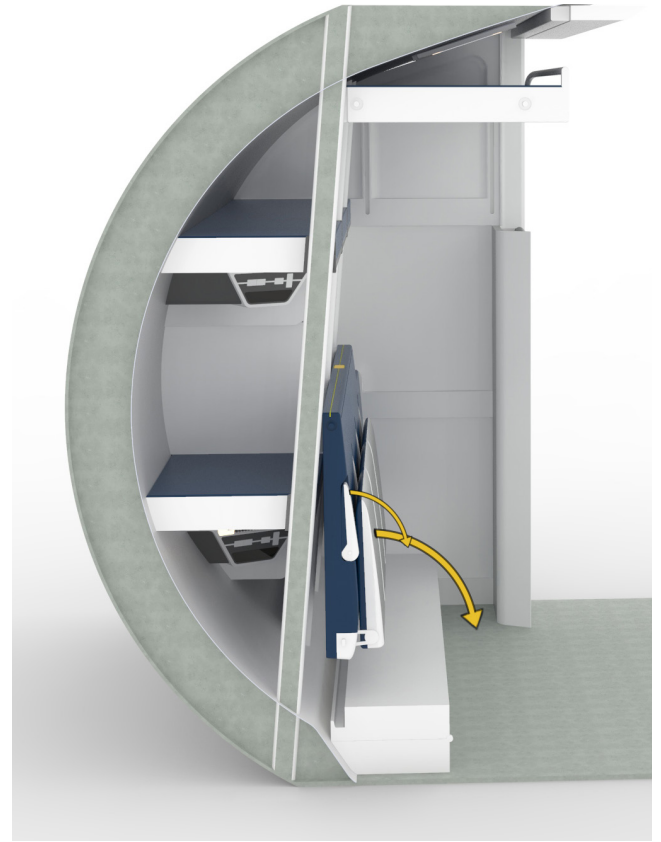
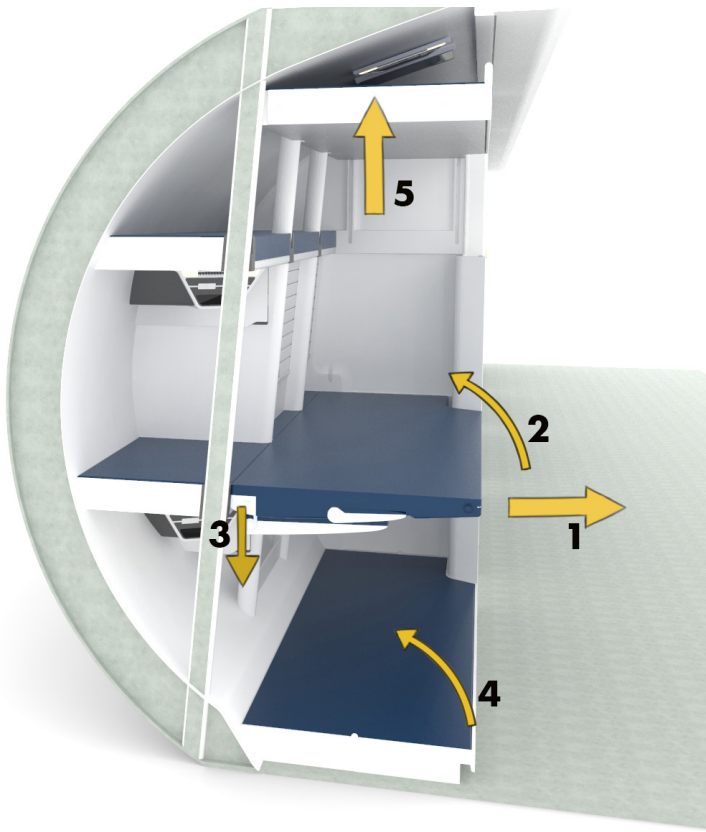


Looking inside the cabins; top, middle and bottom bed starting from the top of the page. Each bed has a personal control panel available. This controls lights for reading, a personal air-flow, calls a flight attendant and controls the personal curtain. Next to that it also shows a fasten your seatbelt indication and of course a seatbelt. Which is necessary for when the plane experiences turbulence for instance. Finally, all beds are equipped with oxygen masks, if cabin pressure would be lost during cruise flight. The top bed has this built in in the ceiling, the middle and bottom bed have the oxygen mask located behind the personal control panel.



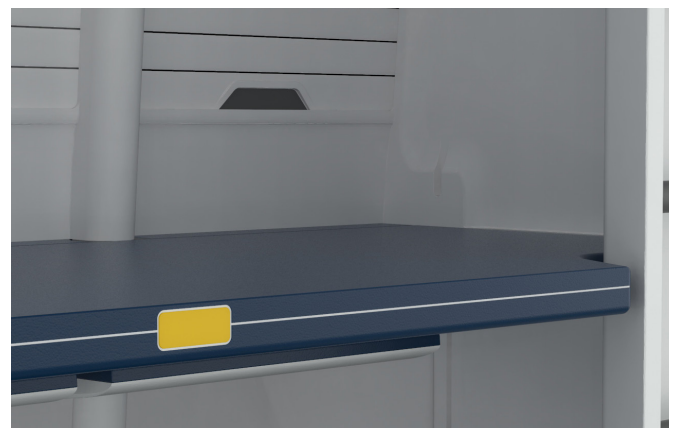
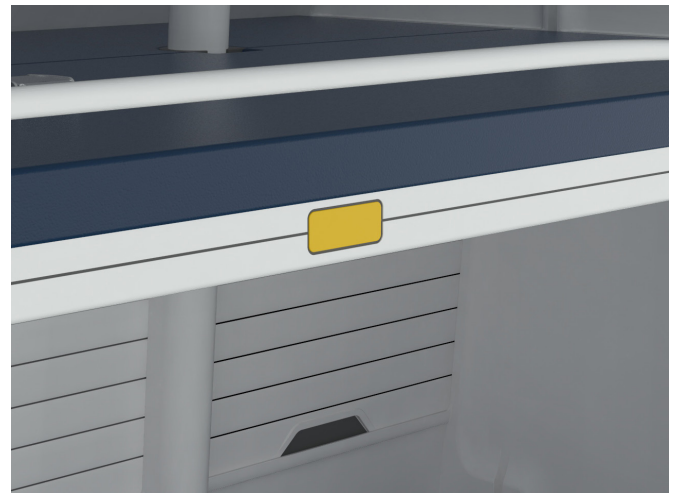
Each bed has their own In-Flight Entertainment system and a curtain that can be rolled down with buttons on the control panel to create privacy while sleeping.





When cabin crew indicates landing will be starting in 10 minutes the beds should be transformed back to the seats. This is done as following:

- 1.** Pushing the orange button and pulling the bed a little bit towards yourself to get it out of the fixed position.
- 2.** Turning the bed back to create the backrest for the seats.
- 3.** Lowering the bed/backrest to sitting height.
- 4.** Folding the bottom bed back to create foot-space for sitting (this can be done as first step as well). This is again possible after pushing the orange button that releases the bed from its fixed position.
- 5.** Pushing the top bed back towards the ceiling to create more space. This is also done by pushing the orange button and releasing it from its fixed position. Also, this step can be performed as first step as well.
- 6.** Folding down the seats and arm rests and get ready for landing.





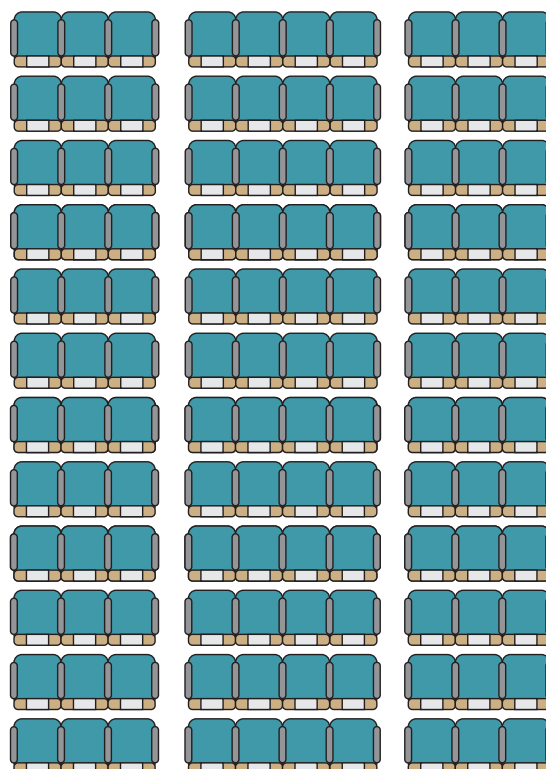
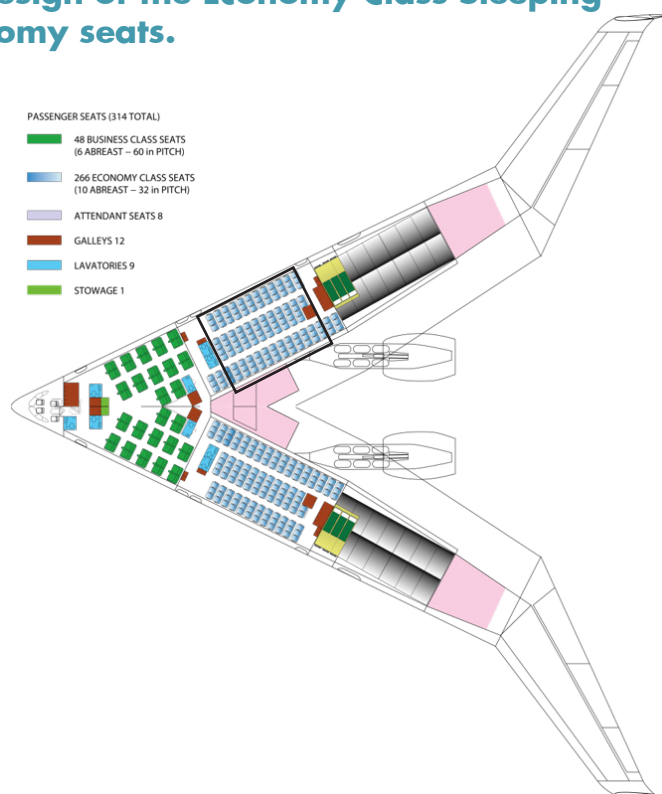
6.3 Placement Inside Flying V

How the placement of the beds change the lay-out of the Flying V interior

For the base of the interior for the Flying V is a regular economy class interior has been chosen. This section shows how the design of the Economy Class Sleeping Facility can be combined with regular economy seats.

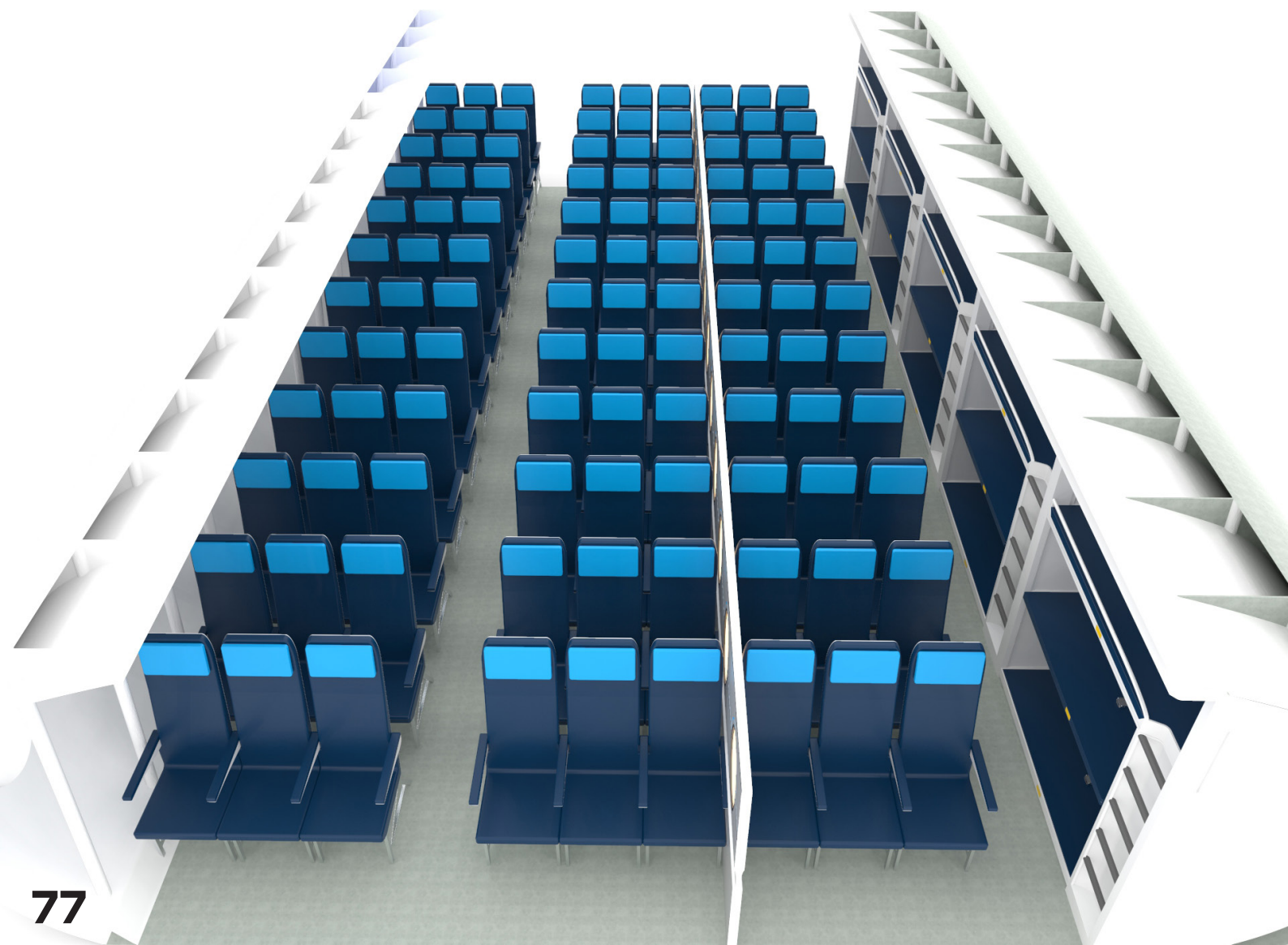
Although the fact that the Flying V is a concept plane meant to be flying in 2050, and the fact that a new innovative interior for this aircraft is being designed simultaneously with this project, a regular 10 abreast economy class has been used as a base for the design. This choice has been made because personally I found it too easy to take up extra space for the beds and indicate that the other parts of the new interior just should occupy less space. To make the Economy Class Beds as realistic as possible it was determined that they should be combined with regular economy class seats, and that no capacity should be lost.

The area of the plane that have been adjusted to place the beds is indicated with a black rectangle in the top view of the Flying V. This equals the amount of 11 and a half middle rows; removing the toilet and replacing it with seats to simplify it makes it 12 middle rows, 12 window rows and 12 rows on the inside of the V. This equals to 120 seats as depicted on the right.

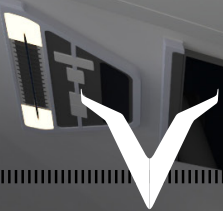


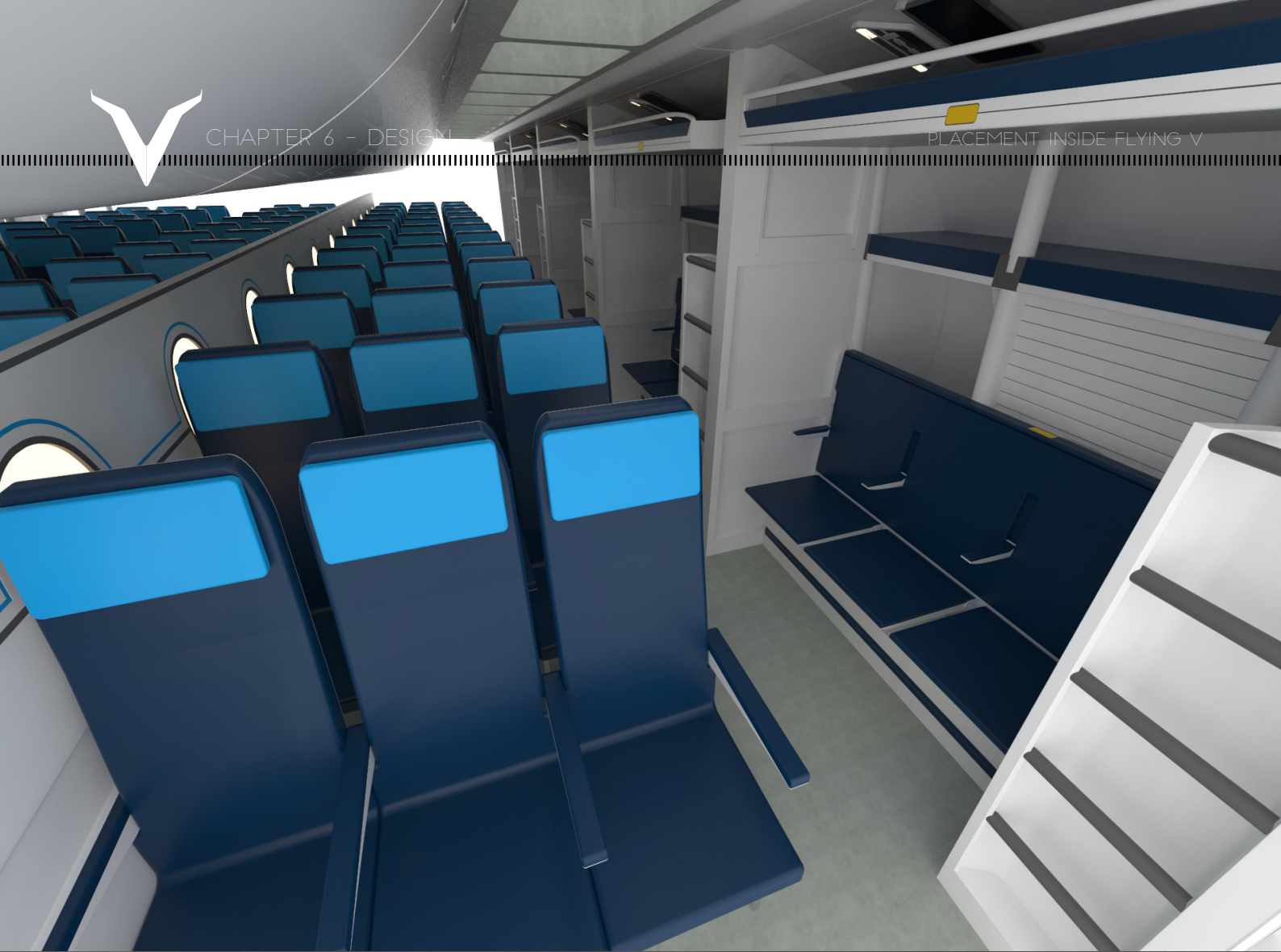


By moving the aisle and changing the lay-out no capacity is lost. The lay-out depicted below consist of 108 seats and 15 beds. Which means a total capacity of 123 passengers. Hence, applying this lay-out creates space for an extra 3 passengers. The economy seats used are 18inch seats, with a seat pitch of 32 inch, aisles comply to set regulations. Measurements will be discussed further on in this report. The lay-out with the Economy Class Sleeping Facilities have a row of 3 seats placed next to the window, just like a regular economy class lay-out. The middle row consists of 2 times 3 seats, divided by a wall with digital windows. On the inside of the V the Economy Class Beds are located, with skylights in the roof above the aisle. These windows in the ceiling make sure there is extra daylight inside the aircraft. The next couple of pages show several images of this adjusted economy class lay-out.















6.4 Measurements

Measurements of the Bed Design and the total interior lay-out

To show how everything fits inside the Flying V Airplane and if the design meets the requirements, this section displays the most important measurements.

Length of the beds (inside): 1930 mm

Unobstructed Matrass width (up until the support beams or the curved wall):

Top: 639,63 mm

Middle: 701,51 mm

Bottom: 667,89 mm

Matrass width up to the curved wall:

Top: 1065,45 mm

Middle: 171,06 mm

Bottom: 667,89 mm

Height beds from the ground:

Top: 1533 mm

Middle: 816,6 mm

Bottom: 100 mm

Height between matrass and obstruction above (largest point):

Top: 612,24 mm

Middle: 616,4 mm

Bottom: 665,66 mm

Luggage Compartment:

1190 x 586,4 x 338,94 mm

Folding Seats:

Sitting depth: 435,43 mm

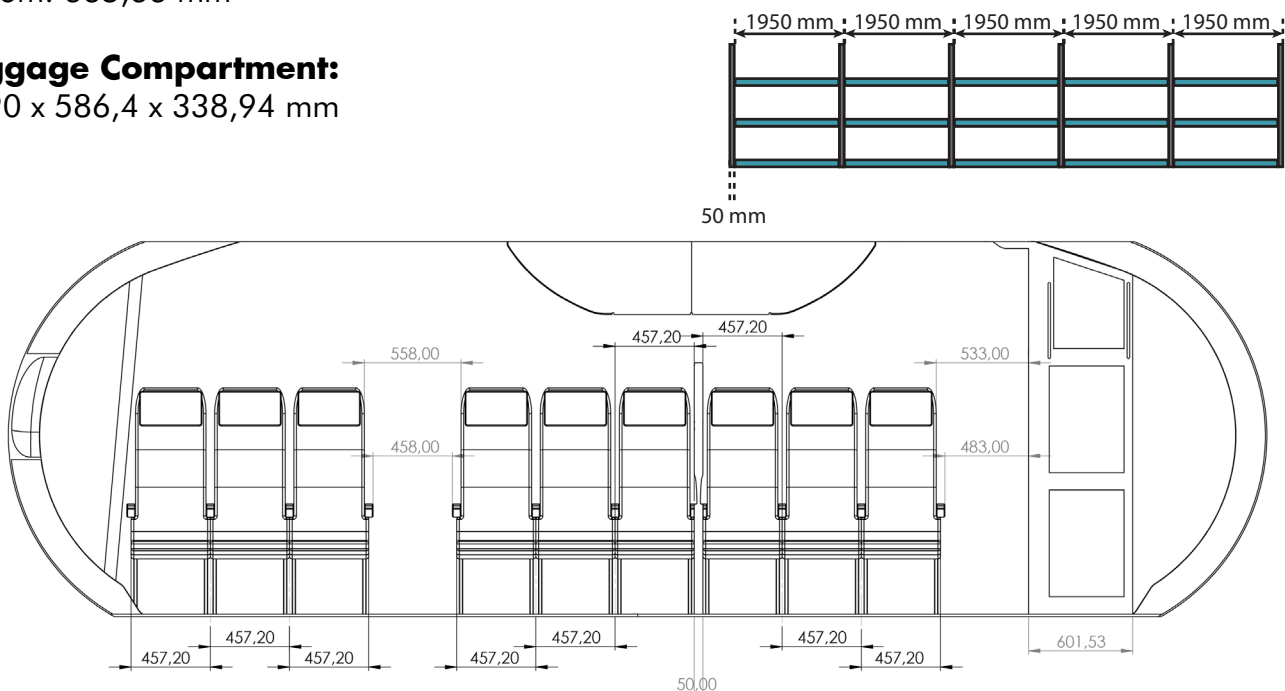
Seat width: 457,2 mm

Seat height: 422,9 mm

Back support height (from seat):
619,68 mm

Width between seats: 40 mm

The measurements of the total lay-out can be seen below. The seat pitch in use is 32 inches, the width of the seats is 18 inches. This to ensure comfort of passengers travelling in normal economy seats. With a length of 1950mm 5 beds fits exactly inside the length of 12 seat rows ($12 \times 32 \times 25,4 = 9753,6$ mm) However the first bed has to be 2000mm because of the frames in between the beds that supports them, it of course has to have a frame at the beginning as well. This either means that all beds have to be 10mm shorter, or that this 50mm frame should be build inside a separation wall already in place in airplanes.





6.5 Appearance

Explaining the appearance of the Design

The way a product looks is very important and has an effect on the perception of potential users of the product. Therefore, it is important to specify how the product should look and the reason for this appearance.

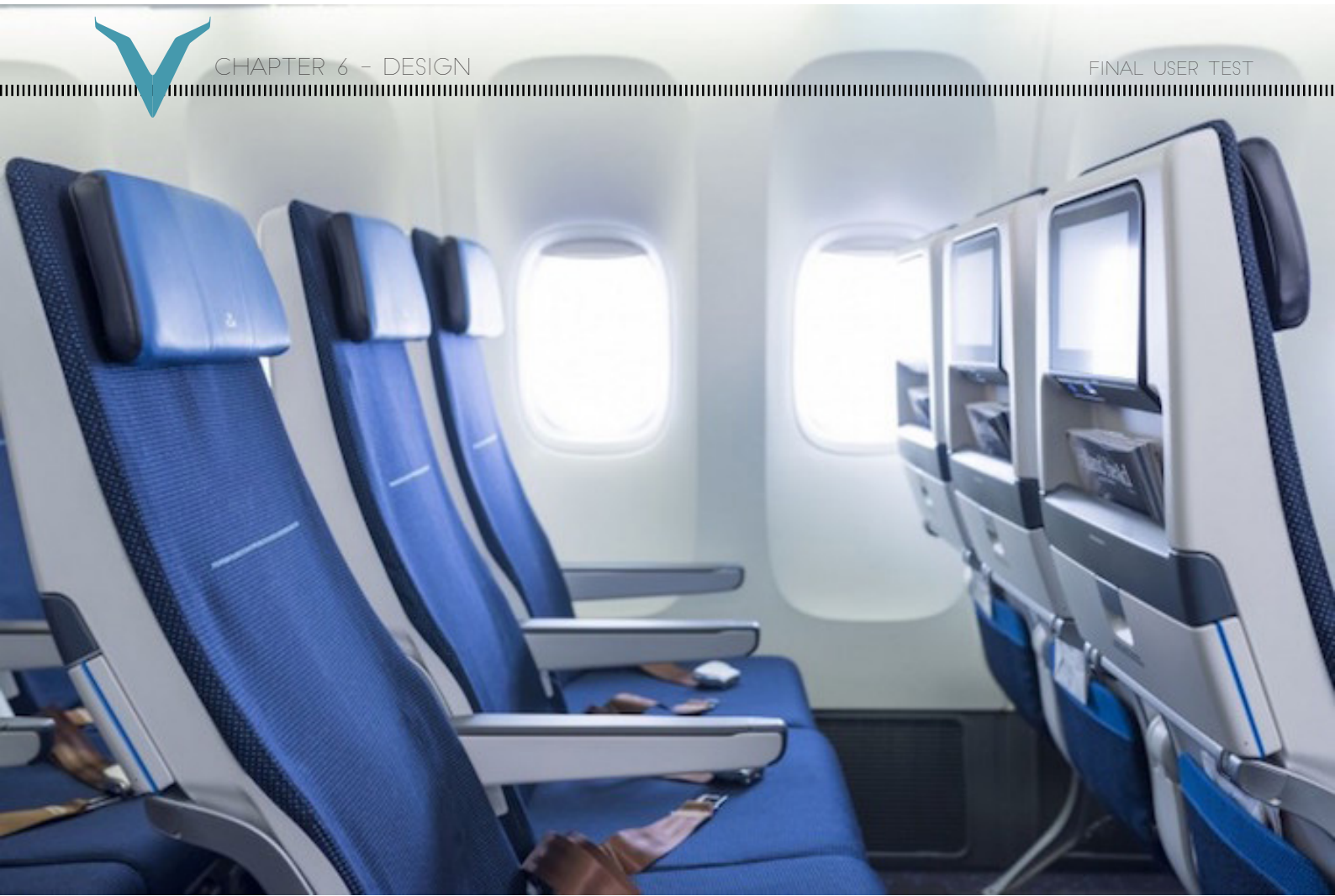
When specifying the desired feeling evoked by the product it can be illustrated as the Emotive Collage as seen in the image on the right. Key-words that fit this Emotive Collage are: Feeling of safety, soft, relaxed, clean.

When designing a sleeping facility it is really easy to compare it to a normal bed. However since these beds are located inside an airplane it is important that it mimics aircraft interior.

The reason it should look like aircraft interior is that the design will be tested with potential users by showing images. When differing the design too much from airplane interior they are familiar with it becomes less recognisable which might influence their opinion about the product. For instance when designing it looking like a nice and soft bed you sleep in every night, it might influence their perceptions on how safe the product is.

Therefore the appearance of the product should fit in with a familiar economy class from KLM.





6.6 Final User Test

Evaluating the design

To evaluate the final design of the economy class sleeping facilities a final user test was performed. This final test investigates the opinion of people concerning the design and use of the economy class sleeping facility. By letting participants fill in a short questionnaire online the overall design was evaluated which resulted in recommendations to improve the design during further development.

Since the design of the sleeping facility is not as conservative as the general airplane interior, a research was performed to find out what the general public thinks about flying while laying down like the design offers, with 3 passengers above each other. The goal of this final test is to find out if people want to fly while laying down in this position offered, and what percentage of the people would consider booking one of these beds. Next to that several other aspects of the beds were tested; time people prefer to spend inside these beds during a

flight and which bed height is preferred. The last section showed participants how the beds fold into seats, with the question if people would take-off in this position given the fact that they would have a bed during cruise flight. Or if they would rather take-off in a normal seat and just sleep in the economy seats. This find out if the folding seats would pose an obstacle for passengers in their consideration of booking an economy class bed.



6.6.1 Method

208 participants were asked to fill in an online questionnaire concerning sleeping inside airplanes during long haul flights in general, and evaluating the design of the economy class sleeping facilities. The goal of this research was to answer the main research question stated below, by using quantitative data.

Main research question:

Do passengers of long-haul flights (6 hours or longer) want to use the designed economy class sleeping facility, and does the expected comfort offered by these beds exceed the score of the experienced comfort of sleeping in economy seats?

Sub research questions:

1. Which bed height level out of the three options is preferred (top, middle or bottom)?
2. Do people want to spend a full flight inside the beds or only part of a flight?
3. Does the opinion of booking a bed change by showing respondents that during taxi, take-off and landing they will be seated on folding seats transformed out of the beds?

6.6.2 Participants

In total 204 respondents filled in the online questionnaire. Out of these 204 participants 20 had never been on a long-haul flight (6 hours or longer). Since these 20 persons never experienced a long-haul flight, they were thanked for their trouble and directed straight to the end of the questionnaire. Therefore, in total 184 participants filled in the full questionnaire with relevant data. The age of respondents ranges from 17 to 75 years. Females made up 54,35% of the respondents, 45,65% of the respondents were males.

6.6.3 Pilot

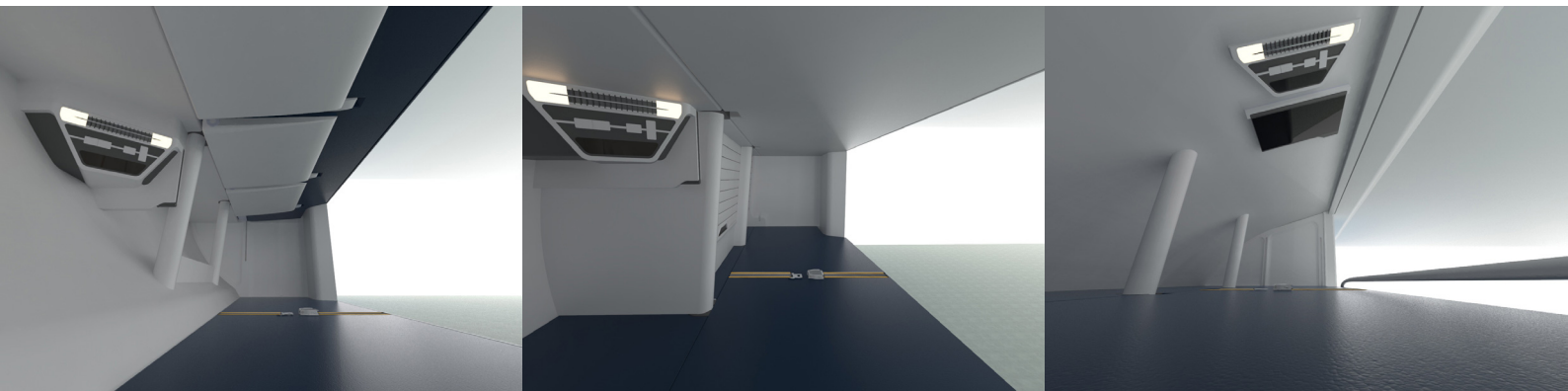
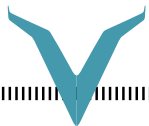
A rough draft of the questions intended to be asked in the questionnaire were sent to the supporting staff of this project for evaluation, remarks were taken into account and applied. Subsequently, the questionnaire was sent to a small group outside the faculty of Industrial Design Engineering, to find out if everything worked properly and there were no inconsistencies or mistakes. After this first group did not find any inconsistencies the questionnaire was distributed to a larger audience.

6.6.4 Stimuli

Respondents were shown several images accompanying the questions posed. When clicking on the questionnaire the first thing shown is the Flying V airplane, to support the explanation of the research and to grasp the attention of potential participants.



The image of the row of economy seats on the previous page has been used as stimuli in the questionnaire as well. The following page shows all other images used as stimuli during the questionnaire, the full questionnaire is located in Appendix D where they can be seen combined with the questions the images support.





6.6.5 Apparatus

Research was done digitally; participants were asked to fill in a Google Form. Both an English and a Dutch version was available.

6.6.6 Procedure

An online questionnaire was distributed, the first question asked was: Have you ever been on a flight which was 6 hours or longer? If a participant answered yes, they would continue to the next section, the following message was shown at the no option: Thank you for taking the trouble to fill in this questionnaire. Sadly, this questionnaire is about airplane interior for long haul flights (6 hours or longer). Therefore, your data will not be relevant since you never experienced a flight this long. People who answered no could not continue the questionnaire. Questions below this point were either multiple choice or rated on a 7-point Likert scale. The whole questionnaire can be seen in Appendix D.

After the first section three general questions were asked about: age, gender and nationality. Subsequently the third section consisted of general questions about sleeping in airplanes. The following three questions were asked in this third section:

1. Do you sleep on long flights? (Flights that take 6 hours or longer)
2. Out of your experience, can you rate the comfort level of sleeping in economy class seats?
3. Would you like to sleep while laying down on a long flight?

These questions had the intention to let people think about their experience of sleeping on a long flight, next to the fact of gathering data which can be used to compare with the data retrieved from the questions about the design of the sleeping facility asked further on. A normal row of three KLM economy seats next to a window were shown in this section.

In the fourth section of the questionnaire several images of the design were shown, with the beds in sleeping position (see stimuli section). The following questions were asked in this section:

1. Can you rate the expected comfort level of these airplane beds?
2. Would you rather sleep in these beds or on a normal economy seat?
- 2.1 Why did you choose this option?
3. Considering the fact that these beds cost the same as a normal economy seat, would you book one of these beds when flying 6 hours or more? Taxi, take-off and landing will be done while sitting on a seat, so does consuming your inflight meals.
4. Imagine having a flight of 12 hours, would you rather have the bed for the entire flight, or for a part of the flight?
- 4.1 Can you explain your previous choice?
5. Which bed would you prefer to have during your flight?

The goal of these questions was to find out the opinion of participants towards the design of the sleeping facility. Do they expect the comfort to be larger than the comfort experienced of sleeping in economy class seats, and would they want to use the beds during a flight? Also, it needs to be investigated if people want to spend an entire flight inside the beds or part of the flight. As it is expected that on a 12-hour flight the majority of people would not want to spend the whole flight in a bed. Therefore, the answer has implications in possible further development of the working principle of the sleeping facility. Finally, by asking which bed has the preference of possible passengers it can be investigated if adjustments have to be made to the design create less difference in bed preference.

Finally, the last section shows that the beds transform into the seats meant for taxiing, take-off and landing. This is intentionally done to see if the opinion about the sleeping facility changes. Therefore, they are asked if they would want to take off in the folding seats of the beds and have a bed available during cruise flight, or if they would rather take-off in normal economy seats and just sleep there.



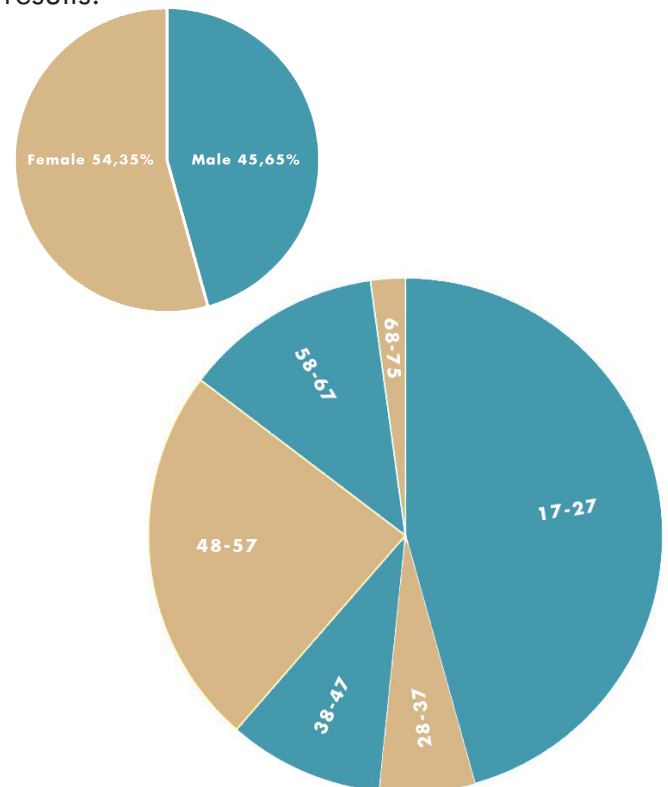
6.3.7 Measure

Participants either rated questions on a 7-point Likert scale or a question was multiple choice, with exception of the question about the age of the participants and the questions to explain their choice. Where possible, average scores and/or percentages will be shown in the results. Explanations of respondents will be used to explain scores if necessary.

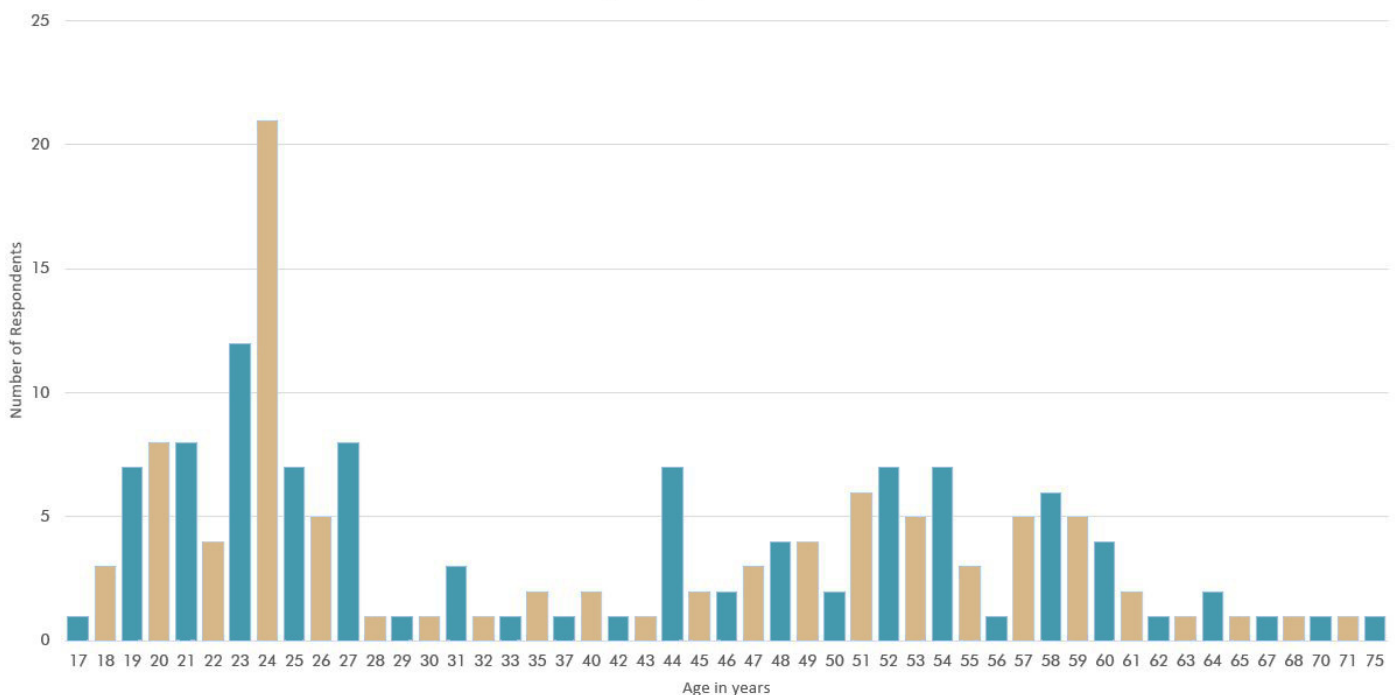
6.6.7 Results

As mentioned before 204 people responded to the questionnaire, out of those 204 people 184 participants indicated they had experienced a long-haul flight of 6 hours or longer. Since the sleeping facilities are meant for long-haul flights only these 184 responses will be used. Starting with the demography of the respondents. Age of respondents differs between 17 and 75 years. 54,35% of respondents identified themselves as female, the remaining 45,65% were male. A majority of respondents is Dutch, with the exception of three respondents; a Canadian, Norwegian, and Indian.

Because of the many different ages of participants, a good image can be created what the general public thinks about the proposed interior design. Also, the almost even distribution of male and female respondents should take away the factor that gender influences the results.

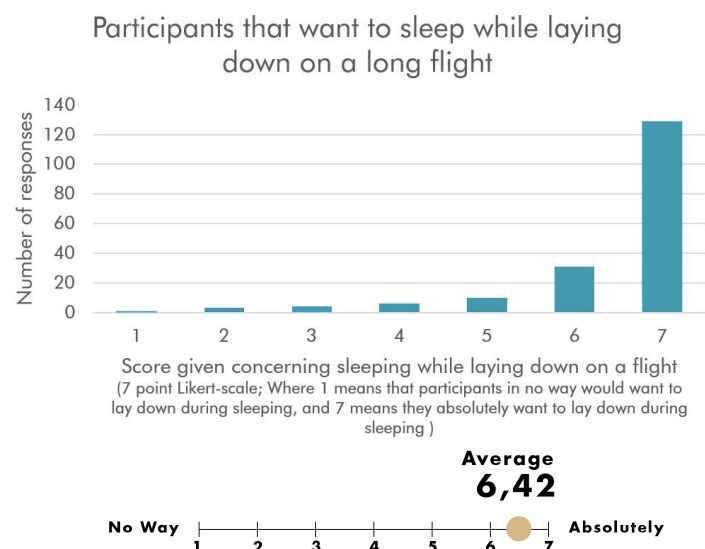
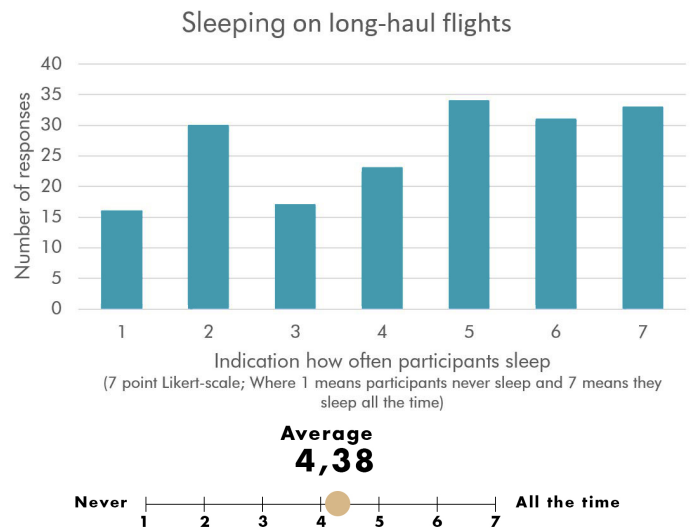


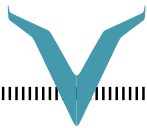
Age of Respondents





The second section of the questionnaire consisted of three questions about sleeping in current airplanes. Results of question 1 indicate that the majority of people do sleep on long flights, an average score of 4,38 indicates that respondents only sleep partly during flights. This can be explained by looking at question 2 and 3 of the second section. Question 2 shows that sleeping in economy class seats is rated really low on comfort score, with an average score of 2,63. At question 3 the majority of respondents indicate that they would like to sleep while laying down on a long flight with an average score of 6,42. This shows that people do want to sleep during a long flight, but it is found uncomfortable in a general economy seat. The fact that the majority of people would like to lay down during a flight to sleep emphasizes the fact that people want to sleep during a flight, but that it is found difficult because of the sleeping comfort experienced in economy seats. Also, the fact that the majority of respondents would like to lay down and sleep during a long flight confirms that there is a market for the design proposed in this project.

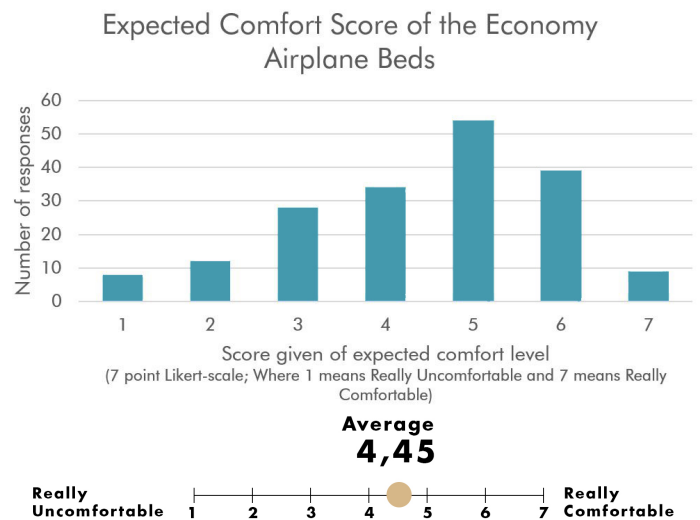




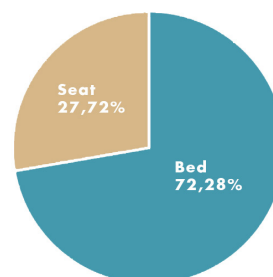
The third section shows several images of the Economy Class Sleeping Facility while being in sleeping position. The first question of section three asks the respondents to score their expected level of comfort. With an average score of 4,45 these beds score way higher than the comfort score given to the economy seats in previous section, which had an average of 2,64. This is emphasized by the answer of the second question of this section, where 72,28% of respondents indicate they would rather sleep in the economy class beds than in normal economy seats. When asked if potential passengers would book this economy class bed even more people answered with yes, 79,35% indicated they would book this bed given the fact that it is the same price as a normal economy seat. However, 45,65% of all respondents indicated they would book it depending on the time of the flight. 20,65% indicated they would not book a bed, this means that 7,07% of respondents indicated that they would rather sleep in economy seats at the second question of this section, and changed their mind a question later by choosing to book a bed.

Question 4 of this section investigated how long people would want to spend inside the economy class beds. This was done by sketching a situation of them taking a flight of 12 hours. Resulting in the fact that a majority of respondents would like to spend half of the flight inside the sleeping facility. Repeatedly, striking to see is that in this question only 13,04% of people responded that they would not want a bed. This means that another 7,61% changed their mind and would want a bed for part of the flight.

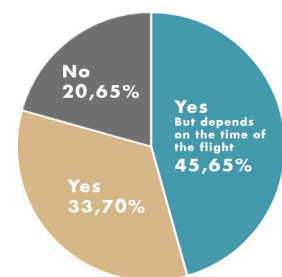
Finally, this section concluded with the question which bed had the preference of potential passengers, to investigate if a specific bed is wanted the most. As can be seen in the graph the preferences towards beds don't differ that much, with the most popular bed chosen by 36,96% and the least popular bed chosen by 28,80%.



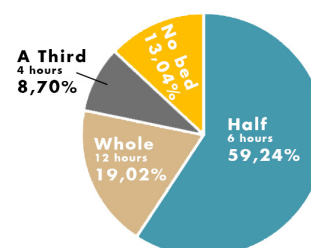
Preference of Sleep Location in Airplane



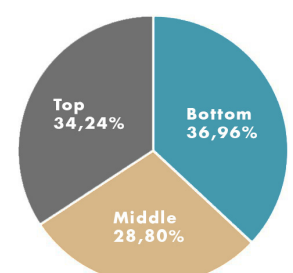
Would people want to book the Beds?



On a flight of 12 hours, how long do people want to spend in the beds?



Bed Preference





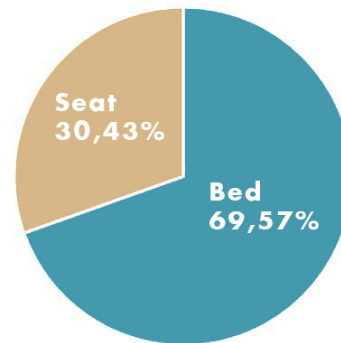
Finally, the last section of this research showed participants how the beds transform into seats where they would be seated during taxi, take-off, landing and potentially their inflight meal. Subsequently they were asked if they would want to take-off in the seats transformed out of the beds and have a bed to sleep in during cruise flight, or if they would rather take-off in a normal economy seat and just sleep there during cruise flight. This was done to find out if people would recoil on their previous decision when seeing they would be seated on a folding seat. Results show that 69,57% still want the bed, which is a slight decrease of 2,71% when comparing it to the first question of section 4.

6.6.8 Discussion

I intentionally did not mention how much room people would have in each bed to see what people would perceive. The middle bed was found to be the least popular bed, although it has the largest unobstructed mattress width. This might change when a prototype of the beds is tested and people can actually experience each bed.

Some respondents thought the beds would be really hard because of the appearance, this could possibly be changed by depicting a sleeping person inside one of the beds. Therefore, giving the image a softer look by a person peacefully sleeping with a blanket and a pillow.

Percentage that chooses for the beds after seeing the folding seat arrangement





6.6.9 Conclusion

This final research has resulted in the evaluation of the final design. First, summarizing this research by taking a look at the main- and sub-research questions and answer them. Subsequently the next section will use the formed conclusions to form recommendations for further development.

Main research question:

Do passengers of long-haul flights (6 hours or longer) want to use the designed economy class sleeping facility, and does the expected comfort offered by these beds exceed the score of the experienced comfort of sleeping in economy seats?

To answer the main research question; Yes, people do want to use the design of the economy class sleeping facility. The reason for this being the fact that sleeping in economy seats is found to be very uncomfortable and people expect the beds to offer more comfort. Several reasons given by respondents why they would want a flat-bed to sleep in related to an expected increase in comfort, or the argument that sleeping while lying flat is easier than while sitting upright. People who preferred a seat supported this with arguments that they suffered from claustrophobia or thought the beds will be really small. Others were scared of flying or as mentioned before thought the beds would be hard. This perception of the bed being hard can be explained by the relatively clean and hard images shown in the research, and people comparing it to their own, thick and soft mattress.

Sub research questions:

1. Which bed height level out of the three options is preferred (top, middle or bottom)?
2. Do people want to spend a full flight inside the beds or only part of a flight?
3. Does the opinion of booking a bed change by showing respondents that during taxi, take-off and landing they will be seated on folding seats transformed out of the beds?

Considering the first question, the preference of bed was quite even distributed. Each bed offers different advantages which need to be tested in real life to find out if the preference stays distributed like this. While taking a look at the second question it can be concluded that the majority of people would want to spend half of their flight inside these beds. However, this was only asked for a flight of 12 hours, perhaps on a 6-hour flight a majority of passengers would want the bed the entire flight. Or on an extremely long flight which is nearly 19 hours people would want to spend a third of their flight inside the cabin. This all poses their own challenges which will be discussed further on. Finally, by showing potential passengers that they would have to sit on a folding seat the opinion of people hardly changes. Only 2,71% of respondents changed their opinion, leaving 69,57% who still want the economy class bed.

Concluding, there is demand for the Economy Class Sleeping Facility as presented in this form. However, still many challenges remain to make a sleeping facility for economy class reality. How to continue this development will be discussed in the next chapter of the report.





6.7 Conclusion & Recommendations

How the Economy Class Beds should be developed further

As this report concludes, there is a demand for sleeping facilities in economy class while laying flat. Almost 70% of 184 respondents indicated they would want a bed/seating arrangement on a long-haul flight as presented in this report, therefore the Economy Class Bed System should be investigated and developed further.

Since this report shows a quite conceptual design which shows promises it should be investigated further. Firstly, why it should be investigated further is the fact that the Design offers 15 beds in economy class. Each bed being 193 centimeters long. This length is larger than the P95 as stated in the list of requirements so the majority of people should be able to lay down fully flat in these beds. Secondly, the most important selling point of the presented design, the system offers a bed and seat in one without

occupying extra space. By applying the presented lay-out passenger capacity even increases by 3. Research conducted in this report shows that a majority of passengers would like to lay down fully flat during a flight, and 70% of 184 respondents of all different ages indicated they would use the system as presented in this report. All these factors attribute to the conclusion that there is a demand for this design and therefore it is valuable to research and develop further.



An important part of the design that has to be developed further is the transformation system. It has already been proven that folding seats can be designed to comply with all regulations, as flight attendants use folding seats during taxi, take-off and landing. However, the whole system of flipping the bed into a backrest should be developed to ensure it can withstand the force tests all seats have to comply to. Next to that since passengers do not sit in the flight direction it should be investigated if it is necessary to place airbags for safety, like some business class seats have which do not face the flight direction.

Another part that has to be developed further is the height which each bed offers while laying inside. All beds have their own advantage. The bottom bed has easy access and the curved wall moving up, where you can lay against. But the bottom bed also has the smallest total mattress width and the folding seats hanging in their cabin. The middle bed is also quite easy to access, and has the largest total mattress width. However, the middle bed also has the luggage compartments inside the cabin. The top bed is expected to be the hardest to access, and has the wall curving down which decreases the height. It does however offer the biggest surface to lay on, although being partly obstructed by the support beams. These beds should all be tested to see where room should be increased or decreased to offer more comfort and make sure all beds have the same level of popularity.

Another potential development is the lay-out of the plane. At the moment only 15 beds are placed, if it is possible to have the following lay-out more beds could be placed: a row of 3 seats next to the window, aisle, a row of 4 seats, wall, beds, aisle, beds. This basically divides the plane into a bed aisle and a seat aisle, which offers more beds and more privacy for the passengers using the beds. The problem with this is that it should pass the regulatory evacuation time. I suspect this evacuation time will be a general problem for the Flying V since it only has emergency exits at the outside of the V.

Production needs to be investigated as well, in this project I designed 1 bed system with 3 beds stacked above each other. However, since the Flying V has support beams occurring every 700mm it means that each bed is different, which complicates production processes. Finally, the working principle of the booking system should be developed. As the final research showed most people would want the bed half of the time during a 12-hour flight. This means a switch of passengers should be done, which means the bed has to be cleaned during flight. Or some sort of mattress cover should be included. Also, it was indicated that time of day would have an influence on the decision to book a bed, so perhaps the beds only should be placed in planes flying 10 hours or more. Although a long-haul flight starts from 6-hours, if it is a flight during the day, I expect the beds to be less popular. 6 hours during the day is a time which can be quite easily spend watching movies or listening to music. Therefore, the working principle is really important to be investigated.

APPENDIX





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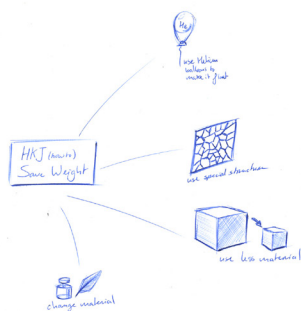
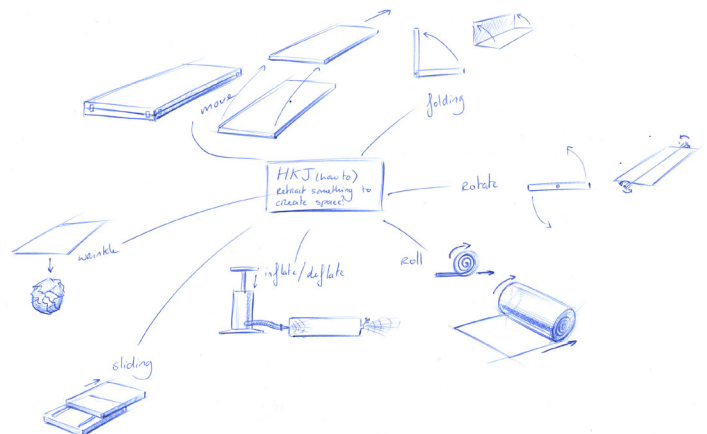
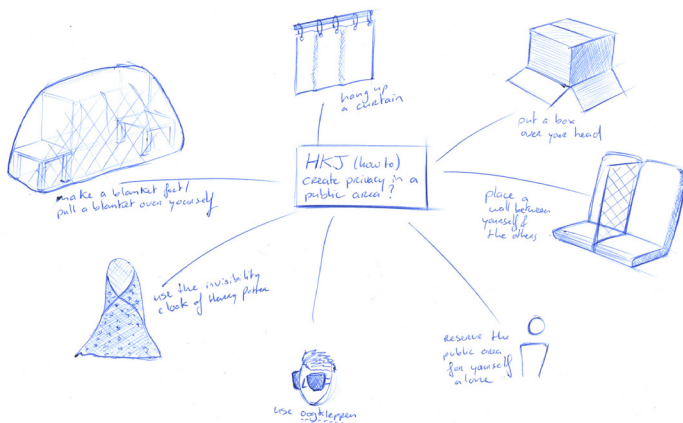
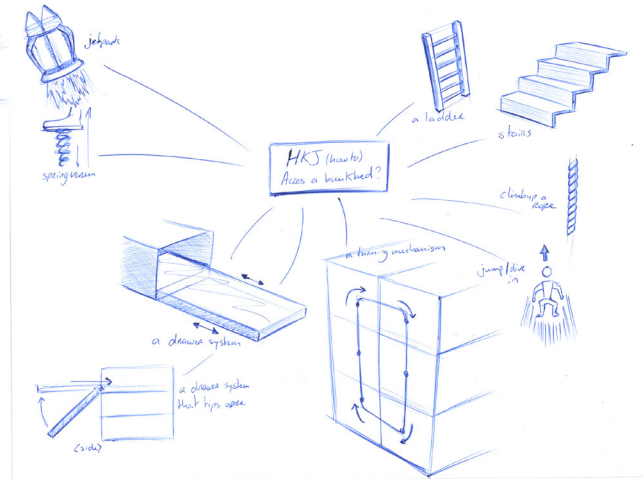
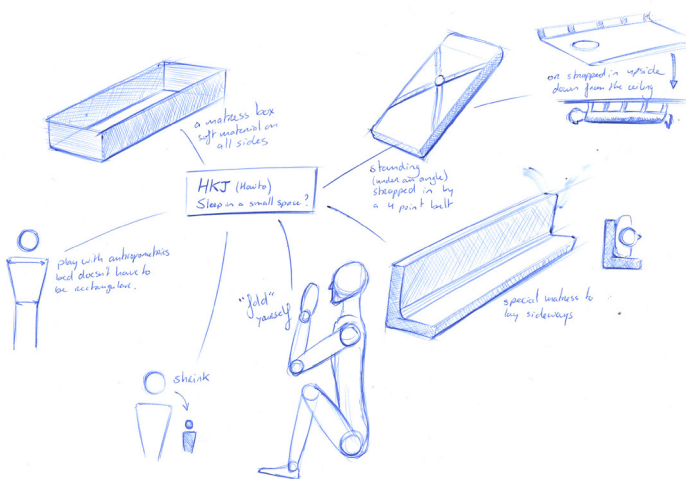
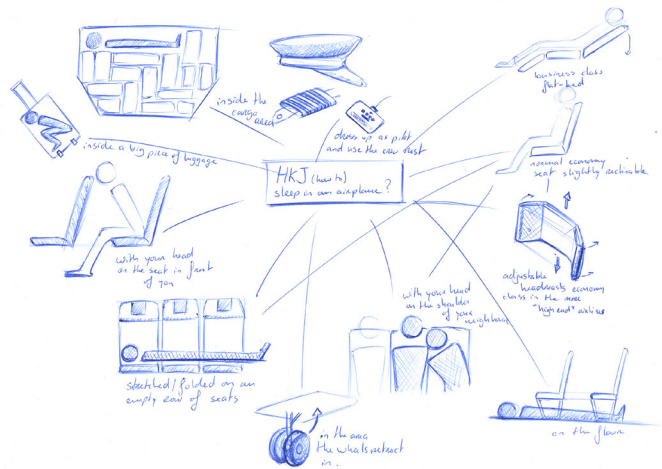
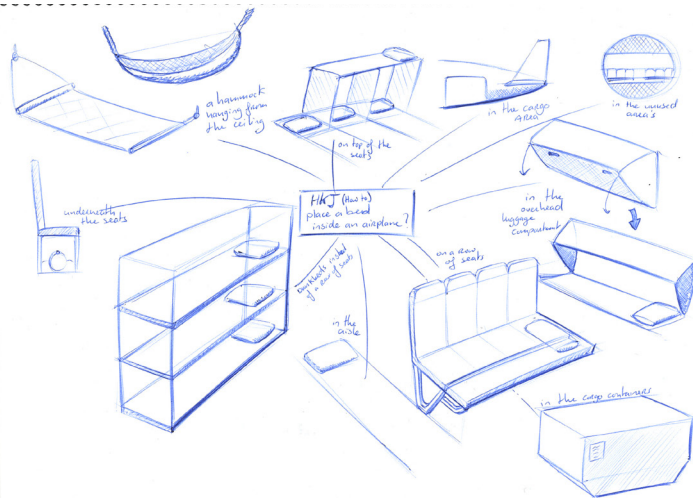
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B. How To's

Ideation



C. User test 1 - Sleeping Cabin Test

10 Participants testing 2 prototypes

Sleeping Cabin Test

In this test you will test 2 sleeping cabins meant to be inside airplanes for economy class passengers to sleep or relax in during flight. Before we start testing some general questions.

*Required

1. Age *

2. Body length (in cm)

3. Gender

Mark only one oval.

- ☐ Female
☐ Male

4. What is your favourite sleeping position?

Mark only one oval.

- ☐ On my side
☐ On my back
☐ On my belly
☐ Other: _____

5. Do you sleep while travelling by airplane?

Mark only one oval.

1 2 3 4 5 6 7
Never ☐ ☐ ☐ ☐ ☐ ☐ ☐ All the time

6. Would you like to lay down fully flat in cruise flight? (Cruise flight is the middle of the flight, so in between taking-off and landing)

Mark only one oval.

1 2 3 4 5 6 7
Absolutely not ☐ ☐ ☐ ☐ ☐ ☐ ☐ Definitely

Sleeping Cabin 1

7. When standing in front of the sleeping cabin, what is your perceived level of comfort?

Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

8. What do you expect the level of convenience to be concerning entering and leaving the sleeping cabin?

Mark only one oval.

1 2 3 4 5 6 7
Really inconvenient ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really convenient

9. Out of your experience, rate the level of convenience entering and leaving the sleeping cabin

Mark only one oval.

1 2 3 4 5 6 7
Really inconvenient ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really convenient

10. Rate the level of spaceousness inside the cabin

Mark only one oval.

1 2 3 4 5 6 7
Not spacious at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really spacious

11. Could you lay down in your favourite sleeping position?

Mark only one oval.

1 2 3 4 5 6 7
Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Definitely

Sleeping Cabin 2

12. When standing in front of the sleeping cabin, what is your perceived level of comfort?

Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

13. What do you expect the level of convenience to be concerning entering and leaving the sleeping cabin?

Mark only one oval.

1 2 3 4 5 6 7
Really inconvenient ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really convenient

14. Out of your experience, rate the level of convenience entering and leaving the sleeping cabin

Mark only one oval.

1 2 3 4 5 6 7
Really inconvenient ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really convenient

15. Rate the level of spaceousness inside the cabin

Mark only one oval.

1 2 3 4 5 6 7
Not spacious at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really spacious

16. Where you able to you lay down in your favourite sleeping position?

Mark only one oval.

1 2 3 4 5 6 7
Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Definitely

Concluding

17. Wich of the two sleeping cabins has your preference?

Mark only one oval.

- ☐ Sleeping cabin 1
☐ Sleeping cabin 2

18. Rate sleeping cabin 1 on overall comfort

Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

19. Rate sleeping cabin 2 on overall comfort

Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

20. Considering the fact that you can sit in upright position while taking-off and landing, and while food is being served. Would you book a sleeping cabin seat instead of a normal economy seat if they are priced the same?

Mark only one oval.

- ☐ Yes
☐ No

21. Would you pay extra for a sleeping cabin? Considering it is a 10 hour flight, and a normal economy ticket is 600 euros (returning flight)

Mark only one oval.

- ☐ No
☐ 10-25 euros
☐ 25-50 euros
☐ 50-75 euros
☐ 75-100 euros
☐ 100-125 euros
☐ 125-150 euros
☐ more than 150 euros

22. Do you have any remarks/improvements?

D. User Test 2 - Final User Test

204 respondents, 184 relevant

Airplane Interior Design

Thank you for participating! In this questionnaire you will answer some questions about airplane interior and judge a new interior design meant for the concept plane depicted below.

The questionnaire is fully anonymous, results of this questionnaire will be used in my Master Graduation Report.

*Required

Flying V - concept plane



1. Have you ever been on a flight which was 6 hours or longer? *

Mark only one oval.

- ☐ Yes -> Please continue with the questionnaire
☐ No -> Thank you for taking the trouble to fill in this questionnaire. Sadly, this questionnaire is about airplane interior for long haul flights (6 hours or longer). Therefore, your data will not be relevant since you never experienced a flight this long. Skip to "Airplane Interior Design."

Airplane Interior Design

The questionnaire is fully anonymous, results of this questionnaire will be used in my Master Graduation Report.

2. What is your age? *

3. What is your nationality? *

Mark only one oval.

- ☐ Nederlands (Dutch)
☐ Other: _____

4. What is your gender? *

Mark only one oval.

- ☐ Male
☐ Female

Airplane Interior Design

5. Do you sleep on long flights? (Flights that take 6 hours or longer) *

Answer between 1 and 7. Where 1 means you never sleep on a plane and 7 means you always sleep while travelling by plane.

Mark only one oval.

1 2 3 4 5 6 7
Never ☐ ☐ ☐ ☐ ☐ ☐ ☐ All the time

6. Out of your experience, can you rate the comfort level of sleeping in economy class seats? *



Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

7. Would you like to sleep while laying down on a long flight? *

Mark only one oval.

1 2 3 4 5 6 7
No way ☐ ☐ ☐ ☐ ☐ ☐ ☐ Absolutely

Airplane Interior Design

The following questions are about a newly designed interior part shown in the pictures below. These are beds where economy class passengers can lay down and sleep/relax on a long haul flight. Taxi, Take-off and Landing will be done while sitting upright, as this is obligatory.

Passengers lay down on 3 mattresses placed above each other, provided with everything regular economy seats also have: In flight entertainment, lights, fresh air supply, seatbelt for turbulence and so on. Next to that blankets and pillows will be provided by the airline, and you can create privacy with a personal curtain.



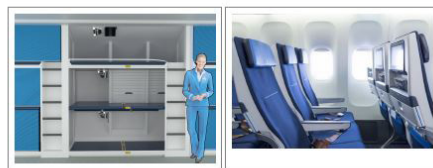
8. Can you rate the expected comfort level of these airplane beds? *

Mark only one oval.

1 2 3 4 5 6 7
Really uncomfortable ☐ ☐ ☐ ☐ ☐ ☐ ☐ Really comfortable

9. Would you rather sleep in these beds or on a normal economy seat? *

Mark only one oval.



☐ Bed ☐ Economy Seat

10. Why did you choose this option? *

11. Considering the fact that these beds cost the same as a normal economy seat, would you book one of these beds when flying 6 hours or more? Taxi, take-off and landing will be done while sitting on a seat, so does consuming your inflight meals. *

Mark only one oval.

- ☐ Yes
☐ Yes, but it depends on the time of the flight (day/night)
☐ No

12. Imagine having a flight of 12 hours, would you rather have the bed for the entire flight, or for a part of the flight? *

Mark only one oval.

- ☐ The entire flight
☐ Half of the flight (6 hours)
☐ A third of the flight (4 hours)
☐ I don't want a bed

13. Can you explain your previous choice? *

14. Which bed would you prefer to have during your flight?
Mark only one oval.



☐ Top Bed



☐ Middle Bed



☐ Bottom Bed

15. Can you explain your choice? *

Airplane Interior Design

The beds transform into seats to create sitting space for passengers that booked the beds. Passengers will sit in upright position during Taxi, Take-off and Landing as this is obligatory by law. Passengers will also sit upright in while consuming their in-flight meals.

These seats have the same dimensions as normal economy class seats. Next to that they provide more leg room compared with normal economy seats.

Beds in sleeping position



Transformed to seats



16. Considering the fact that these seats comply with all obligatory safety regulations, and offer the same space as normal economy seats. Would you rather: *



☐ Take off in normal economy seats and just sleep while sitting upright in the seat



☐ Take off in the bed-seats and have a bed to sleep in during cruise flight.