Appendix

A. Furnishing information
B. Circularity of the cabin
C. Windows vesus OLED screen
D. Conclusion 1:1 scale model test
E. Results VR while seated
F. Results VR while standing
G. Fuselage structure
H. Assignment

Appendix A Furnishing information

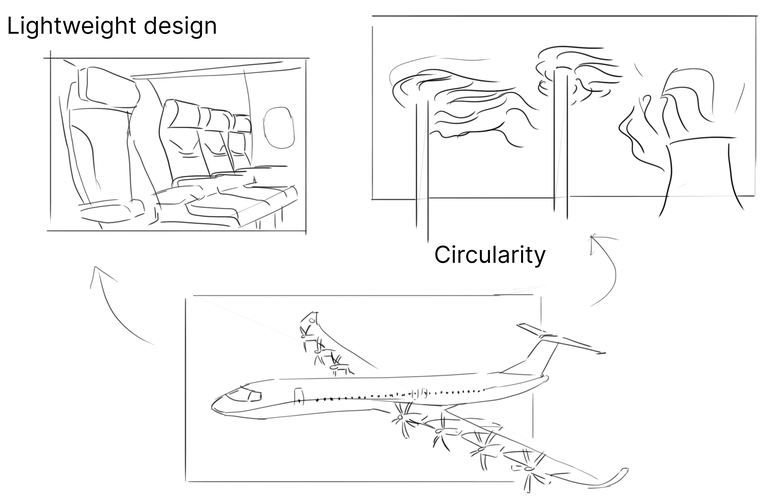
Feature	Economy Class (KLM Cityhopper)	Business Class (KLM Cityhopper)
Seat Pitch	30-31 inches (76-79 cm)	32-33 inches (81-84 cm)
Seat Width	17-18 inches (43-46 cm)	Wider, typically 19-20 inches (48-50 cm)
Seat Recline	Minimal recline (6-8 degrees)	Enhanced recline for better comfort
Weight	Approx. 8 kg per seat	Heavier due to more padding and features
Materials & Comfort	Slimline design, ergonomic padding	Premium materials, more padding
In-Seat Amenities	USB charging ports, seatback pockets, tray table	USB ports, more storage, larger tray table
Entertainment	No built-in screens (use personal devices)	No screens, use personal devices
Seat Configuration	2-2 layout (no middle seats)	2-2 layout (no middle seats)

Category	Facilities
Cabin Layout	Business Class (J) and Economy Class (Y) seating. For example type: Recaro SL3710. 2-2 seating configuration (no middle seats) in both classes. Seat pitch (legroom) economy class 76-79 cm (30-31 inch). Seat pitch in business class 84 cm (33 inch).
In-Flight Services	Food and baverage services
Entertainment Options	Personal electronic devices can be used on board. Limited in-flight entertainment (IFE) options, typically no seat-back screens on regional jets. USB- connection
Galley	Facilities at the front of the aircraft: such as refrigerators, ovens, storage spaces, preparation area
Restrooms	Two accessible restrooms located at the front and rear of the cabin.
Cabin Crew	Flight assistence preparing your meals and safety instructions
Wi-Fi	Some aircraft may offer in-flight Wi-Fi.
Luggage	Allowance for hand luggage (typically one piece, plus a personal item). Checked baggage policies depend on the fare type

	Class	Weight	Traytable	IFE	Recline	Headrest
Recaro, SL3710	Economy, Short Haul	8 kg	Yes	No	Fixed at 15°	No
Recaro, BL 3710	Economy, Short Haul	10 kg	Yes	Optional	Yes	Yes
Recaro, CL3710	Economy, Long Haul	12 kg	Yes	Yes	Yes	Yes
Recaro, BL 3530	Economy, Short Haul	10 kg	Yes	Optional	Yes	Yes
Expliseat, TiSeat	Economy, Short Haul	4 kg	Yes	No	Yes	No
Geven, SuperEco	Economy, Short Haul	7.9 kg	Yes	No	No	No

Appendix B Circularity of the cabin

Airplane graveyard (Dearden, 2015)



Lifetime and End-Of-Life
Many aircraft become obsolete after a limited number of years in operation, with no comprehensive solution currently available to address their end-of-life (EOL) phase. As a result, planes that aren't used anymore are often abandoned in desert storage facilities. This highlights the lack of a structured EOL strategy within the aviation industry. This approach neglects the potential for circularity and sustainability in handling retired aircraft.

The cabin interior also faces sustainability challenges. Unlike the airframe, cabins are rarely fully dismantled at the end of their lifecycle. Instead, they are frequently replaced, with retrofits typically done every 5–7 years, as noted by Della Vecchia et al. (2022). This replacement cycle is short compared to the timelines for other aircraft updates.
So, the master thesis of Hafidzun Alim (2024) tells us that it is important to add material passports to the aircraft cabin to enhance the sustainability of EOL management, These tools provide detailed documentation of the materials used in aircraft cabins, aiding dismantlers in making informed decisions and supporting circular practices. By adopting such approaches, the aerospace industry can transition towards more sustainable EOL practices, reducing waste and promoting circularity.

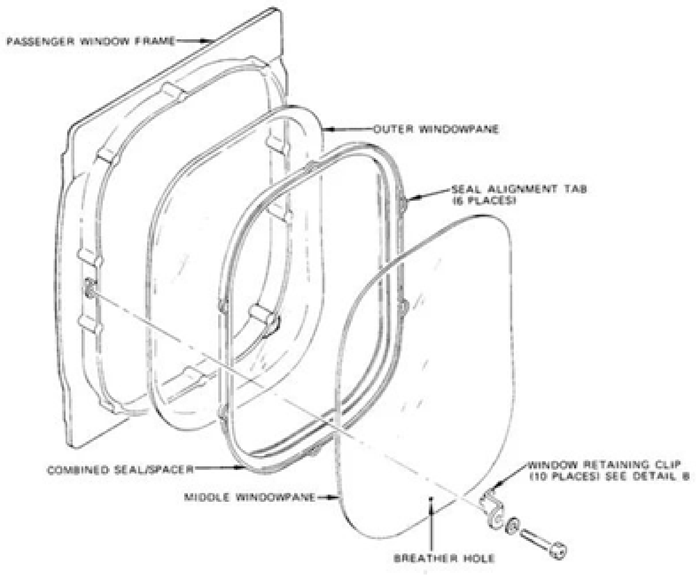
Lightweight vs. circularity
In aircraft cabin design, achieving a balance between lightweight construction and circularity presents a significant challenge. Lightweight materials (such as composites) are prioritised to reduce fuel consumption and emissions during operation. However, these materials often lack recyclability, complicating end-of-life (EOL) management and limiting their contribution to circularity. On the other hand, circular materials, which are easier to dismantle and recycle, may increase the overall weight of the cabin, potentially undermining fuel efficiency.

- Lack of a structured EOL strategy within the aviation industry
- Add material passports to the aircraft cabin (seats) to enhance the sustainability of EOL management

Appendix C Windows vesus OLED screen

Windows versus OLED screens
Replacing windows with OLED screens in an aircraft, such as the E190 cityhopper, offers significant weight reduction benefits for the fuselage.

Eliminating windows reduces the weight to direct saving of 392 kg: making the fuselage nearly 20% lighter, according to the study of Moruzzi and Bagassi (2020). Additionally, this initial reduction triggers a snowball effect, where every kilogram saved during the preliminary design phase leads to approximately 1.25 kilograms saved in the final project. This results in a total weight reduction of 492 kg for the E190 (Cittyhopper). Such savings not only improve fuel efficiency but also enable airlines to optimize payload capacity or range. The use of OLED screens further enhances passenger experience by providing customisable displays, that can take away electronics in the seats, for example.



Current aircraft window (The Science Behind Aircraft Cabin Windows, n.d.)

The future of aircraft cabin displays (Devon et al., 2024)

Appendix D Conclusion 1:1 scale model test

Step 1: Boarding

Action	Frequency	Description
Place luggage next to yourself	7 times	Place the luggage beside you, in the place of your neighbour.
Place luggage in front of yourself.	0 times	Place the luggage in front of you.
Place luggage underneath yourself.	1 time	Place the luggage under your seat.
Place luggage on the seat next to yourself.	1 time	Place the suitcase on the seat next to you.
Hold the luggage in your hand.	1 time	Hold the luggage in your hand.

Action	Frequency	Description
Unfold	8 times	Unfold to open the compartment.
Slide	1 time	Slide the flap to place the luggage in the compartment.
Remove the entire flap	1 time	Take out the entire flap to place the luggage.

Step 2: Action during the flight

Action	Frequency	Description
Luggage on lap to open	5 times	Open the luggage while it is placed on your lap.
Luggage in compartment to open	1 time	Open the luggage without removing it from the compartment.
Luggage between legs to open	2 times	Open the luggage while it is placed between your legs.
Luggage on the floor to open.	2 times	Open the luggage while it is placed on the floor, on the place where the compartment is located.

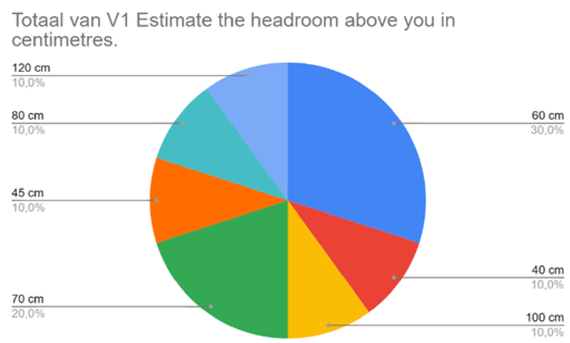
Action	Frequency	Description
Unfold	2 times	Unfold to open the compartment.
Slide	8 times	Slide the flap to place the luggage in the compartment.
Remove the entire flap	0 times	Take out the entire flap to grab the luggage.

Step 3: Disembarking

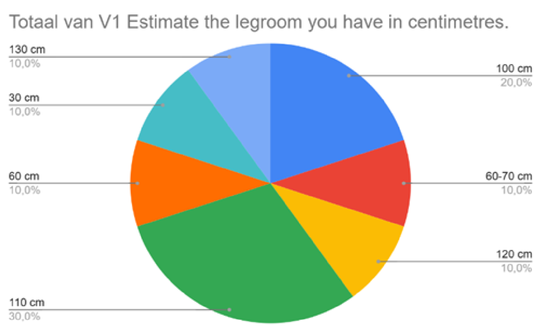
Action	Frequency	Description
Place luggage next to you	7 times	Put the luggage beside your seat, before disembarking. You make use of the space of your neighbor.
Place luggage between your legs	2 times	Position the luggage between your legs while closing the compartment.
Sit on the other seat	1 time	Move and sit on the other seat while closing the compartment.

Action	Frequency	Description
Unfold	1 time	Unfold to open the compartment.
Slide	9 times	Slide the flap to take the luggage out the compartment.
Remove the entire flap	0 times	Take out the entire flap to take out the luggage.

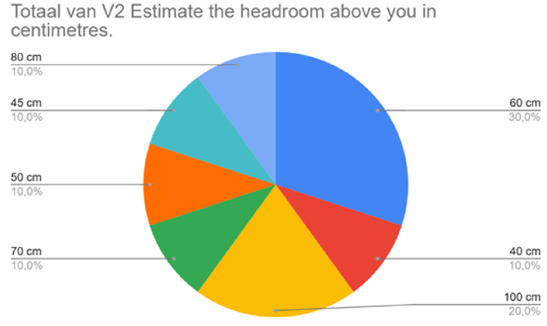
Appendix E Results VR while seated



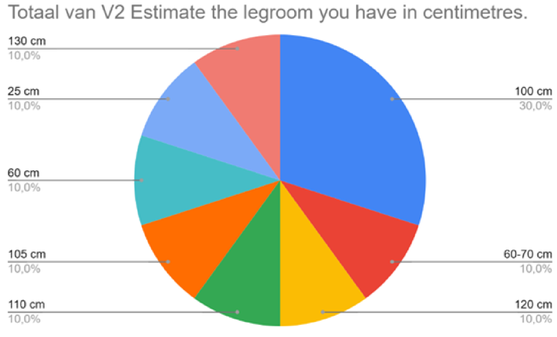
Headroom V1



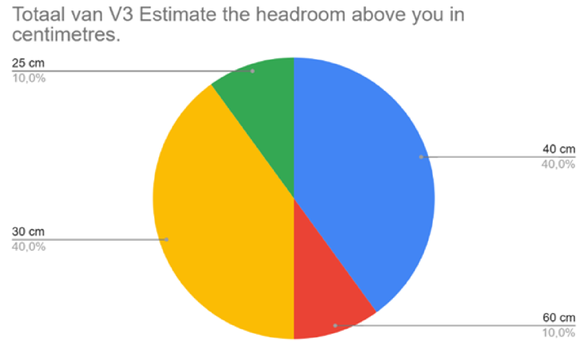
Legroom V1



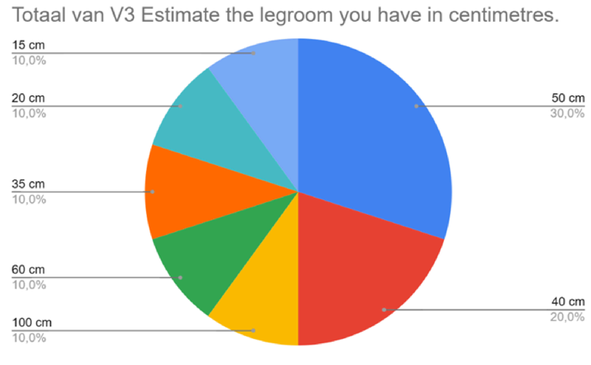
Headroom V2



Legroom V2

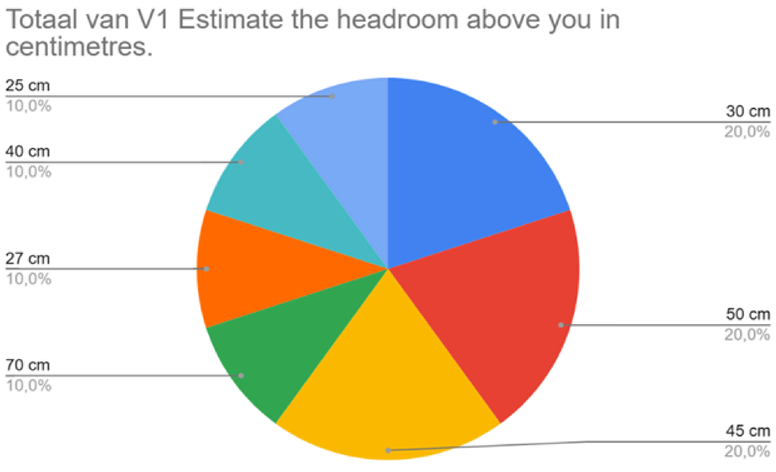


Headroom V3

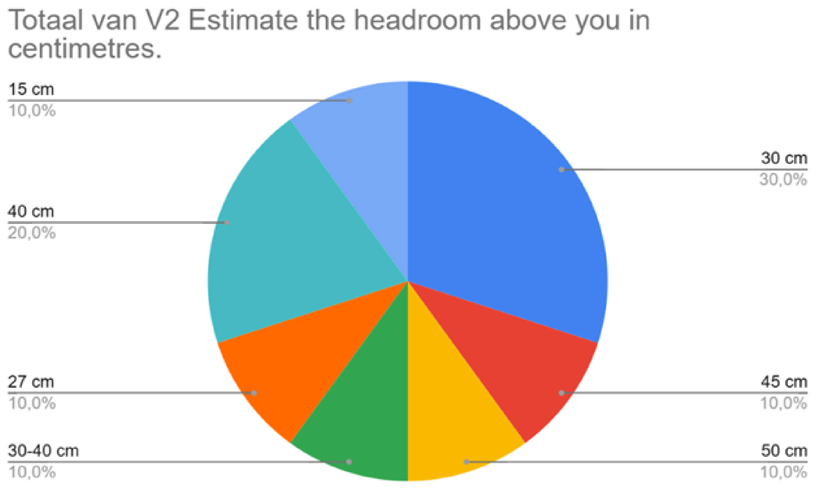


Legroom V3

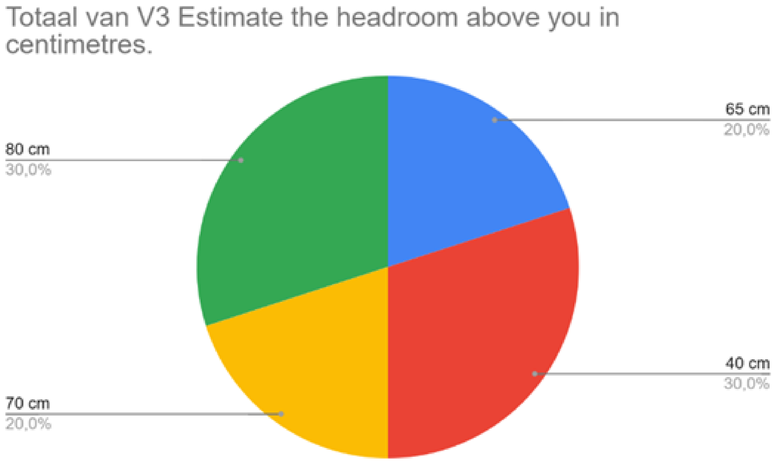
Appendix F Results VR while standing



Headroom V1



Headroom V2



Headroom V3

Appendix G
Fuselage structure

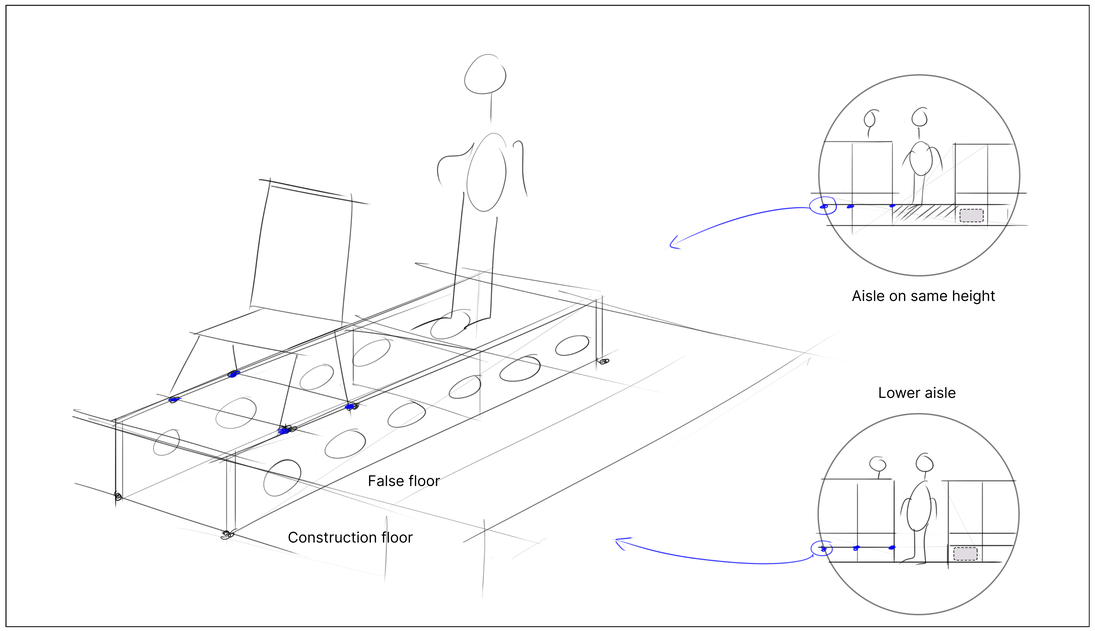


FIGURE 6.13: Length beams (option 1)

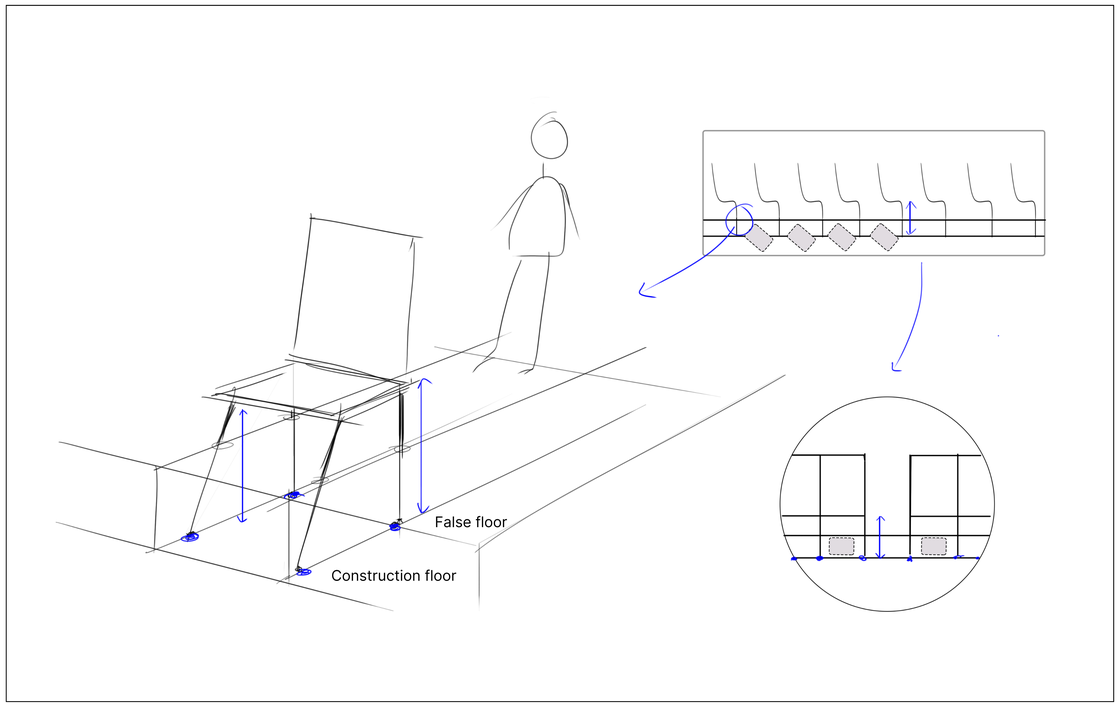


FIGURE 6.14: Increased legs seat (option 2)

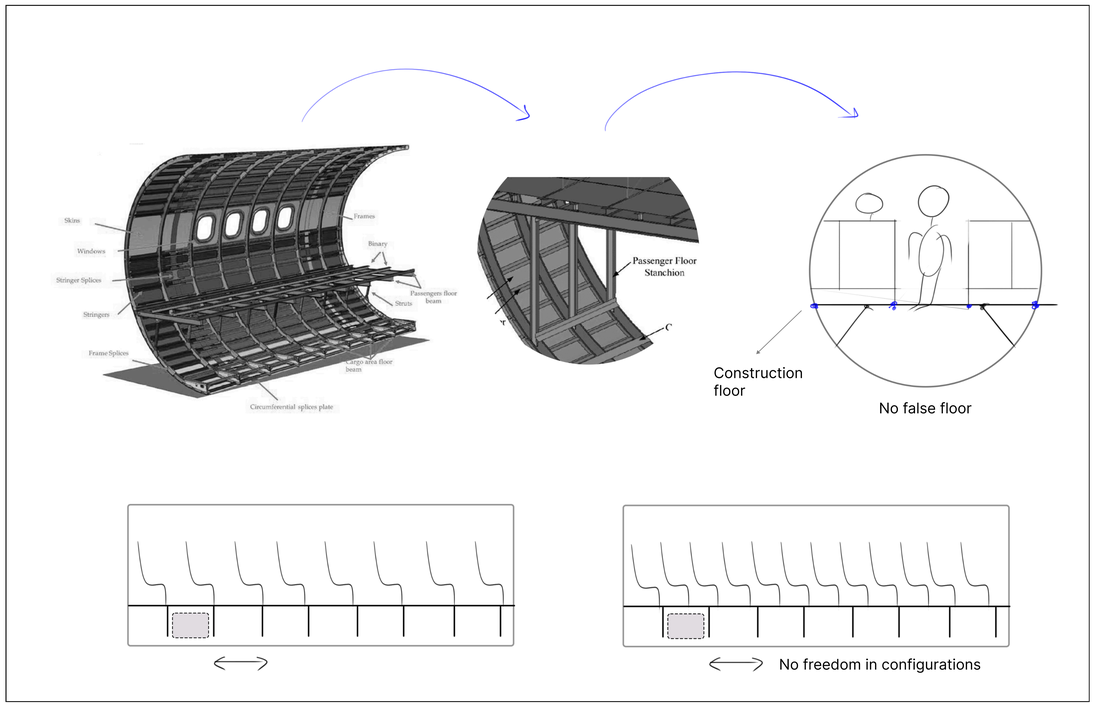


FIGURE 6.15: Struts/stanction (option 3)

Appendix H Assignment

DESIGN FOR our future

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME
Complete all fields and indicate which master(s) you are in

Family name	van Duivenboden	7437	IDE master(s) IPD ✓ Dfl ☐ SPD ☐
Initials	T.W.		2nd non-IDE master
Given name	Tosca		Individual programme (date of approval)
Student number	4659775		Medisign ☐
			HPM ☐

SUPERVISORY TEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Erik Tempelman	dept./section	Materials manufacturing
mentor	Gerbera Vledder	dept./section	Emerging materials
2nd mentor	Daniel Rosen Jacobson		
client:	Elysian		
city:	Delft	country:	The Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Erik Tempelman — Digitally signed by Erik Tempelman Date: 2024.10.16 10:28:16 +02'00'

Name Erik Tempelman Date 1 okt 2024 Signature

CHECK ON STUDY PROGRESS
To be filled in **by SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total ____ EC

Of which, taking conditional requirements into account, can be part of the exam programme ____ EC

★	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Robin den Braber — Digitaal ondertekend door Robin den Braber Datum: 2024.10.18 12:37:16 +02'00'

Name Robin den Braber Date 18 okt 2024 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	★	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

★	**ALLOWED** to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen — Digitally signed by Monique von Morgen Date: 2024.10.23 10:53:34 +02'00'

Name Monique von Morgen Date 23 Oct 2024 Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Tosca van Duivenboden Student number 4,659,775

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Aircraft interior for Elysian E9X

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Approximately 50% of all flights are short-range flights under 650 miles (Elysian Aircraft, 2023). Electrifying these shorter flights could significantly reduce aviation's carbon footprint. Elysian is developing an electrical aircraft (see figure 1) capable of covering all these short-range routes and aims to revolutionize an electrical flying experience for 90 passengers over distances of up to 800 kiometres.

In Elysians aircraft, the batteries are placed in the wings, which opens up the opportunity to rethink the seating layout. This provides more flexibility to explore new seating arrangements that can enhance user comfort during the flight or during boarding. Additionally, it allows for a new look at the lightweight materials and structures of the standard seat.

Thereby, the mission of Elysian is to create a 'zero emission' aircraft. This means that the interior of the new aircaft must comply with a sustainable life cycle. The future passenger must be aware of their transportation choices and will undergo a new experience by flying with an electrical aircraft. This means attention must be given to the end-of-life phase of the aircraft. According to a study by Airbus, the number of aircraft built in the coming years will nearly double, as shown in Figure 2a ("Airbus Global Market Forecast 2023," 2023). Additionally, many airplanes will end up in landfills (see Figure 2b, an aircraft boneyard in America (Dearden, 2015b)). Currently, 47% of cabin products remain unrecycled, with 25% of that being contributed by aircraft seats (Hafidzun Alim, 2024). This highlights the need for improved circular practices and the importance of integrating CLSC (closed-loop supply chain) in the aerospace sector.

➔ *space available for images / figures on next page*

Appendix H Assignment

introduction (continued): space for images

image / figure 1 Elysian aircraft exterior

image / figure 2 2a) Number of aircrafts in the future by Airbus| 2b) Boneyard of aircrafts in America.

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The challenge lies in optimizing the seating for Elysians new aircraft to align with a vision of sustainable aviation. Currently, airplane seats are not as environmentally friendly as they could be, due to the use of materials such as foam, textile, and metal frames. To achieve a future oriented design, the new interior must:

- Improve the environmental impact and durability by using sustainable materials and new structures. It will ensure longer lifespan and easier disassembly for reuse at the end of its lifecycle.
- Meet the specific seating layout requirements of Elysians new airplane design (E9X).
- Create an aesthetic and functional experience that aligns with the expectations of future passengers, reflecting the look and feel of air travel in 2033.
- Improve the ergonomics of the passenger during the flight.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Create a seating prototype to optimize the layout of the aircraft, the sustainaibility and the experience of the future user of the electrical aircraft (Elysian EX9).

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

This project follows the double diamond approach, consisting of four phases: discover, define, develop, and deliver. Throughout this method, I will need to push myself to set goals in order to achieve the final objective and keep and to monitor the process. I added the phases preparation and design in the planning, because the that will be the core of the project.

The project will end with the creation of a physical (or digital) seating product for the Elysian aircraft.

To create a applicable seating, it is necessary that the product (and expierence) will be tested during the proces by the ergonomics or the experience of the user in the future.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	2 okt 2024
Mid-term evaluation	26 nov 2024
Green light meeting	28 jan 2025
Graduation ceremony	24 feb 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	21
Number of project days per week	5,0

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

Decisiveness: I really have to break down my larger goals into smaller (weekly or monthly) goals. By breaking down larger goals into smaller, more manageable tasks, in collaboration with my coaches, It can help me understanding how each step will contribute to my ultimate objective.

Academic writing: I find it challenging to write academically, and to structure a clear report without using too much words or information. How can I ensure my project remains scientific? What (validation) tests should I conduct? I need to stay focused on working methodically.

Hard skills: As an IPD student, I want to further develop my hard skills during this phase, particularly in elaborating, visualizing, or conceptualizing ideas. Think about 3D modelling or using 3D scanning to get test results for ergonomic or material testresults.