Master Thesis

Designing the Next Generation Aircraft Cabin Experience

A 2040 Vision of Air Travel Passenger Experience

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Collins Aerospace

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This document serves as the report for the MSc. Thesis entitled ‘Designing the Next Generation Aircraft Cabin Experience’.

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Collins Aerospace
An RTX Business

Preface

Since I was little, I have always been fascinated by mobility. Designing airplanes, cars or trains was the main reason for me to choose Industrial Design Engineering at the TU Delft. During my educational career I have tried to pursue this dream. First by participating in the Automotive Minor where we had to reimagine a urban mobility system for the future. Secondly by joining the Delft Hyperloop student Dream Team as a design Engineer, visualizing the passenger experience of an innovative future mobility system, the Hyperloop. And finally, finishing my educational career at Collins Aerospace, where I have the privelege to design the full cabin experience of the next generation single-aisle aircraft.

The following Greenlight Report documents the last phase of my MSc. Thesis, focused on the visionary redefinition of the aircraft cabin experience for 2040. This report aims to familiarize the reader with the general structure of the project, the parties involved, and the methodological justification. The emphasis is on the analysis of current friction points and the strategic 'Framing' that laid the foundation for the formulated design mandate. This project is being carried out under the academic supervision of the Faculty of Industrial Design Engineering (TU Delft) and with the indispensable support of the EU Innovation Hub of Collins Aerospace.

Executive Summary

Commercial aviation is currently defined by a period of profound innovation inertia. While aerospace engineering has made significant leaps in propulsion efficiency and airframe materials, the interior passenger experience has remained conceptually static for decades. This stagnation is most critical in the single aisle aircraft segment. Historically designed for short to medium haul journeys, these narrowbody platforms now dominate global fleets and are increasingly deployed on transcontinental routes exceeding ten hours. The Airbus A321XLR serves as the primary technical and dimensional reference point for this thesis because it represents the vanguard of this evolution. A critical misalignment exists between the physical constraints of a narrowbody cross section and the physiological requirements of long duration travel. Passengers are now confined in a fuselage's diameter for durations previously reserved for widebody aircraft, leading to measurable physiological and psychological stress.

This graduation project, conducted in collaboration with Collins Aerospace and TU Delft, seeks to redefine the aircraft cabin for the year 2040. The research phase began with a human centered analysis of current friction points, using a quantitative survey of passengers and crew members to validate industry pain points. The results were telling, as over sixty percent of respondents identified the boarding process as the primary source of frustration. Beyond procedural delays, the lack of personal territory and the inability to move or stretch during the cruise phase emerged as dominant sources of dissatisfaction. These insights provided the empirical foundation for a design mandate focused on spatial flexibility and operational flow.

To navigate the uncertainty of a two decade horizon, the project applied the Vision in Product Design methodology. By clustering over two hundred context factors ranging from the rise of artificial general intelligence to the demographics of an aging global population, a future context was built. This strategic framing identified a shift from passive consumption toward active well being. The project proposes a move away from the traditional class hierarchy, where space is allocated solely by ticket price, toward a needs based modular ecosystem. This approach recognizes that a traveler's requirements change based on their specific intent for the journey, whether that is restorative sleep, focused productivity, or social connection.

The architectural foundation of the 2040 cabin is a three zone holistic system structured around a natural noise gradient. The forward section is designated as a quiet zone, acting as a sanctuary for rest. To resolve the boarding bottleneck, this area features a revolutionary twin aisle configuration that enables simultaneous luggage stowing and passenger ingress. By relocating storage to a central overhead compartment, the design eliminates the typical aisle lock caused by passengers blocking the flow. The middle of the aircraft houses a decentralized central workspace for the crew. This mid cabin placement halves the maximum service distance for flight attendants and significantly improves accessibility for passengers with reduced mobility. The rear of the aircraft is designated as a social zone where engine and aerodynamic noise are naturally at their peak. This area is anchored by a dedicated lounge and self service coffee corner, providing a communal hub for movement and kinesthetic relief.

The seating systems within this ecosystem are designed to prioritize human well being through restorative ergonomics. In the quiet zone, an organic S shape geometry allows seats to intertwine, maximizing bed length and privacy without increasing the total footprint. The relax zone utilizes an asymmetrical layout featuring turnable work seats for solo professionals and comfort benches that eliminate the compromise of the middle seat. For social groups, the rear section includes specialized family benches designed for parents traveling with small children. This variety allows for a total capacity of one hundred and forty eight passengers while offering a level of comfort previously unseen in narrowbody configurations.

To counteract the psychological weight of long haul confinement, the design utilizes emerging display technologies. Digital skylights and hybrid windows project skyscapes synced to circadian lighting principles, assisting passengers in their biological recovery. The final proposal remains technically grounded by utilizing floor mounted tracks compatible with required dynamic safety testing. By balancing radical spatial reimagining with credible engineering and commercial yield, this vision provides a future proof blueprint for the next generation of air travel. It demonstrates that the single aisle aircraft of 2040 can be a living part of a personal rhythm that restores rather than drains the traveler.

Abbreviations

AI	Artificial Intelligence
AGI	Artificial General Intelligence
BWB	Blended Wing Body
CMF	Color, Material and Finish
DOB	Dynamically Optimized Boarding
DOF	Direction of Flight
FAA	Federal Aviation Administration
IFE	In-Flight Entertainment
IoT	Internet of Things
LCC	Low-Cost Carriers
LH	Long-Haul (flight)
LOPA	Layout of Passenger Accommodations
MSP	Mobility Service Platform
OEM	Original Equipment Manufacturer
OTA	Online Travel Agency
PRM	People with Reduced Mobility
PSI	Passenger Space Invasion
SAA	Single Aisle Aircraft
SAF	Sustainable Aviation Fuel
SH	Short-Haul (flight)

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Analysis: This phase focuses on mapping out the current reality through user analyses, behavioral patterns, and an in-depth evaluation of Collins Aerospace's product position. The goal is to define the problem clearly.

Framing: This is where the bridge to the future is built. By clustering contextual factors, a future context is created, leading to the definition of a desired future interaction and the ultimate project vision.

Design Development: In this phase, the strategic visions are converted into tangible design solutions. This is done through an iterative process of generating concepts and elaborating them in detail into a functional design.

Final Design: The final phase involves the complete elaboration of the chosen concept. The focus is on presenting the final visual and technical specifications, supported by renders and visual storytelling.

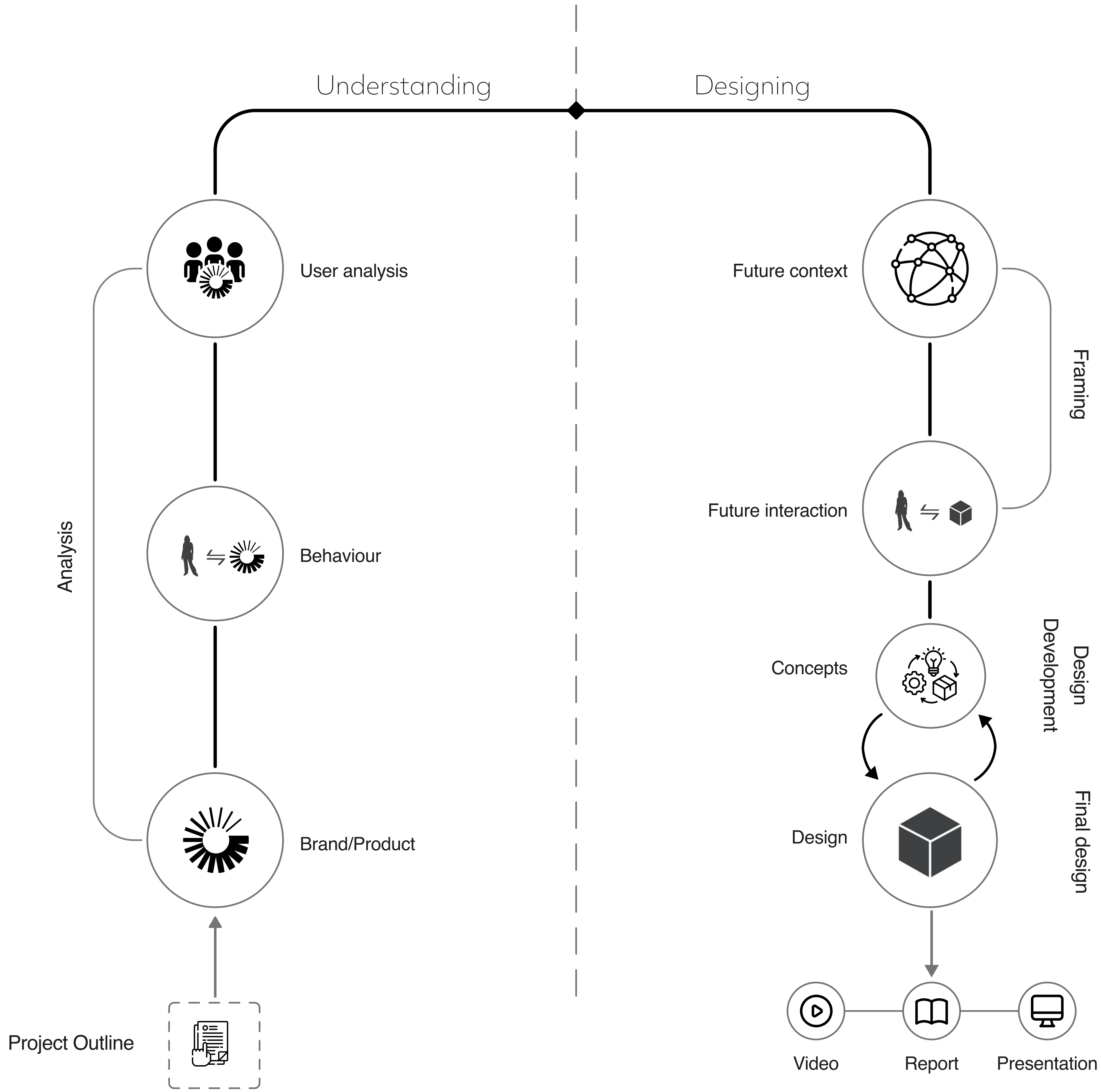
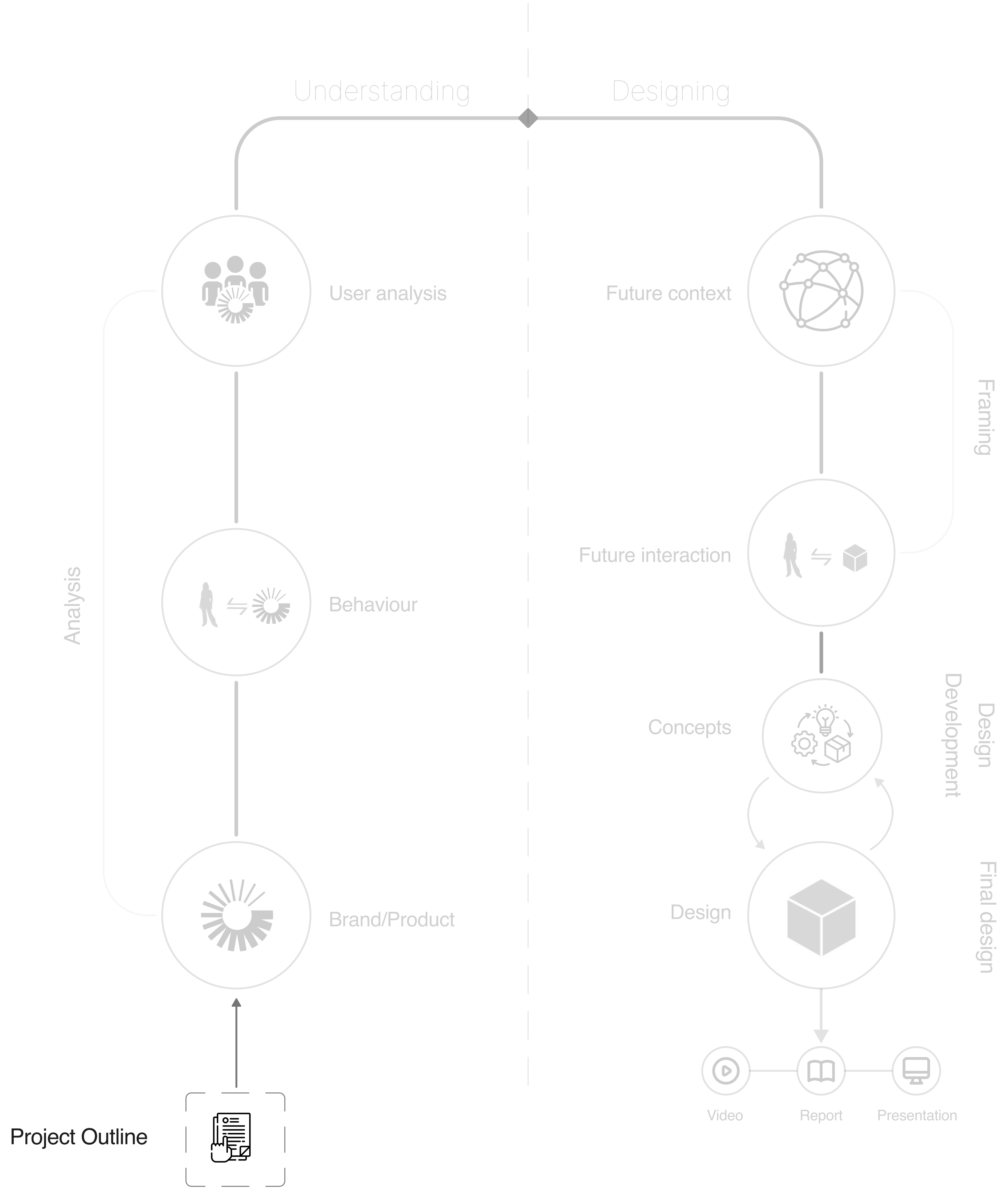


fig.1 Project process structure visualization

1 Project Outline

The following section is designed to make the reader acquainted with the general structure of the project and this report. It provides information about both parties involved, the main project objective and elaborates more on the design topic. In conclusion, this chapter offers an in depth explanation about the method used.



1.1 Thesis Introduction

This project takes place in the domain of aerospace interior design, with a focus on shaping the future of aircraft cabin experiences. Hosted by Collins Aerospace's EU Innovation Hub, it aims to explore how emerging societal trends, sustainability goals, and technological advancements can be translated into visionary cabin concepts for the 2040s. The Innovation Hub specializes in sustainable materials, intelligent systems, and user-centered design, providing a rich environment for future-focused innovation.

Key stakeholders include passengers, crew members, airlines, and Collins Aerospace itself. Passengers increasingly expect more personalized, connected, and comfortable travel experiences. Crew members require environments that enhance efficiency and well-being. Airlines seek cost-effective and sustainable solutions, while Collins Aerospace looks to maintain its leadership in innovation and design excellence.

There are significant opportunities to serve these interests by leveraging advancements in smart technologies, sustainable materials, and adaptable cabin layouts. These innovations can lead to enhanced passenger satisfaction, operational efficiency, and reduced environmental impact. However, limitations such as strict safety regulations, cost and weight constraints, and the slow pace of change in commercial aviation must be considered.

The project offers the chance to create an inspiring and feasible vision for the next generation of air travel, one that balances creativity with practicality and addresses the evolving needs of diverse user groups.

Problem Definition: The Long-Haul Single-Aisle Paradigm

The Industrial Context

Commercial aviation is currently defined by a profound innovation inertia. While aerospace engineering has made significant leaps in propulsion efficiency and airframe materials, the interior passenger experience has remained conceptually static for decades. This stagnation is most critical in the Single-Aisle Aircraft (SAA) segment. Historically designed for short-to-medium-haul journeys, these narrowbody platforms now dominate global fleets and are increasingly deployed on long-thin transcontinental routes exceeding ten hours.

The Experience Gap

A critical misalignment exists between the physical constraints of narrowbody cross-section and the physiological requirements of long-duration travel. Current configurations fail to address three converging pressures:

Operational Inefficiency: The boarding process remains the primary bottleneck for airline profitability. "Aisle-lock" and inefficient luggage stowing contribute to increased turnaround times, which directly impacts the high-utilization models favored by modern carriers.

Physiological and Psychological Stress: Long-haul confinement in high-density cabins exacerbates passenger fatigue, reduced mobility, and a lack of personal territory, leading to a measurable decline in passenger satisfaction.

Demographic Evolution: By the 2040 horizon, the rise of Gen Alpha and an aging global population will demand a shift toward Universal Design. Current cabins are not engineered for the accessibility needs of diverse travelers or those with reduced mobility (PRM).

The Core Challenge

The central design problem lies in the tension between visionary desirability and conservative complexity. Any attempt to reimagine the cabin must navigate the rigid physical boundaries of strict safety certifications and the cost-sensitive nature of the industry.

This project investigates design opportunities within cabin architecture and modular seating ecosystems to identify a new configuration, one that delivers measurable improvements in operational flow and inclusive comfort without compromising the technical viability required for future aviation standards.

Design Opportunity

In the future, **smart technologies**, sustainable materials, and **adaptable cabin layouts** can lead to enhanced **passenger satisfaction**, operational efficiency, and reduced environmental impact.

Core Challenge

How can the 2040 aircraft cabin be redefined to **bridge the gap** between high-density **spatial efficiency** and the **holistic well-being** of the traveler?

1.2 Project Team

This chapter introduces the key parties involved in the implementation and supervision of this graduation project. It describes the roles, responsibilities, and unique contributions of both the academic authority (Delft University of Technology) and the industrial facilitator (Collins Aerospace) to ensure the quality and relevance of the final result.

Collins Aerospace

Collins Aerospace, a business unit of RTX (Raytheon Technologies), is a global leader in technologically advanced and intelligent solutions for the aerospace and defense industry. The company combines broad expertise with an extensive portfolio to address the most complex challenges in aviation and to meet the demands of a rapidly evolving market. Collins Aerospace is headquartered in Charlotte, North Carolina, and employs over 70,000 people worldwide.

In the Netherlands, the EU Innovation Hub has been established to support the development of future-focused aircraft interior products. Its main areas of expertise include sustainable advanced materials, intelligent sensors and systems, innovative cabin designs, and customer experience research. The Hub acts as a driver of innovation by bridging design, engineering, and research to envision the aircraft of tomorrow.

ROLE
Collins Aerospace serves as the facilitator of this graduation project. The EU Innovation Hub in Houten, led by my supervisor **Arnau Castillo**, provides the working environment and resources for the project. In addition, **Jeff McKee** contributes as my technical supervisor, offering expertise on innovative cabin solutions and project management. Their guidance ensures that the project is aligned with both industry standards and Collins Aerospace's vision of shaping next-generation cabin experiences.

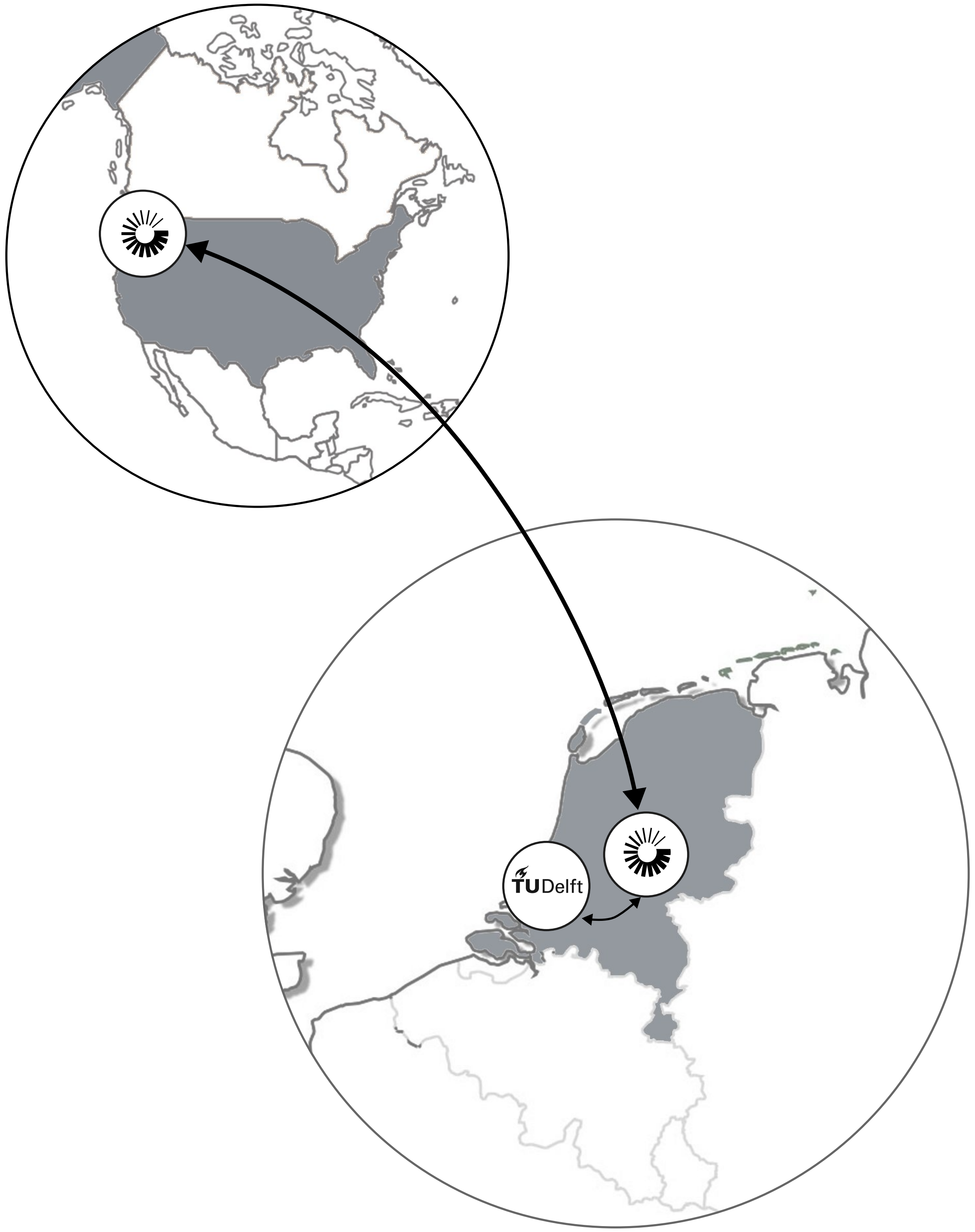
Faculty & Supervisory team

Delft University of Technology is the educational institute for which this graduation project is executed. More specifically, the project is conducted at the faculty of Industrial Design Engineering (IDE) within the context of the master track Integrated Product Design (IPD).

ROLE
The TU Delft is the academic Authority in this project, with **Elmer van Grondelle** as my chair, and **Martijn Haans** as my mentor. Their role is to offer guidance when needed and constructive criticism in order to guarantee the project is properly carried out. In the end, their role is to assess the final result from an academic point of view.

Graduate Student

Finally, I am the executing party in this project, connecting Collins Aerospace and TU Delft to achieve the best possible results for everyone. This project has provided me with the unique opportunity to experience working for a massive company like Collins, concluding my educational career in Delft as a more evolved designer, and person.



1.3 Design Topic

The central challenge of this internship is to analyze future travel trends, ranging from business and leisure travellers to families and multi-demographic groups, and assess the evolving demands on cabin space and crew environments. I will explore how connectivity, sustainability, comfort, and new service systems can be harmonized in both long-haul and short-haul aircraft.

The ultimate goal is to deliver an aspirational design concept of a next-generation aircraft cabin, supported by compelling visuals that provoke thought and spark imagination. I will engage in trend research, stakeholder analysis, creative ideation, and visual storytelling, culminating in a high end cabin design that inspires the industry toward the next evolution of air travel.

The original project description from Collins Aerospace can be found in Appendix A.

Research Questions

RQ 1. What will passengers expect from air travel in 2040?
- RQ 1.1 What are the biggest annoyances for passengers in modern aviation?
- RQ 1.2 What will the passengers of the future look like?
- RQ 1.3 What would passengers most like to do during a flight?

RQ 2. How can cabin spaces be adaptable to various demographics?
- RQ 2.1 What type of cabin spaces are wanted by future air travelers?
- RQ 2.2 Which different demographics compose the future air travelers in 2040?

RQ 3. How can crew environments be optimized for efficiency and well-being?
- RQ 3.1 What are current annoyances for cabin crews in modern aviation?
- RQ 3.2 What will be the role of cabin crews in the next generation SAA?

The Product

One of the core capabilities Collins Aerospace offers is the complete cabin experience in commercial aviation. They are a world leader in designing, developing and manufacturing cabin interior products and services that deliver innovation, reliability and efficiency. The broad range of offerings include aircraft cabin seating, lighting and engineering solutions, oxygen systems, food and beverage preparation and storage equipment, galley systems, water and waste systems, and advanced lavatory systems. Collins Aerospace also collaborate closely with its customers to provide customized cabin interior reconfiguration, program management and certification services.

Timeframe

The year this project focuses on is 2040. The choice for 2040 is primarily based on two factors:

1. **The pace of innovation and adoption within the aviation industry:** Commercial aviation is a conservative sector where safety regulations, cost constraints, and long development cycles result in relatively slow implementation of new technologies. Major changes to cabin design therefore require long-term horizons to become feasible. Research shows that cabin innovations typically align with new aircraft generations, which occur roughly every 15–20 years. Situating this project in 2040 allows for sufficient time for new technologies, sustainable materials, and accessibility-focused solutions to mature and be adopted at scale.
2. **Evolving societal expectations and passenger demographics:** By 2040, air travel will need to respond to increasing demands for inclusivity, accessibility, and personalization, while balancing strong sustainability goals. Considering the growing diversity of passenger groups and the rising emphasis on universal design, this timeframe ensures that accessibility-driven innovations are both relevant and necessary.

Thus, positioning the project in 2040 provides a realistic yet forward-looking context in which to reimagine single-aisle aircraft cabins.

The Focus

Collins Aerospace is a global leader in aerospace innovation, with extensive capabilities and expertise to address the most complex challenges in a rapidly evolving market. In the Netherlands, this mission is embodied in the EU Innovation Hub, which drives the development of advanced aircraft interior technologies. The Hub's key areas of focus include sustainable materials, intelligent systems, innovative cabin design, enhanced passenger experience, and manufacturing technologies.

This thesis positions itself within that context by exploring the next generation of single-aisle aircraft cabin experiences, with a particular emphasis on space optimization. For airlines, two of the most critical factors influencing costs are weight and time. While weight affects fuel efficiency and sustainability, time directly impacts profitability through boarding and turnaround processes. Optimizing cabin space to improve ingress and egress efficiency therefore offers significant potential to benefit both airlines and passengers.

A central aspect of this research is accessibility, ensuring that future cabin layouts can accommodate diverse passenger demographics while maintaining efficiency. Additionally, the ability to retrofit interior segments to adapt to evolving demands is a key factor for long-term flexibility in aviation. By combining these considerations, the project aims to create a forward-looking vision for more inclusive, efficient, and adaptable cabin environments.

Project Goals

The goal of this project is to inspire both Collins Aerospace's EU Innovation Hub and Delft University of Technology by presenting a personal vision on the future of commercial aviation. The focus lies on creating a next-generation cabin concept for single-aisle aircraft that demonstrates how innovative layouts and accessibility solutions can enhance efficiency, inclusivity, and overall passenger experience.

It was agreed beforehand that the project should result in a visionary yet feasible design, consistent with the projected timeframe of 2040. This ensures that the outcomes are neither too abstract nor detached from practical industry constraints. Both Collins Aerospace and TU Delft therefore expect a clear design rationale grounded in thorough research and structured methodology.

The strength of this project lies in translating a future-oriented vision into a tangible cabin design prototype, supported by sketches, renders, and visual storytelling. In doing so, the project aims to provoke new perspectives within the aerospace industry while aligning with Collins Aerospace's mission to pioneer sustainable, intelligent, and user-centered cabin solutions.

1.4 Stakeholders

The Stakeholder Map (figure 2), presented in the format of Mendelow's Matrix (Influence/Interest), is crucial for defining the relationship between this design project and the parties involved.

Collins Aerospace/RTX and TU Delft are the primary driving forces of this project. They determine the frameworks and resources and require continuous, close involvement in all project decisions.

Then you have air travelers (passengers), cabin crew and airlines. Although they have the greatest user interest and are directly affected by the results, they do not exercise direct control over the project direction. Their wishes and feedback are the input for desirability and must be thoroughly and regularly informed.

Also the OEM's (Airbus, Boeing) have great influence in this project. They determine technical and safety feasibility through strict rules and requirements, but have little day-to-day interest in the design details. They must be kept satisfied by not exceeding the set frameworks.

In short, the matrix focuses attention on balancing the frameworks of Collins Aerospace and the requirements of regulators with the in-depth needs of passengers.

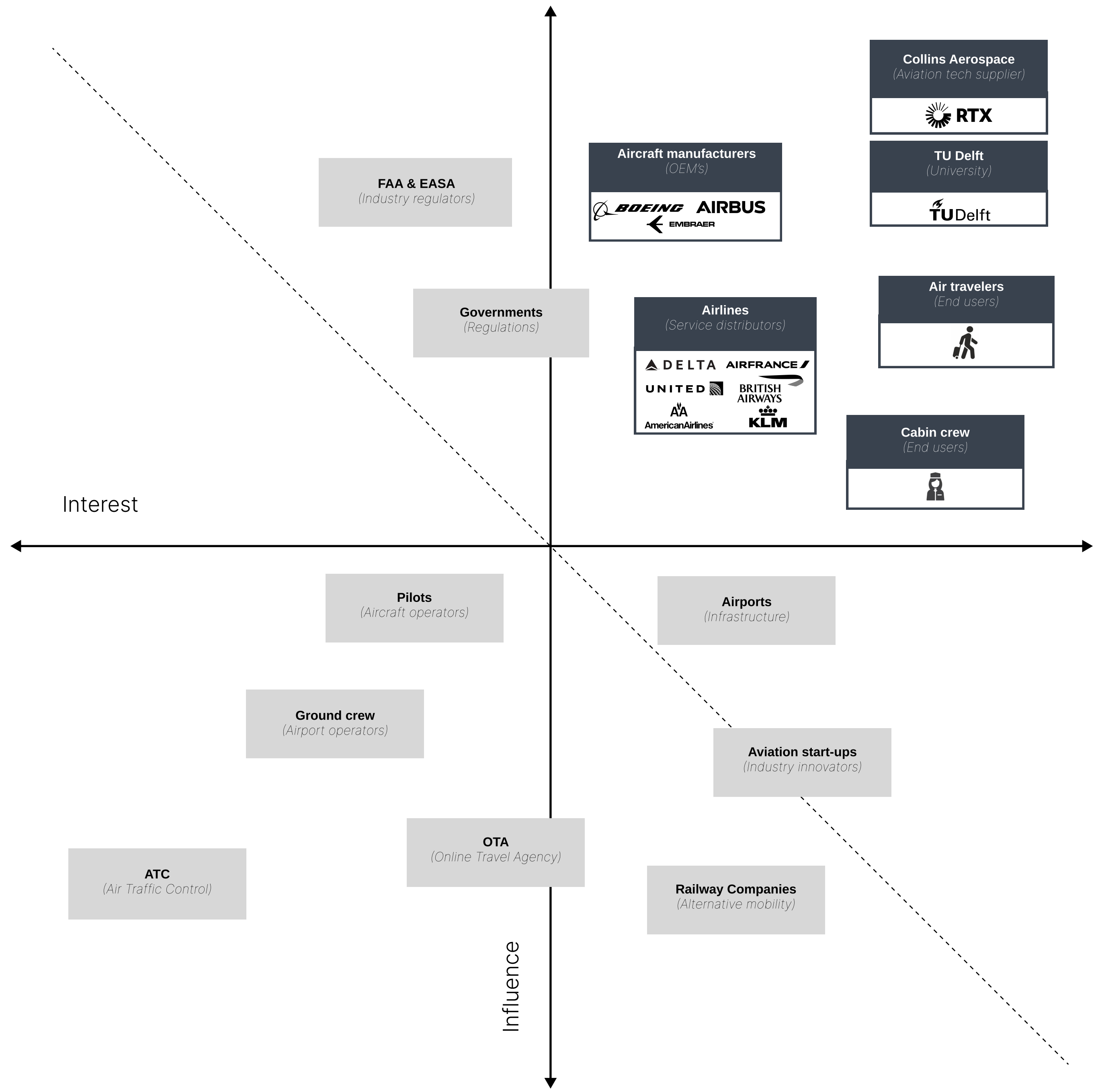


fig.2 Stakeholder Map, Mendelow's Matrix

1.5 Design Methods

During my studies at the Faculty of Industrial Design Engineering, I acquired a wide range of practical knowledge and validated methods. Many of these tools, which are essential for structuring complex design issues, are documented in the Delft Design Guide (Daalhuizen, Van Boeijen, et al.).

In addition to the overarching Vision in Product Design (ViP) methodology, a variety of complementary tools were used in this graduation project:

- Analysis & Validation: Techniques such as Online Surveys and Stakeholder Maps (Mendelow's Matrix) were used to validate user needs and analyze the influence of market players.
- Strategy & Definition: SWOT analysis was applied to determine Collins Aerospace's strategic position, which was crucial for establishing the design mandate.
- Context & Behavior: Models such as the Passenger Journey and Personas were used to map the emotional experience and behavior of air passengers, which was essential for defining the holistic comfort concept.

This methodical approach ensures that the design is underpinned by both academic depth and market reality, which increases the robustness and relevance of the proposed 2040 vision.

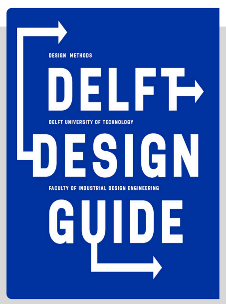


fig.3 Delft Design Guide, Daalhuizen, Van Boeijen, 2014.

fig.4 ViP Vision in Design, Hekkert, Van Dijk, 2014.

Vision in Product Design

ViP (Vision in Product Design) is a design method developed in Delft that forces designers to work out the vision and intended impact of a product in detail, long before it is actually materialized.

For a project that focuses on the future of aviation in 2040, ViP is crucially important because of the following characteristics:

- Future-oriented: ViP starts by defining the likely future context. This prevents the project from becoming yet another adaptation of an existing problem ('yet another seat'), but forces it to look for fundamentally new possibilities ('how can we improve communication or peace and quiet on board?').
- Interaction-Centric: The ViP method posits that products are merely a means to an end. The designer must first determine the raison d'être (the purpose) and the desired interaction ("What do I want people to experience?") before defining the product itself.
- Context-Driven: The suitability of each proposed interaction is determined by the specific context for which it is designed. In this project, this means that the vision of comfort is directly derived from the 2040 Context Factors.

ViP thus provides the academic framework for building a human-centered vision that is strong enough to drive the innovation process.

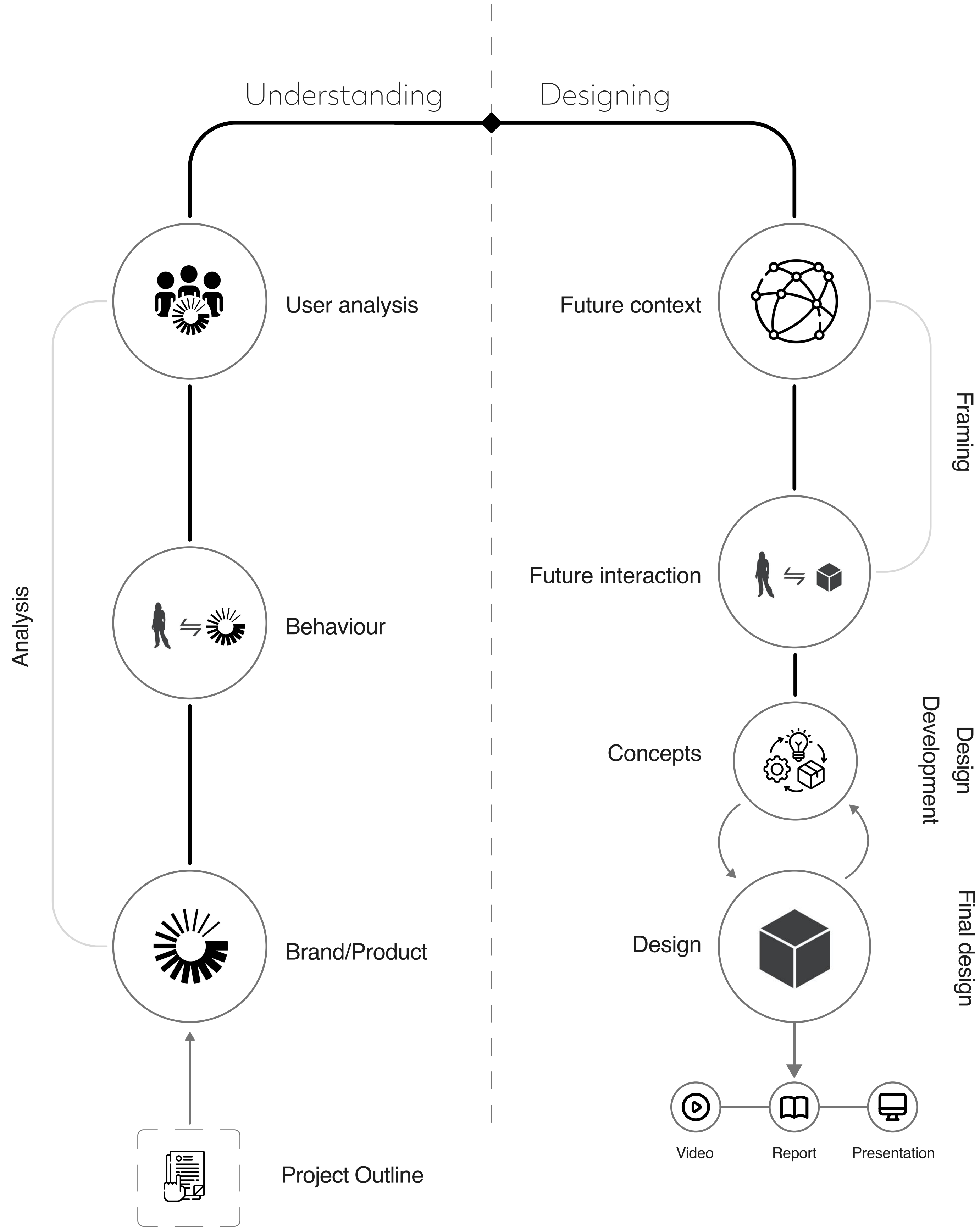
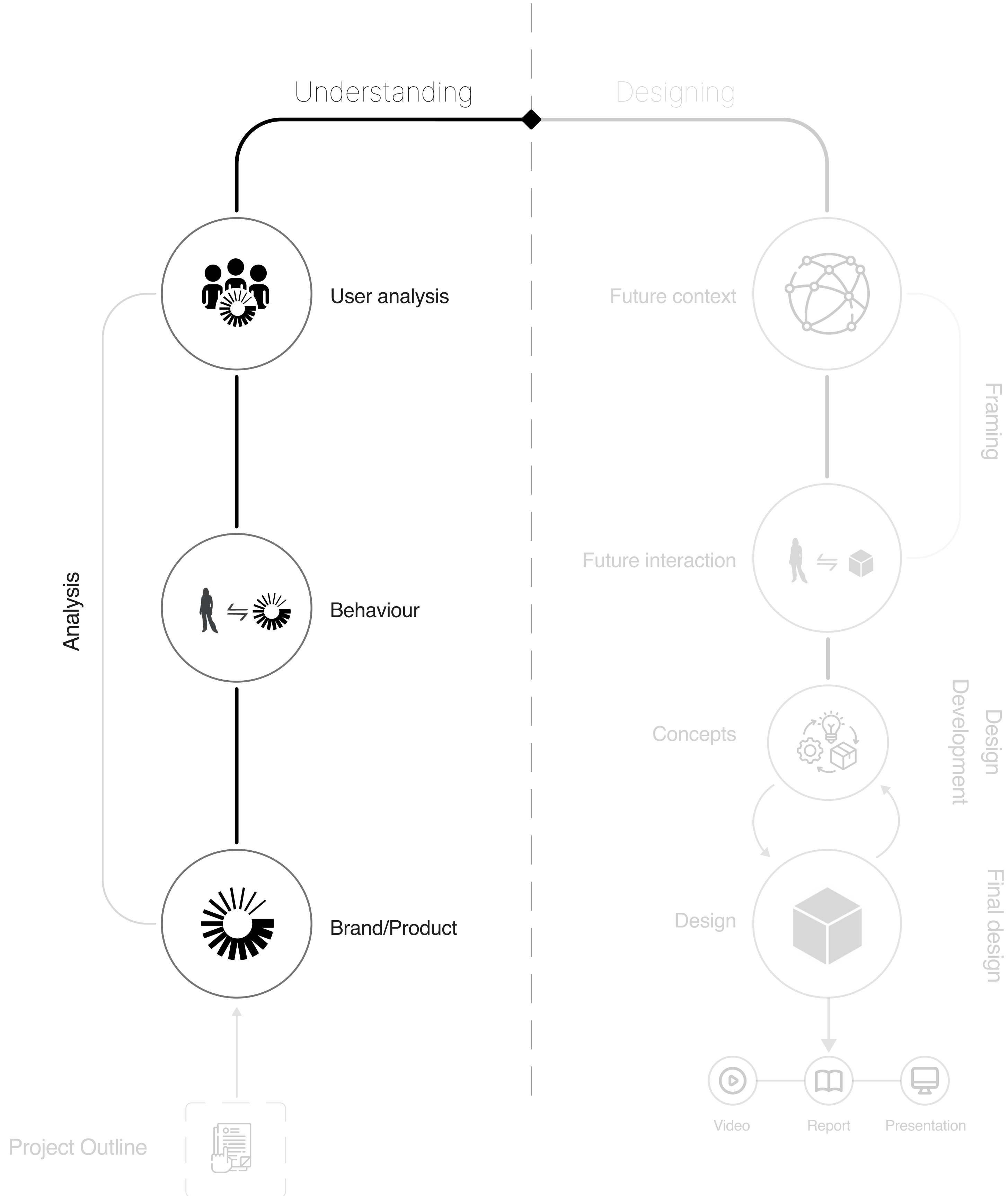


fig.5 Project process structure visualization

2 Analysis

This chapter marks the start of the project and serves as the fundamental 'Understanding' phase. The primary objective is to gather all the necessary knowledge to clearly define the complex design problem. The analysis focuses on three key pillars: an in-depth evaluation of the market and Collins Aerospace's brand values, a study of current behavior and historical perceptions of comfort among airline passengers, and identifying the key needs and frustrations of current users through research. The insights extracted from this section lay the solid foundation for the following steps.

1. Collins Aerospace
    - Company Values
    - Brand Identity
    - Brand Image
    - Design Principles
    - SWOT Analysis
2. History of Aviation
3. Interaction
    - Reasons of Air Travel
    - Comfort
    - Passenger Journey
4. Passenger Perspective (Survey)
5. Passenger Personas
6. Conclusion



2.1 Collins Aerospace

Collins Aerospace is a leading American aerospace and defense technology company and one of the largest suppliers of aerospace and defense products worldwide. The company was formed in 2018 from the merger of Rockwell Collins and UTC Aerospace Systems. Its headquarters are located in Charlotte, North Carolina, and it operates as a subsidiary of RTX Corporation.

Collins Aerospace focuses on designing, manufacturing, and maintaining systems and components for a variety of sectors, including commercial and military aviation, helicopters, aerospace, and airports. Its activities are organized into six strategic business units: aerostructures, avionics, missions systems, connected aviation solutions, power & controls, and, crucial to this project, interiors.

The Collins Aerospace EU Innovation Hub focuses specifically on the commercial aviation market. The interiors business unit supplies a wide range of systems for the cabin experience in this market, including seating products, lighting, lavatory systems, water & waste systems, and critical safety systems such as evacuation systems and fire protection systems. Collins Aerospace is a global leader in the design, development, and manufacture of cabin interior products and services, distinguishing itself by delivering innovation, reliability, and efficiency.They also work closely with customers to provide customized cabin interior configuration, program management, and certification services.

Company Values

The increasing expectations and demands within global aviation have emphasized the importance of delivering exceptional and distinctive cabin experiences more than ever. As the industry rises to the challenge of finding innovative ways to balance convenience, comfort, safety, and efficiency, Collins Aerospace stands ready with the experience and technology to turn its customers' most ambitious goals into reality.

fig.6 Collins Aerospace's brand image overview

Brand Identity

Since Collins delivers products to airlines and aircraft manufactures that have their own design requirements, they tend to not have a design language. Each customer wants a unique solution and this creates a different approach toward what their products need to be and the flexibility they must have to meet multiple company and user needs.

You see in the different design solutions of Collins Aerospace (figure 7) that there is not a global identity between the various projects. There is a lack of design language in the design process, since every project is completely separated from another.

Brand Image

The Collins Aerospace brand image revolves around **advanced, reliable**, and mission-critical aerospace technology, combining innovation with precision engineering for both commercial and military aviation. The company is widely regarded as a supplier of **high-quality, safety-driven** systems that improve aircraft performance and resilience. At the same time, many people associate Collins Aerospace with defense and government programs, reinforcing its image as a key player in safe, advanced, and strategically important aerospace solutions.

Design Principles

Basic design principles the Collins Aerospace team uses when approaching a new project are: simple, pure, purposeful and optimized (meeting Jeff McKee, 2025).

- **Simple:** Reduce to the essential—no extra parts, states, or decisions.
- **Pure:** Preserve integrity of form, material, and intent—nothing ornamental that isn't doing work.
- **Purposeful:** Every decision advances a clear user, business, or safety outcome.
- **Optimized:** Tune the system for performance, lifecycle cost, and sustainability without sacrificing experience.

fig.7 Collins Aerospace's design language overview

S W O T

Strengths

- **Global Market Leader:** World leader in designing and manufacturing cabin interior products.
- **Innovation Hub:** Dedicated EU Innovation Hub focuses on sustainable materials, intelligent systems, and user-centered design
- **Extensive Product Portfolio:** Offers a broad range of products from seating and lighting to galley and lavatory systems

Weaknesses

- **Lack of Unified Design Language:** Due to high customer (airline) customization, there is a lack of a global design identity, resulting in project-separated design solutions.
- **Design Constraints:** The need to adhere to internal design principles of simplicity, purity, purposefulness, and optimization.
- **Focus on Traditional Aircraft:** Primary market strength is in components for existing aircraft, requiring a significant shift to embrace radically new visions.

Opportunities

- **Market Turning Point (2040):** The projected replacement cycle for current SAA fleets creates a unique design opportunity for Next-Gen SAA platforms.
- **Undiscovered Market Segment:** Opportunity to define a new, compact class between traditional Business Class and Premium Economy (the 'Business Down' concept).
- **Evolving Passenger Demands:** Increasing global demand for personalization, inclusivity, accessibility, and connectivity.

Threats

- **Strict Regulatory Environment:** Commercial aviation is a conservative sector with strict safety regulations, slow pace of change, and long development cycles.
- **Cost and Weight Pressures:** Airlines prioritize operational efficiency, meaning the design must overcome significant cost and weight constraints that impact fuel efficiency and sustainability.
- **Existing Pain Points:** Failure to address critical user experience issues (like inefficient boarding/disembarking) negatively impacts passenger satisfaction and airline profitability, risking market stagnation.

fig.8 SWOT Analysis visualization

SWOT Analysis

The SWOT analysis is an essential strategic tool that compares Collins Aerospace's internal strengths and weaknesses with the external opportunities and threats in the market. The analysis helps to:

- Validate the design flaws (W: slow throughput and uncomfortable seats) and link them to the lack of a uniform design style (W).
- Justify the focus on a new class as a commercial opportunity (O) that aligns with market trends for personalization and efficiency.
- Act as a final filter for the Idea Phase, ensuring that each design is feasible (T: taking into account strict regulations and costs) and relevant (S: utilizing the Innovation Hub).

2.2 History of Aviation

1930s

1936

1941

1949

1959

1914-1927

New and exciting vs. noisy and uncomfortable. An experience that few could afford to cherish or regret.

Initially, pilots and occasional passengers sat in open cockpits, completely exposed to wind and weather. Although larger European aircraft offered some luxury, the flying experience at that time was structurally rough, noisy, and uncomfortable.

Customers

The audience consisted mainly of pilots. Most early aircraft could only accommodate one additional passenger, if any. There were hardly any airlines that carried passengers, and the few that did exist rarely survived for long. Those that did exist focused exclusively on wealthy travelers who could afford the high ticket prices. During this period, most airlines generated their income by transporting mail for the federal government. Apart from the occasional pleasure flight in the reserve seat of a stunt plane such as the Curtiss Jenny, few Americans flew as passengers in airplanes, and even fewer used airplanes as a regular means of travel.

fig 9. The interior of an Aeromarine Airways airliner. Note the wicker seats. Aeromarine Airways flew for four years, from 1920-1924.

1927-1941

Despite the airlines' optimistic advertising, early air travel was both expensive and unpleasant.

Air travel at this time was noisy, cold, and unsettling. Because aircraft did not have pressurized cabins, they remained at low altitudes, which led to frequent weather disruptions and high levels of airsickness. Despite attempts by airlines to improve comfort, flying before the 1940s was still a grueling experience.

Customers

Due to the significant costs, access to air travel was strictly limited to the wealthy and the business segment. The price of a round-trip ticket between the coasts was close to half the price of a new car ($260), which explains why most people continued to rely on trains or buses. Despite this economic barrier and the inconveniences experienced, commercial aviation continued to attract tens of thousands of adventurous passengers each year. The growth was impressive: the sector grew from 6,000 passengers in 1929 to 450,000 in 1934 and reached 1.2 million in 1938, although this still represented a minuscule group of travelers.

fig 10. Passengers on a Ford Tri-Motor. This photo was probably used to promote air travel.

1941-1958

The 1950s marked a turning point in American travel culture: in 1955, for the first time, more people traveled by plane than by train. This shift in preference was confirmed in 1957 when airplanes replaced ocean liners as the most popular means of transportation for the transatlantic route.

The end of World War II resulted in a sharp increase in passenger traffic. As soon as travel restrictions were lifted, airlines were inundated with demand. This dynamic led to the creation of new airlines and the introduction of revolutionary technologies in civil aviation.

Customers

Mass air travel began, but it was not accessible to everyone. African Americans were discouraged from flying due to widespread discrimination; many airports in the United States were segregated and offered inferior facilities. Although the airlines themselves were not legally segregated, these unequal conditions meant that, until the rise of the civil rights movement, air travel remained primarily a white activity.

fig 11. United Air Lines DC-7 Brochure

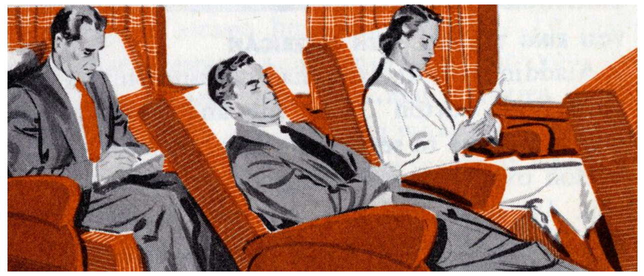


fig 12. With the increase in flight speeds and passenger numbers in the 1950s, airlines discontinued their expensive sleeper services.

Jet Lag Before Jets

Even before the advent of jet aircraft, rapidly crossing multiple time zones began to cause physiological problems for passengers. The disruption of the body's natural rhythm, caused by shortened or lengthened days and nights, made sleeping considerably more difficult. Although this phenomenon was later given the term 'jet lag', it was initially experienced after long-distance flights with fast piston engines and turboprop aircraft. As flying became more common and popular in the late 1950s, American airlines brought a new level of speed, comfort, and efficiency. However, the steady increase in passenger traffic resulted in a decline in personal service. The initial thrill of aviation began to give way to stress, turning flying from an adventure into a mere necessity.

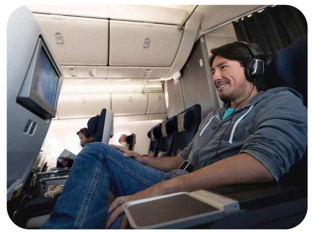
1965

1970s

1971

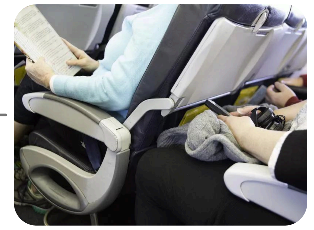
1998

2000s



2000s

2010



1958-2001

Jet passenger service began in the United States in the late 1950s with the introduction of Boeing 707 and Douglas DC-8 airliners.

The jet engine was the tech game changer that let them make bigger and more productive planes. The stuff that came after, like deregulation and the computer revolution, plus the safety crackdown after 2001, totally changed the flying experience for good.

Customers

The introduction of jet aircraft briefly made Atlantic crossings highly fashionable and prestigious, leading to the emergence of a new, exclusive group of travelers: the "Jet Set." However, falling fares in the 1970s made flying accessible to a much wider audience, quickly undermining the elitist character of the jet age. Profound cultural changes in the 1960s and 1970s transformed the aviation industry. More and more people were flying, making air travel less exclusive. Between 1955 and 1972, the number of passengers quadrupled, and by 1972, nearly half of all Americans had flown, although business travelers still made up the majority. A small percentage developed into loyal, repeat travelers, or "frequent flyers."

fig 13. Some 707 flights were all-first class, others all tourist class, and others a mix separated by partitions.

fig 14. Both sides of a typical UK paper Air Miles voucher

Air Miles

A frequent flyer program is an airline's loyalty program that allows members to earn points or miles by flying, which can be redeemed for tickets and upgrades. Major players in this market include Flying Blue (Air France-KLM), AAdvantage, MileagePlus, and SkyMiles. Participation offers the opportunity to achieve elite status, which comes with additional privileges such as bonus miles, lounge access, and priority boarding.

2001-Now

Increased security and Low-Cost Carriers

Following the attacks of September 11, 2001, the aviation industry underwent a transformation that has permanently altered the flying experience. Driven by the need to maximize security and the simultaneous pressure to improve cost efficiency, the period after 2001 was characterized by a fundamental shift in both operational procedures and passenger expectations.

Customers

The emergence and dominance of budget airlines (LCC) led to the further democratization of flying. Customers were exposed to extremely low base fares, which made flying accessible to an unprecedented, broad section of the population. Instead of being a luxury or prestigious activity, flying became an everyday means of transport for short and medium distances.

This new customer base accepted the unbundling of services, whereby extras such as baggage, meals, and seat selection had to be paid for separately. The traveler became a price-conscious consumer who put together his or her travel experience 'à la carte'. The result was a more functional, efficient, but often less comfortable and intimate travel environment than in previous decades.

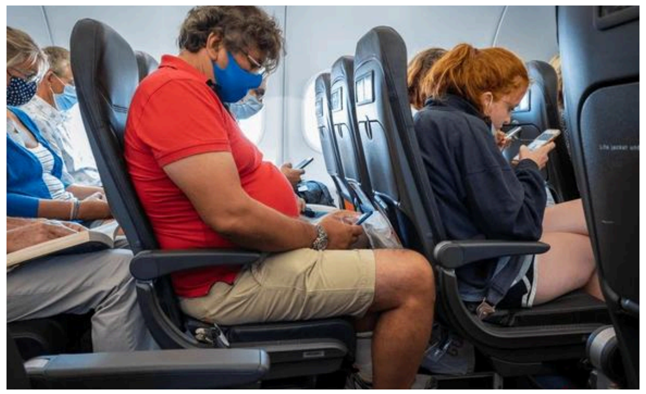


fig 15. LCC's fit as much seats possible in their aircrafts, reducing legroom.

fig 16. Security control having strict rules and methods to increase safety.

Security

The most significant change for passengers after 2001 was the increased security measures. Strict rules for liquids (the 100 ml rule) and extensive screenings (the mandatory removal of shoes and belts) became the norm. Although these measures were essential for safety, they resulted in longer waiting times and transformed the airport experience into a stressful, regulated, and often unpredictable procedure.

2.3 Interaction

This chapter focuses on mapping the dynamic relationship between the passenger and the flight journey, which is essential to the ViP methodology. In order to develop a credible future vision (Framing), it is crucial to understand the current interaction. This includes both the physical and psychological comfort factors and the emotional highs and lows of the entire journey. The analysis of user interaction serves as an empirical basis for identifying the most urgent points of friction and the deepest unmet needs of the traveler. This enables us to define the design task from a human-centered perspective, rather than solely based on technological possibilities.

Reasons of Air Travel

Passengers choose to fly for various reasons, including vacations, family visits, or business trips. The aviation industry is an expansive sector that creates lucrative opportunities for airlines. Several studies point to a strong correlation between travelers' final flight choice and the comfort they experience on board. This implies that comfort is a significant factor that attracts customers. Given the increase in the number of passengers flying, attention to passenger comfort during the journey is crucial.

In the passenger selection process, decisions are initially made based on direct connections, flight times, and costs. Only then do factors such as marketing initiatives (including loyalty programs) come into play (Rosa Hendrikx, 2021). Comfort, previous experiences, and reliability with regard to delays then play a role. On shorter routes, the risk of delay carries more weight, while on long-haul flights, the comfort element plays a more prominent role in decision-making.

Comfort

Comfort is a crucial issue in aviation and is directly linked to whether a passenger decides to book with the same airline again. We are still in the early stages of fully understanding how the overall comfort experience is created. Both 'soft' factors, such as the attention of the cabin crew and the pre-flight experience, play a role, as do physical characteristics such as the seat itself, lighting and temperature. In addition, there are processes that influence each other.

As Peter Vink et al. (2011) described, comfort encompasses a multitude of concepts. In Dutch dictionaries, for example in the Van Dale dictionary from 2000, comfort is defined as:

> *"freedom from pain, well-being."*
> - Van Dale

Although there are countless definitions of comfort, one aspect is undisputed: comfort is always a subjective experience.

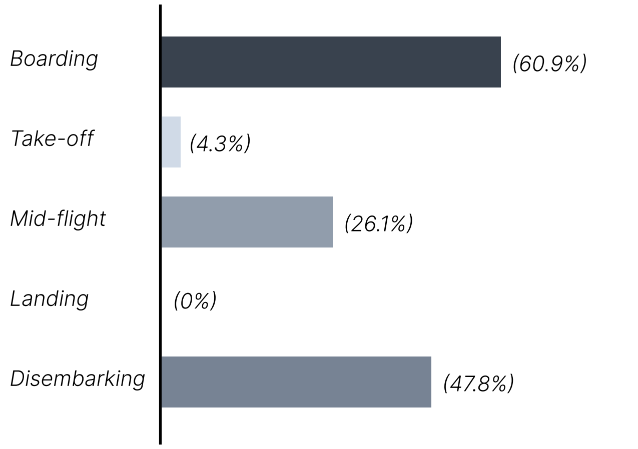
Online Survey

For the purpose of rapid, exploratory validation of the literature and identification of urgent pain points, a quantitative survey was conducted among 23 respondents, air travel passengers and cabin crew members. See appendix C for a full summary of all responses. Although the sample size is limited and primarily serves as an indication in this middle phase, the results confirm the crucial themes from the literature study and sharpen the focus of the design problem. It will help answer the previously stated research questions.

RQ 1.1 *What are the biggest annoyances for passengers in modern aviation?*

RQ 3.1 *What are current annoyances for cabin crews in modern aviation?*

In graph 1, you can find the results of the research question at which stage of air travel people experience the most discomfort or frustration.

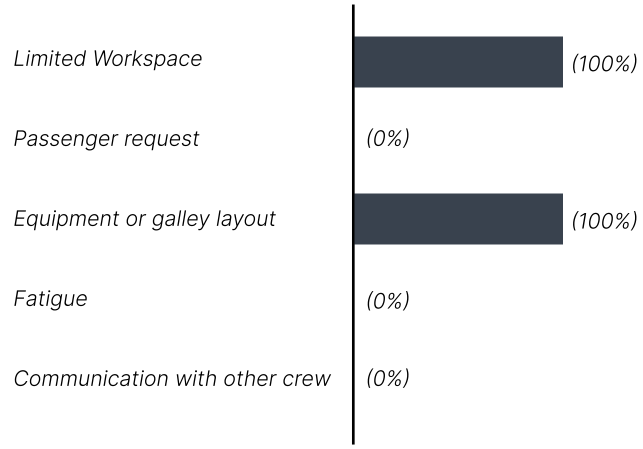


graph.1 Stages during air travel that cause most discomfort or frustration. (Survey)

The literature emphasizes that comfort, although subjective, is strongly influenced by physical and ergonomic factors. This is strongly validated by my own findings. The survey confirms that elements related to the seat are the most crucial and dominant sources of discomfort during flight. Specifically, legroom is consistently cited as the determining factor for comfort levels, a conclusion that supports the general literature, particularly for taller individuals. The need for improvement is echoed in direct quotes from respondents, who call for:

> *"Wider seats for comfort and privacy."* - survey respondent

To enrich the passenger perspective, the survey was also expanded to include responses from cabin crew. Three crew members, all employed by KLM, participated in the survey, providing a targeted sample of operational challenges. The results, which paint a clear picture of their biggest bottlenecks during a flight, are shown in detail in graph 2.



graph.2 Cabin crew member's biggest challenges during a flight. (Survey)

This underscores the immediate design challenge of exploring new cabin layouts that optimize physical and psychological space for the passenger, despite the weight and space constraints in aviation. The findings therefore justify the focus on the Interiors business unit and the search for an innovative seating configuration.

fig. 17 Ample legroom. Seat pocket enlarges the problem.

Seating
The comfort of airplane seats has long been an important focus area in research and development, leading to the development of countless concepts for both individual seat designs and seat layout configurations.

Vink's studies indicate that legroom and the seat are the most crucial elements influencing comfort. Additional analyses of travel reports mention hygiene and cabin crew as significant factors, while interviews emphasize the importance of personal space. The importance of legroom is also confirmed in other studies and is considered the decisive factor in terms of comfort. Less legroom leads to lower comfort scores, especially for taller people. Although the aviation industry is aware of this problem and is making efforts to increase legroom within the same seat pitch, our own survey showed that seating comfort caused the highest level of dissatisfaction among passengers.

"The seats could be way more comfortable. Also more space for stretching your legs." - survey respondent

fig. 18 Peter Vink in the cabin design concept for TU Delft's Flying-V with a staggered seating line up.

Additional research indicates that the future of aviation will bring significant changes in seat configurations. In new aircraft designs, such as Blended Wing Body (BWB) passenger aircraft, cabin layouts will be more flexible and diverse than is currently the case. This emphasizes the ongoing focus on innovation in seat design to meet the growing comfort needs of passengers.

Lighting
Light and color are extensively studied as environmental factors that influence human well-being. A literature review by Sokolova and Fernández-Caballero (2015) shows that color directly influences emotions and is therefore used in various fields, including psychology, medicine, design, and architecture. Although the authors identified universal trends in color perception, caution is advised when using specific colors for different socio-demographic groups, as people may respond differently to the same stimuli.

This insight is particularly important for the design of cabin lighting in aircraft, given the diverse composition of the international audience on board. The use of cooler tones, such as blue and green, in the cabin has been scientifically linked to a feeling of calm and tranquility. Airlines often apply this during nighttime hours or rest periods to promote relaxation and sleep. By adjusting the color temperature of the lighting to the biological clock (circadian rhythm) of passengers, airlines can try to mitigate the effects of jet lag. These are different types of lighting fulfilling specific roles:

- **Ambient Lighting:** Provides general lighting for the cabin.
- **Task Lighting:** Assists passengers with specific activities, such as reading or working.
- **Footwell Lighting:** Guides passengers and increases safety during boarding and disembarking.
- **Safety Lighting:** Provides better visibility in emergency situations.

fig. 19 Ambient Lighting provides general lighting for the cabin

The benefits of advanced lighting are multifaceted, including reducing jet lag, creating a more relaxed environment, improving safety, and providing energy efficiency through LEDs.

Although other comfort factors cause significant discomfort (such as seating comfort), our own survey showed that lighting was rated by passengers as the factor with the highest satisfaction within the cabin experience. This suggests that the aviation industry is effective in managing this environmental factor.

fig. 20 Task Lighting assists passengers with specific activities, such as reading or working.

Boarding
Turnaround time (the period that an aircraft is at the gate) represents a significant operational overhead. Reducing it by just one minute can save a large airline more than $50 million annually (Jaehn and Neumann, 2014). Speeding up processes is also essential for busy airports and improves the passenger experience by minimizing delays.

The survey showed that boarding is the phase of the flight in which passengers experience the most discomfort or frustration (see graph 1).

This frustration is related to obstructions on board that interrupt the flow (Ferrari and Nagel, 2005). Although optimized boarding methods are often inefficient, the design problem is directly linked to friction in the cabin layout, specifically:

- **Aisle Interference:** Passengers stuck in the aisle.
- **Seat Interference:** Seated passengers blocking access to nearby seats.

This highlights my primary design task: "Redesigning the cabin layout to achieve space optimization that improves both operational efficiency for the airline and comfort for the passenger."

Finally, research into aircraft boarding processes proposes the Dynamically Optimized Boarding (DOB) method. This strategy aims to shorten boarding time and minimize obstructions on board, while taking passenger needs into account, such as boarding in groups.

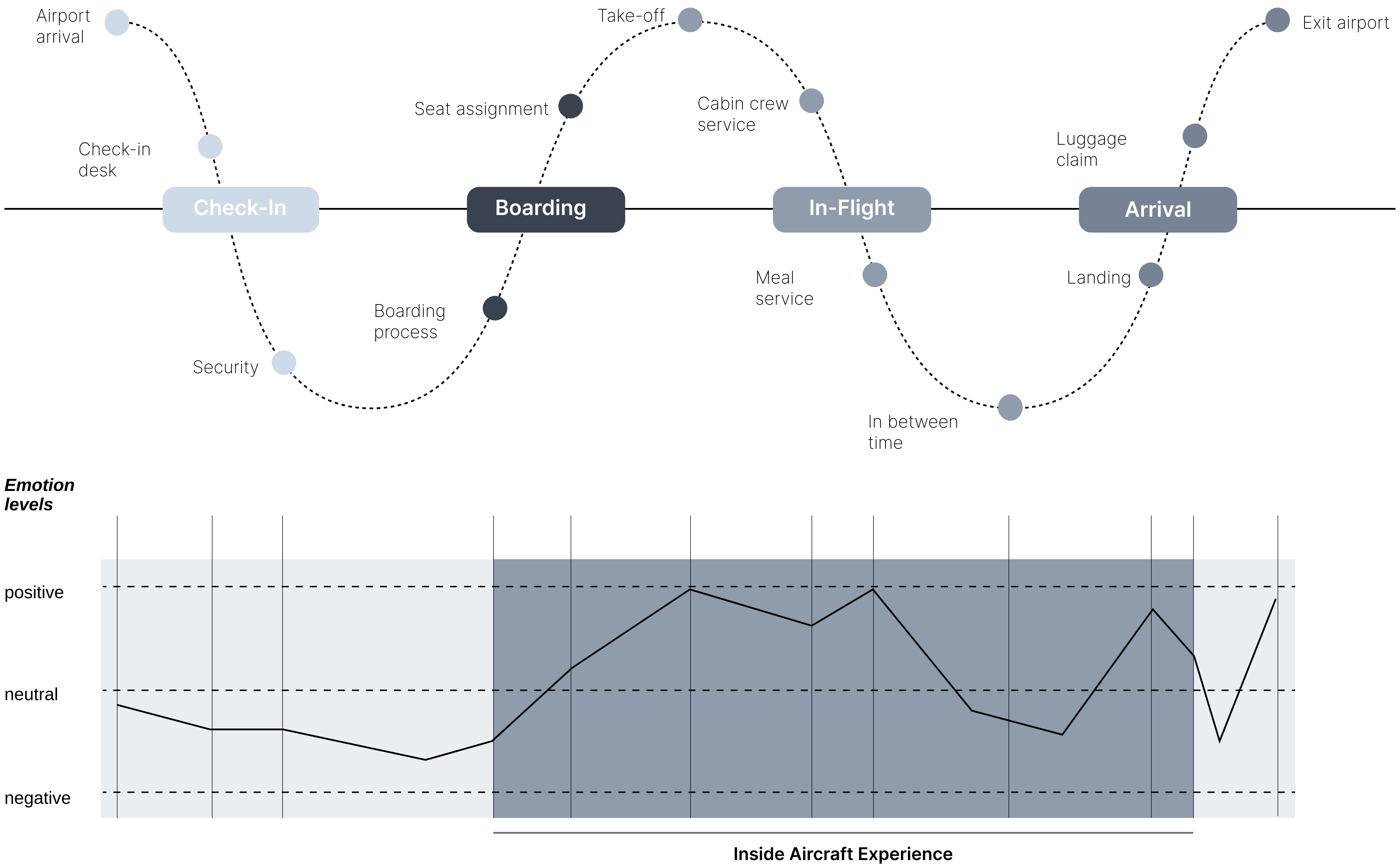


fig. 21 A customer jouney visualization and a map of the emotional timeline of passengers recorded during the flight. (Bouwens, 2018)

Passenger Journey

The passenger journey reveals clear time-bound patterns in comfort perception: the highest comfort is reported immediately after takeoff and upon arrival at the destination, while the lowest comfort is consistently experienced during the cruise phase (between meal services) and when stowing luggage (Bouwens, 2018). This finding requires that design and service innovations should primarily focus on improving the experience during the cruise phase and the moments of friction surrounding luggage.

"It's hard to find overhead luggage space. People trying to pass by, everyone is very impatient during this phase." - survey respondent

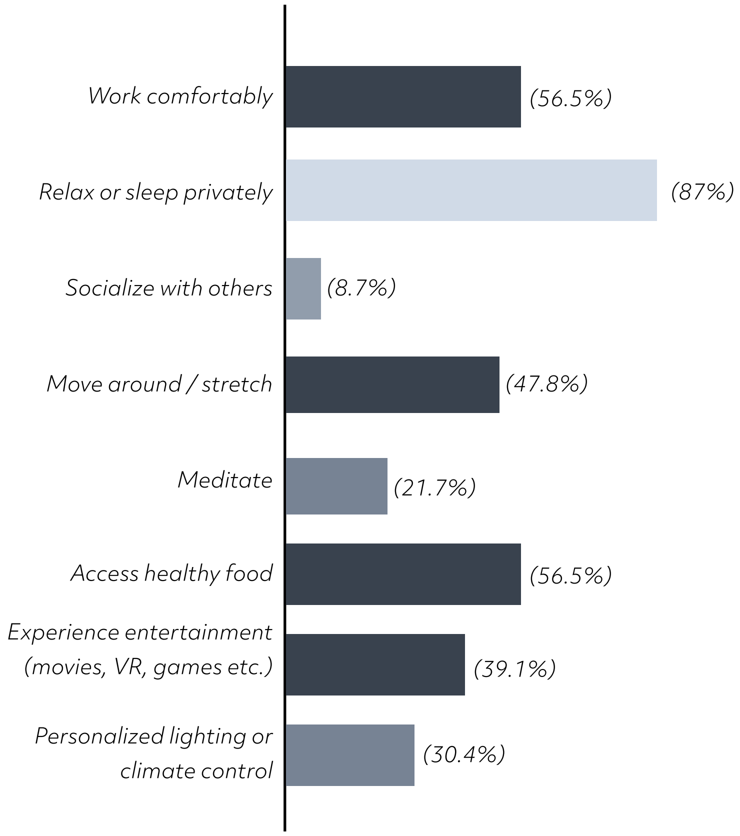
2.4 Passenger Perspective (Survey)

The focus on the passenger experience extends beyond just the seat; it extends to the procedural aspects of the journey. Quantitative analysis provides crucial insight into this by identifying the most frustrating stages of the process. The data shows that the highest level of discomfort and frustration is not experienced during the flight itself, but rather during the transitional moments: Boarding was cited by 60.9% of respondents as a source of discomfort, followed closely by Disembarking at 47.8% (see Appendix C). This empirical result confirms that the inefficiency of passenger flow is a primary problem that negatively affects the overall travel experience. The primary focus of the design phase is therefore directly justified in addressing space optimization and efficient inflow and outflow to remedy the operational bottlenecks of the Single-Aisle Aircraft. In addition to this friction in the process, the data provide an answer to:

RQ 1.3 *What would passengers most like to do during a flight?*

RQ 2.1 *What type of cabin spaces are wanted by future air travelers?*

When passengers were asked to design their ideal cabin, needs emerged that transcend the current monofunctional layout, see figure 22, and quotes from the survey respondents:



graph.3 Stages during air travel that cause most discomfort or frustration. (Survey)

'If you could improve one thing about your air travel experience today, what would it be?'

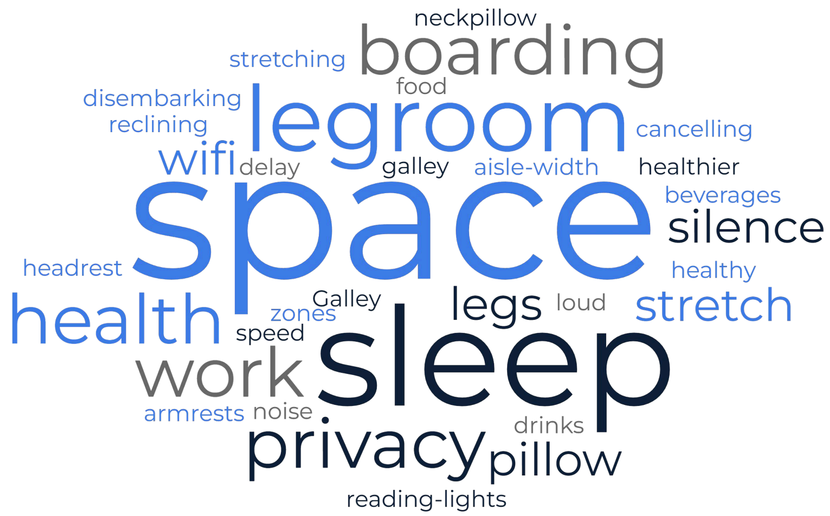


fig. 22 A word cloud map of survey respondents to the question above.

Passengers' needs with regard to the ideal cabin are extremely diverse and transcend the current monofunctional layout. The analysis reveals four primary needs that determine the desired future interaction (RQ 1.3). The strong demand for private space for relaxation and sleeping emphasizes the need for seclusion and rest.

"Better sleep." - survey respondent

The need to be able to work in a focused manner underscores the demand for suitable ergonomics and quiet zones.

"Better seats and wifi access." - survey respondent

At the same time, there is a clear desire for movement, stretching, or exercise, which calls for public and flexible zones.

"Being able to easily walk around so that I can stretch once in a while if you are not seated next to the aisle." - survey respondent

Finally, the desire for flying to be part of the experience. Nowadays people look up to the journey and are not enjoying it. This should change.

"Make sure that flying doesn't feel like lost time." - survey respondent

2.5 Passenger Personas

Demographic characteristics such as age, gender, or origin do provide some information about people's behavior, but two 50-year-old men from Rotterdam with similar incomes may still be completely different types of travelers.

One may be primarily looking for luxury and efficiency when flying, expecting seamless, exclusive service. The other, on the other hand, may value sustainability and social interaction most highly, consciously choosing the most environmentally friendly flight and enjoying contact with fellow passengers.

That is why superficial groupings are not sufficient. Instead, personas create a more in-depth view about passenger needs and motivations.

Rosa Hendrikx (2021) identified six segments that formed the base for the need based personas (see Appendix D). It is important to emphasize that not every traveler fits seamlessly into a single persona. The personas created should therefore be considered fluid and flexible models, rather than strict, static categories.

An individual traveler may identify with several personas at the same time to varying degrees. Furthermore, travelers may transform from one persona to another over time, for example because they take different types of routes (business versus private) or because they gain more flying experience and their needs shift as a result.

The personas should serve as a tool for understanding the spectrum of behaviors and underlying needs, not as a definitive classification of the person behind the traveler.

fig.23 Rosa Hendrikx' six need based personas plotted on a tension model. (Hendrikx, 2021)

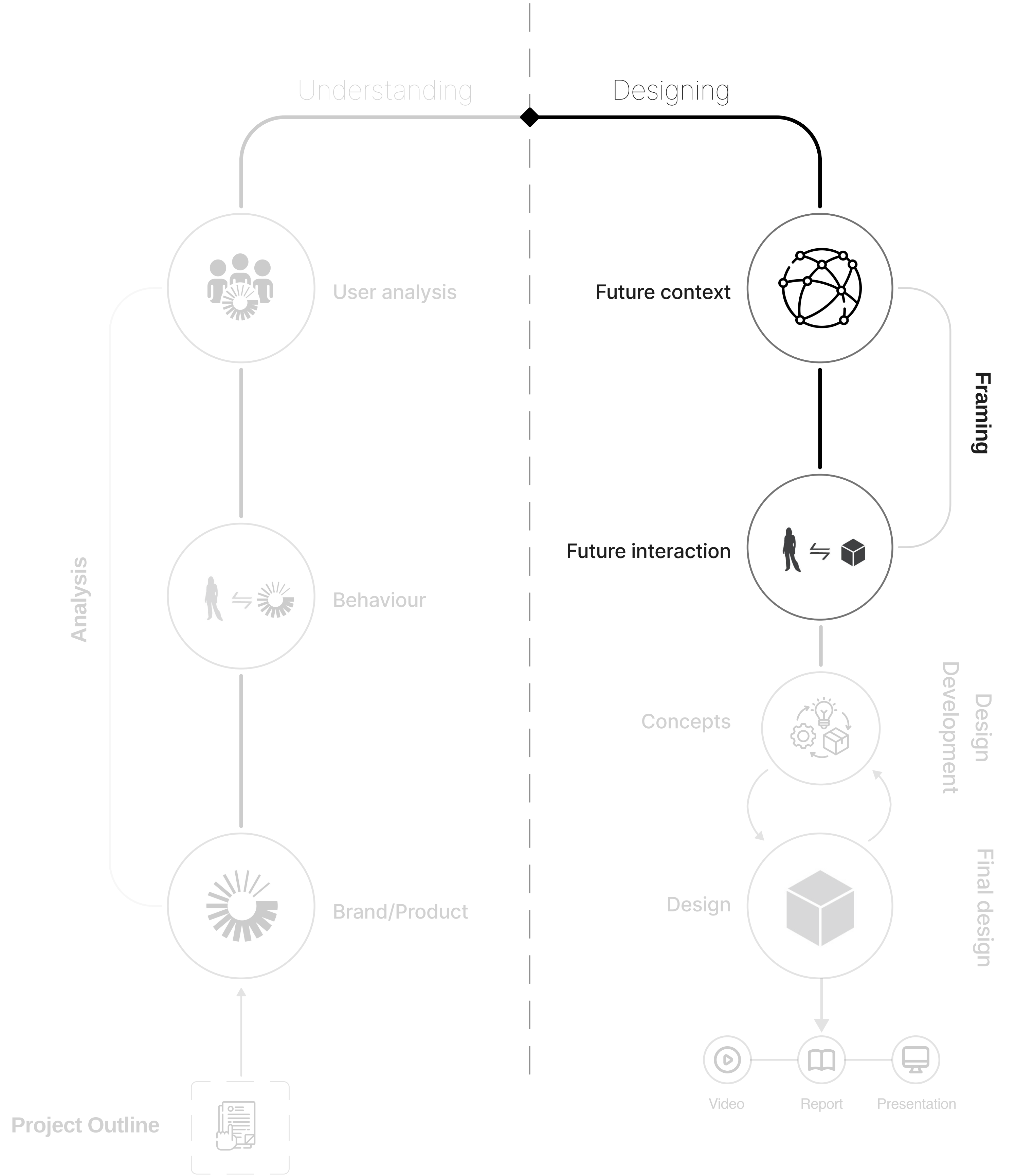
2.6 Conclusion

The analysis phase has successfully dissected the current state of affairs in commercial aviation and identified two critical bottlenecks that necessitate a rethinking of the Single-Aisle Aircraft (SAA) interior. First, the online survey proves that the highest level of passenger frustration lies in the procedural transition moments, particularly during boarding and disembarking. This points to a fundamental problem of operational inefficiency resulting from the static cabin layout, a factor that directly impacts costs for airlines. Second, seat comfort remains the dominant source of dissatisfaction during the flight, highlighting the need for innovation within Collins Aerospace's Interiors business unit. The collected data and the exploration of Collins Aerospace's focus on sustainability and efficiency lead to the conclusion that the design problem is not just a matter of aesthetics, but must primarily focus on creating spatial flexibility that both improves flow and meets the physiological comfort needs of the passenger. This two-part problem requires a strategic, forward-looking vision for the Design Development phase.

However, a survey sample of 23 respondents is considered low. Ideally, a second survey with a broader reach should be reconsidered for more accurate data.

3 Framing

This phase marks the transition from a broad market analysis to a well-founded design strategy (the 'Designing' phase). Building on the knowledge gathered about Collins Aerospace's current pain points and dynamics, Framing has three objectives: To determine the 2040 future context by applying the ViP method to trends and developments. To define four possible future scenarios through clustering, including the associated design goals. And finally, synthesizing these insights into a clear design mandate and mission that forms the basis for the final Design Development.



3.1 Thesis Domain

This study explores the future of passenger comfort within single-aisle aircraft (SAA) cabins, specifically targeting the strategic horizon of 2040. This date represents a critical industrial shift as the current generation of short- and medium-haul aircraft, the long-standing backbone of commercial aviation, approaches the end of its economic life. The projected decline of these legacy fleets coincides with the widespread entry of Next Generation SAA, which are expected to dominate the market by the end of the next decade.

Beyond mere improvements in fuel efficiency and environmental sustainability, this transition provides a rare, ground-up opportunity to fundamentally redesign the interior passenger compartment. By focusing on 2040, this research anticipates the unique engineering and design challenges presented by these new platforms. This forward-looking approach allows us to move past the constraints of current cabin architectures and make a foundational contribution to defining the global standards for on-board comfort in the mid-21st century.

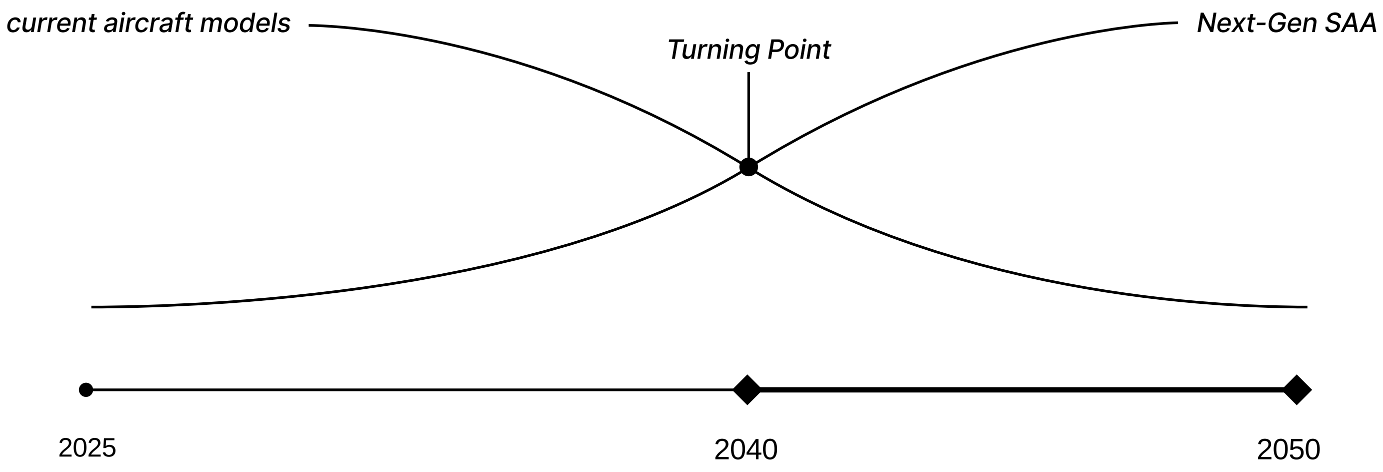


fig.24 Visual representation of the turning point of aircraft models.

This dissertation adopts a holistic definition of comfort, transcending traditional ergonomics to encompass the physical and emotional well-being of diverse passengers. By framing the cabin as a dynamic environment where accessibility, atmosphere, and service systems converge, the research moves beyond static layouts to prioritize inclusive, meaningful experiences for all travelers regardless of age or background. This approach balances the human need for care and ease with the practical constraints of airline operations, ultimately aiming to define the future standard for comfort in next-generation aircraft.

-A ***fluid*** *cabin experience that enhance* ***leisure travel*** *comfort in single-aisle aircrafts in 2040-*

3.2 Context Building

Applying the ViP methods gave me the opportunity for a unique insight in the future of passenger behaviour and experiences. For this you must gather so called 'context factors', which helps predict a likely future scenario. Here is some information about the gathered context factors for this project:

- Over **230 context factors** were gathered from more than 70 different sources;
- In the domains: Demographical, sociological, economical, biological, ecological and technological;
- These factors consist of Developments, Trends, Statements and Principles

The original collection of context factors, derived from the literature, market, and usage study, was reduced through a step-by-step filtering process to create focus. First, the factors were clustered based on their thematic content (e.g., technology, macro-economics, policy). The clusters were then evaluated on two crucial criteria: Relevance and Impact: The factor must have a direct, significant influence on the aircraft interior in 2040 and on Collins Aerospace's project mandate.

This process resulted in a limited set of critical factors, which formed the fundamental building blocks for shaping the future vision. For the full list of context factors see Appendix E.

AGI Proximity and Ubiquitous Automation

AI will move from assisting to autonomously managing most white-collar and specialized technical tasks (e.g., legal discovery, financial analysis, software development).

Maximalist Escapism

Flying becomes part of the adventure, involving bold, sensory-rich travel and rejecting mediocrity.

The Trillion-Sensor World

The Internet of Things (IoT) will explode into trillions of connected devices, with every physical asset monitored and managed by AI in real-time. The "digital space" will be a central economic zone, transacting in sovereign and decentralized digital currencies.

Air Travel Rise

Global air-travel demand is expected to at least double by 2050. Extreme weather will cause at least 40% more flight delays by 2035.

Fluid Identities

People shift between multiple selves (professional, personal, digital) more easily. Work resorts have further elevated into wellness sanctuaries and purpose-driven community hubs.

Community-Led Resilience Movements

As trust in national institutions wanes, local communities will emphasize autonomy and resilience, focusing on local food supply (vertical farms), micro-grids for energy, and community-based disaster response in the face of frequent climate shocks.

Body in Motion

Health, nutrition and micro-recovery are becoming more and more important for people. Physical and digital interfaces could be shaping bodily awareness.

The Rise of Digital Tribes and Contested Reality

People will increasingly seek comfort and validation in online "identity silos," reinforcing belief systems and creating a deeply polarized media environment. Trust in major institutions (government, media, science) will continue to be highly variable.

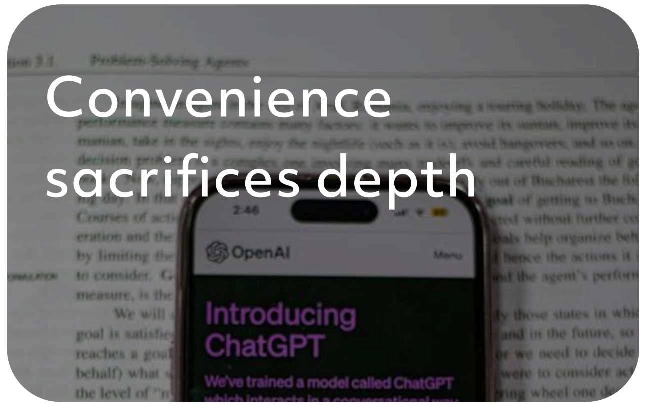
3.3 Clustering

After gathering and critically reviewing the final selection of context factors it was time to start searching for relations between these factors. In the end we could define ten clusters that describe the findings in the future context. There is overlap in which clusters contain what factors, but this is only logical, as most factors are very much in relation to each other.

Shaped by institutional and social pressures, the individual often loses their agency to the overwhelming demands of the collective.

Evolution thrives on inequality, but the resulting "progress" demands a constant, critical look at who is being sacrificed to sustain it.

Driven by connectivity, the world is evolving into a single city-nation, necessitating a move toward centralized, unified governance.

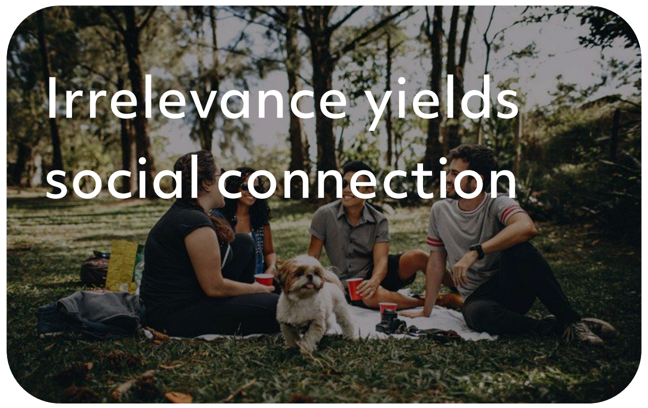


Hyperconnectivity automates our thinking and erodes individual authenticity, resulting in social isolation disguised as constant digital presence.

As automation frees us for self-discovery, universal abundance results in a life of partial satisfaction without true fulfillment.

We use nature-inspired tech to transcend human limits and engineer the endurance we naturally lack.

Hyperconnectivity isolates us, but crisis activates our empathy—transforming systemic distrust into authentic human solidarity.



Automation replaces traditional work with social freedom, driving our evolution toward a more unified, collective humanity.

Hyper-surveillance transforms data into a tool of "digital communism," where the fight for trust and autonomy defines the modern human experience.

To survive the rise of AI, humanity must resolve its competitive paradox and trade individual identity for a unified, collective discipline.

3.4 Demographics of 2040 Air Travelers

This chapter focuses on defining the future user by identifying the key demographic and generation-specific shifts in 2040. By analyzing the evolving expectations and luxury needs of generations such as Gen Alpha, Z, and Y, the foundation is laid for an inclusive design that responds to the diversity of the future air traveler.

RQ 2.2 *Which different demographics compose the future air travelers in 2040?*

"For Gen Alpha, technology and commerce are just part of daily life —integrated into how they learn, play, and connect." - PWC-Gen Alpha Survey Report

Gen Alpha

Born: 2010-2024
16-30 years old in 2040

Gen Alpha will be a highly tech-savvy, diverse, and environmentally conscious generation, **growing up with advanced AI, immersive technologies,** and a globalized worldview, with a focus on sustainability and digital connectivity.

Gen Z

Born: 1997-2009
31-43 years old in 2040

Gen Z will be a diverse, tech-immersed, and socially conscious generation, leading in innovation, sustainability, and **digital entrepreneurship** while navigating a rapidly evolving global economy.

Gen Y

Born: 1981-1996
44-59 years old in 2040

Gen Y (Millennials) will be a highly educated, career driven, and tech integrated generation, **balancing family life and work** while shaping industries through their focus on sustainability, digital innovation, and social values.

Gen X

Born: 1965-1980
60-75 years old in 2040

Gen X will be a **key leadership generation**, balancing career advancement, financial stability, and family life while guiding the transition to new technologies and shaping societal norms around work and retirement.

Boomers

Born: 1945-1964
76-95 years old in 2040

Boomers will largely be a retired generation, focusing on health, legacy, and wealth transfer, significantly influencing caregiving industries and intergenerational financial dynamics

3.5 Future Vision

Cluster Relations

The set clusters form relationships within the established domain. It is necessary to analyse these relations in order to establish the framework of the future vision scenarios.

RQ 1.2 *What will the passengers of the future look like?*

The found relations between the clusters and thus the factors are visualised in the framework. In short, we can distinguish:

Cohesion and Profoundness (top)

- Digital alienation is healed by crisis-driven empathy
- Irrelevance yields social connection

Sacrificing and Divergence (bottom)

- Competition drives costly human progress
- The desire for data-driven control erodes trust

Trust and Consensus (right)

- External power shapes a compliant, fluid self
- Connectivity requires centralized order
- Cooperation demands discipline, identity resists unity

Strive and Aspire (left)

- Techno-fixation on nature's solution
- Convenience sacrifices depth
- Freedom unlocks discovery, not necessarily fulfillment

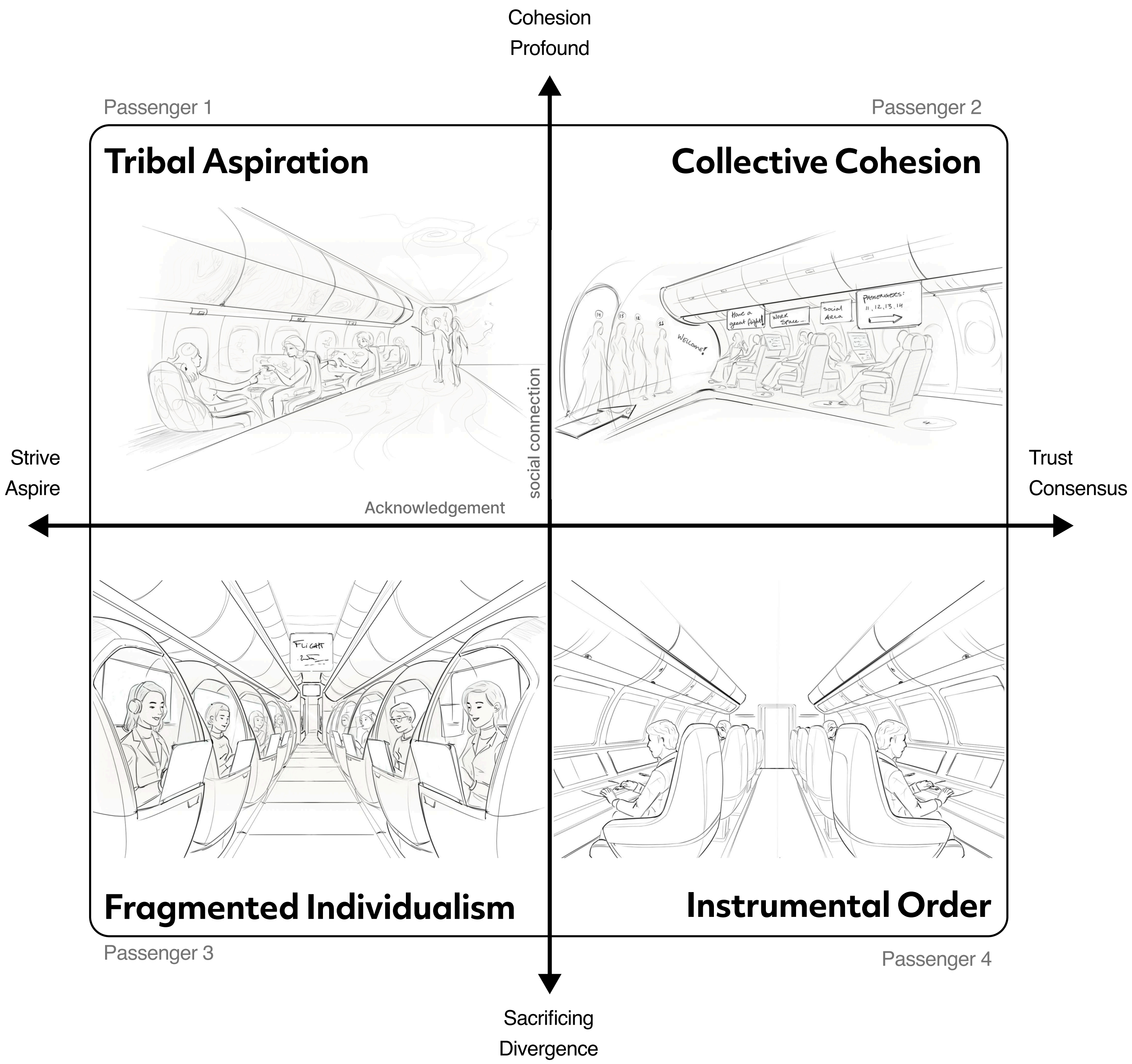


fig.25 Future Vision framework axes

Framework Axes

Two axes were established for a relatively simple framework, in which all clusters logically fitted. After long deliberation, also with help from experienced ViP method users, the following behaviour was found:

Cohesion / Profoundness vs. Sacrificing / Divergence

A strong feeling of **collectivism** and profound **social connection** versus **growing apart** and an erosion of trust.

This axis addresses the question of whether future travel will focus on profound, shared experiences and connectedness, or whether passengers will be forced to make individual sacrifices and diverge (e.g., in space or comfort) in favor of economic and efficiency requirements.

Trust / Consensus vs. Strive / Aspire

Complete **trust** and consent towards external powers and **cooperation** versus the pursuit of **fulfillment** and personal **acknowledgement.**

This axis questions whether society will be characterized by collective trust and consensus (for example, on climate technology and data use), or by a culture of aggressive ambition and competition to gain priority, luxury, and status.

By selecting these two independent and influential areas of tension, four distinct and plausible future scenarios are created, which form the basis for the strategic framing of the design assignment.

3.5.1 Framework Focus

Tribal Aspiration

Strong social bonds, tribe-feeling and profound purpose meet an appetite for expressive, surface-level experiences. Societies emphasize belonging and identity through curated communities and ritualized consumption; people crave depth but often get aspirational, designed experiences that look and feel meaningful (techno-nature aesthetics, curated empathy moments). The world mixes nature-inspired technological fixes with social rituals that make people feel “part of something”.

Design goal: Create a cabin experience that nurtures belonging and health-consciousness through the perception of organic flexibility.

Experience quality: Symbolic connection, ritualized interaction, natural resonance, emotional depth beneath shared experiences.

Key design principles:
- Use materials and lighting that feel alive (organic textures, dynamic ambiance).
- Design spatial layouts that reinforce togetherness without forcing communication.

Validation criteria:
- Reported feelings of belonging and emotional calm.
- Passengers identify themselves as part of a “shared story.”
- Increased positive peer interactions without explicit social pressure.

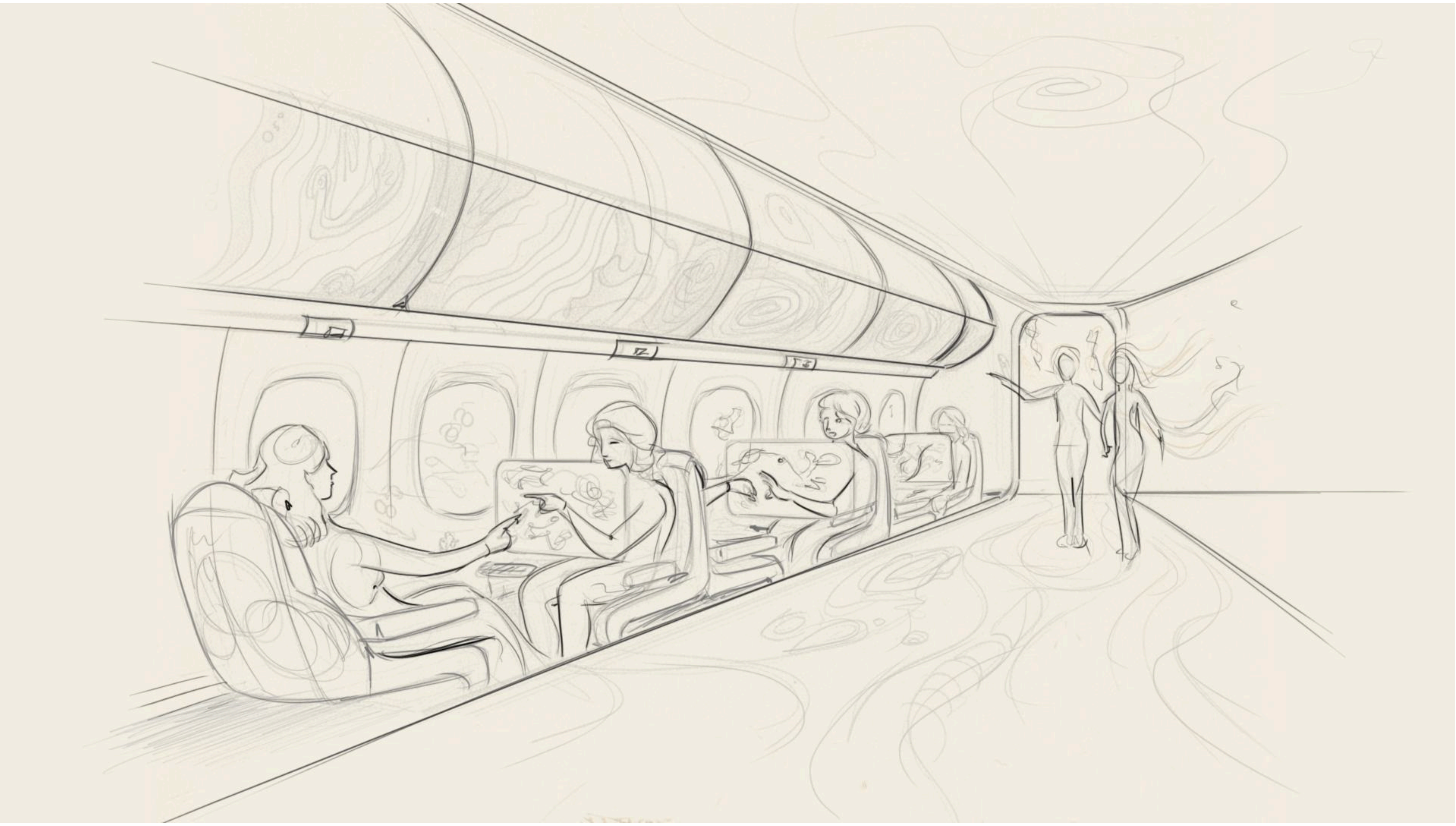


fig. 26 Sketch of the future vision scenario ‘Tribal Aspiration’. (Sketch was developed with the help of Gemini)

3.6 Mission Statement

I want people to experience air travel as a state of effortless flow. A moment where movement feels natural, supportive, and free from friction. Within this world, technology quietly anticipates needs so passengers can shift fluidly between focus, rest, and reflection without interruption or decision. I want people to feel empowered by trust, to let go of control without losing agency, and to sense that the cabin moves with them rather than around them.

Through this, air travel becomes not a pause between destinations, but a living part of one's personal rhythm, a seamless extension of everyday life that restores rather than drains.

In 2040, we want leisure air travellers to:

experience air travel as a state of ***effortless flow***

and we want to provide:

a sense that the ***cabin moves with them*** *rather than around them*

3.7 Human-Product Interaction

Interaction Analogy

Imagine a multi-generational, "luxury mountain retreat center" where several families or small groups are staying together for a week.

The people have different interests, but a shared goal. Everyone is there for rest, rejuvenation, and personal growth, but in their own way. They are located remotely on top of a mountain, completely isolated from external stimuli.

The space nurtures belonging without forcing. The design invites connection but doesn't demand it. The feeling is one of "Simultaneous Solitude and Shared Presence." You are deeply engrossed in your private activity (working, sleeping, meditating), yet you are constantly and subtly aware of the calming, non-intrusive presence of others pursuing their own peaceful goals in the same beautiful, resonant space.

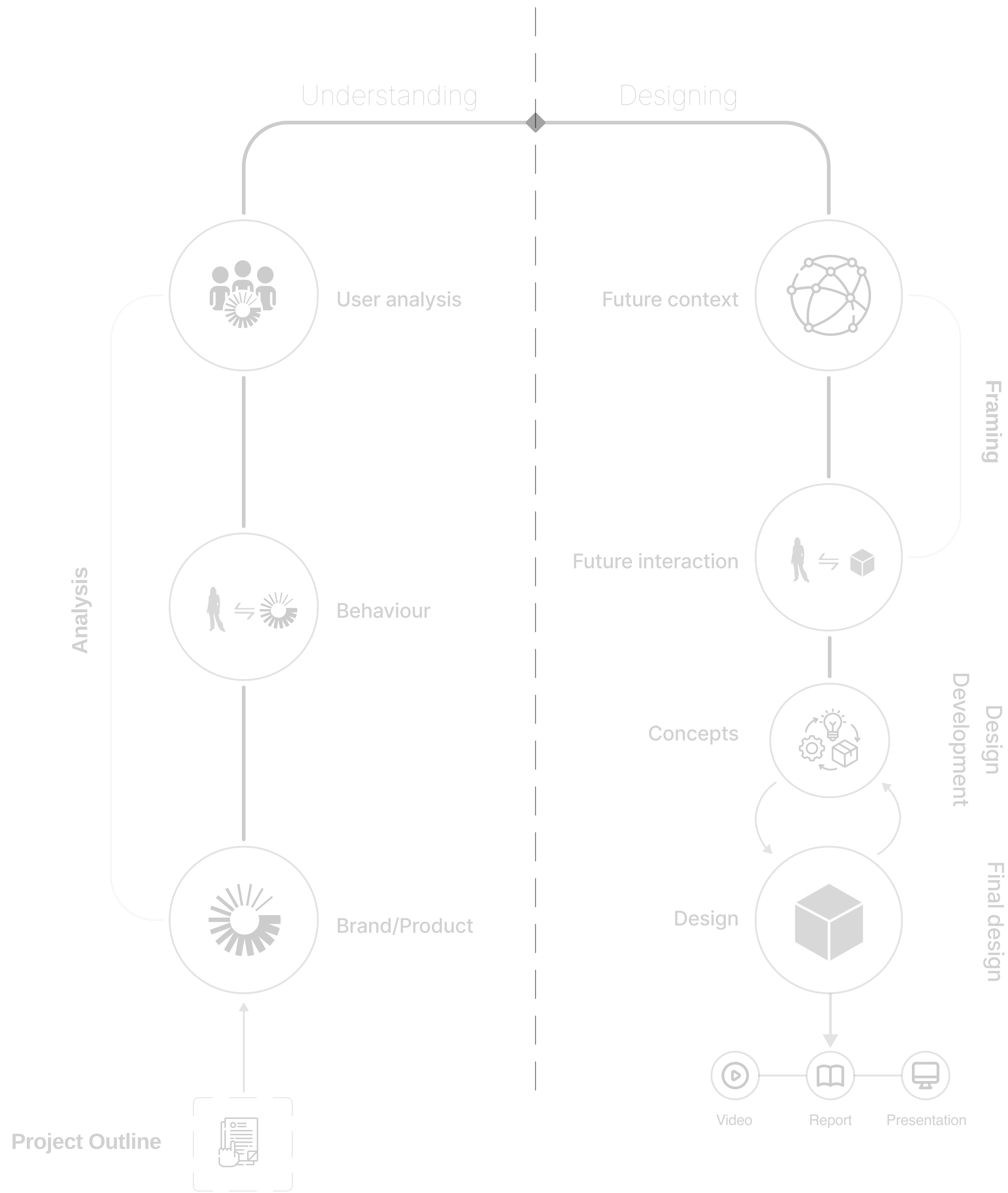
fig.27 Visual representation of the interaction analogy: luxury mountain retreat center. (This image was generated by Gemini)

3.8 Conclusion

The Framing phase converted the results of the analysis into a clear and strategic design mandate for 2040. By applying the ViP methodology, the collected context factors were translated into two fundamental, uncertain latent tensions, from which four distinctive future scenarios were defined. From the synthesis of these scenarios, the Tribal Aspiration vision emerged as the most relevant and desirable framework, as it best aligns with the deep-rooted passenger desire for authenticity, well-being, and a sense of connection, combined with the possibility of privacy. This vision is made concrete by the strategic mandate to define a new ‘Comfort Class’, also known as the ‘Business Down’ concept. In doing so, Framing has successfully transformed an abstract, future uncertainty into a dual design goal: an experience-oriented goal (Simultaneous Solitude & Shared Presence) and a product-oriented goal (an economical, comfortable, and efficient seating concept for SAAs). The project focus has thus been narrowed, and the Design Development phase is now strategically substantiated and ready to generate concrete concepts.

4 Design Baseline

This chapter establishes the Design Baseline, synthesizing the visionary research and human-centric insights from the previous sections into a definitive design mandate. It anchors the speculative 2040 vision in the technical reality of the Airbus A321XLR, outlining the spatial constraints and regulatory requirements that serve as the fundamental parameters for the subsequent ideation phase.



4.1 The Single-Aisle Long-Haul Paradigm

To navigate the transition from current aviation constraints to the speculative landscape of 2040, this research uses the Airbus A321XLR as the primary technical and dimensional reference point. Although the design process strives for revolutionary cabin experiences, anchoring the concept development in a proven, high-quality narrowbody aircraft ensures that the proposed innovations remain within the realm of credible engineering for the next generation of aircraft.

Airbus A321XLR Reference

The selection of the A321XLR is predicated on its status as the current vanguard of single-aisle evolution. Traditionally, narrowbody aircraft were confined to short-to-medium-haul missions. However, the A321XLR has disrupted this dichotomy by offering a range of up to 4,700 nautical miles, enabling flight durations exceeding 10 hours.This shift introduces a critical "experience gap":

- Physiological Stress: Passengers are confined in a narrower cross-section (3.70 meters) for durations previously reserved for widebody aircraft (5 meters+).
- Operational Strain: Crew workspaces (galleys) and lavatory ratios designed for 3-hour hops are now stretched to accommodate full-service long-haul missions.
- Tribal Dynamics: The "shared presence" in a narrowbody cabin over 10 hours intensifies the need for privacy and movement.

Reference Airline: American Airlines A321XLR LOPA

While several carriers have ordered the Airbus A321XLR (see Appendix F for the LOPA of each airliner), the American Airlines (AA) configuration has been selected as the definitive Layout of Passenger Accommodations (LOPA) reference for this thesis. This choice is based on three strategic factors: market leadership, operational range, and the existing industrial partnership with the project client, Collins Aerospace.

As the first U.S. carrier to operate the A321XLR (designated as the "32Q"), American Airlines is a pioneer in the "long-thin" route strategy. Their deployment of this aircraft on transcontinental routes (e.g., JFK to LAX) and upcoming transatlantic missions (e.g., JFK to Edinburgh) provides a real-world dataset for flights nearing the 10-hour mark. This aligns perfectly with the research focus on extended-duration narrowbody travel, where traditional cabin comfort reaches its physiological limit.

fig.29 American Airlines Airbus A321 XLR.

Configuration Details

The American Airlines A321XLR LOPA (20J / 12W / 123M) serves as the volumetric starting point for this research. A critical observation derived from this layout (as illustrated in Figure 28) is the asymmetrical distribution of service infrastructure:

- Front Galley Loading: The forward galley is dedicated almost exclusively to the 20 Business Class ("Flagship Suite") seats. This creates a high-touch, premium service zone with a high crew-to-passenger ratio.
- Rear Galley Overburden: Conversely, the remaining 135 passengers (Premium Economy and Main Cabin) are serviced entirely from the rear galley. This results in an unequal distribution of labor and physical movement, as crew members must navigate the entire length of the narrow aisle to reach the midpoint of the cabin.

American Airlines
Airbus A321 XLR
LOPA

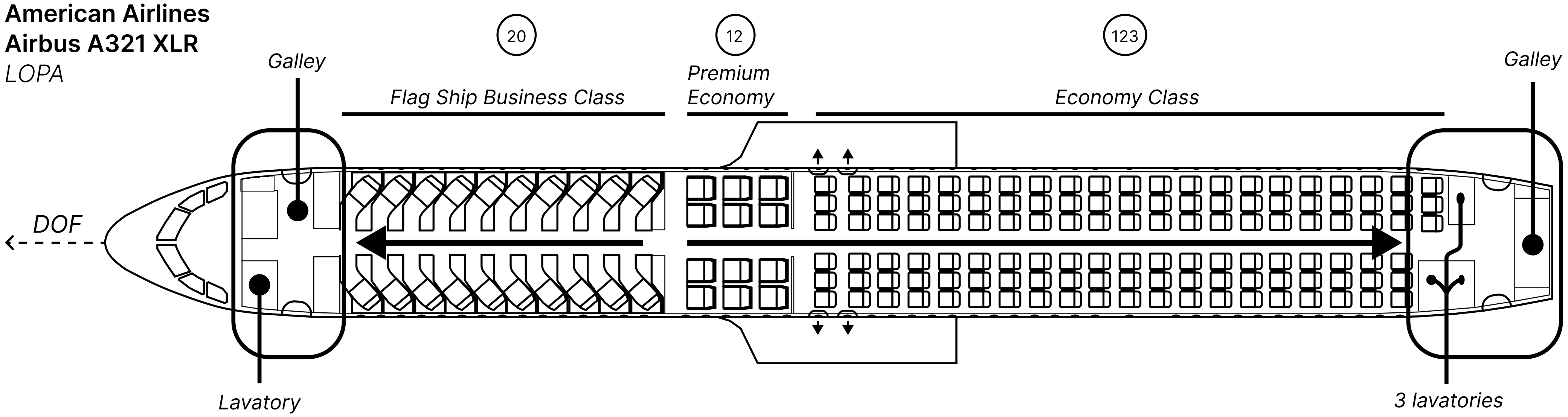


fig.28 American Airlines Airbus A321 XLR Layout of Passenger Accommodations.

Spatial Constraints and Dimensional Framework

While widebody cabin solutions provide a useful benchmark for long-haul comfort, this project focuses specifically on the Next Generation of Single-Aisle Aircraft (SAA) for ultra-long-haul missions. The following parameters define the design scope:

- Reference Aircraft Type: The primary focus is the Airbus A321XLR (or Neo). It is critical to note that while the length of this airframe has been extended to accommodate more fuel and passengers, the fuselage width remains identical to the original A320 family.
- Design Implications: All development must occur within this narrow, fixed cross-section. Every design decision must balance the high-density requirements of a narrowbody with the physiological needs of a 10-hour flight.
- Operational Efficiency: A key constraint is the maintenance of Fast Turnaround Times. As identified in Chapter 2, "Boarding & Disembarking" remains the primary bottleneck for SAA operations. Therefore, any revolutionary cabin layout must facilitate, rather than hinder, the rapid flow of passengers and crew to meet the economic requirements of the client, Collins Aerospace.

Fuselage Cross-Section and Volume

The primary spatial constraint is the standard narrowbody fuselage cross-section of 3.70m (12ft 2in). Although the 2040 successor to the A321XLR may utilize advanced composite materials to optimize internal volume, the outer diameter is assumed to remain constant to maintain aerodynamic commonality.

Implication: This width dictates the maximum limit for any of the future concepts. Any attempt to increase passenger density or comfort must be solved through volumetric efficiency within this fixed 3.70m envelope.

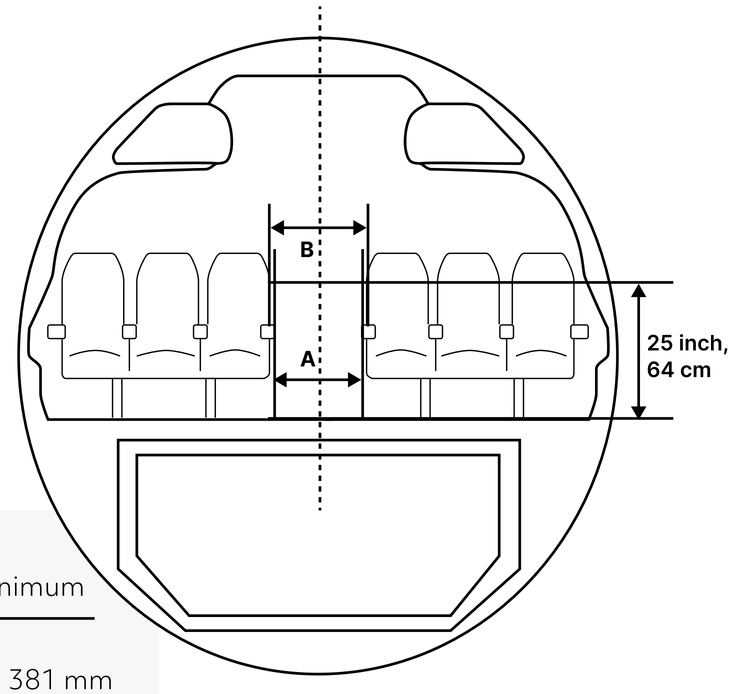
Payload-Range and Weight Optimization

A critical factor for the viability of long-haul single-aisle missions is the weight-to-efficiency ratio. The design assumes that by 2040, advancements in propulsion and structural weight reduction will allow for the integration of modular cabin elements, such as the 3-zone crew workspace, without compromising the 10-hour flight capability established by the A321XLR.

Regulatory Aisle Requirements

The cabin layout must adhere to FAA safety specifications regarding egress and crew movement. Federal regulations (e.g., 14 CFR § 25.815) specify minimum aisle widths based on passenger capacity to ensure rapid evacuation.

- Capacity Category: Given that the A321XLR successor operates in the category of 20 or more passengers, specific minimum widths apply.
- Dimensional Limits: The design must maintain a minimum aisle width of 381mm (15in) at heights below 635mm (25in), and 508mm (20in) at heights above that threshold.
- Operational Goal: While these are the legal minimums, the design development will aim to exceed these during boarding phases (as discussed in Chapter 2) to resolve the "Boarding & Disembarking" bottleneck, without compromising the 3.70m cross-section during flight.



Number of seats	A minimum	B minimum
<10	12 inch, 305 mm	15 inch, 381 mm
11-19	12 inch, 305 mm	20 inch, 508 mm
>20	15 inch, 381 mm	20 inch, 508 mm

fig.30 Minimum aisle width for different aircrafts (Oduyoka, n.d.)

4.2 Design Principles

This section establishes the foundational design principles and technical requirements necessary to translate the visionary 2040 mission into a tangible cabin environment. By integrating Professor Peter Vink's ergonomic comfort thresholds with stringent aviation safety regulations, these parameters provide the analytical framework for the subsequent development of the modular seating ecosystem and spatial layout.

Seat & Anthropometry

In multiple studies, Vink demonstrated that if an airline has a fixed amount of extra space to give, increasing seat width (e.g., from 17" to 18") yields higher comfort scores than increasing seat pitch (legroom). Width allows for more postural variation, which is critical for reducing fatigue (Vink, 2023).

A seat width of 18 inches is identified as a critical threshold. Below this, shoulder and elbow collision significantly increases discomfort. Above this, passengers report significantly better sleep and relaxation.

Vink also found that the shape of the seat shell is more important than the thickness of the foam. A well-contoured hard shell can be more comfortable than a flat, thick cushion because it distributes pressure more evenly.

Passenger Activities & Behavior

- Activity-Based Design: Comfort depends on what the passenger is doing.
- Dining: Requires an upright posture (90°).
- Resting: Requires a reclined posture (120°+).
- Sleeping: Current economy seats fail here. Vink's research shows that the inability to raise legs or lie flat is the number 1 inhibitor of deep sleep.

Privacy vs. Socializing

According to Peter Vink's principles, comfort is significantly influenced by a passenger's control over their social environment. For 10-hour single-aisle missions, the design must balance two conflicting needs:

- Individual Privacy: Solo travelers require visual and acoustic shielding to achieve "Simultaneous Solitude". This is facilitated by space-efficient s-shape cocoons that provide personal territory.
- Social Connectivity: Families and couples, primary demographics for the A321XLR, often find fixed seating that prevents facing each other a major complaint. The 2040 ideation addresses this through a social spine, a neutral zone that facilitates "Shared Presence" without encroaching on private areas.

Service & Hygiene

The Hygiene Baseline: In an analysis of 10,000+ trip reports, Vink found that if a cabin is perceived as "dirty" (crumbs, stains), passengers will rate the physical seat comfort lower, even if the seat is brand new.

Crew Interaction: "Friendly crew" is a significant variable in the comfort equation. Positive social interaction can mitigate minor physical discomforts (e.g., "The seat was tight, but the crew was lovely").

Requirements

Minimum Aisle Widths

FAA regulations state a minimum aisle width of 381mm (15") below 64 cm height, and 508mm (20") above that, for aircrafts with more than 20 passengers. For this ideation, an aisle width between those values - 17" (or 43 cm) - was used for ease and speed of placement.

Seating angles

Regulations by the FAA dictate a maximum variation from the DOF of 18°. These maximum angles were used during ideation, however further regulations regarding reversed seating were not yet considered in detail.

Lavatories

Following Peter Vink's principles of reducing passenger stress, the lavatory count must be optimized for long-haul density. On a 10-hour mission, a standard narrowbody ratio (often 1:50 or higher) leads to "aisle dwell time" and discomfort. For the 2040 "Comfort Class," a ratio closer to widebody standards (approximately 1:35) is required to ensure physiological well-being and prevent congestion in the 3-zone workspace.

Galley capacity

For a long-haul flight of this duration, the aircraft must typically accommodate two full meal services plus snacks and beverages.

A standard A321 configured for long-haul missions requires approximately 10 to 14 full-size equivalent (FSE) trolleys to store meals, waste, and duty-free goods (Jeff Mckee, 2025).

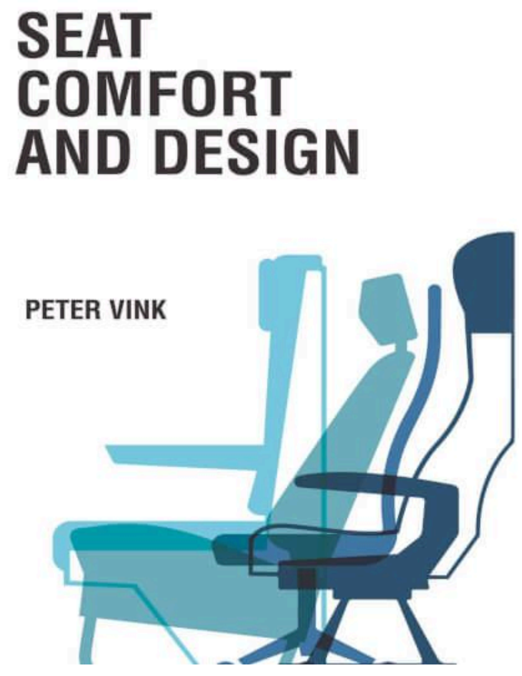
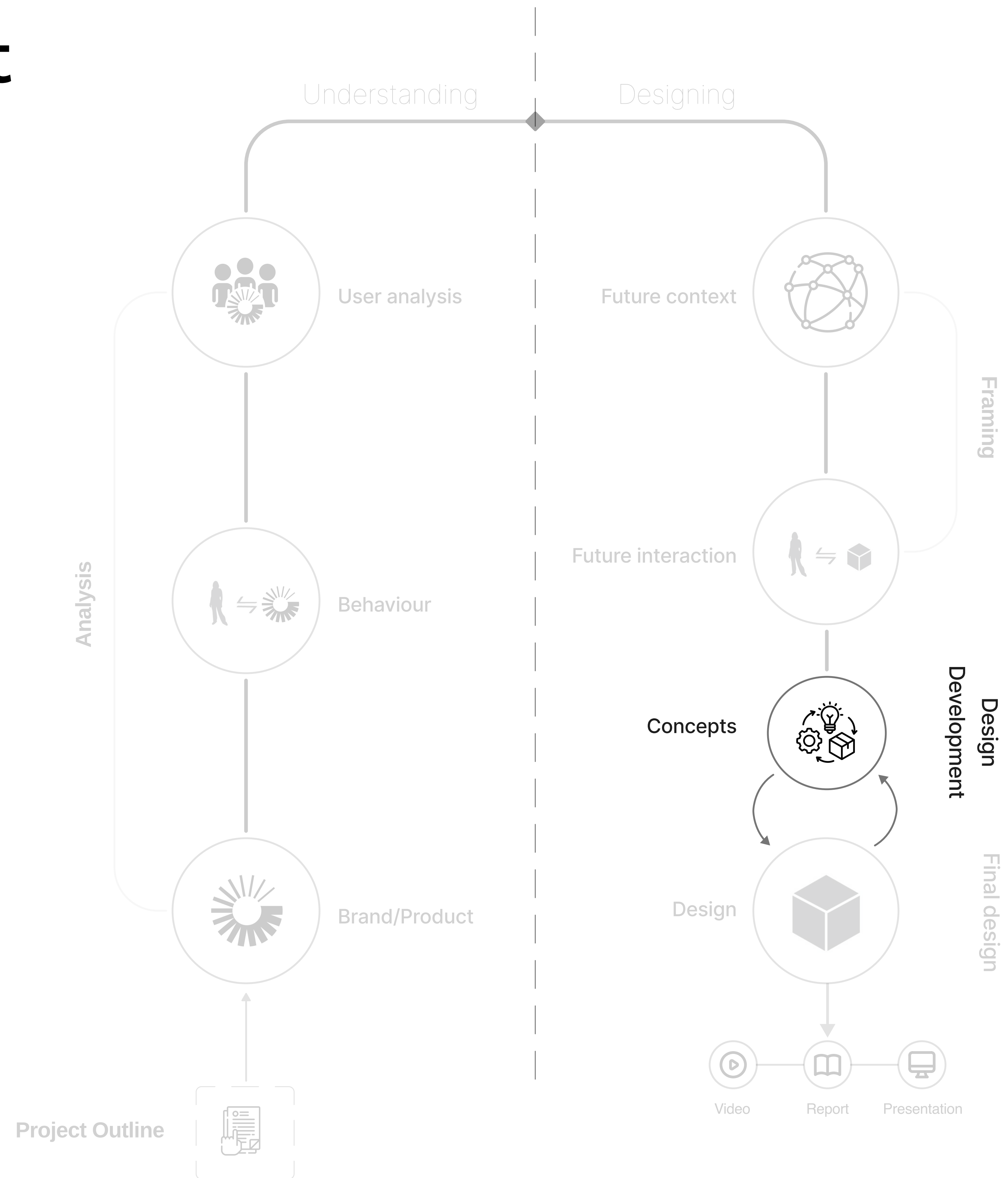


fig.31 Peter Vink's book, Seat Comfort and Design, 2023.

5 Design Development

This chapter documents the design development and ideation phase, where the visionary redefinition of air travel is converted into tangible, technically grounded cabin solutions. By narrowing the project focus through a series of brainstorming methodologies, this section bridges the gap between abstract future scenarios and a commercially viable design mandate.

1. Start of the Ideation phase
2. Cabin Architecture
    - Cabin Workspace
    - Luggage Compartments
    - Lighting & IFE
3. Passenger Flow
4. Seating Concepts
    - Concept 1: The Hammock Cocoon
    - Concept 2: The "Hybrid Flex" Class
    - Concept 3: A Modular Ecosystem
    - Seat Concept Selection
5. Design Proposal
    - Floorplan Foundation
    - Modular Seating Foundation



5.1 Start of the Ideation Phase

The idea phase marks the transition from theoretical research and parametric frameworks to the creation of tangible design solutions. This process began with an extensive exploratory sketching phase, based on the Delft Design Guide (2013), to develop interior concepts that align with the refined mission. By systematically exploring different directions, the earlier “Zen Mountain Lodge” vision was translated into concrete physical design possibilities.

The goal of this phase was to transform the vision into a new aircraft zone that responds to an unexplored market segment. In doing so, rough ideas were brought together in design directions that bridge the gap between traditional Business Class and Premium Economy.

By applying these structured methods, the idea phase rose above random creative impulses. The result is a strategic “Business Down” product that meets both the requirements of the technical lead, Jeff McKee, and the needs of the future leisure traveler.

Ideation Areas

Given the vast scale and multifaceted nature of the aircraft interior, the ideation process has been subdivided into three strategic pillars. This categorization ensures that every aspect of the passenger journey, from structural integrity to individual rest, is addressed with technical precision and design clarity.

The three identified ideation areas are:

1. **Cabin Architecture:** This area focuses on the structural "bones" of the interior, including the positioning of monuments, the strategic layout of zones, and the integration of luggage compartments.

2. **Passenger Flow:** Here, the focus shifts to circulation and movement. This pillar addresses the spatial dynamics of the boarding process and the necessity for fluid in-flight movement, such as walking and stretching.

3. **Seating Systems:** The final pillar centers on the passenger's immediate interface. It explores the kinematics, restorative ergonomics, and modular configurations of the seats themselves to fulfill the design mandate.

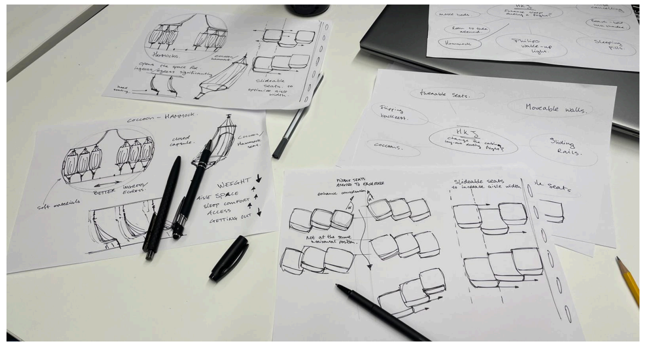


fig.32 Me making sketches during the Ideation phase

Brainstorming Methodology: The 'How To' Method (HKJ)

To translate the "Zen Mountain Lodge" vision into tangible solutions, the 'How To' method was applied to generate design opportunities for the new future class. This structured brainstorming technique reframes research conclusions into actionable design challenges, allowing for both macro-level floorplan ideation and micro-level functional solutions.

The brainstorming focused on three primary pillars derived from the 2040 vision:

1. **How to create privacy?** Focuses on achieving Simultaneous Solitude. By utilizing space-efficient seat shells, the layout provides individual 'territory' for solo travelers without the exclusionary footprint of a full-flat suite, fostering a sense of calm within the shared environment.
2. **How to promote movement?** Explores the 3-zone workspace and "Social Spine" to alleviate rear-galley congestion and encourage passenger circulation during 10-hour flights.
3. **How to create spaciousness?** Addresses the 3.70m width constraint by utilizing vertical tiering and visual comfort principles to break the narrow "tube" perception of the cabin.These "How To's" served as the bridge between the high-level future scenarios and the realistic, commercially relevant product requested by Jeff McKee.

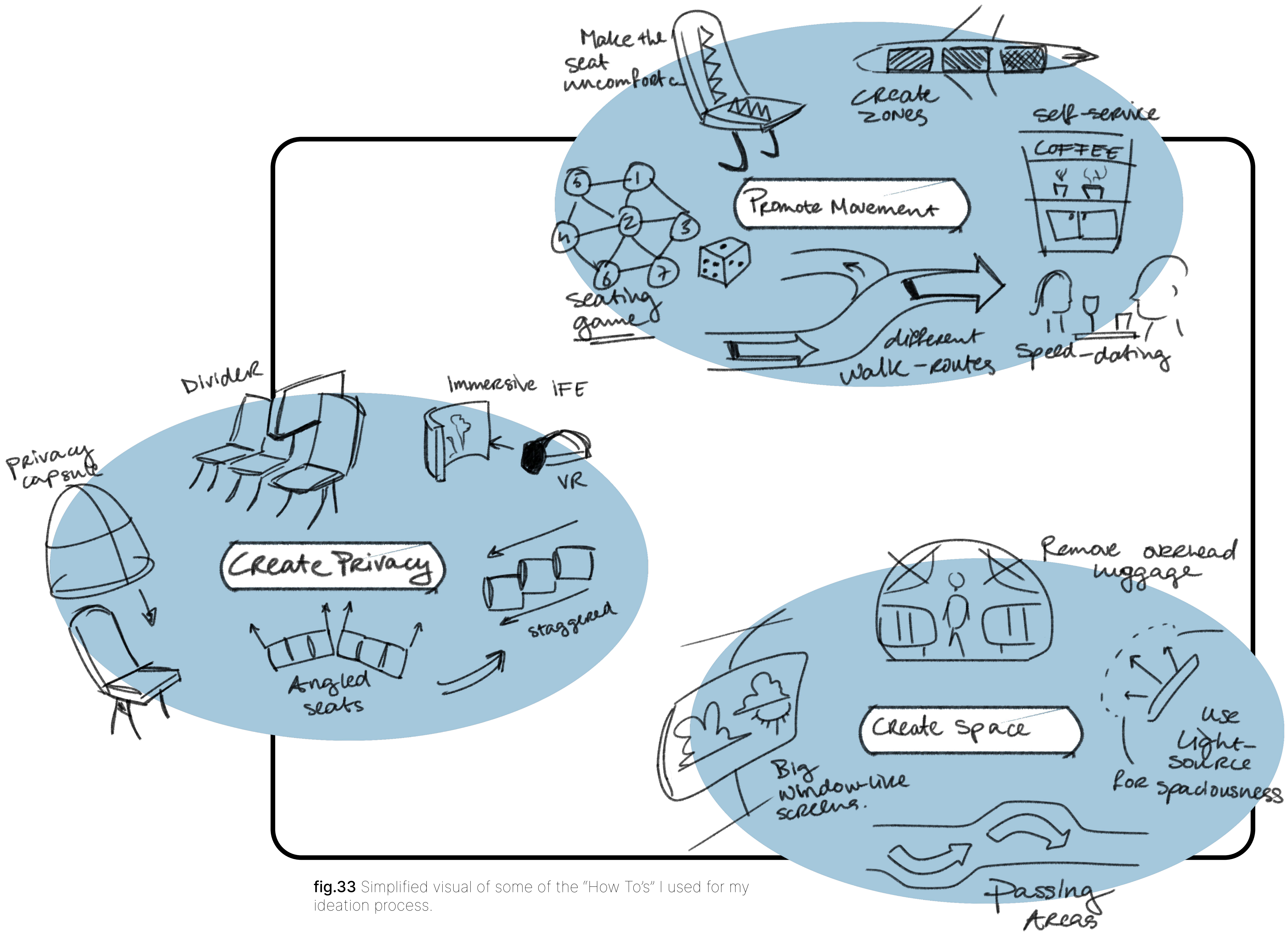


fig.33 Simplified visual of some of the "How To's" I used for my ideation process.

VR Testing

To bridge the gap between initial sketching and technical 3D modeling, I integrated Virtual Reality (VR) as a tool within my iterative design process. In the complex environment of aircraft cabin design, relying solely on 2D drawings and screens can be limiting. By utilizing VR during the early ideation phase, I was able to immerse myself in the environment at a 1:1 scale, allowing for an immediate and intuitive understanding of volume, reach zones, and passenger sightlines.

This immersive approach proved valuable not only for rapid prototyping but also for concept selection. By virtually walking through different layout iterations, I could objectively evaluate how each configuration influenced the cabin's flow and the feeling of personal territory. This high-fidelity feedback loop allowed me to move beyond theoretical assumptions and select the most promising design directions with confidence before proceeding to detailed development in Blender.

fig.34 Me using VR for the ideation phase evaluation.

5.2 Cabin Architecture

The Cabin Architecture chapter examines the core structural and infrastructural elements of the 2040 interior, specifically focusing on the reimagining of cabin workspaces, the strategic management of luggage compartments, and the immersive integration of lighting and In-Flight Entertainment (IFE) systems. By shifting from a conventional "one-size-fits-all" layout to a strategically zoned environment, this section explores how decentralized service distribution and sensory optimization can enhance both operational efficiency and passenger well-being within the narrowbody cross-section.

Current Airplane Distribution

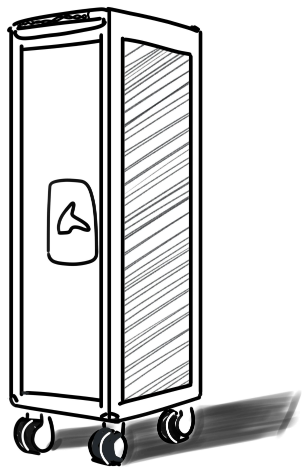
A critical observation of American Airlines' cabin distribution reveals a significant asymmetry in service infrastructure. The forward galley is utilized almost exclusively for the 20 premium seats, while the remaining 135 passengers rely entirely on the rear galley for service (meeting Jeff McKee, 2025). This imbalance forces crew members to navigate the entire length of the single aisle to reach the midpoint of the cabin. This results in frequent "aisle-lock" and operational bottlenecks that hinder both service efficiency and passenger movement during 10-hour missions.

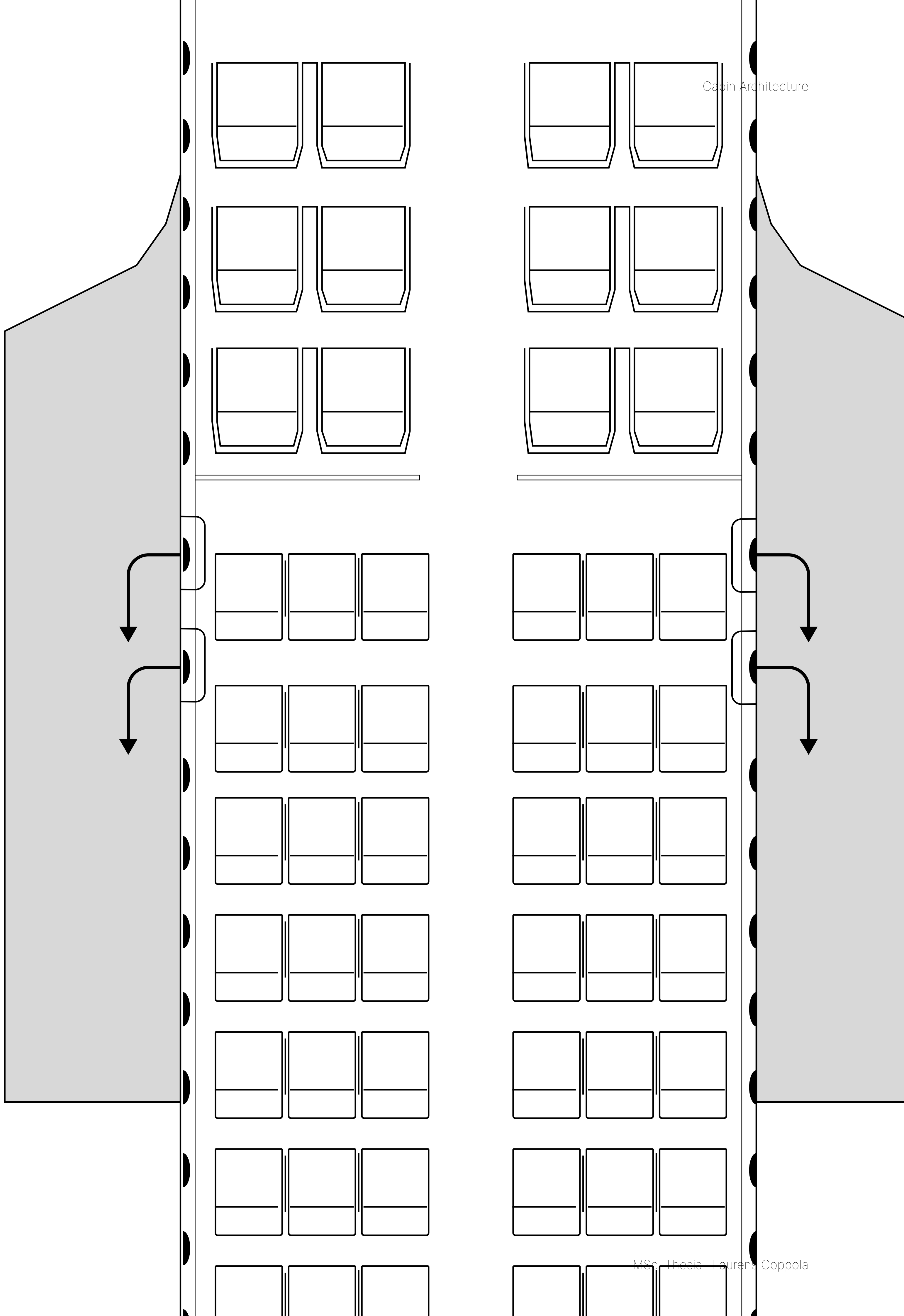
Cabin Crew Workspace

In contemporary commercial aviation, crew workspaces are centralized in forward and aft galleys, designed as high-density hubs for meal preparation and service logistics. These areas have strictly standardized hardware specifications, containing specialized inserts such as convection ovens, coffee brewers, water boilers, and trash compactors. The primary storage component is the Full-Size Equivalent (FSE) trolley, which is secured in dedicated "dead-load" compartments during takeoff and landing. And in these workspaces you can find the crew jumpseats.

Trolley Count

To sustain passengers throughout a 10-hour long-haul flight, the aircraft architecture must accommodate the logistics for two full meal services in addition to snacks and beverages. Meeting these operational demands for a standard A321 requires a storage capacity of approximately 10 to 14 full-size equivalent (FSE) trolleys, which are essential for housing meals, managing waste, and storing duty-free goods.





5.2.1 Cabin Workspaces

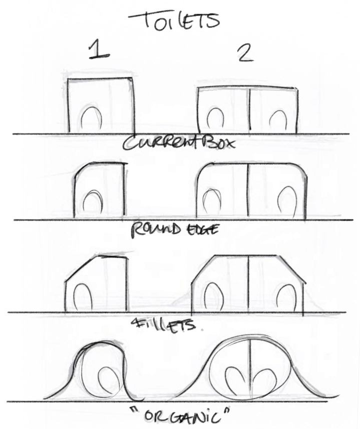
During the ideation of a 3-zone workspace, a consultation with Jeff McKee provided critical steer for refining the operational logic of the floorplan. Rather than treating the forward, middle, and aft sections as isolated pockets, McKee recommended viewing the aircraft as a single connected system. This systemic approach requires a deep consideration of the flow of people, specifically how cabin crew navigate the narrow single-aisle and how passengers with reduced mobility (PRM) access essential facilities.

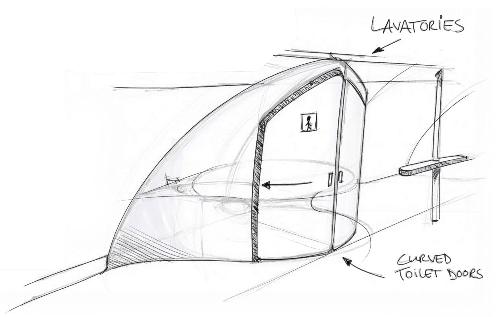
By breaking up traditional galleys and introducing decentralized service nodes, the design facilitates better accessibility for PRMs by reducing the travel distance to lavatories from any point in the cabin. Furthermore, this shift challenges the traditional service model; instead of relying solely on heavy, full-length trolley runs that block the aisle, the broken-up galley structure enables flight attendants to adopt more agile service methods. This refinement directly addresses the boarding and disembarking bottleneck while aligning with the technical requirement for a realistic, commercially viable product for 2040.

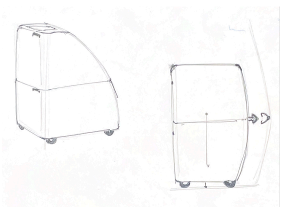
Centralized Logistics

To validate the feasibility of the decentralized Social Spine, a volumetric audit was performed against the baseline of the American Airlines A321XLR. While the AA configuration centralizes 135 passengers around a single rear galley, the 2040 layout redistributes the service load across three nodes.

To ensure Catering Credibility for a 10-hour mission, I designed modular point-of-use storage units that accommodate the required 10 to 14 full-size equivalent (FSE) trolleys. This shift not only reduces cabin crew fatigue; it mathematically halves the maximum service distance for flight attendants, directly addressing the operational burden identified in the analysis phase.







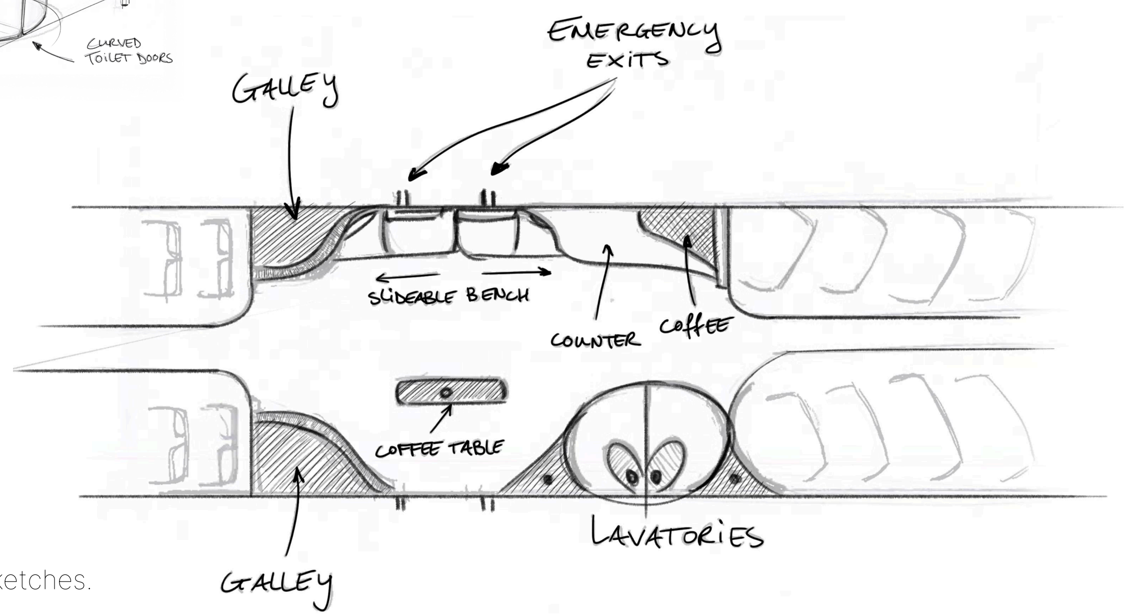


fig.35 Lounge sketches.

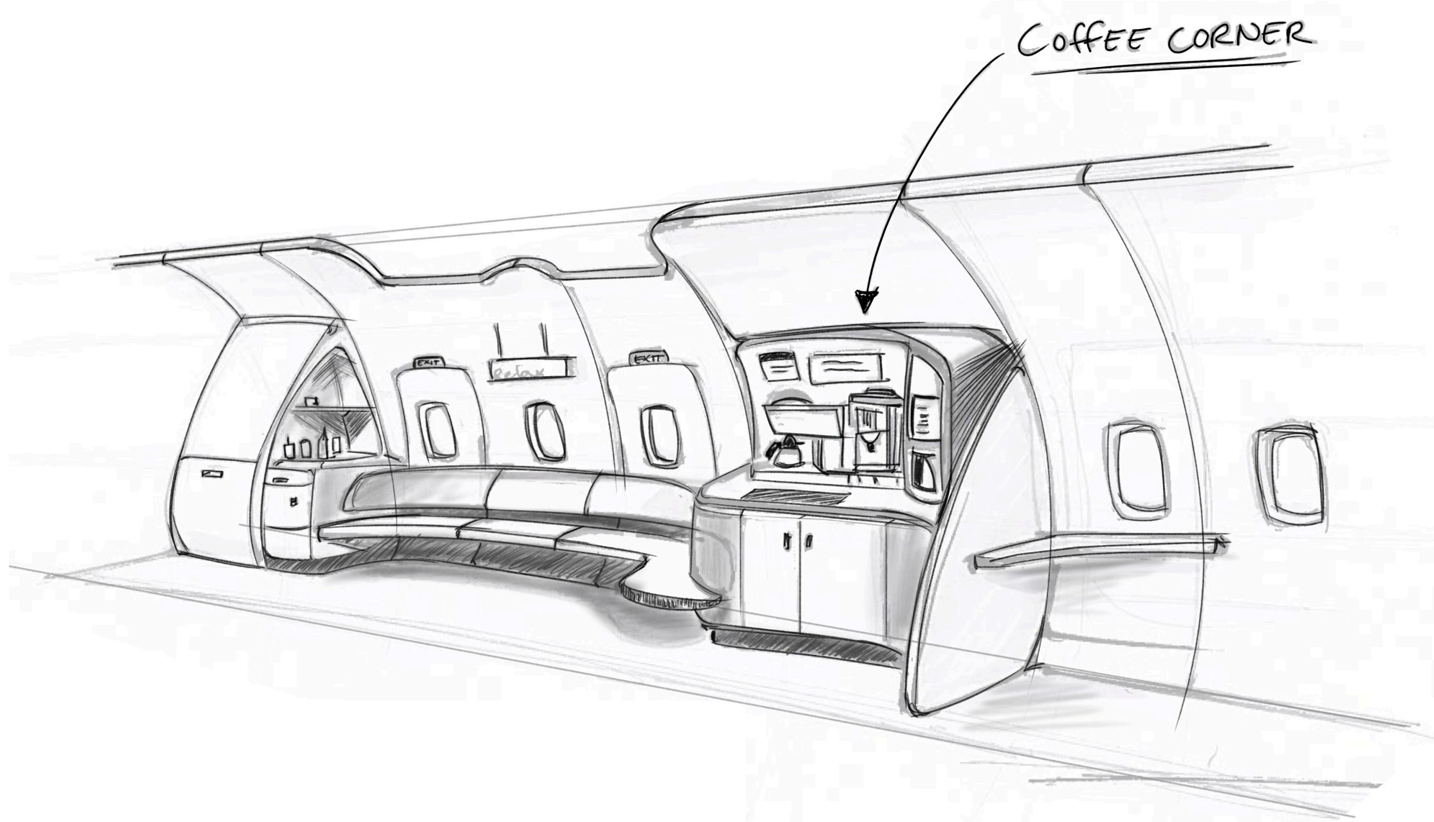


fig.36 Frames from my historic analysis. They show lounge areas in airplanes in the 70s.

Lounge

The reintroduction of a dedicated lounge area shifts the cabin from a seat-centric model to a holistic, experience-driven environment. Historically a luxury staple now lost to high-density layouts, the 2040 lounge serves a dual purpose: a social hub for interaction and a kinesthetic relief zone for stretching and movement. By integrating this into the framework, we democratize access to restorative spaces. This intervention disrupts the traditional rigid grid, transforming the cabin into a dynamic landscape that prioritizes both social connection and physical well-being for all passengers.

Acoustic Zoning

A core innovation in the 2040 cabin is the transition from traditional class-based seating to Acoustic Zoning: Quiet Zone, Relax Zone and the Social Zone. By aligning the floorplan with a natural "noise gradient," the cabin architecture manages the psychological complexity of long-haul travel without spatial conflict. This strategy acknowledges the technical reality that the rear of a single-aisle aircraft is naturally noisier due to engine and aerodynamic wind noise.

5.2.2 Luggage Compartments

The optimization of boarding and turnaround times, identified as a critical bottleneck within the industry, is inextricably linked to the management of carry-on baggage. The current paradigm of storing luggage in overhead bins is a major contributor to the boarding bottleneck: passengers blocking the aisle while lifting their suitcases into the overhead compartments collectively cause significant delays.

To address this, the ideation phase explored radical alternatives that redefine baggage storage while aligning with the third "How To" objective: creating a more spacious and pleasant sense of space.

Exploring Overhead Bin Removal

A key design strategy for 2040 is the removal of traditional overhead luggage compartments. Eliminating these bulky structures significantly increases the vertical volume of the cabin, directly contributing to the vision of a light, open, and soothing interior experience. This opening of the ceiling also enables the implementation of new ideas such as a digital skylight, which would otherwise be impeded by standard luggage compartments.

However, this shift requires a fundamental repositioning of hand luggage: a solution that remains accessible to passengers but is no longer visually and spatially disruptive.

Under-Seat Storage

Relocating luggage to the space beneath the seat is a solution frequently explored in futuristic transit designs, including high-speed hyperloop concepts, due to its efficiency in lowering the center of gravity and keeping belongings within the passenger's immediate reach. In the context of a comfort class narrowbody, traditional under-seat storage is often hampered by tight pitch and the physical difficulty of bending down in a restricted footprint.

To solve this, the ideation phase explored two "Aisle-First" storage directions:

Lateral Aisle Access: Rather than pushing luggage forward under the seat from a seated position, the seat base is designed with a lateral opening. This allows passengers to slide their standard carry-on bags into a secure compartment directly from the aisle during the boarding process. This prevents the "aisle block" because the passenger does not need to enter the seat row to store their bag.

Mechanical Assistance (Strap/Sled Mechanisms): To assist with the ergonomic challenge of retrieving bags from a low position, a strap-based or sliding sled mechanism was ideated. This allows the luggage to be pulled out toward the aisle or the passenger's feet, ensuring that even in a high-density configuration, accessibility is maintained without physical strain.

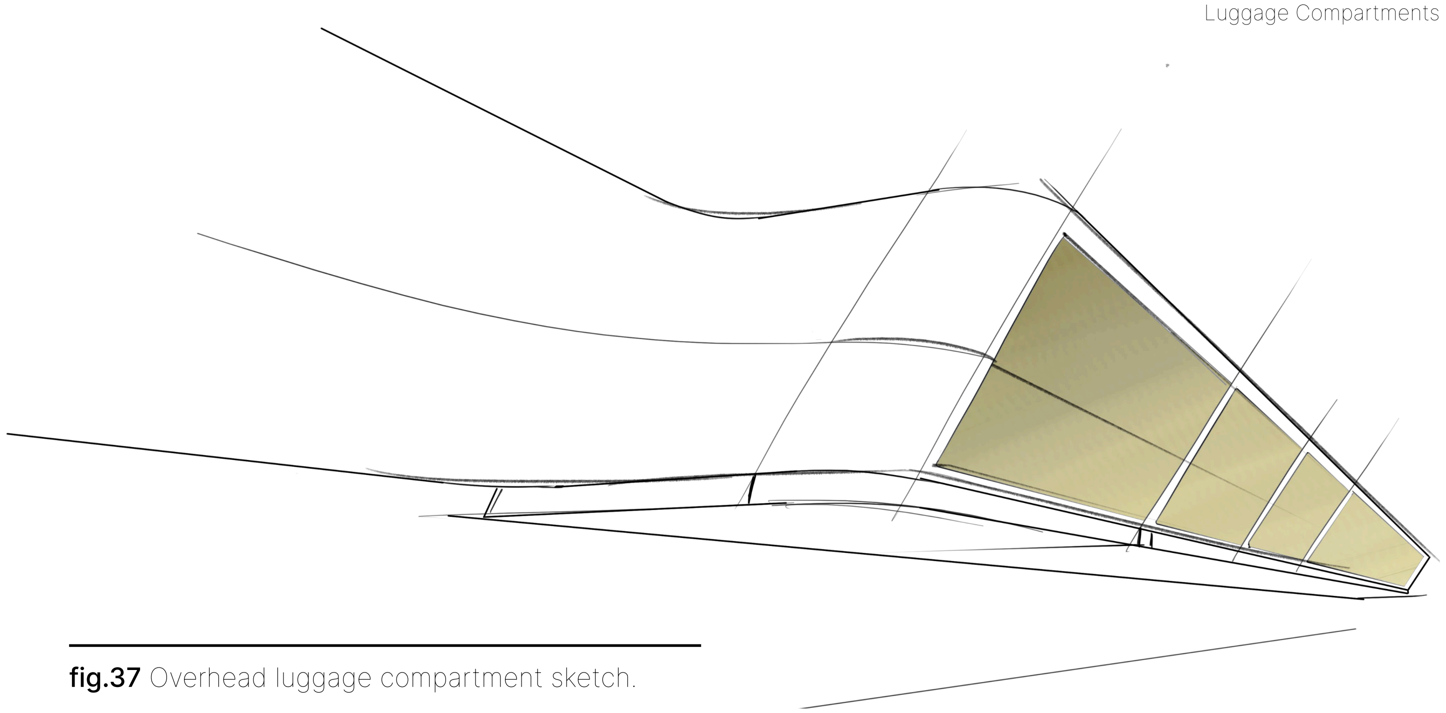
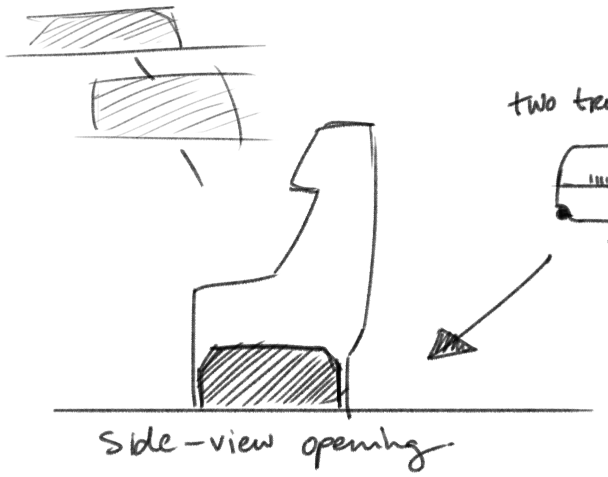
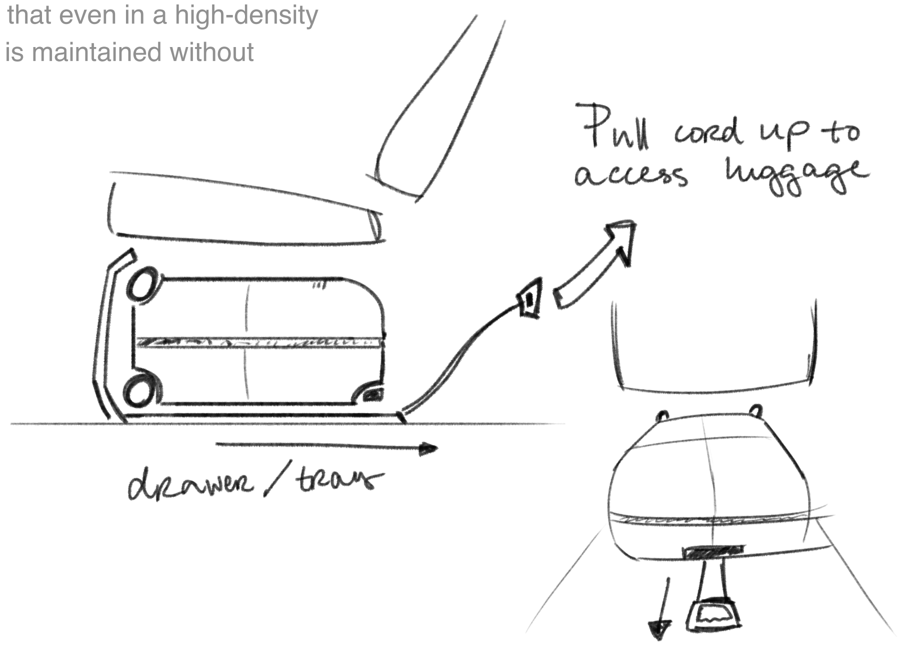


fig.37 Overhead luggage compartment sketch.

Strategic Implications for Storage

Reflecting on the "complexity-versus-efficiency" challenge, the initial investigation into under-seat storage revealed significant ergonomic and technical hurdles within the high-density footprint of a single-aisle cabin. Due to these spatial constraints and the potential for increased mechanical failure, it was determined that maintaining overhead luggage compartments is the most feasible approach to ensure commercial viability. While conventional lateral bins remain the baseline, this project identifies an opportunity to reimagine their placement to better facilitate passenger flow. If future architectural iterations explore a multi-aisle configuration, a central overhead luggage compartment could be implemented to allow for simultaneous access from both sides. This potential direction would target the "aisle-lock" bottleneck identified in the analysis phase while respecting the "conservative complexity" required for aerospace certification.





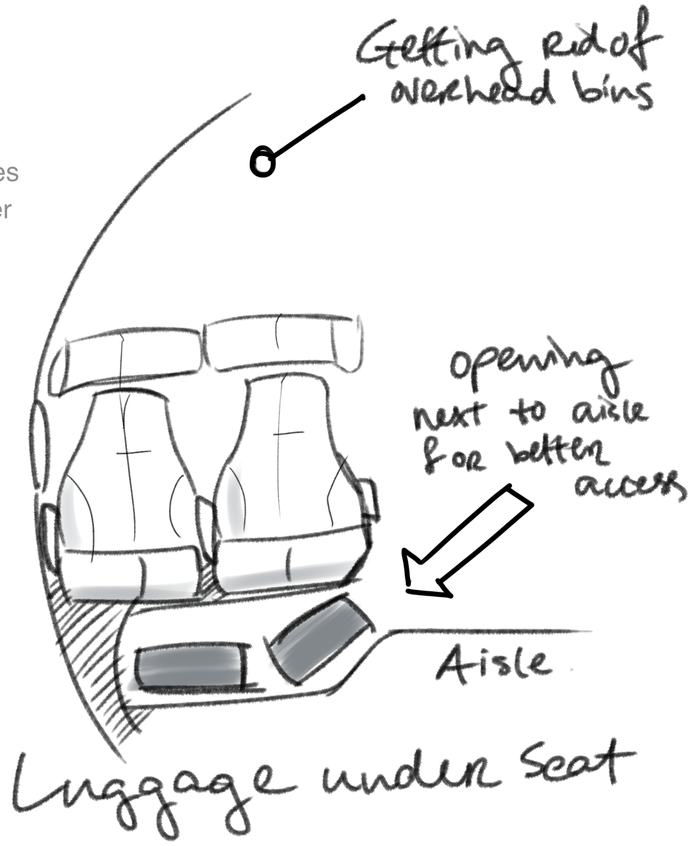


fig.38 Luggage compartment exploration sketches.

5.2.3 Lighting & IFE

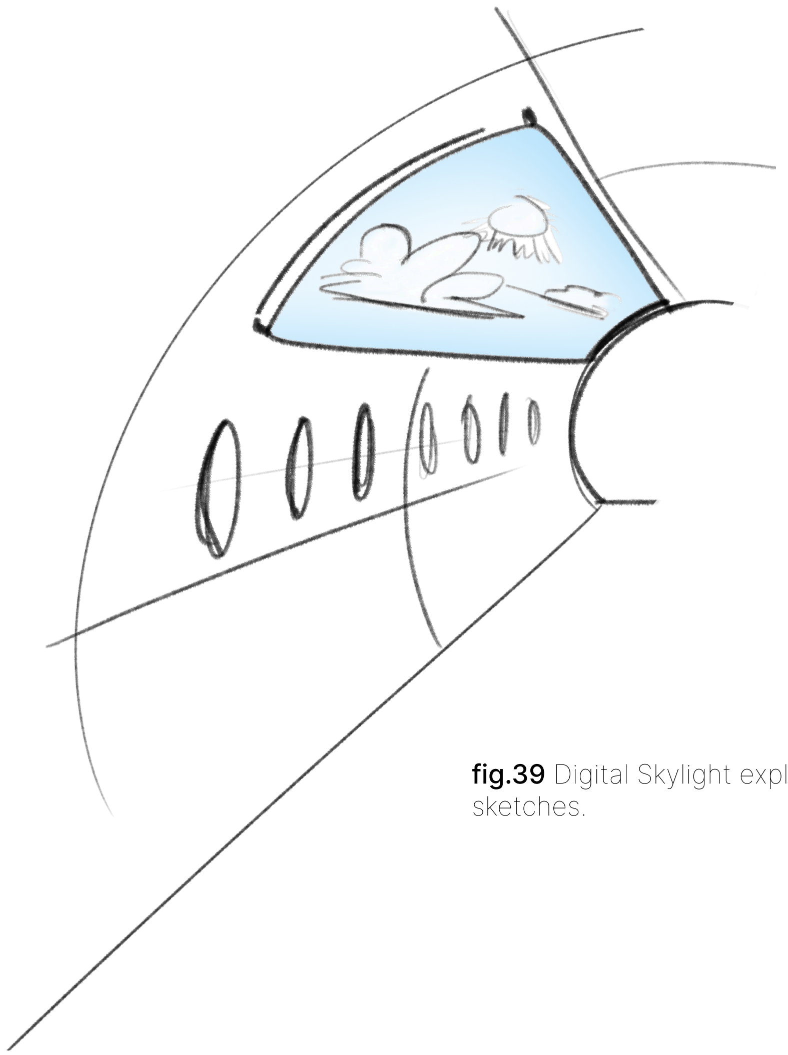
This section of the interior ideation focuses on the sensory environment, specifically through lighting and In-Flight Entertainment (IFE). To tackle the spaciousness design challenge, the design leverages emerging display technologies to overcome the physical limitations of the narrow A321XLR fuselage.

The Digital Skylight

An important technological development for the future is the possibility of replacing or supplementing traditional cabin walls with high-definition screens. Although a fuselage without physical windows would offer structural and weight advantages, the A321XLR baseline requires the retention of real windows.

To overcome this limitation, the design utilizes the vertical space freed up by relocating the overhead luggage compartments. Installing “Digital Skylights” directly above the existing window openings creates a more expansive visual horizon. These screens can display razor-sharp exterior images, subtle sky gradations, or landscapes that match the flight's destination.

This vertical extension effectively breaks through the perception of the narrow tube shape of the cabin, making the space feel considerably wider and more connected to the outside world.



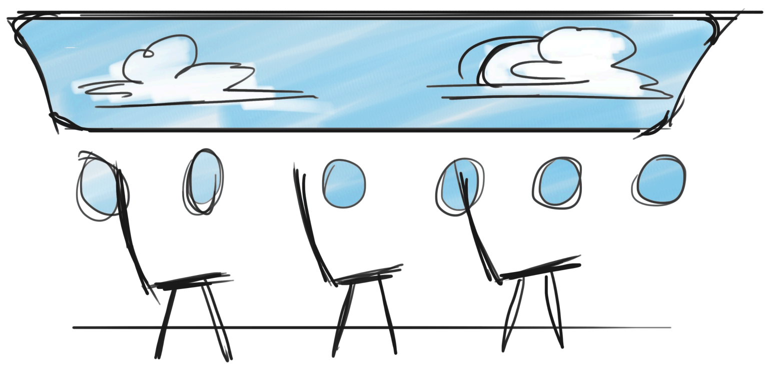


fig.39 Digital Skylight exploration sketches.

In the aft section of the aircraft, the digital window concept is extended to the ceiling. Because this area is designated as the high-activity Social Zone, the ceiling is integrated with large-scale LED panels that mimic a skylight or an open canopy. By projecting a bright, open sky or subtle evening stars during "night mode," the design counteracts the natural tapering of the A321XLR’s rear fuselage. This prevents the back of the plane from feeling cramped or dark, ensuring the Social Lounge remains an inviting hub for interaction.

The IFE system is not treated as a standalone screen but as a part of the cabin’s lighting ecosystem. During rest periods, the digital windows and ceiling panels sync with the seat-side IFE to create a coordinated "night mode." This transition uses circadian lighting principles, shifting from energizing blue tones during service to warm, amber hues for sleep, to assist passengers in their physiological recovery. By integrating the IFE into the architecture of the cabin, the design moves toward a truly immersive environment that supports the holistic well-being of the 2040 traveler.

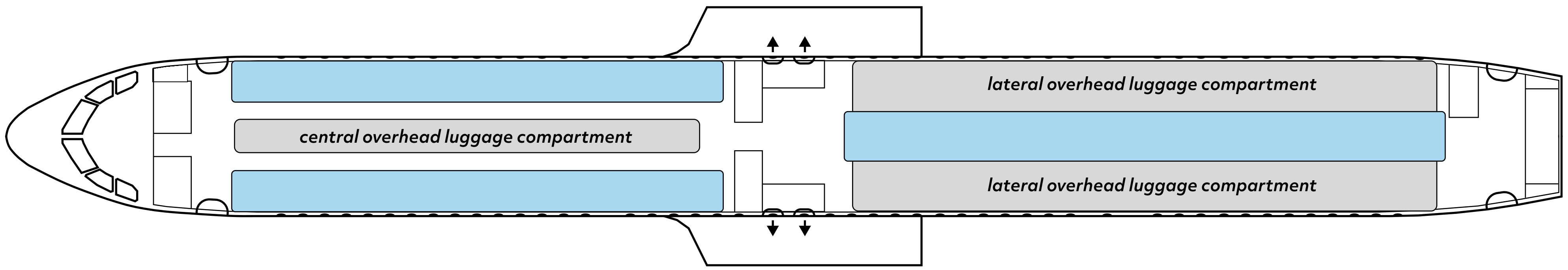


fig.40 Top view of luggage compartments and Digital skylight position.

5.2.4 Conclusion

The architectural foundation of the 2040 cabin moves away from a traditional "one-size-fits-all" layout toward a strategically zoned, 3-zone workspace characterized by a central distribution model. This systemic approach, refined through consultations with Jeff McKee, treats the aircraft as a single connected system rather than a series of isolated sections. By decentralizing service nodes, the design significantly enhances accessibility for passengers with reduced mobility (PRM) while enabling flight attendants to adopt more agile service methods that alleviate the "Boarding & Disembarking" bottleneck.

Central to this layout is the implementation of Acoustic Zoning, which utilizes the natural "noise gradient" of the narrowbody aircraft. Recognizing that the rear of the cabin is naturally louder due to aerodynamic and engine noise, the floorplan designates the forward section as a sanctuary for focus and rest, while the aft becomes the high-activity Social Zone. This zone is anchored by a dedicated lounge area: a multi-functional hub designed for socialization and kinesthetic relief that disrupts the traditional rigid seating grid.

Regarding baggage management, while radical under-seat and lateral-access storage concepts were explored to optimize turnaround times, the final design retains overhead luggage compartments to ensure commercial viability and manage technical complexity. To mitigate the "aisle-lock" caused by stowing bags, a hybrid approach is adopted: a dual-aisle forward configuration utilizes a central overhead compartment to streamline boarding, while the rear maintains standard lateral compartments.

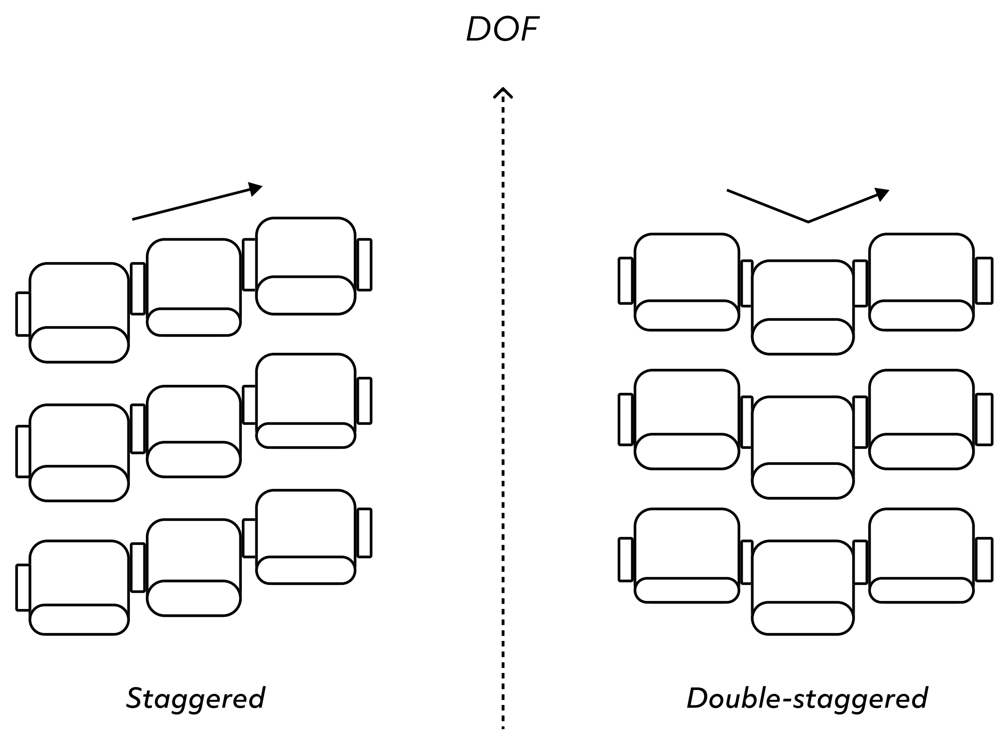
Finally, the sensory environment is optimized by fully integrating lighting and In-Flight Entertainment (IFE) systems into a singular cabin ecosystem. By utilizing emerging display technologies such as the Digital Skylight and circadian LED panels, the design effectively breaks the perception of the narrow tube airframe. This integration not only assists in the physiological recovery of the traveler through coordinated light cycles but also maximizes the perceived sense of spaciousness within the physical constraints of the A321XLR fuselage.

5.3 Passenger Flow

In the development of seating layouts for the 2040 narrowbody cabin, spatial accessibility is a critical driver for both commercial efficiency and passenger well-being. By rethinking the single-aisle architecture through the lens of ingress, egress, and in-flight mobility, the design aims to resolve long-standing operational bottlenecks.

Seating Orientation

The orientation of a seat relative to the Direction of Flight (DOF) is a critical parameter for passenger safety during takeoff, landing, and emergency deceleration. According to FAA regulations (14 CFR § 25.562), seats must be designed to protect occupants against head injury and spinal loading. Currently, the FAA generally limits the angle of a seat to a maximum of 18 degrees relative to the longitudinal axis (DOF) for standard certification. Orienting seats within this 18-degree envelope allows for "angled" or "herringbone" configurations that can improve legroom or privacy, but exceeding this limit requires complex and costly "side-facing" certification, which often involves additional restraints like airbags.



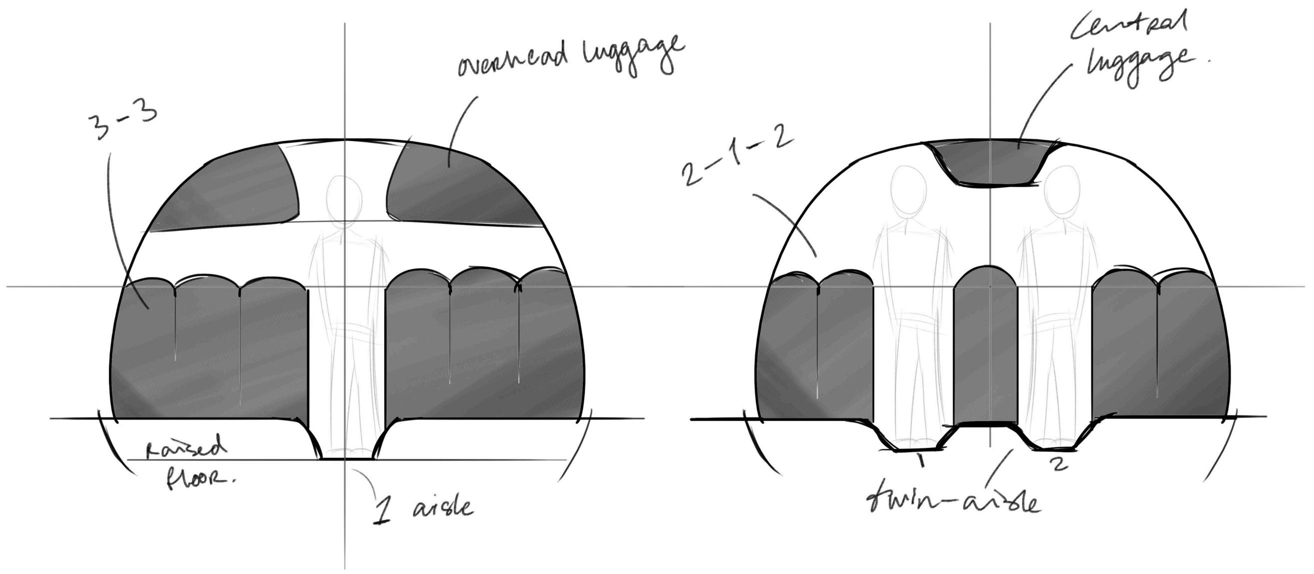


fig.41 Twin aisle exploration sketches.

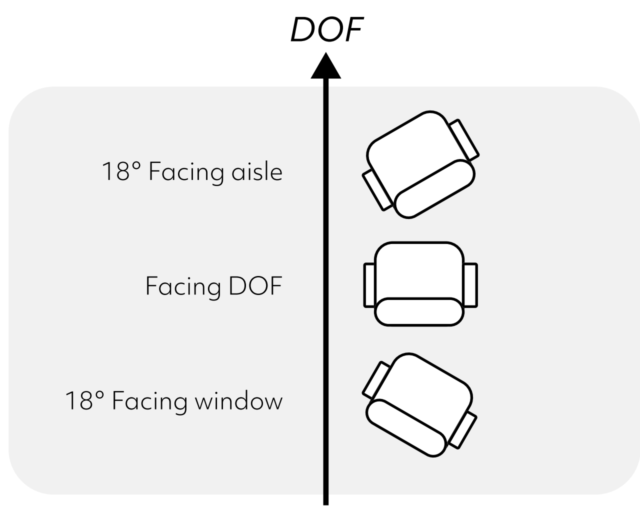
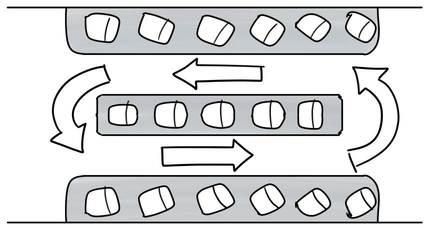


fig.42 Seating orientations.

Seating Configuration

While the conventional economy configuration (three seats placed abreast in a linear row) is the industry standard for efficiency, it often fails to meet the comfort requirements of a 10-hour flight. This ideation explores alternative configurations inspired by avant-garde aeronautical projects such as the TU Delft Flying-V.

A key area of exploration is the use of staggered seating. Unlike traditional rows where passengers are shoulder-to-shoulder, staggering the seats (moving the middle seat slightly forward or backward) creates additional lateral space and a greater sense of individual territory. This approach, validated by research into the Flying-V's cabin, demonstrates that even within a fixed fuselage width, rethinking the grid can significantly enhance the perceived spaciousness and ergonomic support for the passenger.



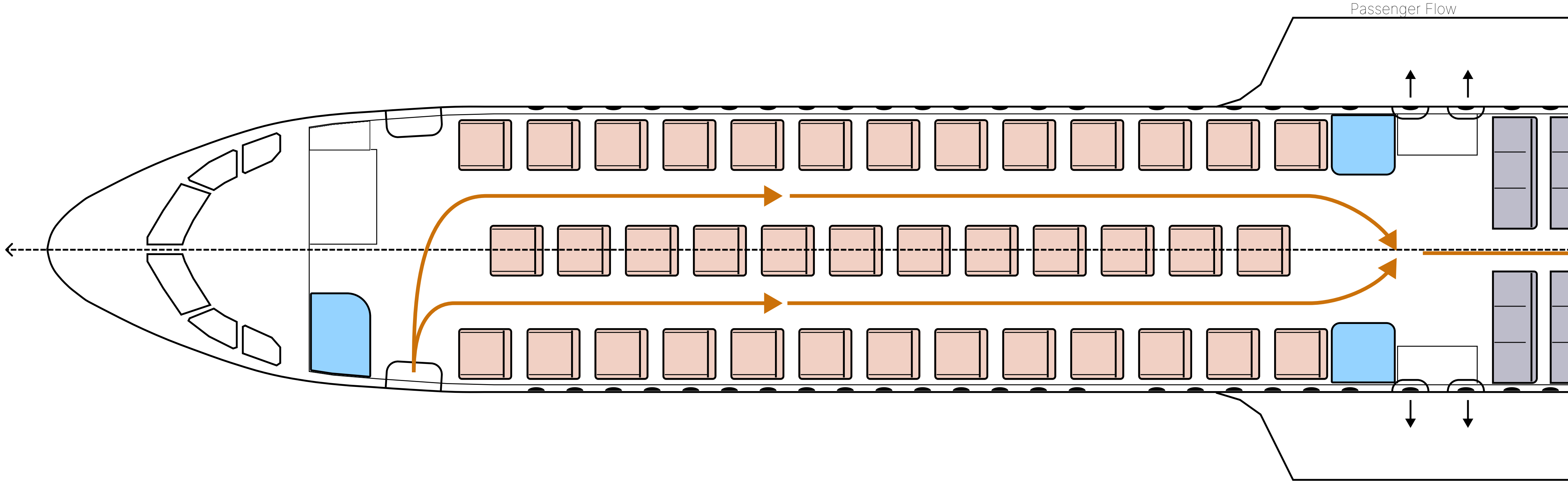
Boarding and Turnaround Efficiency

Research into the current air travel experience identifies boarding as one of the most significant pain points, characterized by high stress levels and operational delays. For airlines, optimizing ingress and egress time is vital to reducing **turnaround time**, which has a direct impact on profitability. For passengers, a congested boarding process sets a negative tone for the entire journey. To address this, the ideation phase involved exploring non-traditional layouts that move beyond the limitations of a single longitudinal aisle. By investigating twin-aisle configurations and dedicated **passing areas** within the A321XLR's width, the design seeks to allow passengers to stow luggage and take their seats without halting the entire flow of the cabin, thereby streamlining the transition from the gate to the cruise phase.

Economy Line-ups

The study began with a comparison of traditional and experimental economy configurations:

- 3-3 Configuration: The conventional industry standard which maximizes density but often leads to the "middle-seat" complaint and restricted lateral movement.
- 1-3-1 and 2-1-2 Configurations: These layouts were explored to increase the number of passengers with direct aisle access. By splitting the seat blocks, the cabin achieves a more open feel, though it requires precise management of the aisle width to remain within FAA safety minimums of 508mm.
- Staggered possibilities: Inspired by the TU Delft Flying-V research, these arrangements move seats out of a linear grid to create "shoulder-room" overlap, allowing for a more ergonomic fit within the curved fuselage walls.



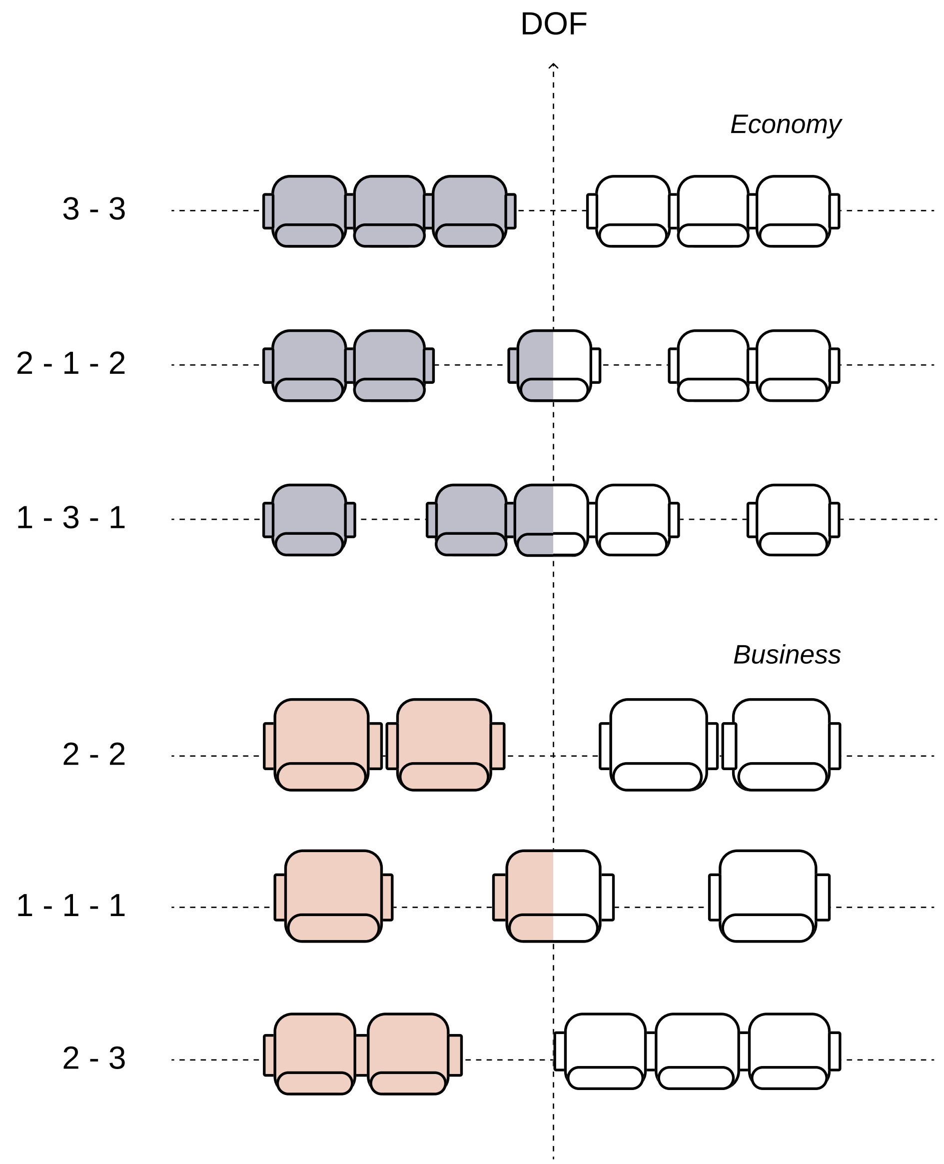


fig.43 Exploration of different seating line ups.

Premium and Business Class Line-ups

To provide more luxury in a more compact form, various premium layouts were evaluated:

- **2-2 Configuration:** A typical Premium Economy standard that provides wider seats but lacks the individual privacy required for the 10-hour "Zen Mountain Lodge" vision.
- **1-1-1 Configuration:** This "Flagship" inspired layout provides maximum privacy and direct aisle access for every passenger. The ideation focused on how a 1-1-1 layout could be implemented to bridge the gap between high-density economy and low-density business suites, offering a new experience within the technical "box" defined by the A321XLR dimensions.

fig.44 Boeing 707 with a 2-3 seating line up.

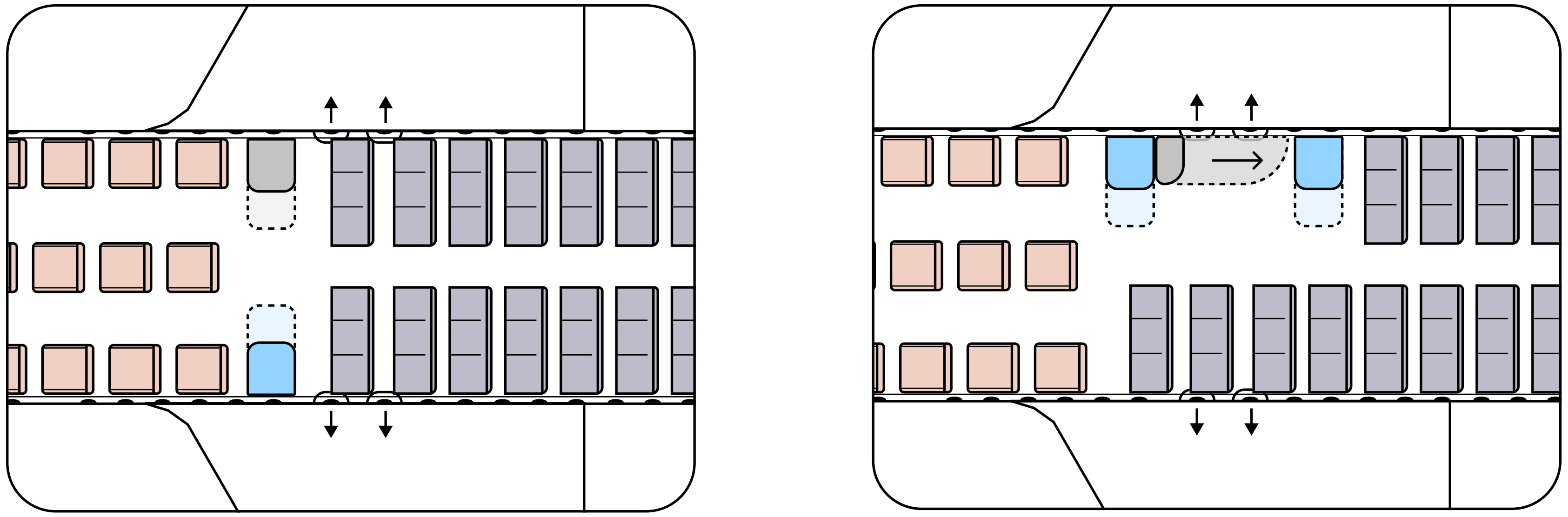


fig.45 Explorations of different set-ups of the central workspace.

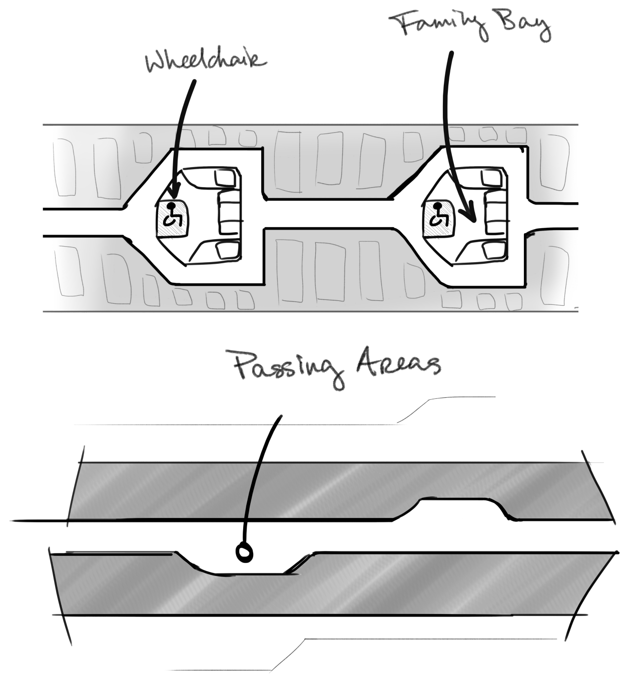
In-flight Movement

On long-haul missions exceeding 10 hours, the ability to move and stretch is a fundamental requirement for passenger comfort and the prevention of physiological issues such as deep vein thrombosis (DVT). However, in contemporary single-aisle aircraft, the cabin frequently becomes "locked" during service periods when trolleys obstruct the narrow aisle, forcing passengers and crew into awkward maneuvers to pass one another. To resolve this, the ideation phase explored integrated Passing Areas as a solution to this gridlock. These dedicated zones provide passengers with the agency to navigate toward the Social Lounge or Central Workspace without interfering with the crew's service flow.

Furthermore, the exploration of the Family Bay addresses the circulation needs of social groups and families. By providing a dedicated breakout space within the cabin, this layout ensures that the most active "tribes" can move and interact without clogging the primary longitudinal aisle. This decentralization ensures that stretching and walking (core activities for long-duration well-being) are facilitated rather than hindered. Ultimately, by treating the aircraft as a connected system, these spatial interventions offer more frequent opportunities for movement that accommodate the needs of all passengers, including those with reduced mobility, more effectively than current continuous tube designs.

Wheelchair Accessibility

Ensuring that the cabin is accessible to all passengers, including those with reduced mobility (PRM), is an essential ethical and regulatory consideration. While the primary focus of this design phase was a new comfort seating experience and service flow, wheelchair accessibility remained a guiding constraint during the exploration of new layouts. The investigation into wider aisle segments and decentralized lavatory placements was conducted with the intent of improving the turning radius and ease of navigation for onboard wheelchairs. By treating the aircraft as a connected system, the 3-zone workspace naturally offers more frequent "breakout" spaces that can accommodate the needs of PRM passengers more effectively than the continuous, narrow tube of current narrowbody designs.



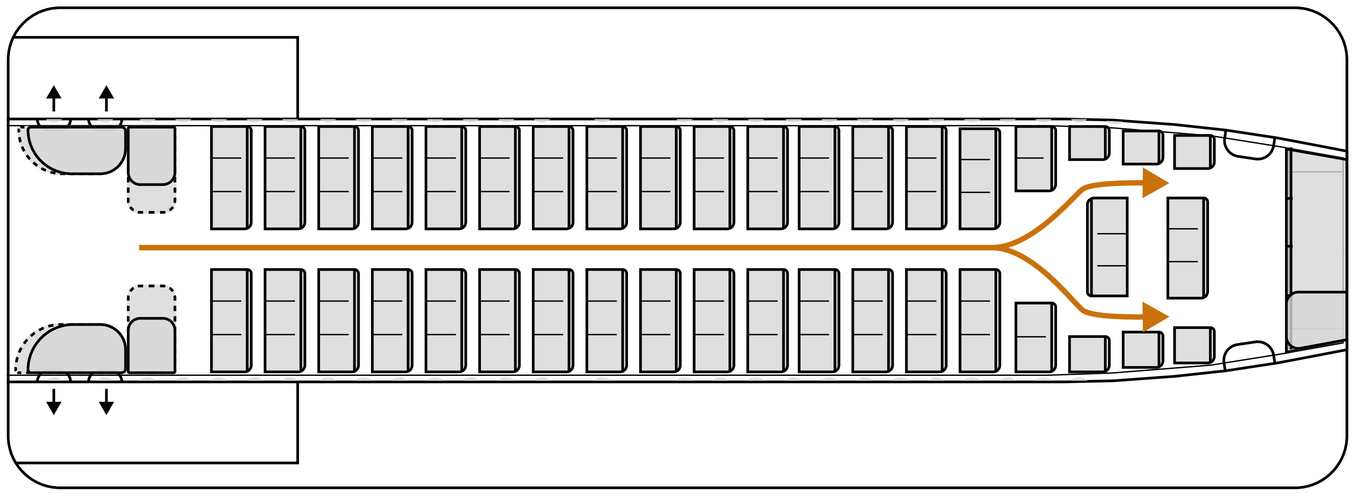


fig.46 Top view of the 'Family Bay' idea in the rear of the cabin.

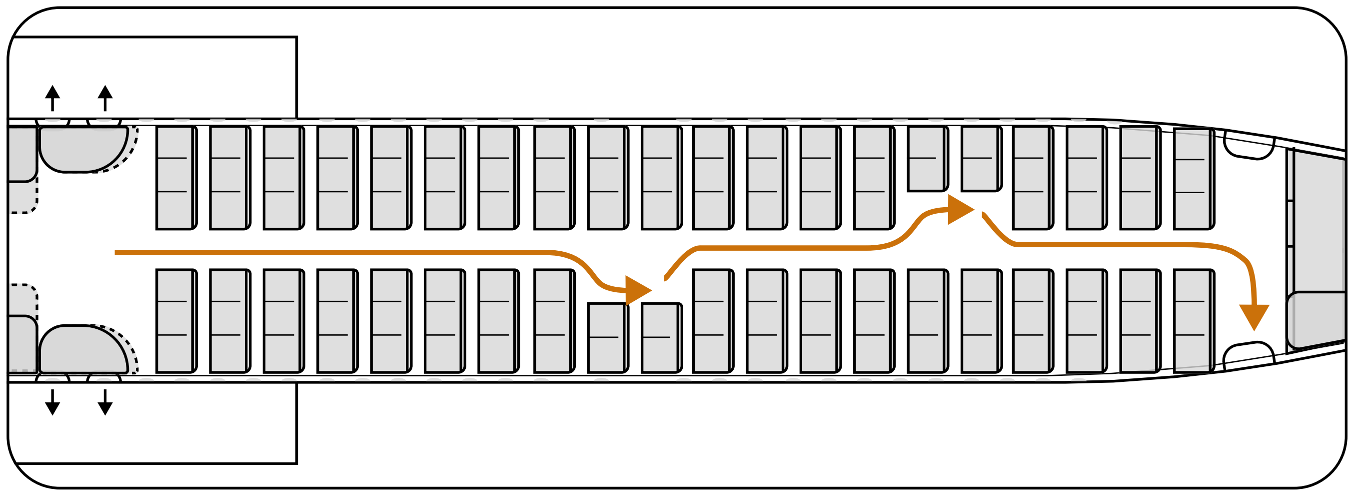


fig.47 Top view of the 'Passing Areas' idea in the rear of the cabin.

5.3.1 Conclusion

The final layout for the 2040 cabin prioritizes operational efficiency and passenger agency by strategically varied seating architectures. To resolve the critical boarding and turnaround bottleneck, a twin-aisle seating configuration was selected for the forward section of the aircraft. This dual-pathway approach facilitates simultaneous luggage stowing and passenger ingress, directly addressing the primary source of airline delays and passenger stress. This configuration is specifically tailored to the Quiet Zone, where solo travelers benefit from increased lateral space and direct aisle access, reinforcing the sense of individual territory.

In the rear of the cabin, the design utilizes integrated passing areas rather than a continuous twin-aisle architecture. This decision ensures that passengers can stretch, move toward the Social Lounge, and bypass service trolleys without the significant loss of seating capacity that a full secondary aisle would require. By combining these two spatial strategies, the cabin moves away from the "aisle-lock" common in current single-aisle aircraft toward a fluid system that supports long-haul well-being and rapid turnaround times while maintaining commercial viability.

5.4 Seating

This chapter focuses on the seat as the most crucial point of contact within the cabin experience. For a ten-hour long-haul flight, the seat is not just a piece of furniture; it is a complex ergonomic and psychological interface that must enable rest, work, and social interaction within a highly confined environment. A professor once told me:

"The seat is the most difficult part of a vehicle to design"
- professor minor People in Transit at IDE

Building upon the research of Professor Peter Vink and the "Zen Mountain Lodge" vision, the seat is identified as the primary determinant of a comfortable journey. Vink's principles emphasize that comfort is a holistic perception, a combination of physical support, tactile quality, and the psychological sense of territory. In this chapter, the design development moves beyond standard pitch and width metrics to explore how diverse seat typologies can accommodate different traveler archetypes.

Strategic Opportunity

This design phase focuses on a new cabin class as a strategic commercial opportunity (SWOT). It positions itself at the intersection of operational efficiency and the growing demand for personalized travel. By going beyond the simple choice between Economy and Business, this new segment caters to a growing group of travelers who are willing to pay extra for specific physical benefits, such as restorative sleep, without taking up the space of a full luxury suite.

This approach is in line with the shift in aviation towards mass customization, where profitability comes from space-efficient designs that still feel personal and exclusive.

Bridging the Experience Gap

Current aircraft cabins are divided into strict classes, which fragments the travel experience. My vision for 2040 replaces this division with a cohesive system that fits with a "shared society."

By blurring the boundaries between luxury and standard travel, a principle we call "Business Down", the benefits of comfortable rest become accessible to everyone. With space-saving seats, this model offers both "simultaneous seclusion" for solo travelers and "shared presence" for families.

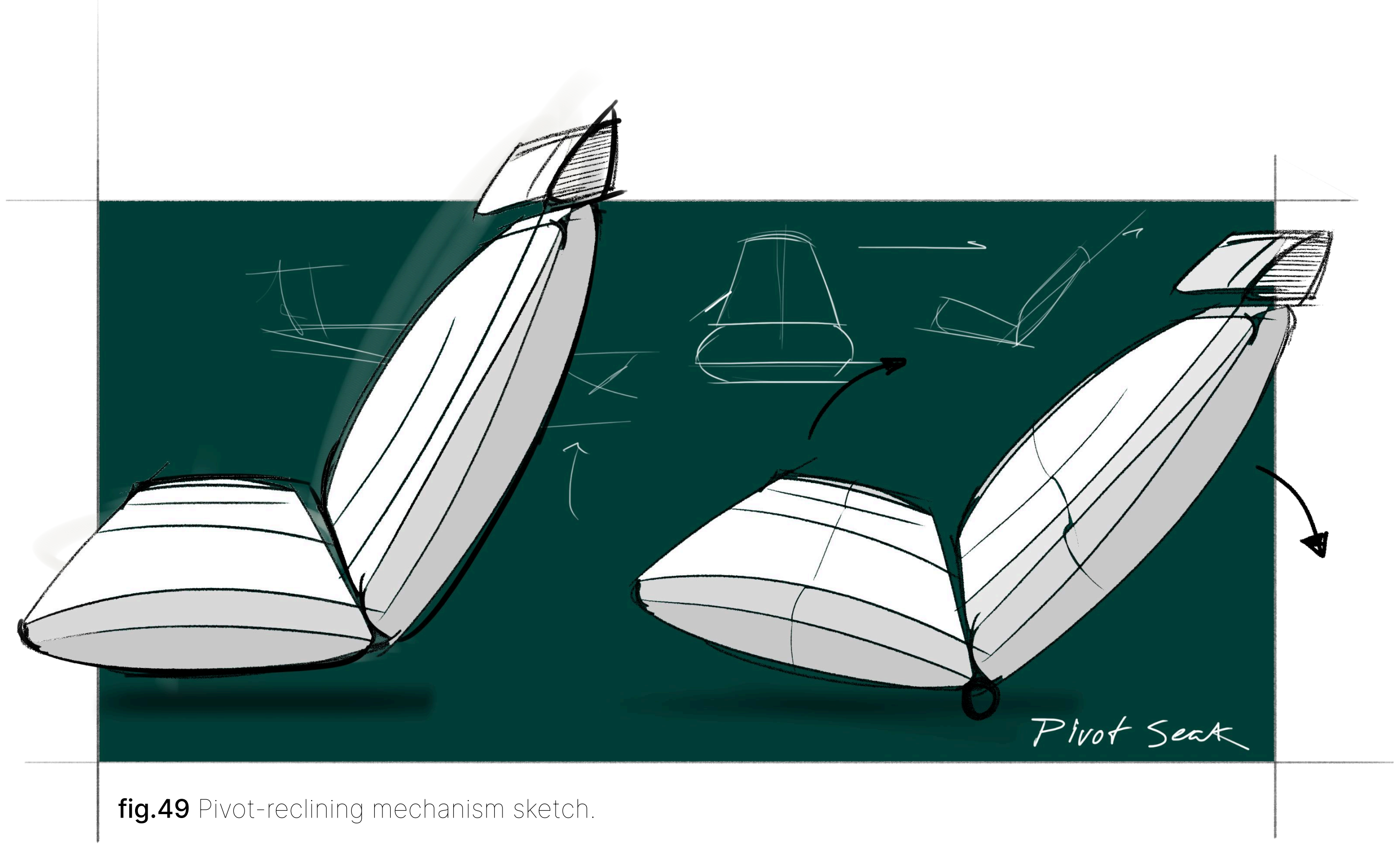


fig.49 Pivot-reclining mechanism sketch.

The result is an efficient cabin with plenty of seating, where collective well-being is central. In this way, the aircraft transforms from separate, isolated compartments into a single connected and inclusive whole.

The Pivot-Reclining Mechanism

Comfort on long-haul flights depends more on the movement of the seat than on the upholstery. Standard seats often give a "sliding" feeling because only the backrest moves. With a pivot reclining mechanism, the entire seat rotates as one unit. According to Peter Vink's research, this is an effective way of increasing one's comfort.

This synchronized movement keeps the passenger in an optimal, ergonomic position. The lower back remains well supported and body weight is better distributed. Thanks to this innovation, deep, restorative rest is possible, even in cabins with many seats. This transforms a limited space into a place of true comfort and well-being.

This mechanism will be used as a principle for some of the upcoming concept, however during this ideation phase, it will not be looked at further into detail.

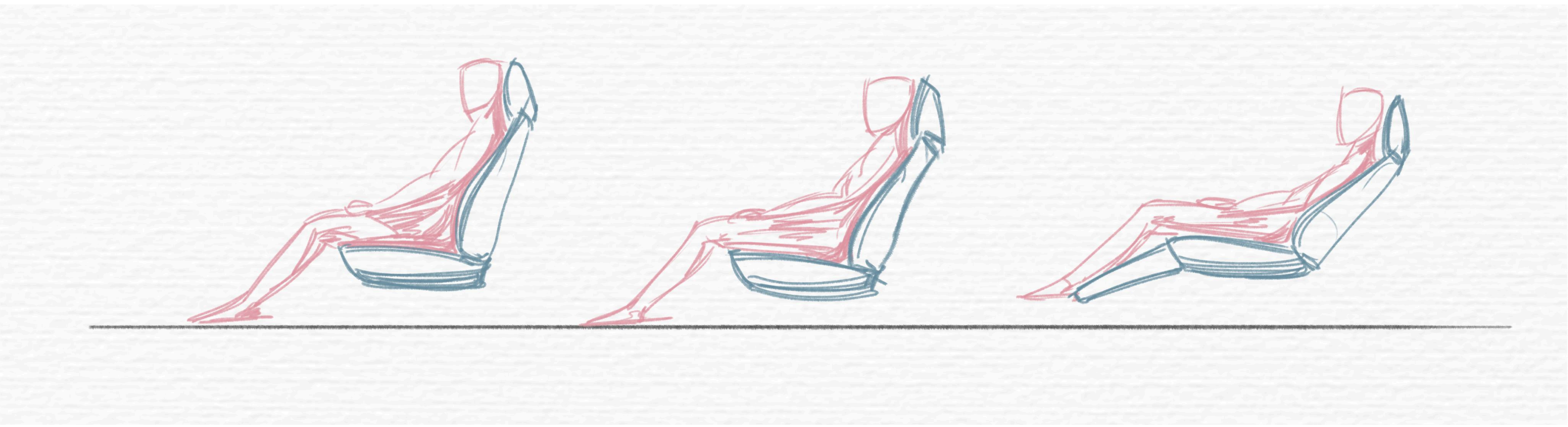
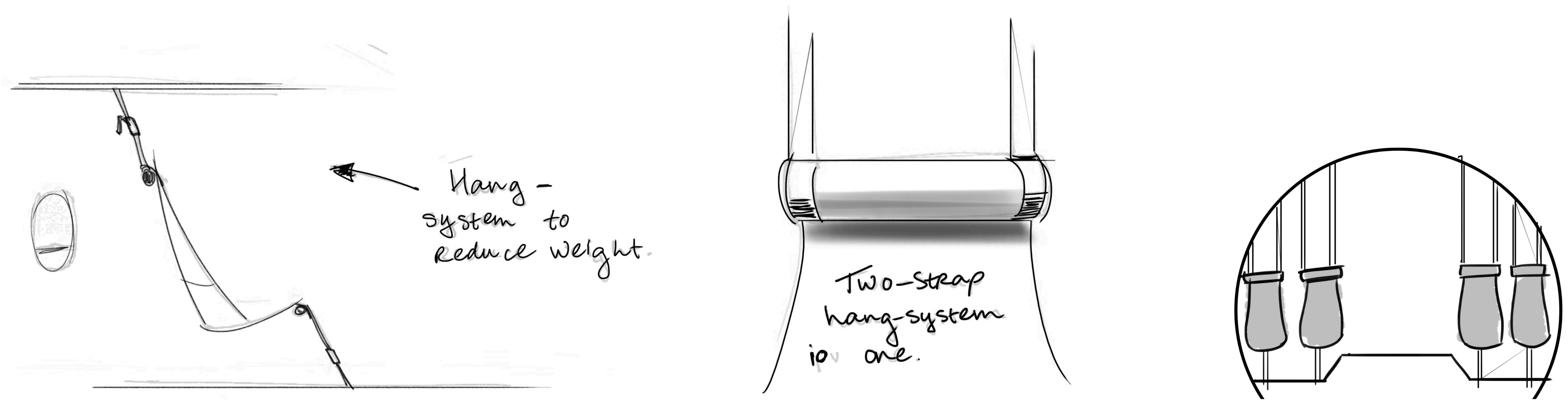


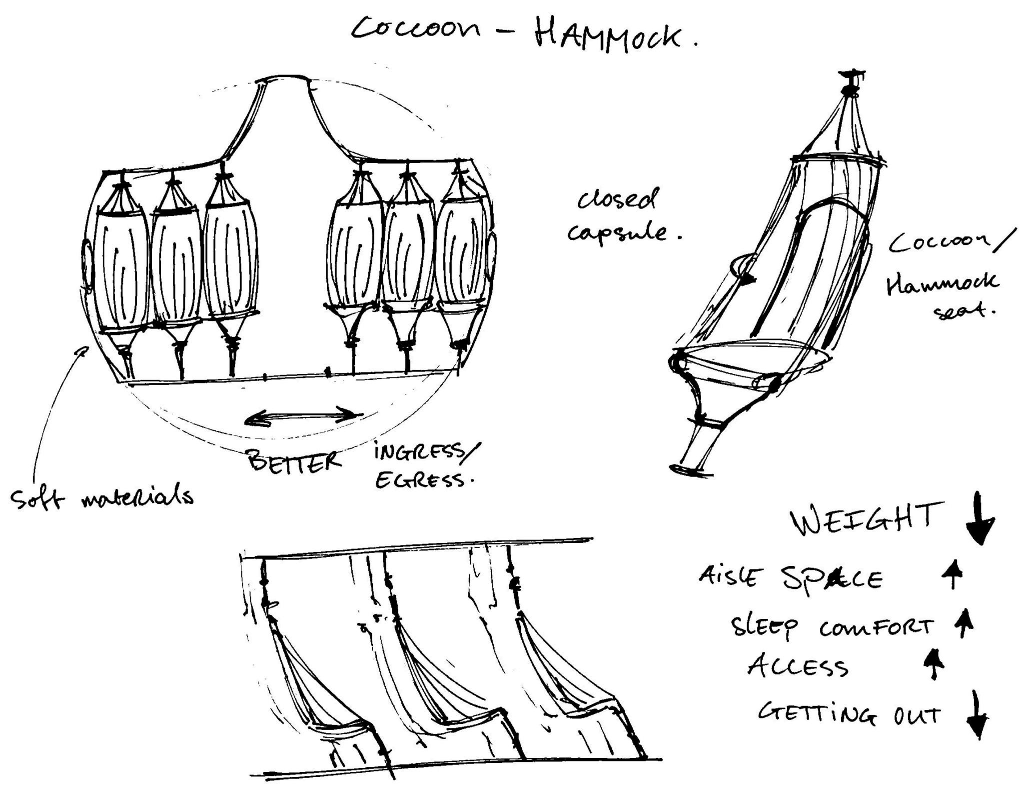
fig.48 Explorative sketches of seating postures.

5.4.1 Concept 1: The Hammock Cocoon

For a more radical leap in cabin design, the hammock-inspired concept replaces traditional hard shells and foam with flexible, tensioned textiles that mold precisely to the passenger's unique body shape. This biomimetic approach effectively eliminates the local pressure points created by rigid seat structures and creates a weightless feeling that is ideal for deep, restorative sleep.

Each seat functions as a private cocoon that completely envelops the traveler in a lightweight, breathable fabric that provides both physical comfort and psychological security. Unlike traditional floor-mounted seats, these cocoons hang from the ceiling. This floating configuration frees up the cabin floor, and because the soft fabric is naturally flexible, the seats can be easily slid aside or bypassed. This flexibility greatly simplifies the boarding process and improves freedom of movement during the flight, transforming the cabin into a permeable, adaptable environment rather than a static grid of obstacles.





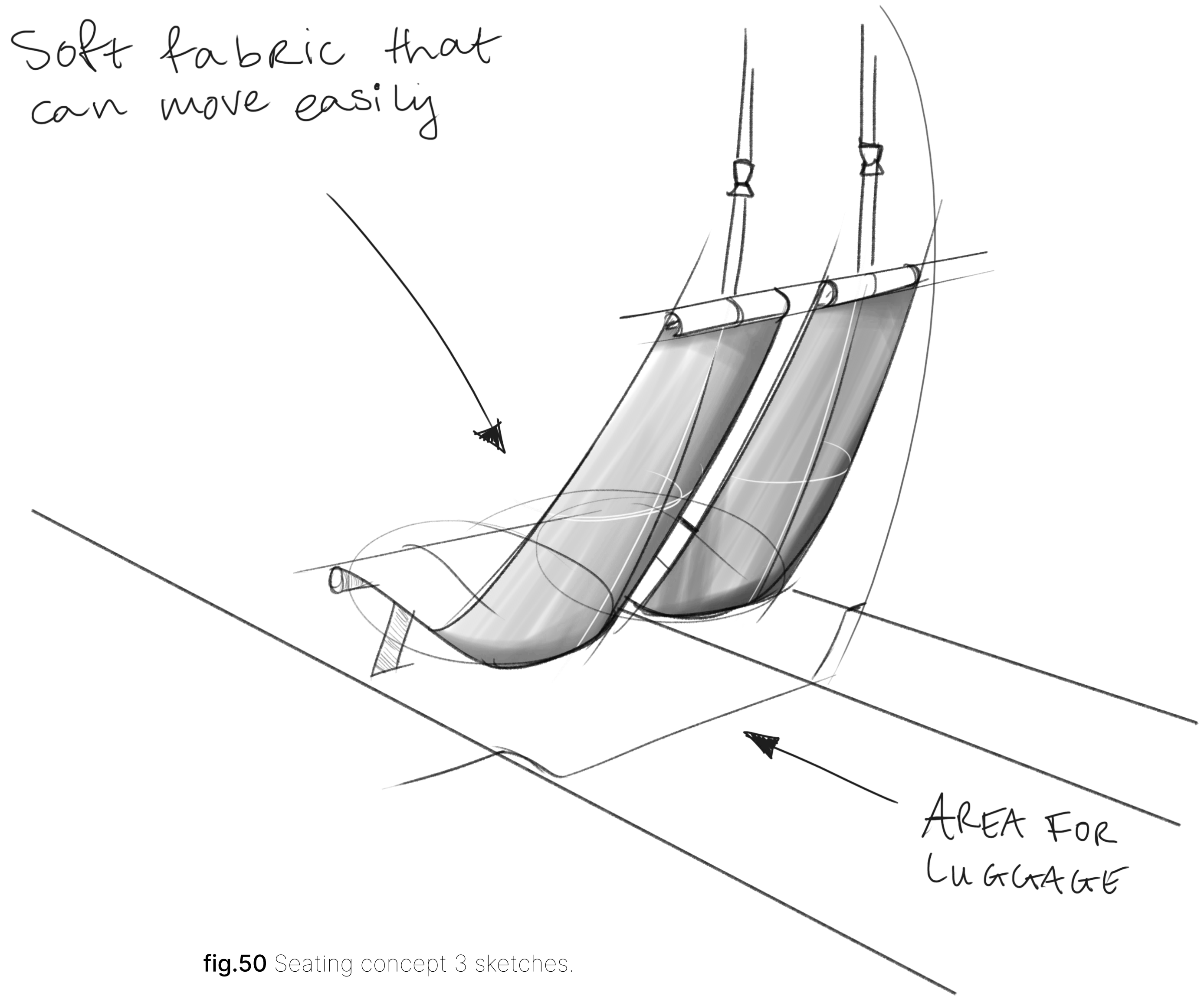
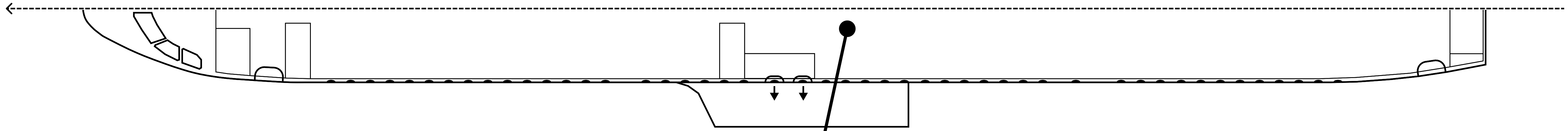


fig.50 Seating concept 3 sketches.

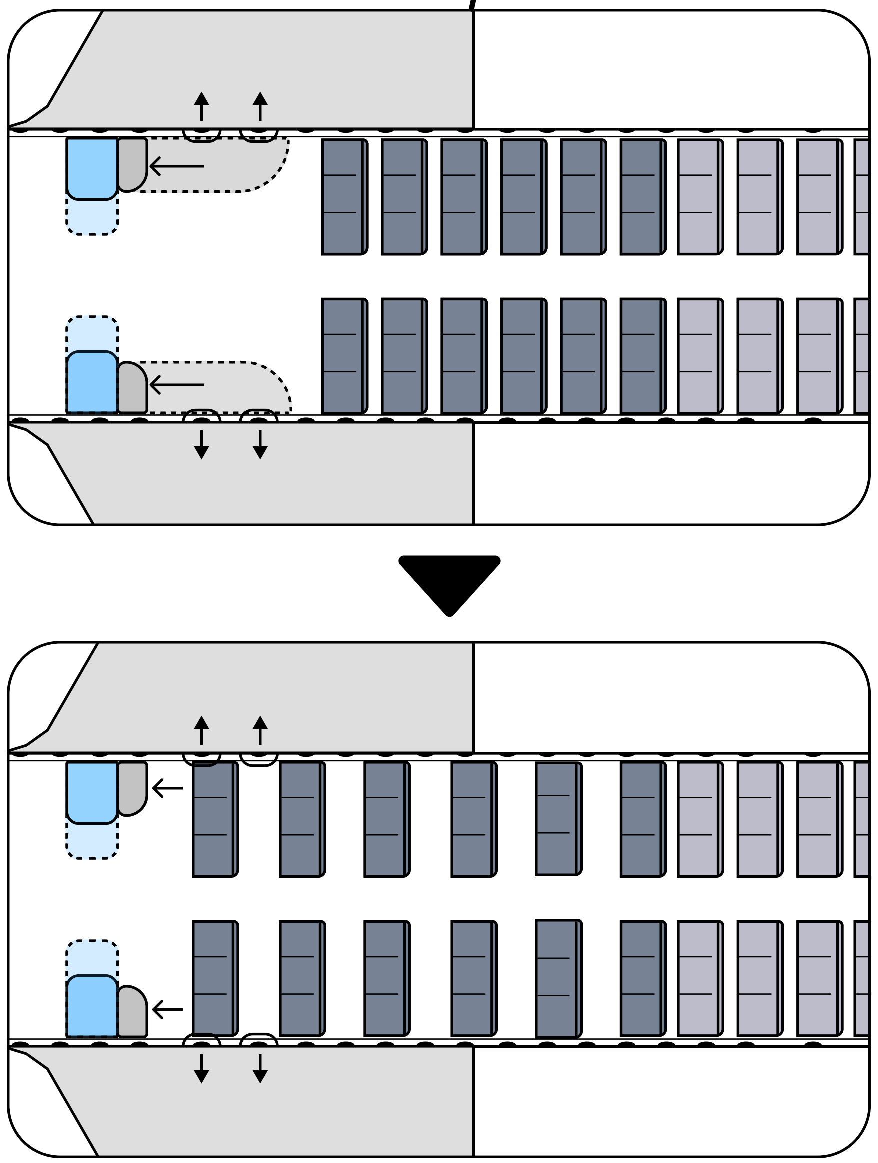


5.4.2 Concept 2: The "Hybrid Flex" Class

A primary concern with introducing a 3-zone workspace and a social lounge is the potential reduction in total seat count. In the highly competitive narrowbody market, losing even a single row of seats represents a significant loss in potential revenue. To counteract this and generate higher yield, I explored a *New Special Class*: a hybrid seating zone that adapts its functionality based on the phase of flight.

The "Hybrid Flex" class is situated directly behind the central workspace. During high-activity phases such as boarding, takeoff, service times, and landing, these seats function as conventional, high-density economy seating. However, once the aircraft reaches cruising altitude and enters "night mode," the space is reconfigured.

Since the central workspace is not fully utilized during sleep cycles, the layout was designed to allow the workspace partitions or storage elements to retract or shift. This recovered space is then used to increase the pitch of the adjacent seating rows. By mechanically increasing the legroom, these seats transform into a premium sleeping environment, offering a higher level of service and comfort that justifies a premium price point, potentially exceeding the revenue of the original seat count.



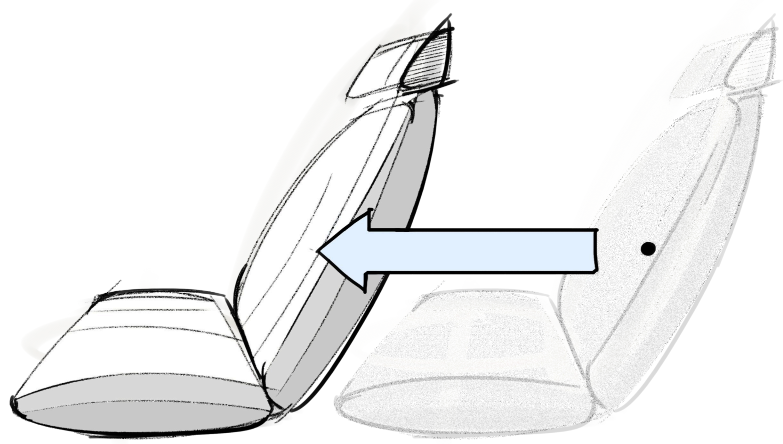
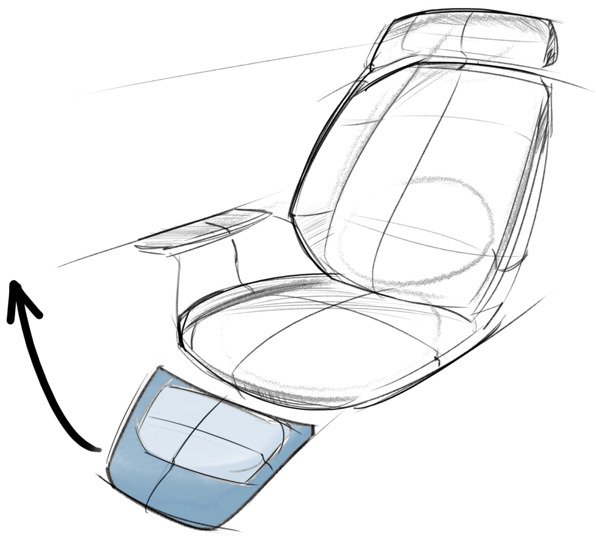


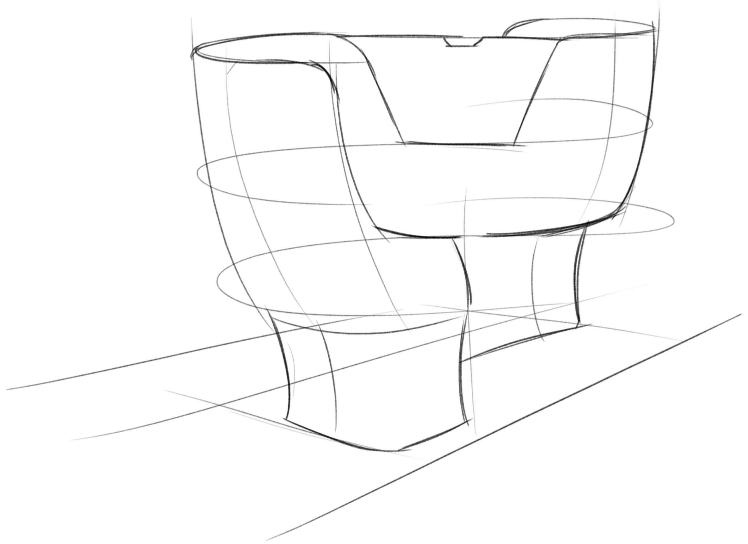
fig.51 Top view of concept 2 'Hybrid Flex' class.

5.4.3 Concept 3: A Modular Ecosystem

The latest concept moves away from the rigid, conventional class system and instead opts for a Modular Ecosystem. In this model, the cabin is no longer a series of separate compartments based on ticket price, but a dynamic landscape of activity-oriented zones tailored to the specific needs and desires of the passenger. By redefining “class” as a “needs-based choice,” the cabin becomes a flexible environment in which travelers choose their setting based on their primary purpose for the flight, whether that is productivity, rest, or social connection.

At the heart of this ecosystem is a modular seat architecture that forms the basis for a wide range of specialized configurations. For those who prioritize deep rest, the system offers a large, optimized sleep seat; for the business traveler, a swivel work seat that supports focus and ergonomic use. Individual travelers can opt for a secluded comfort seat that offers maximum privacy, while larger passengers or travelers who want extra space can select a special comfort seat designed with inclusive ergonomics in mind.





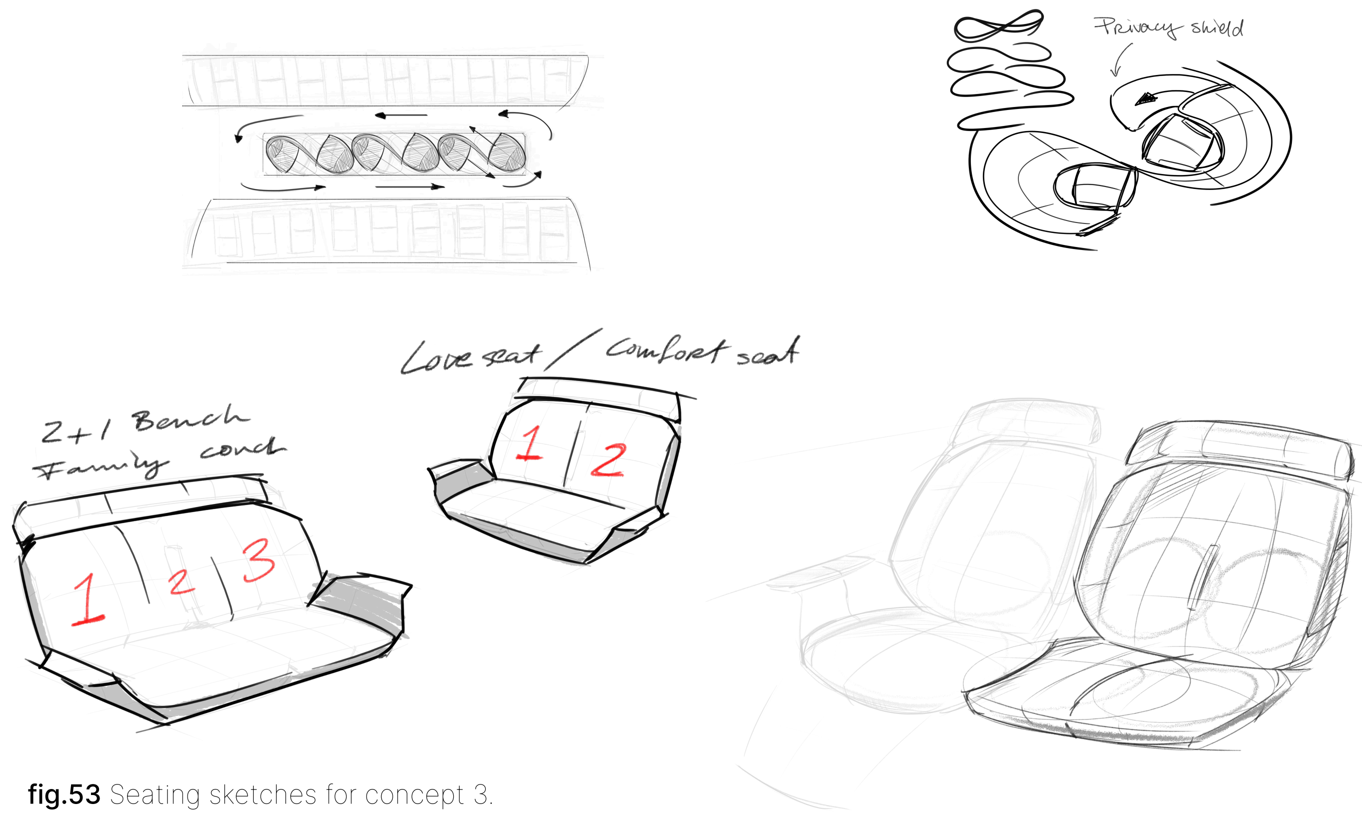


fig.53 Seating sketches for concept 3.

This modularity also extends to social and shared travel, breaking through the “simultaneous isolation” of standard rows of seats. The ecosystem includes loveseats for couples seeking shared space and social benches designed for groups or families to interact naturally. By approaching the aircraft interior as a versatile toolbox rather than a fixed layout, this concept caters to the diverse “tribes” of modern travel, from the solo professional to the parent with young children, within a single cohesive system. This shift allows each passenger to curate their own experience, transforming the journey into a personalized and meaningful one.

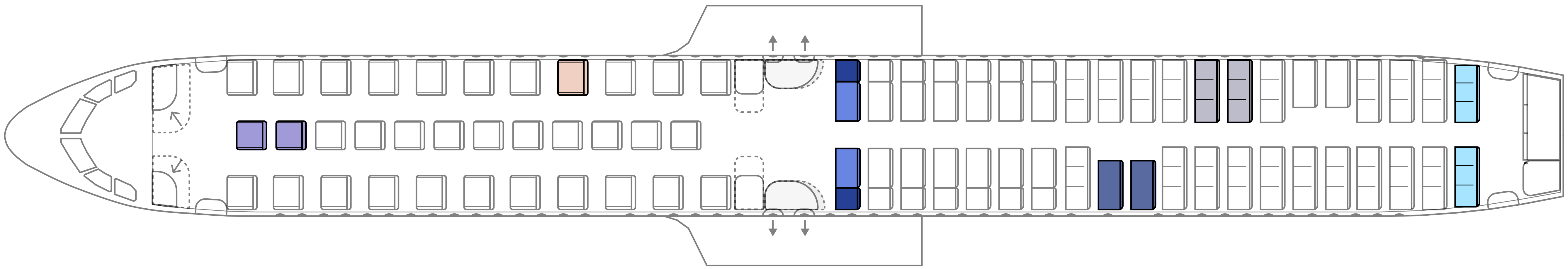


fig.52 Top view of concept 3 ‘Modular Ecosystem’ layout.

5.4.4 Seat Concept Selection

Following the extensive ideation phase, the gathered design principles and seating typologies were synthesized into three distinct seating concepts. While all adhere to the 3-zone workspace and "noise gradient" strategy, they offer different solutions for maximizing revenue and passenger comfort within the A321XLR's constraints. This chapter describes the selection procedure of the seating concepts. I have looked at the SWOT analysis (chapter 2), extensive feedback from my tutors and after that I have made a selection evaluation with the use of a Harris Profile (Delft Design Guide, 2013).

SWOT

In the SWOT analysis we saw that one of the weaknesses of the company is its lack in uniformity. This is due to the variation of orders and clients, and simply because no aircraft is completely supplied by one interior manufacturer company. This weakness is tackled by concept 3.

We should justify the focus on a new class as a commercial opportunity (O) that aligns with market trends for air travel. This opportunity is tackled by concept 2 and 3.

And lastly, the biggest threat according to the analysis will be the strict regulations and cost requirements.

feedback

Mechanical Complexity and Certification Constraints

While the concepts offers a compelling solution to the "Complexity vs. Efficiency" challenge, feedback from Jeff McKee highlighted significant technical hurdles. The primary concern lies in the mechanical complexity of sliding occupied seat rows or large galley components.

Safety Risks: *Moving parts within the cabin floor increase the risk of foreign objects or passenger belongings getting trapped in the sliding tracks.*

Certification Barriers: *Ensuring the structural integrity of a "moving" seat row during emergency scenarios or turbulence is a massive certification hurdle. FAA requirements for seat track attachments are stringent, and a dynamic, sliding system would require extensive testing to ensure it does not fail under 16g loads.*

Consequently, while the idea of a "Hybrid Flex" class remains a strong visionary solution for maximizing revenue in limited narrowbody spaces, it serves as a reminder of the delicate balance between revolutionary spatial design and the "conservative complexity" required for aviation certification.

Technical feasibility

The transition from research to concept selection requires a rigorous evaluation of technical feasibility, particularly regarding aviation certification and operational viability. The Hammock Cocoon, while offering a radical biomimetic leap in comfort, faces significant hurdles under current FAA and EASA Part 25 regulations. Achieving a 16g dynamic safety certification for a ceiling-suspended structure is historically difficult, as it introduces complex load paths into the upper fuselage and complicates emergency egress and Head Injury Criterion (HIC) requirements. Similarly, the mechanically adaptive rows in Concept 2 present high failure risks and concerns regarding the entrapment of passenger belongings within moving floor tracks. Following expert consultations, the focus for this concept should shift from mechanical seat movement to phase-based transformation, utilizing elements like adaptive lighting and multi-functional bulkheads to redefine the space during different flight phases. For a 10-hour A321XLR mission, maintaining commercial credibility also requires ensuring that catering and galley capacities are not compromised by the central workspace. Conversely, the Modular Ecosystem in Concept 3 received positive feedback for its versatile, activity-based approach. The recommendation here is to avoid "de-branding" specialized zones, such as the family area, to ensure these spaces remain inclusive and flexible for all passengers while still providing the specific ergonomic benefits, like bench seating and lavatory proximity, required by their primary target groups.

Concept Evaluation

To determine which direction best satisfies the requirements of the 2040 vision and the technical constraints of Collins Aerospace, a Harris Profile selection method will be applied. This methodology allows for a visual comparison of how each concept performs against key criteria such as:

- **Passenger Comfort:** The ability to facilitate rest and well-being.
- **Movement/Stretching:** The ability to have proper in-flight movement and an optimized boarding process.
- **Complexity:** The ease of certification and mechanical maintenance.
- **Revenue Potential:** The ability to recoup seat-count loss through premium services.
- **Spatial Spaciousness:** The perceived openness of the cabin architecture.
- **Universal Accessibility (PRM):** How easily can a passenger with reduced mobility navigate the aisles and access the lavatories.
- **Certification Pathway:** How difficult is it to prove the design is safe (e.g., 16g impact testing, no entrapment risks).

The Harris Profile evaluation indicates that Concept 3: Modular Ecosystem is the most promising seating direction for the 2040 cabin. By prioritizing activity-based zones and a versatile modular architecture, this concept best addresses the diverse needs of future traveler "tribes" while maintaining the highest balance of comfort, flexibility, and technical feasibility.

Concept 1: Hammock Cocoon

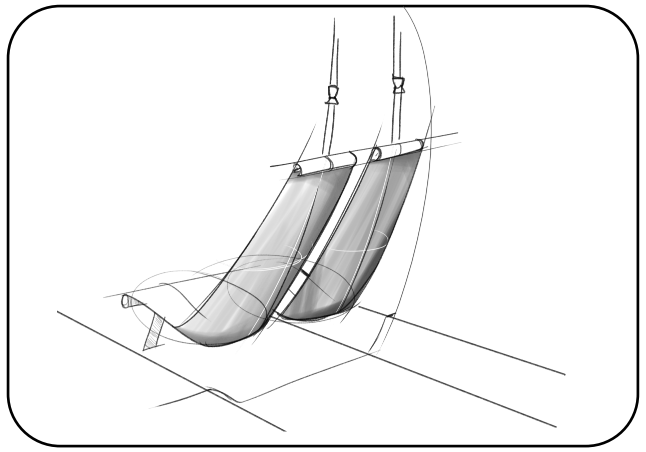
Concept 1 represents a radical leap in biomimetic design by replacing rigid seat shells with flexible, tensioned fabric. This system contours precisely to the passenger's unique body shape, eliminating localized pressure points and fostering the weightless sensation necessary for deep, restorative sleep. Each seat functions as a private cocoon suspended entirely from the ceiling, effectively clearing the cabin floor footprint. Because the material is soft and pliable, the seats can be easily navigated or pushed aside, dramatically simplifying the boarding process and enabling fluid movement throughout the aircraft.

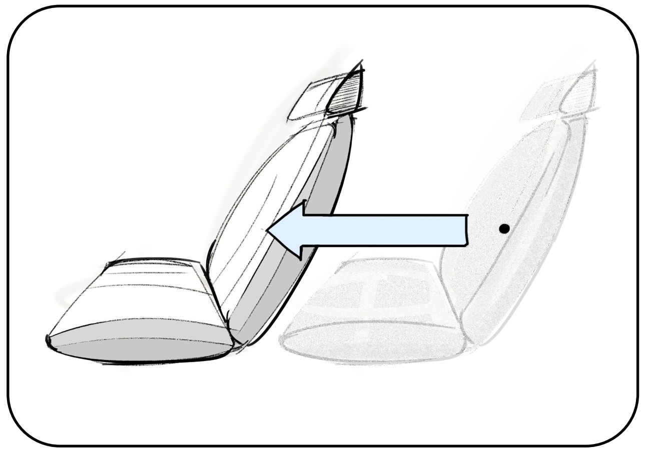
Concept 2: Hybrid Flex

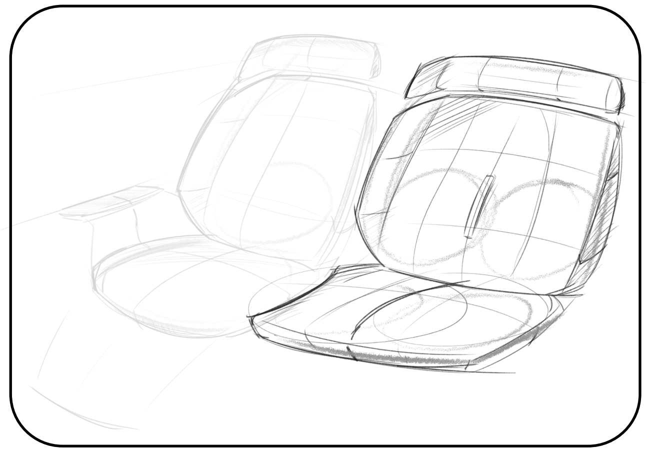
Concept 2 is a high-tech, mechanically adaptive environment designed to bridge the gap between daytime productivity and nighttime recovery through advanced seat kinematics and a flexible floorplan. This system utilizes a "temporal space sharing" strategy: during flight, the footprint of the central workspace is reduced, allowing seat rows to mechanically slide forward. This transformation increases the pitch for passengers during long-haul night cycles, effectively creating a premium sleeping experience without a permanent loss of seat density. By solving the "Complexity vs. Efficiency" challenge, this concept allows the cabin to physically evolve in sync with the passenger's journey.

Concept 3: Modular Ecosystem

Concept 3 moves away from rigid class silos to create a dynamic, activity-based cabin environment. Instead of a fixed layout, this concept utilizes a modular seat architecture that can be configured into specialized solutions, ranging from optimized sleeping chairs and secluded workseats to social benches and love seats for couples. By rebranding "class" as a need-based choice, the system allows passengers to curate their experience based on their specific journey goals, such as productivity, family connection, or privacy. This versatile toolkit transforms the aircraft into a flexible landscape that accommodates diverse traveler "tribes" within a single, coherent framework.







Concept 1: Hammock Cocoon

	--	-	+	++
Comfort			■	
Movement			■	■
Complexity		■		
Revenue Potential		■		
Spaciousness			■	■
Accessibility		■		
Certification	■	■		

Concept 2: Hybrid Flex

	--	-	+	++
Comfort			■	■
Movement			■	■
Complexity	■	■		
Revenue Potential			■	
Spaciousness			■	■
Accessibility			■	
Certification		■		

Concept 3: Modular Ecosystem

	--	-	+	++
Comfort			■	■
Movement			■	■
Complexity			■	
Revenue Potential			■	■
Spaciousness			■	■
Accessibility			■	
Certification			■	

fig.54 Harris Profile of the three concepts.

5.5 Design Proposal

5.5.1 Floorplan Foundation

The reimagining of the cabin floorplan moves away from traditional, isolated galley structures toward a unified, 3-zone connected system. This layout adopts a central distribution of services, which optimizes crew flow and enhances passenger accessibility throughout the 10-hour flight. This structural framework serves as the floorplan foundation for the final design.

Architectural Framework: The 3-Zone Holistic System

To resolve the operational bottlenecks identified in current single-aisle long-haul configurations, the 2040 floorplan adopts a centralized service model. The traditional reliance on large forward and aft galleys is replaced by a 3-zone cabin-crew workspace, designed to function as a holistic, connected system. This shift represents a move toward a more accessible and fluid service environment.

Acoustic and Social Zoning: The "Noise Gradient"

A core innovation in the 2040 ideation is the transition from class-based seating to Atmospheric Zoning. By aligning the floorplan with a noise gradient, the cabin facilitates both "Simultaneous Solitude" and "Shared Presence" without spatial conflict. The cabin is divided into three distinct acoustic zones that increase in social activity as one moves toward the aft. From a technical aviation perspective, the aft of a single-aisle aircraft is typically the loudest part of the cabin due to engine and aerodynamic noise.

By structuring the floorplan around this noise gradient, the design facilitates a shared presence. It creates a realistic system that manages the psychological complexity of long-haul travel by situating diverse passengers in zones that match their specific social and atmospheric needs, rather than their ticket price.

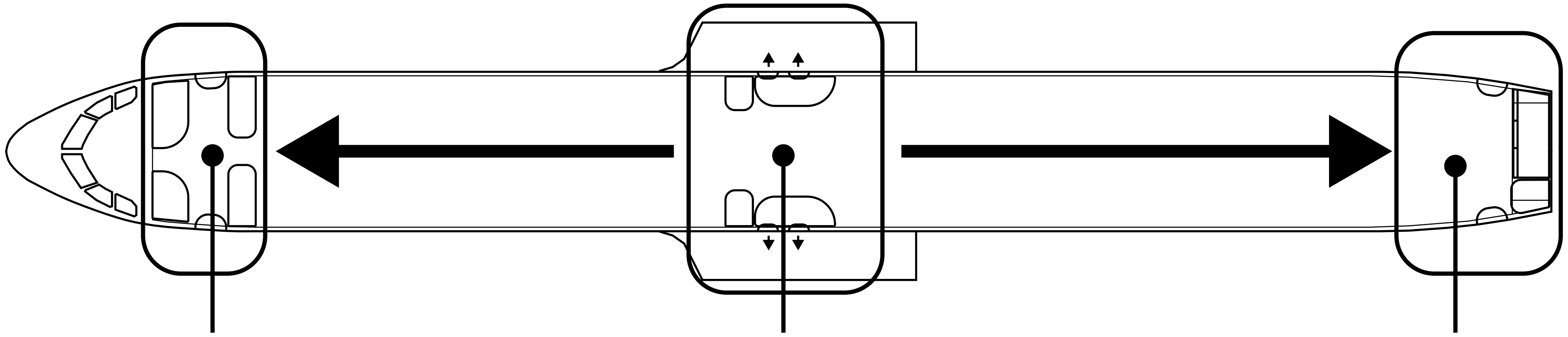


fig.55 3-zone workspace foundation.

Zone 1: The Entry (Forward)

As the primary touchpoint for boarding, the forward entry is designed to function as the "face" of the cabin. Unlike the congested entryways of contemporary narrowbodies, this space is engineered for perceived spaciousness to allow cabin crew to welcome passengers in an unhindered environment. To maintain operational capability, this zone houses one lavatory and a specialized section of the galley tailored for premium service and initial boarding requirements.

Zone 2: The Central Workspace (Mid-Cabin)

Positioned at the aircraft's center, the Central Workspace acts as the primary hub for service distribution. This zone features a large, dedicated workspace for crew members to prepare meals and manage services, effectively halving the travel distance to any point in the cabin compared to a rear-only model. To support the physiological needs of 150+ passengers, two centralized lavatories are located here, ensuring that passengers with reduced mobility have easier access from the middle of the aircraft.

Zone 3: The Social Lounge (Aft)

The rear of the aircraft is designated as the Social Lounge, situated where the noise gradient is naturally at its peak. This area serves as a dedicated space for passengers to stretch their legs and seek social interaction, fulfilling the need for "Shared Presence" without disturbing the quiet zones forward. The zone features a self-service bar to allow for passenger autonomy and includes a fourth lavatory to accommodate the high-activity social group.

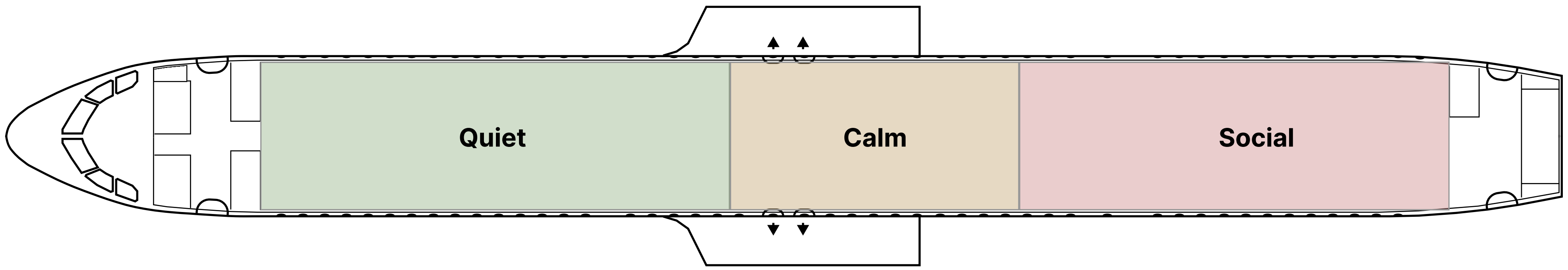


fig.56 Top view of the acoustic zoning foundation.

5.5.2 Modular Seating Foundation

The Modular Seating Foundation establishes the core architectural principle for the final design, moving from concept selection to a functional cabin ecosystem. This modular framework integrates various specialized seating units to accommodate a total of **148 passengers** while fulfilling the restorative requirements of the 2040 vision.

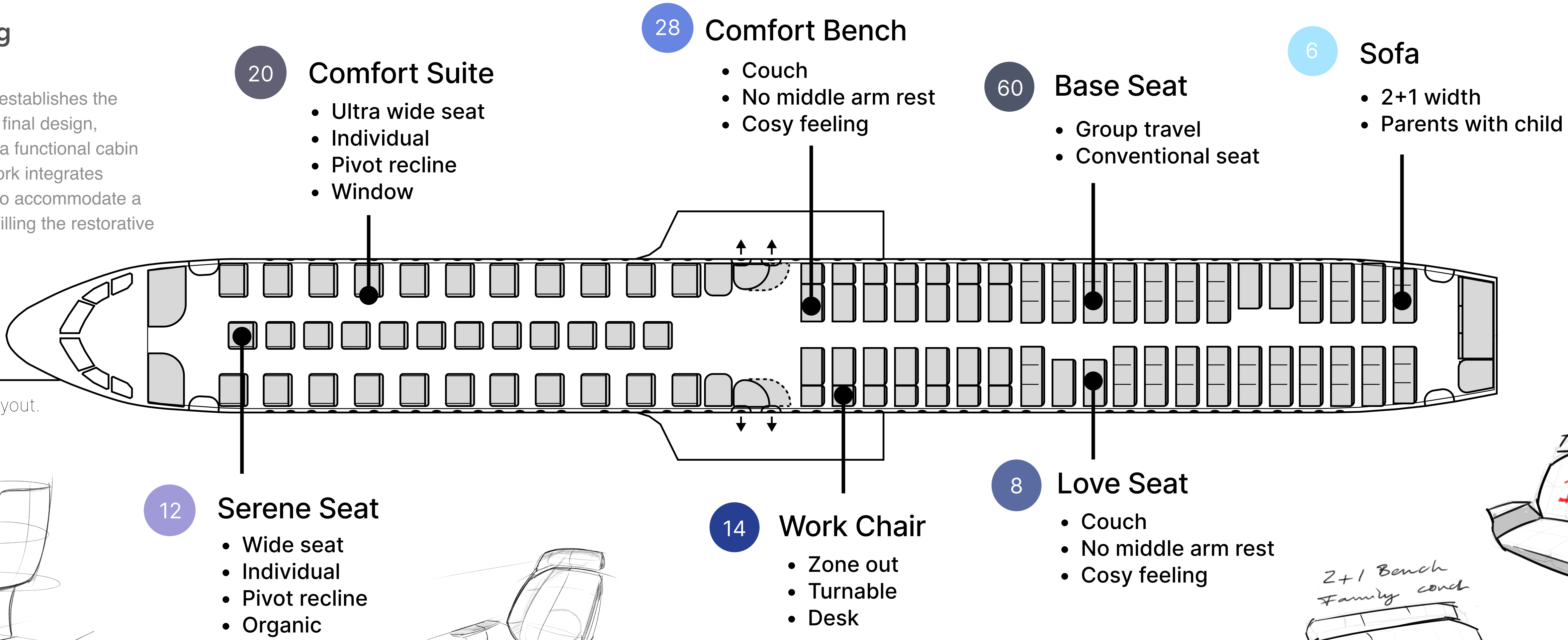
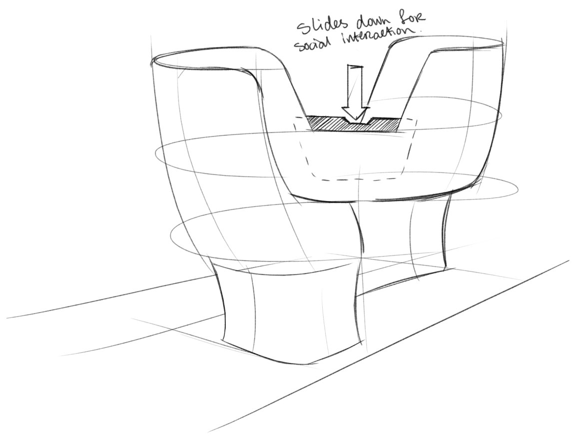
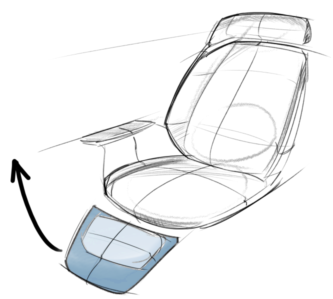
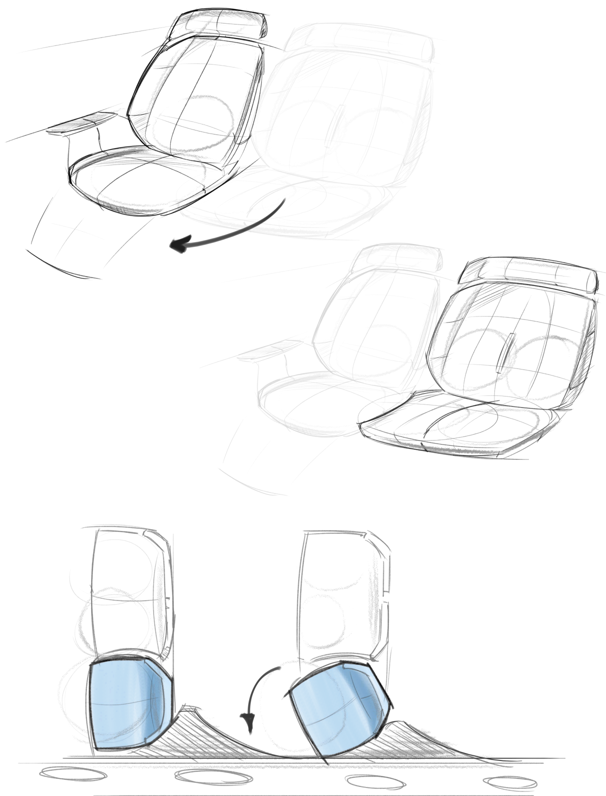
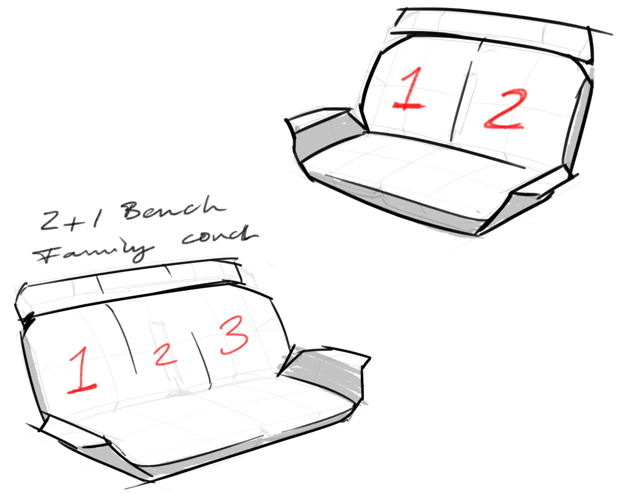


fig.57 Design proposal seating layout.









Serene Seat & Comfort Suite

In the forward section of the aircraft, I explored an innovative S-seat configuration. While the window sides feature conventional luxury seats, the center row between the twin aisles utilizes an intertwined "S" shape. These organic, intertwining shells optimize the fuselage width by nesting passengers together in a way that maximizes privacy and bed-length while minimizing the total footprint.
This "S" geometry creates a sophisticated, high-comfort zone that serves as the flagship of the 2040 interior. These modular concepts form the definitive foundation for this cabin layout seating concept, ensuring that the 3-zone workspace is populated by seating that reflects the diverse social dynamics of future air travel.

Work-Seat & Comfort Bench

To accommodate the duality of the "Relax Zone," I have designed a hybrid row that replaces the traditional three-abreast layout. On one side of the aisle, a turnable work-seat provides individual travelers with a private "cocoon" to zone out, work, or rest. Adjacent to this, a two-person sofa-bench (or love seat) replaces individual seat shells with a continuous, bench-like surface. This design removes physical barriers between companions and allows the seat to be marketed as a "Comfort Seat" for passengers desiring more lateral space. Strategically, this configuration allows for a wider aisle or passing area, improving the overall flow of the cabin.

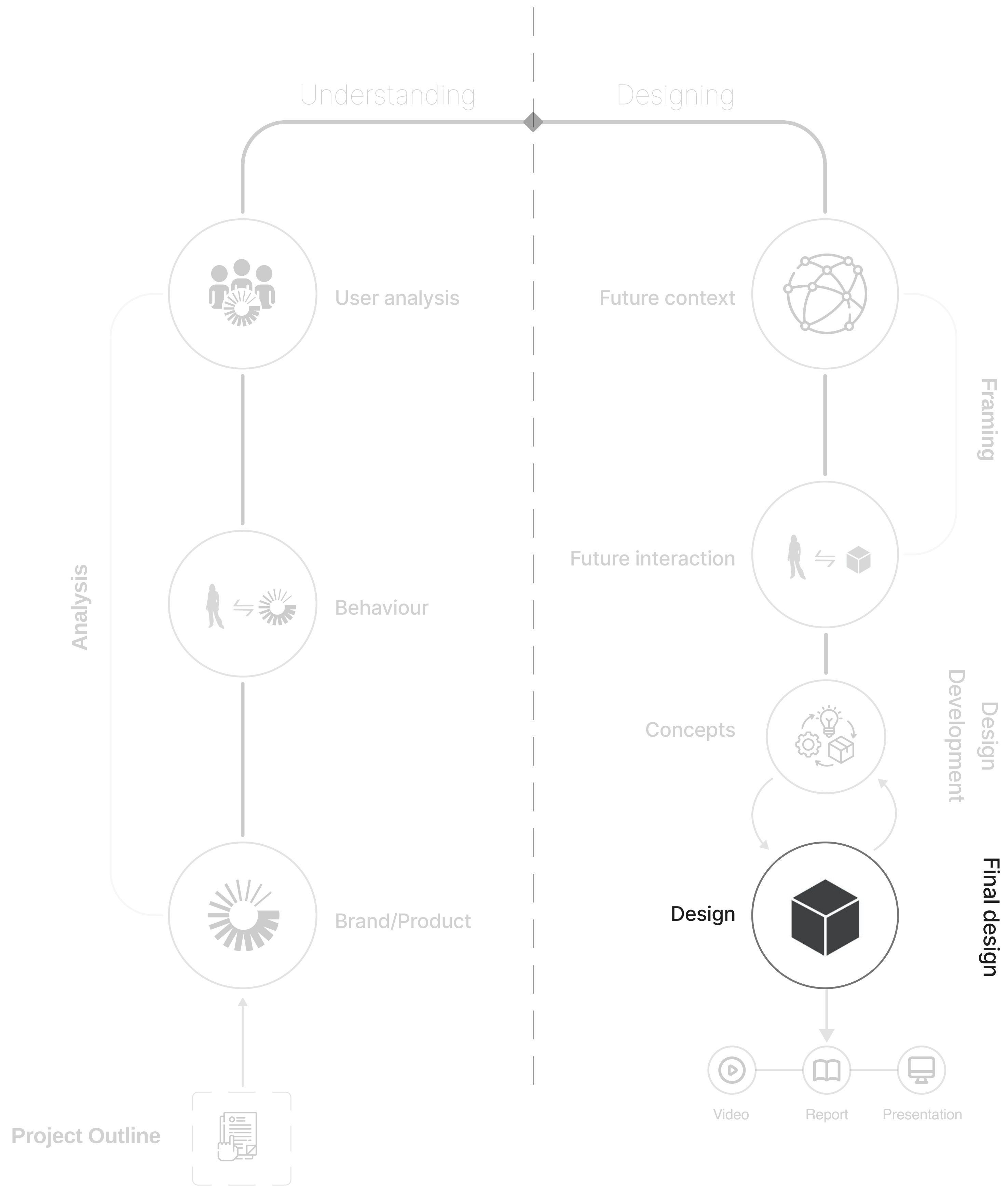
Love Seat & Sofa

As the A321XLR fuselage tapers toward the rear, the reduced width is utilized for the Family Bench. This 2+1 configuration is specifically designed for parents traveling with a small child or small groups who wish to sit together without the obstruction of fixed armrests. Located in the Social Zone, this layout easy access to the rear facilities and the self-service lounge, ensuring that the most active "tribe" in the cabin has a dedicated territory that does not disturb those in the forward sections.

6 Final Design

This chapter presents the definitive 2040 cabin design, detailing the transition from conceptual ideation to a fully realized and technically grounded interior ecosystem. Through high-fidelity visualizations and a comprehensive evaluation of feasibility, desirability, and viability, this section demonstrates how the final proposal fulfills the project's strategic vision for the next generation of air travel.

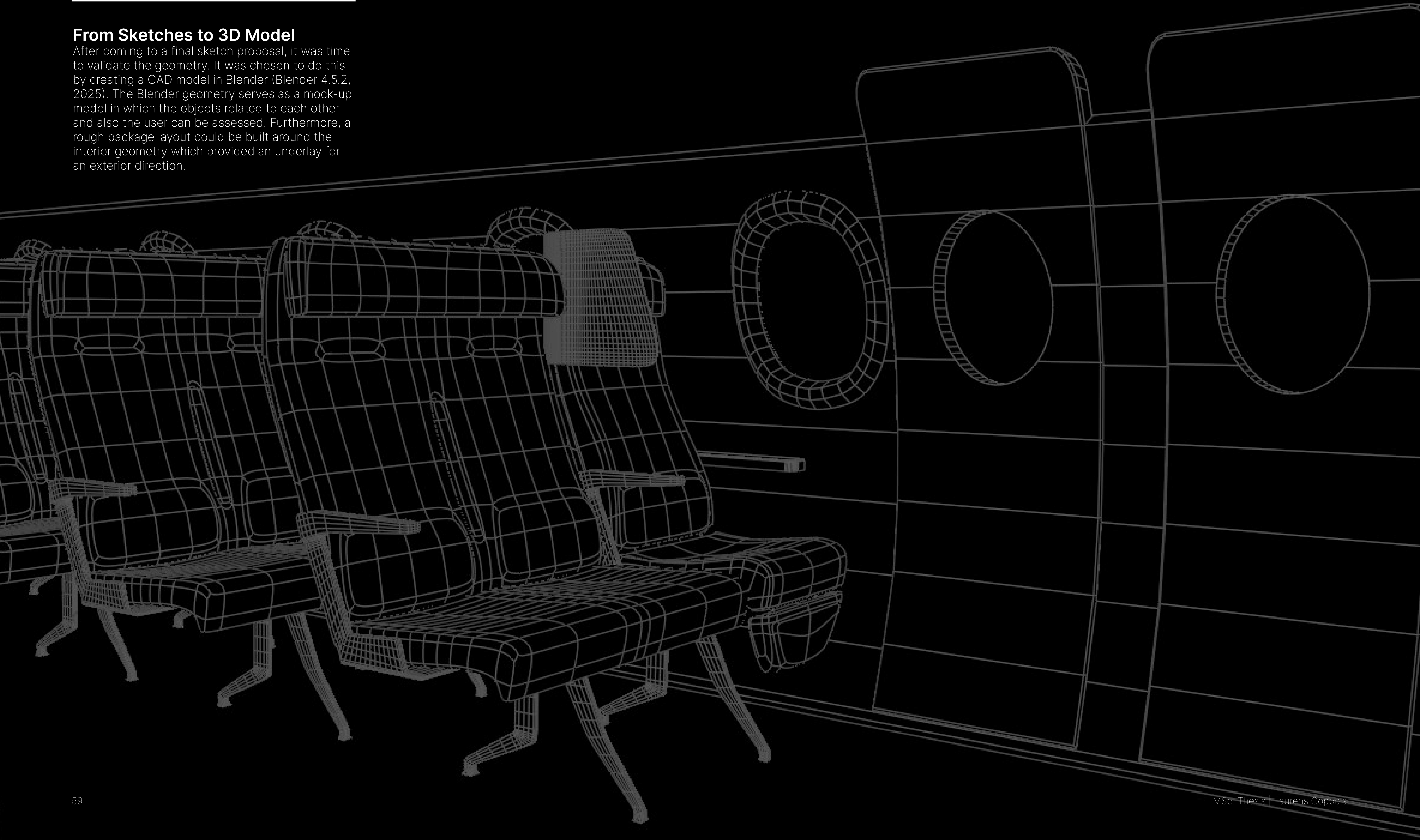
1. CAD Modelling
2. Layout
3. Final Design Visualizations
4. CMF
5. Cabin Impressions using AI
6. Feasibility, Desirability & Viability



6.1 CAD Modelling

From Sketches to 3D Model

After coming to a final sketch proposal, it was time to validate the geometry. It was chosen to do this by creating a CAD model in Blender (Blender 4.5.2, 2025). The Blender geometry serves as a mock-up model in which the objects related to each other and also the user can be assessed. Furthermore, a rough package layout could be built around the interior geometry which provided an underlay for an exterior direction.



6.2 Layout

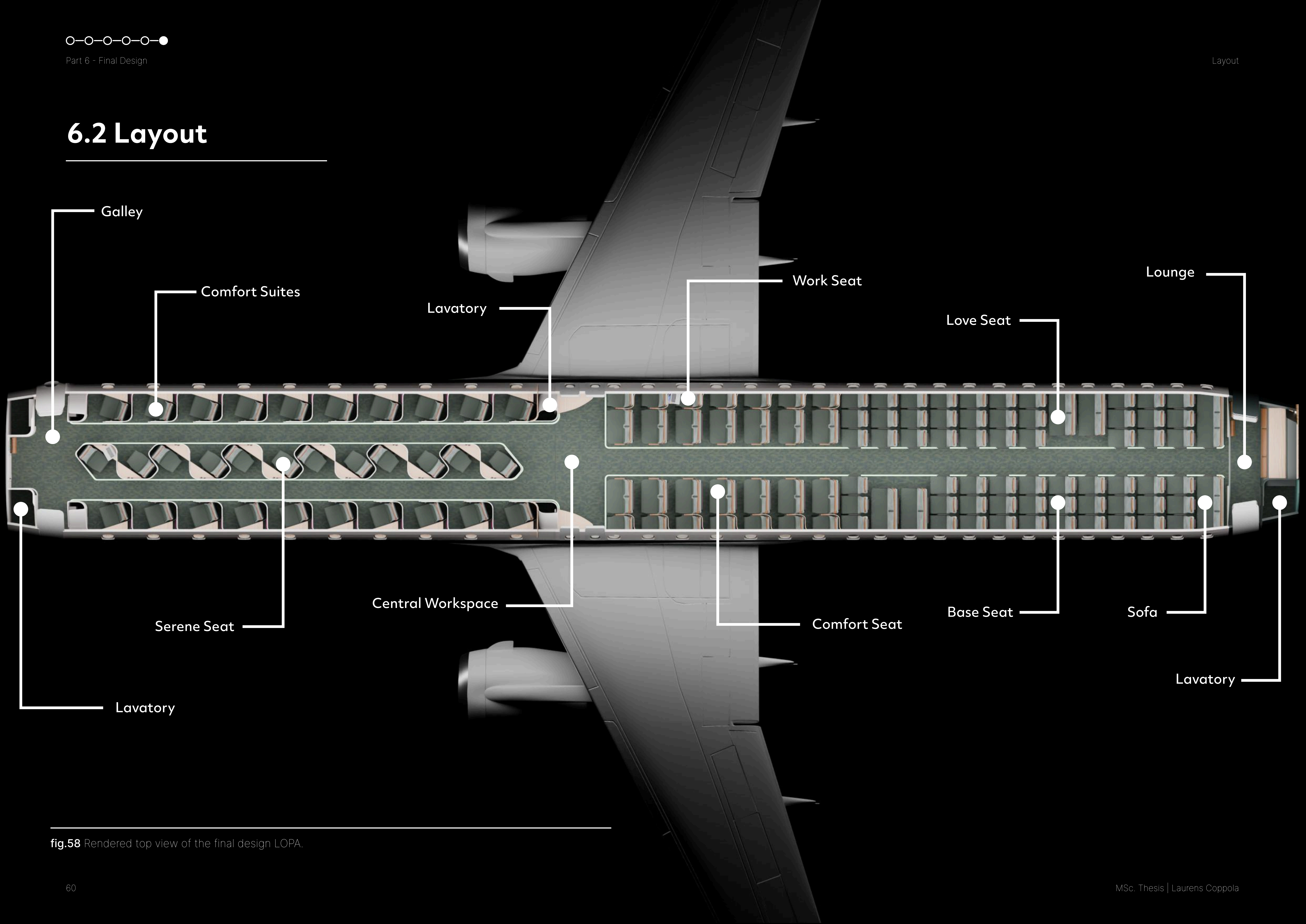


fig.58 Rendered top view of the final design LOPA.

6.3 Final Design Visualizations

Entrance

The forward entrance serves as the definitive face of the aircraft, reimagined as a large, open foyer to eliminate the typical boarding bottleneck. This zone provides a spacious environment for cabin crew to greet passengers, moving away from the cramped corridors of contemporary narrowbodies. Despite its airy aesthetic, the area is highly functional, housing a dedicated forward lavatory for pilot and passenger use, along with a high-capacity galley optimized for the rigorous catering demands of a long-haul flight.

fig.59 Entrance.

fig.60 Entrance features.

Quiet Zone

The Quiet Zone introduces a revolutionary twin-aisle architecture designed to maximize personal space and visual calm while resolving traditional boarding bottlenecks. By relocating storage to a central overhead luggage compartment, the sidewalls are opened to feature expansive digital screen-windows that dramatically enhance the sense of spaciousness by breaking through the perception of the narrow airframe. The seating strategy utilizes a coherent design language defined by organic, fluid structures that harmonize luxury with operational efficiency. Private Comfort Suites line the windows to provide maximum privacy and direct aisle access for an undisturbed journey, while the center section features the Serene Seats. These intertwined, staggered shells optimize the cabin's width to provide a premium, restorative environment specifically tailored for deep long-haul rest.

Comfort suite with a surrounding IFE system

Top view of the s-shaped serene seating structure

fig.61 Schematic top view of the Serene Seats structure.

fig.62 Comfort Suite.

Cabin Lighting

The 2040 cabin architecture leverages the vertical volume freed by the removal or repositioning of traditional overhead bins to accommodate large-scale LED ceiling panels. These panels function as a "Digital Skylight," projecting sharp skyscapes or an open canopy that effectively decompress the interior and break the perception of the narrow fuselage. Central to this atmospheric strategy is a circadian lighting system designed to support the physiological recovery of long-haul travelers. The system transitions from an energizing, bright blue sky during midday service to warm, darker tones during the night cycle, ensuring the cabin experience remains synchronized with the passenger's natural biological clock. This immersive integration of light and technology transforms the ceiling into a dynamic landscape, enhancing the overall sense of spaciousness and connectivity to the outside world.

fig.63 Quiet Zone lighting impression.

fig.64 Atmospheric impression render.

fig.65 Atmospheric impression render.

Central Workspace

The Central Workspace acts as the strategic heart of the cabin's central distribution model, positioned specifically to halve the maximum service distances for the crew. By viewing the aircraft as a single connected system rather than a series of isolated pockets, this zone optimizes operational efficiency while housing two high-capacity lavatories. These facilities are central to ensuring universal accessibility, as their mid-cabin placement significantly reduces the travel distance for passengers with reduced mobility from any point in the cabin. Flanking the emergency exits are two transformable workspaces designed for high phase-based versatility. During critical phases like boarding, takeoff, and landing, these units remain stowed or retracted to ensure a clear, safe egress path and a spacious floorplan. Once the aircraft reaches cruise altitude, these modules deploy into functional service nodes for the crew or interactive stations within the "Social Spine," effectively bridging the gap between safety requirements and the need for fluid in-flight movement.

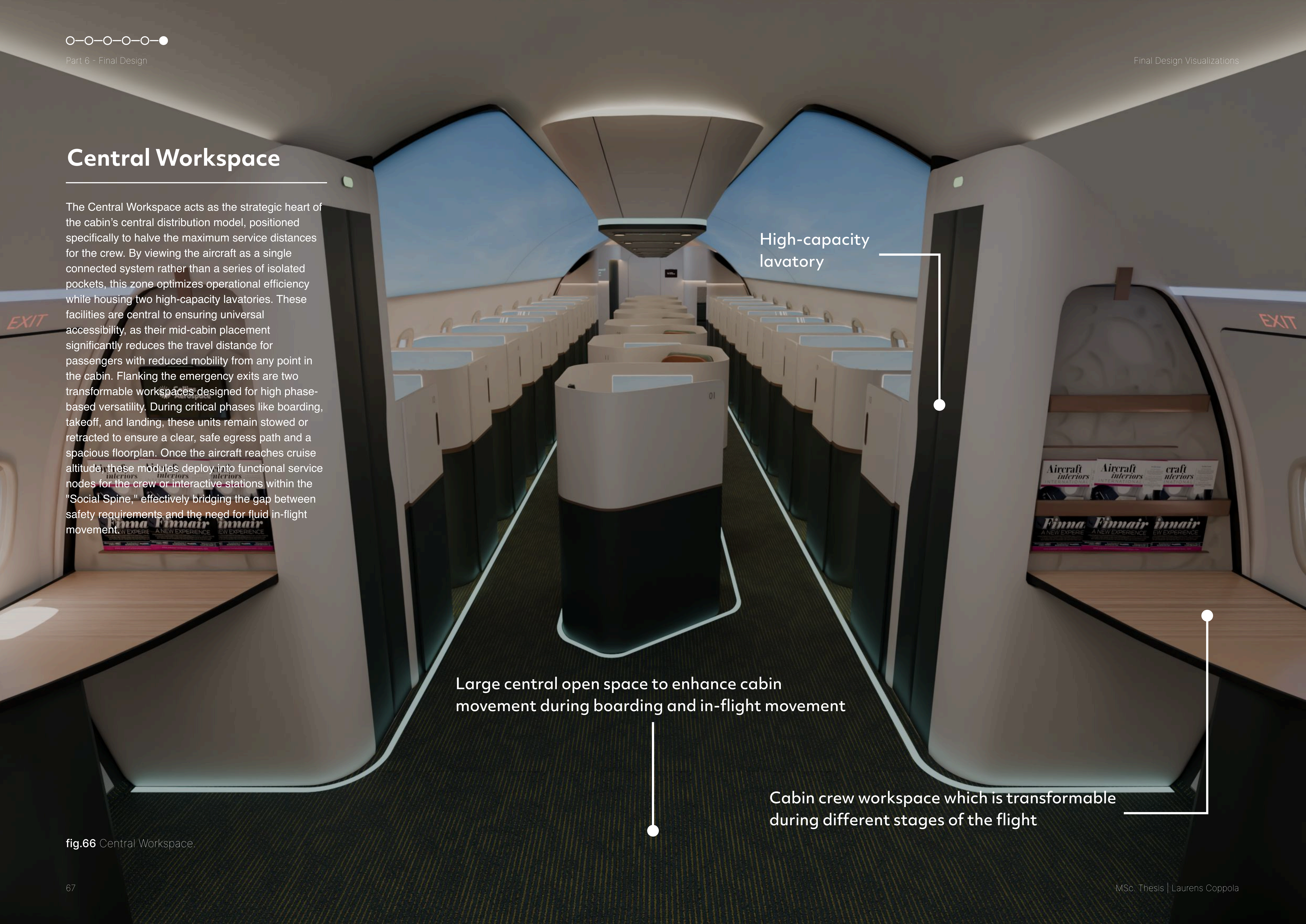


fig.66 Central Workspace.

fig.67 Central Workspace transformation.

fig.68 Atmospheric impression render.

Relax Zone

Positioned as the central acoustic transition of the cabin, the Relax Zone comprises seven rows engineered with extended legroom to prioritize deep passenger recovery and postural variety. This zone utilizes a unique asymmetrical 1-2 configuration that caters to diverse traveler archetypes through a blend of focused productivity and domestic comfort. The window side features an individual turnable work-seat, providing solo travelers with a private, adaptable sanctuary for focused tasks or quiet observation. Adjacent to this, the aisle section consists of the Comfort Bench, a spacious two-person sofa equipped with a foldable armrest. This bench offers exceptional versatility, allowing a pair to share the space or providing a single passenger with a wide, premium bench that evokes a residential feel. By eliminating the traditional middle-seat compromise, this layout reinforces a sense of personal territory and bridges the gap between conventional classes with a more intuitive, inclusive design.

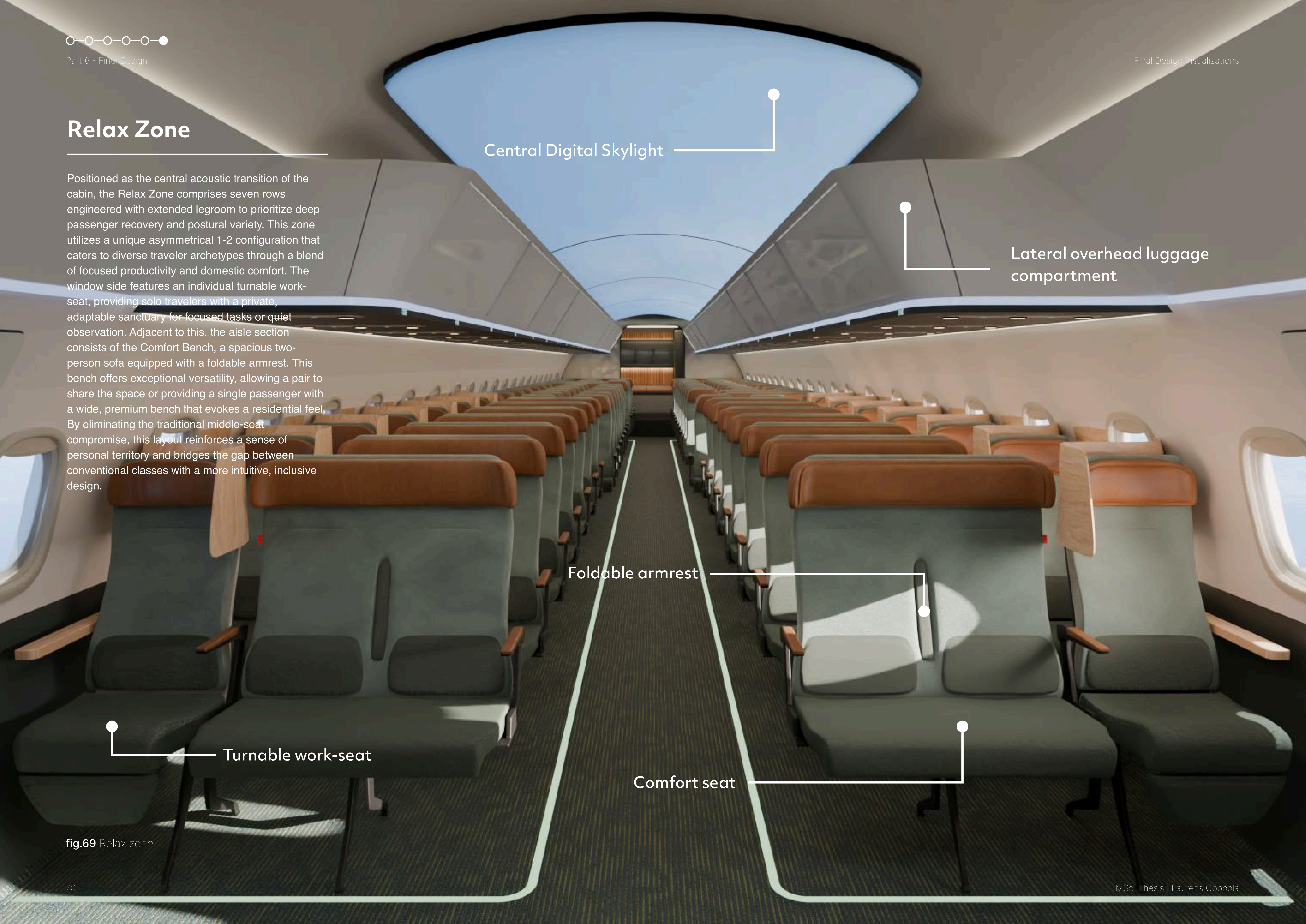


fig.69 Relax zone.

fig.70 Work Seat.

Social Zone

Positioned toward the rear where the noise gradient is naturally higher, the Social Zone is engineered to accommodate the most active travelers within the cabin's modular ecosystem. This section utilizes a strategic integration of seats and innovative passing areas designed to mitigate aisle congestion and facilitate fluid movement during high-traffic periods. Adjacent to these flow zones are the Love Seats, which provide essential lateral space for couples or individual travelers seeking a more relaxed, residential posture. At the far rear, the zone features dedicated Sofas in a 2+1 configuration, specifically tailored to support groups and those traveling with small children in a cohesive environment. To maintain a sense of expansive openness within the tapering fuselage, the architecture utilizes flanking overhead luggage compartments that frame a central Digital Skylight. This ceiling-integrated screen projects a bright, airy canopy that counteracts the narrowing cabin walls, ensuring the Social Zone remains a vibrant and inviting hub for connection and aesthetic relief.

fig.71 Social Zone.

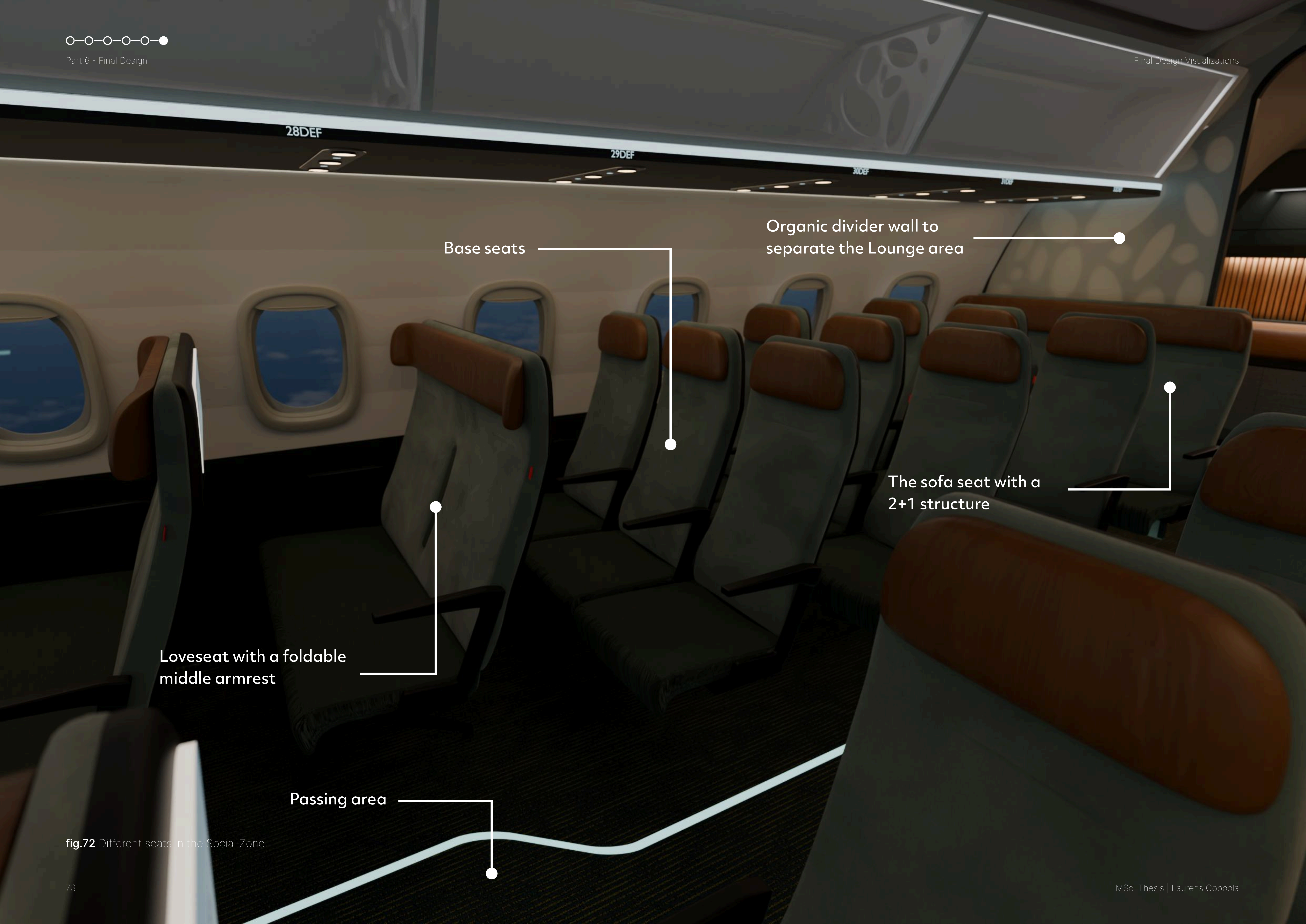


fig.72 Different seats in the Social Zone.

Social Lounge

The social Lounge serves as the final destination of the "Social Spine," acting as a communal anchor that completes the cabin’s longitudinal flow. Specifically designed to ease the physical and mental fatigue of a 10-hour flight, this space provides an essential area for passengers to move around, stretch, and take a break from sitting. Within this organic hub, travelers can socialize or refresh themselves at the built-in self-service bar, which is shaped with smooth, natural curves. A dedicated leaning rail provides a casual spot for conversation, encouraging people to move away from the seating areas and keep the aisles clear. To ensure the zone is fully supported, it integrates a versatile crew workspace for service preparation alongside a dedicated rear lavatory. This layout transforms the back of the aircraft into a welcoming social destination, balancing the operational needs of the crew with the comfort and movement of active traveler tribes.

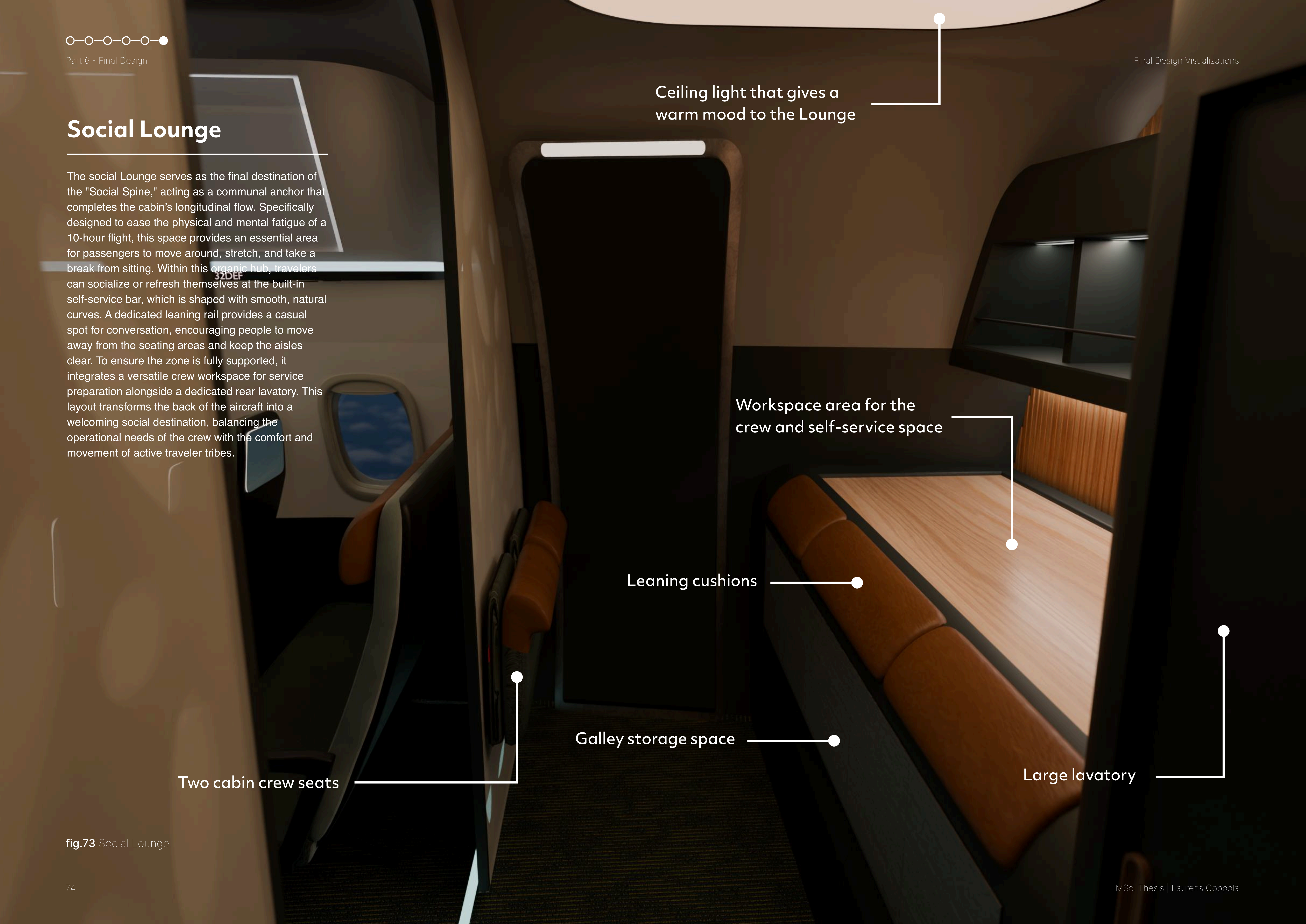


fig.73 Social Lounge.

6.4 CMF

The styling and materialisation of the 2040 cabin are deeply rooted in the Tribal Aspiration future scenario. This vision demands a design language that nurtures a sense of belonging through organic aesthetics and inclusive, human-centric forms.

Materials

The materialisation strategy for the 2040 cabin is heavily inspired by Volvo's recent innovations in sustainable automotive luxury, focusing on textures that evoke a sense of being alive. These materials, including natural wool, woven flax, and wood accents, are used purely for aesthetic inspiration to define a desired look and feel, and do not account for technical aviation safety standards or flammability regulations at this ideation stage. To achieve restorative comfort and support the goal of premium rest, the seating concepts draw from the tactile warmth of breathable natural wool and bio-based woven flax, representing a shift toward residential-style comfort. Furthermore, strategic interior elements, particularly in the Social Lounge and Comfort Suites, incorporate natural wood accents to introduce a biophilic influence that grounds the high-tech environment and reinforces a symbolic connection to the natural world. These material choices are complemented by a palette of warm, organic colors and atmospheric lighting to enhance the overall sense of tranquility and emotional calm throughout the cabin journey.

Styling

The aesthetic direction moves away from the cold, industrial cabin of traditional aviation toward a more organic, warm and supportive environment. Inspired by the interaction analogy, the styling prioritizes soft, flowing lines and nested geometries, such as the intertwined S-Seats. These shapes are designed to evoke a feeling of "Simultaneous Solitude," where the cabin architecture feels like it moves with the passenger rather than around them. By utilizing vertical tiering and digital horizons to break up the fuselage walls, the styling creates an expansive, airy atmosphere that promotes emotional calm and wellness.

fig.74 Volvo's Nordico seat material made out of woven flax.

fig.75 Green natural wool's material impression.

fig.76 Curved natural wood material impression.

6.5 Cabin Impressions using AI

To accurately communicate the atmospheric qualities of the 2040 vision, integrating human figures was essential to making the cabin environment feel "lived." As realistic character modeling is technically demanding within Blender alone, I leveraged the AI-driven design tool Vizcom (2025) to enhance the base geometry. This allowed me to create more evocative scenes by directing the tool to incorporate human presence, warm organic materials, and nuanced lighting, ultimately bridging the gap between technical CAD modeling and compelling visual storytelling.

fig.77 Cabin atmospheric impressions renders realized by Vizcom.

6.6 Feasibility, Desirability & Viability

Feasibility

The final design is technically feasible because it balances radical spatial reimagining with the rigid engineering constraints of the single-aisle aircraft (SAA) platform.

- **Dimensional Integrity:** The layout is engineered to fit within the standard 3.70m narrowbody cross-section. While it introduces a twin-aisle section in the forward "Quiet Zone," it maintains the legal minimum aisle widths required by the FAA (14 CFR § 25.815) for rapid egress.
- **Certification Pathway:** Unlike the ceiling-suspended Hammock (Concept 1), the final design utilizes floor-mounted seating tracks. By avoiding complex moving floor tracks (Concept 2), the design remains compatible with 16g dynamic safety testing.
- **Operational Compatibility:** The design respects the A321XLR mission profile, ensuring that galley capacity can still accommodate the 10–14 full-size equivalent (FSE) trolleys necessary for a 10-hour flight.
- **Technological Maturity:** The use of Digital Windows and immersive LED panels leverages display technologies projected to be lightweight and mature by 2040, allowing them to replace bulky overhead luggage bins without exceeding current weight-to-efficiency ratios.

Desirability

The design directly addresses the primary friction points identified in passenger surveys and behavioral research, fulfilling the "Tribal Aspiration" vision.

- **Solving the Boarding Bottleneck:** Boarding was identified by 60.9% of passengers as the most frustrating stage of flight. The final design solves this through a large forward entrance foyer and centralized luggage storage, which eliminates "aisle-lock" and speeds up the process.
- **Restorative Ergonomics:** Following Peter Vink's principles, the design prioritizes seat width over pitch, using "S-Seats" and "Comfort Suites" to provide the lateral space necessary for varied postures and deep sleep.
- **Simultaneous Solitude & Shared Presence:** The modular seating ecosystem, ranging from Love Seats for couples to private Work Chairs, allows diverse traveler tribes (Gen Alpha, Z, and Millennials) to curate an experience that matches their social needs rather than just their ticket price.
- **Holistic Atmosphere:** The "Noise Gradient" zoning strategy ensures that passengers seeking quiet are physically separated from high-activity social hubs like the Social Lounge, enhancing psychological well-being during long-haul missions.

Viability

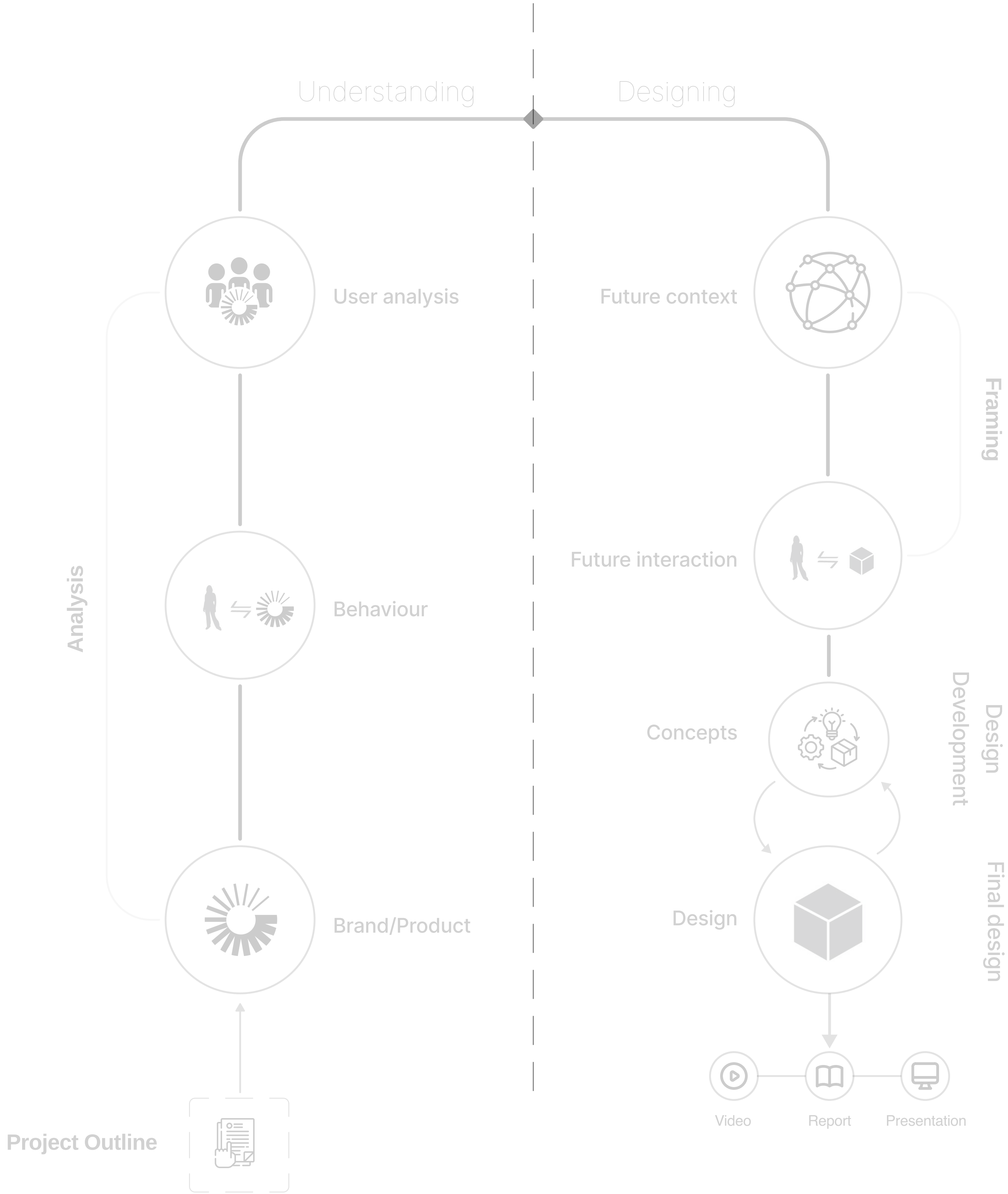
The concept addresses a major undiscovered territory in the aviation market, offering airlines a high-yield alternative to traditional class stratification.

- **The "Business Down" Opportunity:** By bridging the gap between Business and Premium Economy, the design creates a "Comfort Class". This allows airlines to sell premium rest and privacy in a more compact, higher-density footprint than a traditional full-flat suite.
- **Increased Turnaround Efficiency:** For airlines, time is money. Reducing turnaround time by just one minute can save a large carrier $50 million annually. The twin-aisle architecture and hybrid storage solutions are designed specifically to optimize these operational flows.
- **Brand Uniformity:** Concept 3 (Modular Ecosystem) provides a unified design language that can be customized for different airlines while maintaining the core manufacturing efficiencies Collins Aerospace requires.
- **Future-Proofing for Next-Gen SAA:** As legacy fleets reach their economic end-of-life around 2040, this design offers a ground-up standard that aligns with the industry's shift toward long-haul narrowbody travel (e.g., A321XLR), ensuring long-term market relevance.

7 Discussion

This chapter evaluates the project's outcomes against the initial research objectives, positions the 2040 vision within the current state-of-the-art in aviation design, and critically analyzes the limitations of the proposed solutions. By synthesizing design results with academic and industrial benchmarks, this section identifies the broader societal implications and provides a roadmap for future development.

1. Synthesis
2. Recommendations
3. Evaluation
4. Personal Reflection



7.1 Synthesis

To evaluate the success of the 2040 Cabin Experience, we must return to the research questions posed in Chapter 1.

RQ 1: What will passengers expect from air travel in 2040?

The research identified a shift from passive consumption to active well-being. RQ 1.1 (biggest annoyances) highlighted that boarding stress and physical confinement remain the primary friction points. By 2040, RQ 1.2 (passenger profiles) suggests that Gen Alpha and an aging population will prioritize universal design and digital-physical fluidity. Consequently, RQ 1.3 (desired activities) reveals a demand for restorative sleep and kinesthetic relief, which the final design addresses through the Social Lounge and widened seat geometries.

RQ 2: How can cabin spaces be adaptable to various demographics?

The concept of "Atmospheric Zoning" provides the answer. RQ 2.1 (wanted spaces) identified the need for both seclusion and social connection. By utilizing a Modular Ecosystem (RQ 2.2), the design moves away from rigid class silos. Instead, it offers a "needs-based" selection, such as the Family Bench or the Work-Seat, allowing the 148-seat configuration to be curated by the passenger’s specific intent rather than just their ticket price.

RQ 3: How can crew environments be optimized for efficiency?

The analysis of RQ 3.1 (crew annoyances) identified "aisle-lock" and far distibution distances as critical bottlenecks. The study concludes that the role of the crew in 2040 (RQ 3.2) will transition from manual service to hospitality management. The proposed decentralized 3-zone workspace halves service distances and facilitates more agile movement, though its success is highly dependent on the hardware miniaturization discussed in the limitations.

Limitations and Failures

A primary limitation is the tension between spatial flexibility and certification. The initial "Hammock Cocoon" and "Sliding Rows" were discarded due to the 16g load requirements and entrapment risks. Even the final design’s "Modular Ecosystem" introduces a higher degree of part-count complexity compared to standard 3-3 layouts. For Collins Aerospace, this represents a manufacturing challenge: the benefits of personalization must be weighed against the increased maintenance and certification costs of having seven different seat types in a single cabin.

The design assumes a high level of technological maturity for 2040. For example, the "Digital Skylight" and "Hybrid Digital Window" require ultra-lightweight, flexible LED panels that do not yet exist at the scale and weight-efficiency required for aerospace. Furthermore, the volumetric audit for the decentralized galleys assumes a reduction in trolley size that has not been technically detailed. Without this reduction, the loss of seating capacity in the "Social Zone" may not be economically viable for Low-Cost Carriers (LCCs).

7.2 Recommendations

Styling

Privacy Shield (Serene Seat)

A critical refinement for future iterations of the Quiet Zone is the integration of a physical privacy shield for the Serene Seats located in the center section. During the design review, Jeff McKee identified a potential flaw in the twin-aisle layout: because these middle seats are flanked by foot traffic on both sides, passengers may feel overly exposed, as if they are sitting in a hallway rather than a premium cabin. To address this, I recommend developing a protective buffer that reinforces the individual's psychological territory and provides a sense of isolation. While the current staggered geometry successfully optimizes the cabin's narrowbody width, the addition of a dedicated shield would ensure that solo travelers experience a truly secluded and restorative environment, shielded from the constant movement within the dual aisles during long-haul missions.

Privacy Shield (Work Seat)

For the individual work-seats within the Relax Zone, I recommend evolving the current fixed privacy shield into a slidable or retractable mechanism. In the current iteration, the fixed geometry has not yet been fully tested for its impact on passenger ingress and egress, nor for the specific level of psychological seclusion it provides. By introducing an adjustable shield, travelers could minimize the barrier for easy seat access and maximize it during periods of deep focus or rest. This modification would empower the solo traveler to curate their own environment, ensuring that the work-seat remains a truly flexible sanctuary that balances open communication with the need for a private, distraction-free territory.

Seat Legs

Due to the primary focus on engineering a versatile modular seating ecosystem and optimizing complex seat kinematics, the current seat base and leg structures retain a relatively conventional and simplified aesthetic. For future design iterations, I recommend developing a more coherent and biomimetic design language for these components to ensure they harmonize with the organic fluidity of the primary seat shells. Refining these support structures into more sculptural, integrated forms would not only enhance the future vision's aesthetic but also provide a greater sense of visual coherence at the floor level, further connecting up the cabin's architecture.

IFE window integration

While the current curved IFE displays provide an expansive viewing area for window-seat passengers, the visual continuity is currently interrupted by the physical aperture of the conventional window. To achieve a truly seamless and immersive environment, I recommend the development of smart-surface window blinds that function as an extension of the digital display when closed. This integration would eliminate the current visual break, transforming the entire sidewall into a unified, flowing digital horizon while still preserving the passenger's autonomy to open the blind and connect with the real-world view. By merging the physical window with high-definition display technology, the cabin can offer a flexible atmosphere that transitions between a private digital sanctuary and a traditional observation-focused experience, reinforcing the holistic design language seen throughout the 2040 cabin.

Practical

Galley Capacities

To preserve the aspirational nature of the 2040 vision, the design intentionally moves beyond current operational constraints regarding galley capacity and service delivery. By transitioning from traditional trolley-based service to a decentralized distribution model within the 3-zone workspace, the design enables more agile crew interaction and reduces aisle congestion. Future research should focus on detailing the specific hardware and modular point-of-use storage units intended to replace standard trolleys. Furthermore, a comprehensive volumetric audit and capacity calculation for specific long-haul missions are required to ensure that these decentralized nodes fully accommodate the catering demands of extended flight durations.

Luggage Butler System

To further mitigate the primary boarding bottleneck caused by carry-on baggage, I recommend the future development of an automated "butler" logistics system. This concept proposes automatically sorting larger hand luggage prior to boarding and storing it in the cargo area, ensuring only small personal items are accepted into the cabin. While the current architecture retains overhead compartments to maintain commercial viability and manage technical complexity , this automated approach would eventually enable the full removal of overhead structures.

Self-service system

While the final design implements the aft Social Lounge as a self-service "Coffee Corner", I recommend the future integration of a smart service system within the cabin's IFE ecosystem. This digital interface would provide travelers with real-time updates regarding lounge occupancy and available inventory, facilitating a controlled and seamless flow of movement throughout the aircraft. By keeping passengers informed of current bar capacity and stock via their personal screens, the system would prevent overcrowding in the Social Zone while ensuring the area remains an inviting hub for interaction and kinesthetic relief.

Booking System

The proposed 2040 cabin experience transitions from rigid, ticket-price-based class silos to a dynamic, activity-oriented model where passengers select seating based on their primary journey goal. In this Modular Ecosystem, seat selection is driven by traveler's specific needs: a solo professional may prioritize the work seat, a couple might opt for the loveseat, and a passenger requiring increased seating area can select a specialized comfort seat. To successfully operationalize this shift toward mass customization, I recommend the development of a next-generation booking system and a tailored marketing strategy that empowers travelers to curate their own environment. This system must clearly communicate the functional and psychological benefits of each zone, such as productivity, restorative rest, or social connection.

fig.78 Pricavy Shield recommendation for the Serene Seat.

fig.79 Seat legs recommendation.

fig.80 Pricavy Shield recommendation for the Work Seat.

fig.81 Window IFE integration recommendation.

7.3 Evaluation

The initial phase of this project proved to be a significant challenge due to the sheer scale and complexity of the assignment. Designing a comprehensive aircraft cabin is a monumental task for a single designer, primarily because commercial aviation is one of the most strictly regulated industries in the world. Designers must navigate a rigid landscape of safety certifications and "physics boundaries" while working within highly confined spaces that offer very little margin for error. Furthermore, air travel today is characterized by a multitude of passenger pain points and mixed experiences, making it difficult to address every friction point effectively.

The project brief initially was too broad (Appendix A). This was the description: "*The central challenge of this internship is to analyze future travel trends—ranging from business and leisure travellers to families and multi-demographic groups—and assess the evolving demands on cabin space and crew environments. You will explore how connectivity, sustainability, comfort, and new service systems can be harmonized in both long-haul and short-haul aircraft.*

The ultimate goal is to deliver an aspirational design concept of a next-generation aircraft cabin, supported by compelling visuals that provoke thought and spark imagination."

In my ambition to provide a truly holistic vision for 2040, I initially took on too much. I found myself mentally pulled in multiple directions: solving the boarding bottleneck, reimagining seat ergonomics, addressing luggage storage inefficiency, and optimizing confined crew workspaces. Rather than narrowing my focus early on, I eventually decided to tackle all these areas simultaneously. While this increased the workload and the difficulty of getting the project "off the ground," I felt it was necessary to deliver a complete and meaningful cabin experience that truly provokes thought about the future of flight.

Process Evaluation

The Vision in Product (ViP) methodology provided a critical baseline for managing this complexity. Designing for a horizon two decades away is inherently difficult because the future is unknown, yet ViP offers a structured framework to justify design decisions by grounding them in a projected context rather than random creative impulses. However, a personal challenge arose during the "worldview" phase; while defining future user behaviors and societal shifts is a core part of the method, it remains a prediction. It can be difficult to feel fully convinced by these speculative scenarios when the weight of the final design relies so heavily on their accuracy.

As many designers experience, the urge to move into the ideation phase often begins long before the research is complete. Ideas began to surface early on, yet maintaining momentum proved challenging within the environment of Collins Aerospace. Operating within a global organization with thousands of employees with strict confidentiality protocols was a new experience for me. Navigating the corporate structure of such a large industry leader initially made it difficult to gain the necessary traction, requiring a period of adaptation to the pace and requirements of a professional aerospace innovation hub.

Final Design Evaluation

The commercial aviation industry is notoriously conservative, defined by stringent safety regulations, high cost pressures, and long development cycles that often lead to incremental rather than radical change. Throughout this project, I have had to navigate the inherent tension between visionary "blue-sky" thinking and the rigid engineering boundaries of an industry that prioritizes "purity, simplicity, and optimization" above all else. In the early stages of ideation, I experienced firsthand how the weight of these restrictions can stifle creativity; several ambitious concepts were initially cut off because the hurdles regarding certification proved too great.

However, creating a vision for 2040 requires a refusal to be restricted by current paradigms. If we allow ourselves to be scared off by today's certification barriers, we fail to design for the technological maturity and societal shifts of tomorrow. This project proved that while technical feasibility must be respected, it should not lead the creative process in its infancy. By pushing past these early hurdles, I was able to transition from mechanical-focused solutions to a more sophisticated, phase-based atmospheric transformation that remains "credibly engineered" without sacrificing its aspirational core.

Looking back at the original project brief and the numerous challenges encountered, I can say with pride that the final design represents a truly innovative and previously unseen approach to the single-aisle long-haul experience. It moves beyond traditional class silos to offer a holistic, activity-oriented ecosystem that prioritizes human well-being and organic fluidity. By integrating "Tribal Aspiration" with organic CMF inspirations, this design hopefully offers a new blueprint for how airlines can provide a premium restorative environment within high-density constraints. My hope is that this vision sparks inspiration for future designers and companies, providing them with new insights on how to harness organic inspirations to create a connected and meaningful journey for the next generation of air travelers.

7.4 Personal Reflection

Industry Experience

My primary objective for this graduation internship was to gain firsthand experience within a major global corporation. Collins Aerospace, a business unit of RTX, provided a perfect yet imposing environment for this goal, given its status as a global leader in technologically advanced aerospace and defense solutions. Operating as part of a massive organization that employs over 70,000 people and providing military technology, introduced me to a highly structured, hierarchical, and professional corporate culture.

Initially, I felt a degree of skepticism and found the scale of the company somewhat imposing, particularly while having "intern" status within such a vast industrial framework. However, this feeling shifted as I realized the unique nature of my role. I was the sole party working on the vision of Collins Aerospace to define the 2040 cabin experience. Being the only designer dedicated to this specific visionary project was both a privilege and a source of significant professional pressure.

The mentorship I received from Arnau Castillo and Jeff McKee was vital in navigating these complexities. They treated me as an expert in my field, enthusiastically encouraging my explorations while providing necessary technical guidance and the creative freedom. This high-trust environment allowed me to make a tangible impact, which has been validated by the positive internal reception of my design outcome within the EU Innovation Hub.

Despite these successes, the sheer size of a global entity presented clear challenges. Because the organization is so vast and geographically spread, maintaining a sense of unity and momentum is difficult. That is why it is unfortunate we could not visit the U.S. headquarters. Furthermore, the conservative nature of the aviation industry and strict legal restrictions often resulted in delays, such as the late arrival of essential documents, which occasionally hindered the project's pace. These experiences provided me with a realistic understanding of the friction points inherent in large-scale corporate innovation.

Assignment

Getting the opportunity to craft a future vision for a complete aircraft interior has been a true milestone in my journey as a designer. Throughout my educational career, I have intentionally steered my focus toward mobility and complex systems, and this assignment felt like the culmination of those choices. Having previously tackled a similar future-vision project for a Hyperloop concept, I initially felt I had a solid foundation for this type of work; however, the aviation context proved to be far more tangible and grounded in reality. The transition from the more speculative nature of the Hyperloop to the rigorous world of aerospace was both challenging and rewarding.

Working alongside a major industry leader like Collins Aerospace added a significant layer of gravity to the process. Navigating strict regulatory requirements and presenting to high-level stakeholders transformed the project from a standard academic exercise into a position of real professional stewardship. I felt a deep sense of responsibility to respect the heritage of the industry while pushing the boundaries of what is possible. Ultimately, being entrusted with such a high-stakes vision was a "dream" assignment that allowed me to merge my passion for mobility.

Project Management

Reflecting on the management of this project, I realize that the initial phase was perhaps my greatest challenge. The sheer breadth of the subject matter felt overwhelming at first, and without a predefined path to follow, I often felt lost in the face of such an expansive scope. Navigating a project of this scale entirely on my own was a new experience that required a level of self-reliance I hadn't previously tested. Because detailed scheduling has never been my natural forte, I had to be incredibly disciplined to maintain a rigorous timeline. It required a constant, conscious effort to stay sharp and hold myself accountable to strict milestones to ensure the project didn't drift off course.

The documentation process presented its own set of hurdles. My natural design instinct is to explore diverse territories and let ideas evolve rapidly; while these connections made perfect sense in my head, translating that internal mental map into a structured, written narrative was difficult. Keeping up with the report in real-time was a constant struggle, as I found it challenging to weave my various explorations into a single, coherent story that someone else could follow. I also realized throughout the process that documenting setbacks is just as crucial as documenting successes. Even when things didn't go as planned, recording those "failures" was essential to the integrity of the project. Ultimately, despite the steep learning curve and the significant amount of sleep lost during the final push, I successfully met every deadline and finished the project on time.

Result

Being naturally self-critical, I often find it difficult to view a design as truly finished, as there is always an inherent desire to iterate and improve. While I am rarely easily impressed by my own work, looking back, I feel a genuine sense of accomplishment. I must admit that I initially misjudged the technical depth and time-intensive nature of certain design phases, which led to inevitable mistakes and a very steep learning curve. However, navigating these obstacles required me to absorb a vast amount of industry-specific knowledge and experience within a remarkably short timeframe. The setbacks I had during the process resulted in significant leaps forward in my capabilities as a designer. While a few minor elements still leave room for refinement, I am ultimately pleased with the final outcome. I believe the 3D model and the final video successfully reflect the level of design I am capable of delivering, marking a proud and successful conclusion to my first major solo project within the aerospace industry.

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Appendix A

Project Description

This appendix presents the original project description provided by Collins Aerospace. It outlines the initial research mandate and aspirational goals that served as the starting point for this graduation project.

Collins Aerospace
An RTX Business

MSc Graduation Project: Designing the Next Generation of Aircraft Cabin Experiences

Company : Collins Aerospace, an RTX business, is a leader in technologically advanced and intelligent solutions for the global aerospace and defense industry. Collins Aerospace has the extensive capabilities, comprehensive portfolio and broad expertise to solve customers' toughest challenges and to meet the demands of a rapidly evolving global market.

In the Netherlands, Collins Aerospace has created the EU Innovation Hub, whose role is to support the development of advanced technologies for aircraft interior products. The main focus of the Hub is sustainable advanced materials, intelligent sensors and systems, innovative designs and customer experience, and manufacturing technologies.

Website: https://www.collinsaerospace.com/

Description : This MSc Graduation Project offers an exciting opportunity to shape the future of air travel by exploring emerging trends and crafting visionary cabin concepts for the aircraft of tomorrow. Hosted within the Innovation Hub of Collins Aerospace, this project focuses on redefining passenger and crew experiences in line with future societal needs, sustainability goals, and technological advancements.

The central challenge of this internship is to analyze future travel trends—ranging from business and leisure travellers to families and multi-demographic groups—and assess the evolving demands on cabin space and crew environments. You will explore how connectivity, sustainability, comfort, and new service systems can be harmonized in both long-haul and short-haul aircraft.

The ultimate goal is to deliver an aspirational design concept of a next-generation aircraft cabin, supported by compelling visuals that provoke thought and spark imagination (think Airbus 2030 Cabin of the Future).

This concept should address key questions:

- What will passengers expect from air travel in the 2030s?
- How can cabin spaces be adaptable to various demographics?
- How can crew environments be optimized for efficiency and well-being?

You will engage in trend research, stakeholder analysis, creative ideation, and visual storytelling, culminating in a portfolio-worthy cabin design that inspires the industry toward the next evolution of air travel.

We are looking for a proactive, creative, and visionary student with a critical mindset and a passion for future mobility. The ability to translate trends and research into impactful design concepts will be key to success in this internship.

Profile: Industrial Design Engineering faculty student, DOS (Design, Organisation and Strategy) Masters' student. Interest or experience in trend research, concept design, and visualization tools is a plus.

Period: Project start is flexible.

Language: English
Location: Elzenkade 1,3992AD, Houten, the Netherlands (hybrid option possible)
Salary: [redacted]
Contact: arnau.castillo@collins.com / g.a.vandenboogaard@tudelft.nl

Appendix B

Project Brief

This appendix contains the formal Project Brief as approved by the TU Delft supervisory team at the onset of the graduation process. It documents the initial research scope, proposed methodology, and established timelines that served as the procedural foundation for this Master's thesis.

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	Coppola	IDE master(s)	IPD ✔ DfI ☐ SPD ☐
Initials	LD	2nd non-IDE master	
Given name	Laurens	Individual programme *(date of approval)*	
Student number	4869257	Medisign	☐
		HPM	☐

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

Chair	Elmer van Grondelle	dept./section	Form and Experience
mentor	Martijn Haans	dept./section	Form and Experience
2nd mentor	Arnau Castillo		
client:	Collins Aerospace		
city:	Houten	country:	The Netherlands
optional comments	I have chosen Elmer van Grondelle as my chair for his experience in mobility, and Martijn Haans as my mentor to guide the visual presentation of my project. My choice is further supported by successful previous experiences with both.		

! 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)

Elmer van Grondelle - IO
Digitally signed by Elmer van Grondelle - IO
Date: 2025.11.25 15:40:05 +01'00'

Name Elmer van Grondelle Date ____ Signature ____

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Laurens Coppola **Student number** 4,869,257

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

Project title Designing the Next Generation of Aircraft Cabin Experiences

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)

This project takes place in the domain of aerospace interior design, with a focus on shaping the future of aircraft cabin experiences. Hosted by Collins Aerospace's EU Innovation Hub, it aims to explore how emerging societal trends, sustainability goals, and technological advancements can be translated into visionary cabin concepts for the 2040s. The Innovation Hub specializes in sustainable materials, intelligent systems, and user-centered design, providing a rich environment for future-focused innovation.

Key stakeholders include passengers, crew members, airlines, and Collins Aerospace itself. Passengers increasingly expect more personalized, connected, and comfortable travel experiences. Crew members require environments that enhance efficiency and well-being. Airlines seek cost-effective and sustainable solutions, while Collins Aerospace looks to maintain its leadership in innovation and design excellence.

There are significant opportunities to serve these interests by leveraging advancements in smart technologies, sustainable materials, and adaptable cabin layouts. These innovations can lead to enhanced passenger satisfaction, operational efficiency, and reduced environmental impact. However, limitations such as strict safety regulations, cost and weight constraints, and the slow pace of change in commercial aviation must be considered.

The project offers the chance to create an inspiring and feasible vision for the next generation of air travel, one that balances creativity with practicality and addresses the evolving needs of diverse user groups.

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

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)

Commercial aviation has remained relatively conservative, with limited progress in enhancing user experience over the past decades. In particular, single-aisle aircraft, which dominate global fleets, present significant challenges for both passengers and airlines. Current cabin configurations often fail to address growing demands for efficiency, accessibility, and comfort. Boarding and turnaround processes remain slow and stressful, negatively impacting passenger satisfaction, crew performance, and airline profitability.

The core problem is how to reimagine the cabin experience for the 2040s in a way that improves spatial efficiency, streamlines passenger flow, and ensures accessibility for diverse demographics. At the same time, strict safety regulations, cost pressures, and the inertia of the industry impose clear limitations on radical change.

My task is to investigate design opportunities that can tackle these constraints with future needs. By focusing on cabin layouts and accessibility strategies, the project seeks to identify directions that could deliver measurable improvements in operational efficiency and passenger experience.

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 cabin design prototype to demonstrate how innovative layouts and accessibility solutions can enhance efficiency, inclusivity, and passenger experience in the context of future single-aisle aircraft.

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)

Given that the project focuses on the aviation industry 15-20 years in the future, it is challenging to predict the exact context in which the solutions will be applied. To address this, I will apply the Vision in Product Design (ViP) method during the discover and define phases. This method supports research into societal, technological, and cultural developments, helping to establish a coherent vision of future air travel. Insights from ViP will guide the development and delivery phases, where concepts will be generated, refined, and evaluated to create a feasible design proposal that aligns with long-term industry needs and stakeholder values.

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	23 September 2025
Mid-term evaluation	3 Nov 2025
Green light meeting	12 Jan 2026
Graduation ceremony	16 Feb 2026

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	
Number of project days per week	

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)

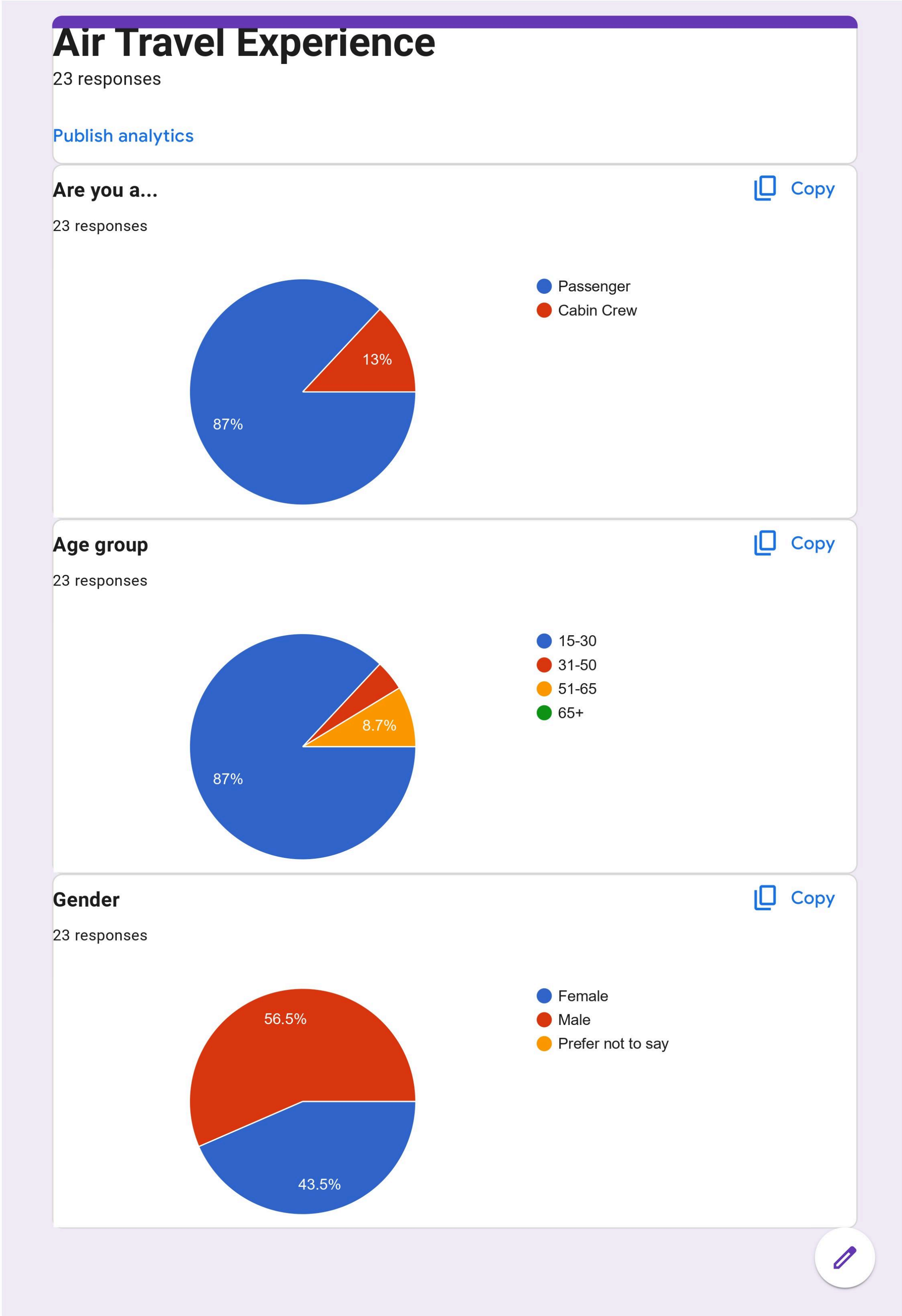
My fascination with future mobility design motivated me to study Industrial Design Engineering. I have actively pursued this interest through the minor People in Transit and by contributing to the Delft Hyperloop team, where I envisioned interior concepts for a novel transportation system. Combined with my strong interest in aviation, this graduation project forms a natural next step in my educational journey.

Aviation, however, is a highly regulated and conservative industry, which makes innovation challenging but also highly impactful when achieved. Collins Aerospace currently does not have a dedicated design department for long-term interior visions, meaning this project offers the opportunity to work at the cradle of change. I see this as a chance not only to apply my design competencies but also to test whether I can communicate and inspire colleagues and stakeholders with compelling visions of future air travel.

Appendix C

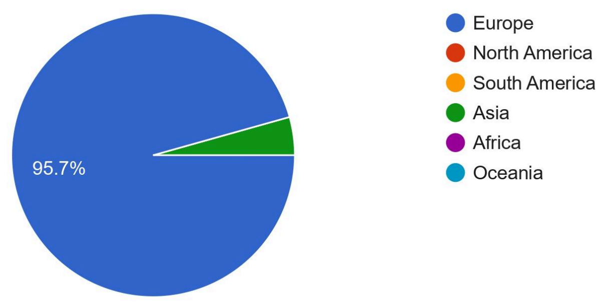
Online Survey

This appendix provides a comprehensive record of the raw data and analytical findings from the Online Survey conducted among 23 air travel passengers and cabin crew members. These responses served as an empirical baseline to validate current industry pain points, specifically regarding the boarding process and seat comfort, and directly informed the development of the 2040 cabin vision.



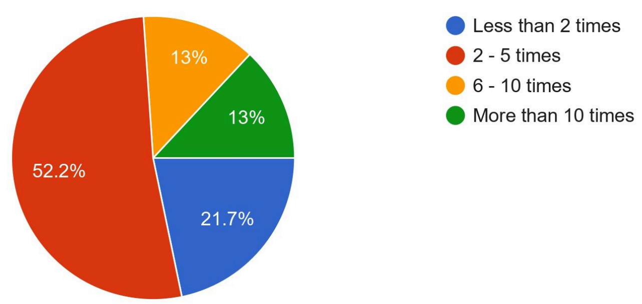
Region where you fly most

23 responses



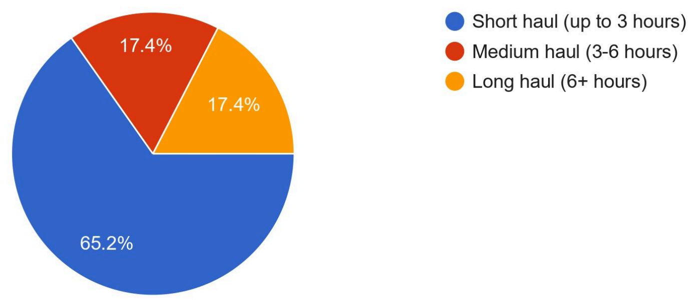
How often do you fly per year?

23 responses



Typical flight duration

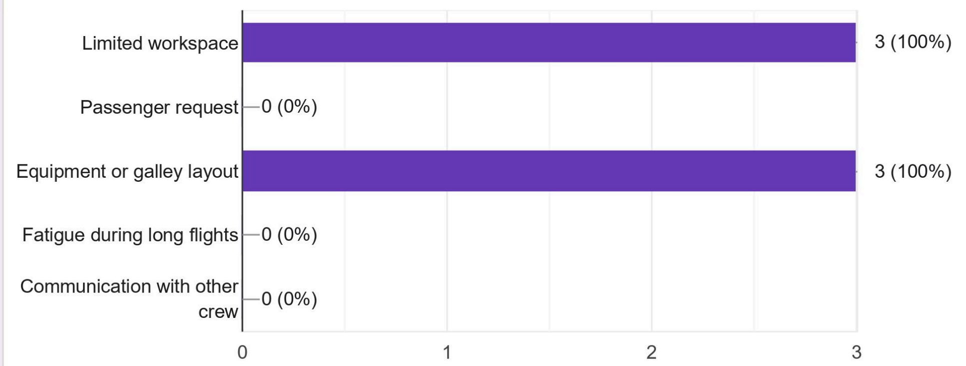
23 responses



(Crew only)

What are your biggest challenges during a flight?

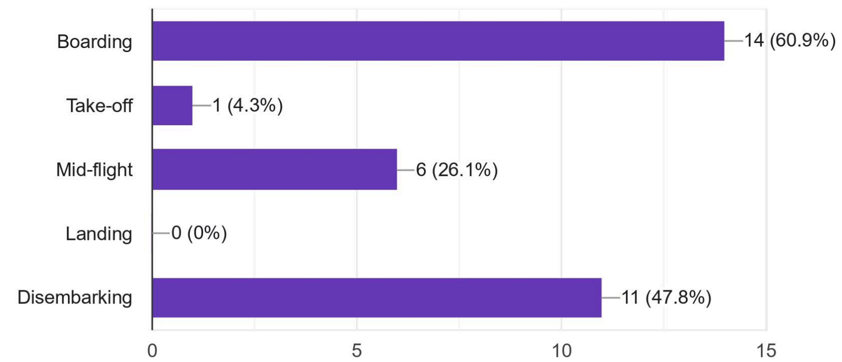
3 responses



Current In-Flight Experience

At which stage(s) of air travel do you experience the most discomfort or frustration?

23 responses



Please rate your satisfaction with the following aspects of your last flight

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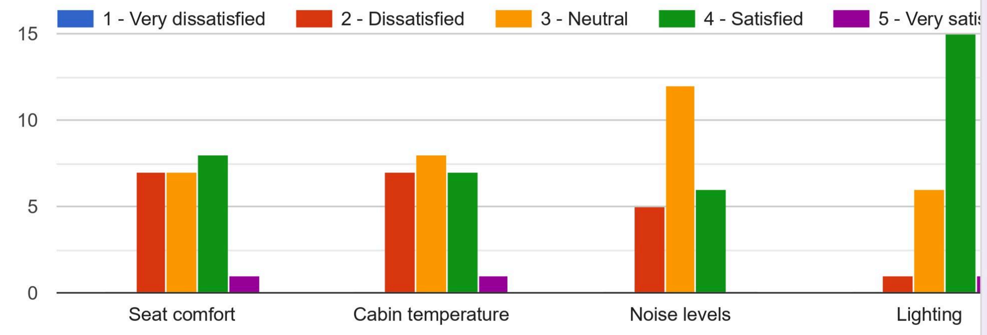
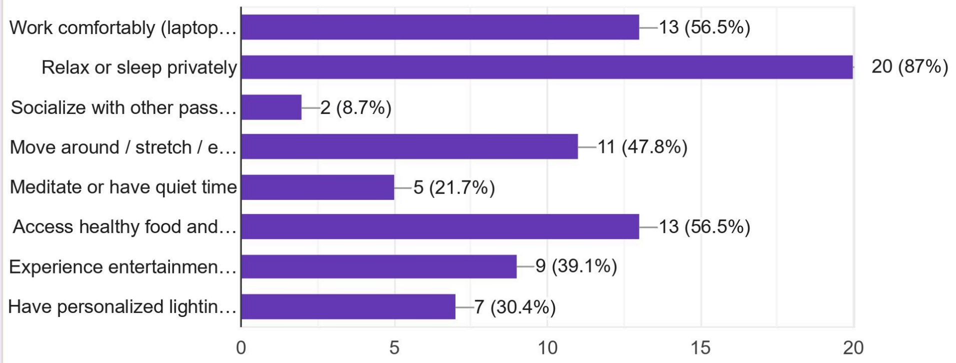


Ideal In-Flight Experience

What would you like to do during a flight if you could design your ideal cabin?

Copy

23 responses



If you could improve one thing about your air travel experience today, what would it be?

23 responses

Instappen en uitstappen vanuit het vliegtuig. Staan vaak lange en langzame rijen omdat mensen langzaam zijn met hun koffers en spullen opbergen

Better ways to move around in the airplane. Now, it sometimes feels like you're inconveniencing other passengers to ensure your legs maintain good circulation. You always have to pass someone, and the aisle isn't wide enough.

More room for productivity

More space onboard

The time and effort it takes from the moment that I leave my house until the airplane is taking off.

Wider seats for comfort and privacy

The seats could be way more comfortable. Also more space for stretching your legs.

More leg space

Broader aisles

The chaos of boarding experience, people are chaotic, hard to find a overhead luggage space, people trying to pass by, everyone is very impatient during this, once everyone sit down then you have this uncertainty of when the flight is going to take of(sometimes it's 5mins, sometimes its 30)

More space in seating and more healthy food options

Seat comfort

Delay

Speed of disembarking

Being able to easily walk around so that I can stretch once in a while if you are not seated next to the aisle

Better sleep

Finding a system to board and disembark more efficiently and comfortably

Efficency with time

Na de landing sta je altijd heel lang te wachten op de mensen voor je die allemaal tegelijkertijd op willen staan om hun spullen te pakken. Een systematische leegloop van het vliegtuig zou wenselijk zijn.

De wachttijd bij disembarking

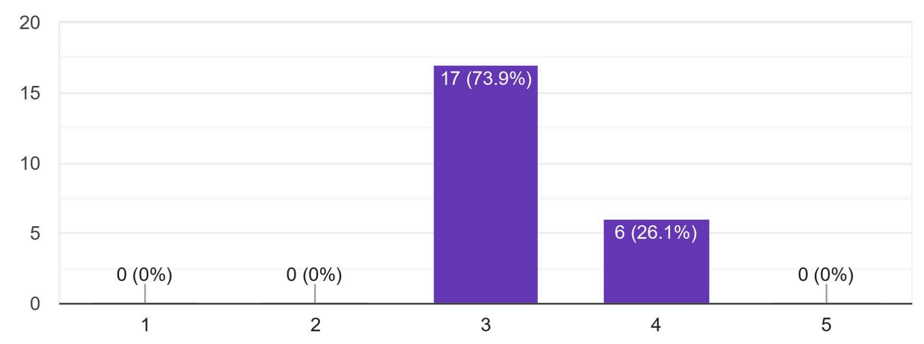
Shorter flight

Galley lay-out and height

Overall, how satisfied are you with current air travel comfort and experience?

Copy

23 responses



Any additional comments or ideas about the future of air travel?

23 responses

-

Nee

No

In the navy, I believe they make sure the food is top-notch, especially on ships with limited space (submarines). I think this was to keep everyone from getting irritated with each other, making it more bearable to live in close quarters for extended periods.

NA

X

Make sure that flying doesn't feel like lost time. So enable people to work, sleep, rest (or do sports even).

Different zones like in the train for speaking out loud or silence/working

Better seats and wifi acces

Keep asking crew for their input as well, as some adaptions on board might make working more difficult ;) (space, galleys, flight time)

I want more personal space and real time efficiency from taking a flight (the whole experience actually takes your whole day for you to arrive from A to B if you have a 3-4 hours of flight that day)

More food options

no

Business class passenger

I don't need everything during the flight that is in my carry-on bag, but I want a charger, iPad and maybe like a bottle of water. I want to take all of this out the bag before sitting, but it takes some time and blocks other people. I dont think I am the only one that has this. It is a little bit of an awkward moment always.

It should be more similar to train travel

Sta plaatsen zodat je goedkoper een ticket kan scoren voor korte vluchten en zo kan de luchtvaartmaatschappij meer passagiers kwijt.

More privacy

More sustainable

Healthier food

Appendix D

Passenger Personas

This appendix presents the six need-based passenger personas derived from the research of Rosa Hendrikx (2021) in her thesis, "A service design vision for air-rail journeys." These fluid models provide a nuanced understanding of traveler motivations and behavioral patterns, serving as a critical tool for mapping the diverse user requirements and interaction goals within the 2040 cabin ecosystem.

Determined Survivor

I just want to get to my final destination in the easiest and efficient way as possible.

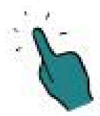
Efficiency
Clearness
Overview

It would depend if it's cost effective. If it's cheaper I will do that.But also factoring the time as well. I factor in like a flight to Amsterdam, then how much time I have to wait for the train. - Australian traveller

Self-sufficient manager

I am independent and want to complete this journey as far as it's possible on my own.

Control
Autonomy
Freedom

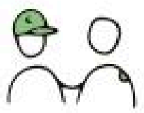


When I have a lot of options so I can decide if I want to take this train or a different one. A different time of travel. Even different types of seats. - English traveller

Vulnerable rookie

I am not sure about this, I need someone who gets me through this.

Support
Guidance
Safety

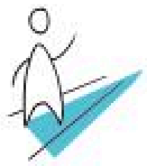


Because I can go from central to central. Like the Eurostar, you get from the central of London to the central of Amsterdam. It's feels like less hassle and much easier - English traveller

Certainty seeker

I just want to know where I stand and what is going to happen. No surprises please.

Certainty
Informed
Prepared



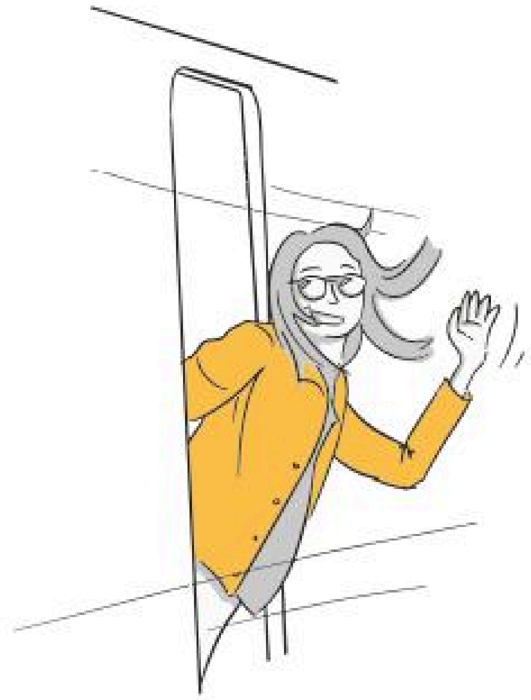
I think like this combination is good. Because you are more motivated to take the train. It's kind of planned for you. - German traveller

Peaceful collaborator

During this journey I want to get my mind off, so as long when it a bit comfortable and relaxed I am a satisfied person.

Comfort
Unwind
Internal peace

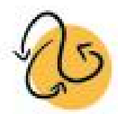
The comfort. The ease. Being able to sit in your seat. Being able to walk to the next carriage. And there will be a bar there or something. - English traveller



Spontaneous adventurer

Let's go!

Flexibility
Spontaneity
Inspiration



Environmental aspect, would be reason number one, and the experience. It is just amazing to be in a train. - German traveller

Appendix E

Context Factors & Clusters

This appendix documents the collection of over 230 context factors gathered across demographical, technological, and ecological domains to predict the aviation landscape of 2040. This information was critical for identifying future tensions and building the strategic clusters that served as the academic foundation for the project’s future vision and design mandate.

Context Factors

- **Technological Autonomy:** Technologies like ubiquitous personal devices, remote work, and personalized AI tools empower individuals with unprecedented control over their own lives, careers, and information consumption, potentially weakening dependence on traditional collective structures (like the office or local community).
- **Lack of solidarity:** Increased global connectivity, travel, and migration can weaken local, national, or familial ties, leading individuals to prioritize their own choices, careers, and personal networks over inherited collective identities.
- **Emphasis on Self-Expression:** Westernized cultural trends, heavily amplified by social media, continue to focus on personal identity, self-actualization, and challenging traditional norms.
- **Organized Cooperation:** Problems like climate change, pandemics, and complex global supply chains require coordinated, collective action at national and international levels. Individual solutions are inadequate.
- **Rise of Authoritarianism/Nationalism:** In many parts of the world, there's been a resurgence of strong national identities and state-centric ideologies, where the needs of the nation or state are explicitly prioritized over the rights or desires of the individual.
- **Digital Platforms as New Collectives:** While technology enables autonomy, the centralized nature of major social media and digital platforms often creates new, powerful forms of digital collectives, where group dynamics, consensus, and conformity within the network are highly influential.
- **Economic Inequality:** As wealth gaps widen, collective political and social movements may gain strength as people organize to demand systemic change and fairer distribution of resources.
- **Situational Prioritization:** People may be highly individualistic in their careers, consumption habits, and personal goals, yet strongly collectivistic when addressing a shared crisis (like a natural disaster or economic downturn).
- **Regional Splits:** Societies with strong state control (like China or Russia) are likely to remain firmly rooted in collectivism (or state-centric nationalism), while many Western and Northern European countries may lean more heavily toward liberal individualism.
- **Digital Tribes:** The rise of online communities and subcultures—often called "digital tribes"—will likely replace some traditional local collectives (like neighborhood groups or religious institutions).
- **AGI Proximity and Ubiquitous Automation.** AI will move from assisting to autonomously managing most white-collar and specialized technical tasks (e.g., legal discovery, financial analysis, software development).
- **Massive Job Disruption** and the potential necessity of new economic models (e.g., Universal Basic Income) to manage structural unemployment.
- **Precision Medicine and Human Enhancement.** Genetic sequencing will be routine and inexpensive. Gene editing (CRISPR), advanced synthetic biology, and personalized RNA therapeutics will make many currently incurable diseases treatable. Human enhancement (cognitive and physical) will become accessible, though likely exacerbating wealth inequality.
- **Increased Life Expectancy** in developed nations; growing ethical and economic divide between the "enhanced" and the rest of the population.
- **The Trillion-Sensor World.** The Internet of Things (IoT) will explode into trillions of connected devices, with every physical asset monitored and managed by AI in real-time. The "digital space" will be a central economic zone, transacting in sovereign and decentralized digital currencies.
- **Zero Privacy** by modern standards, highly efficient resource management (smart cities/grids), and immense power vested in the entities that control the data.
- **Global Peak/Plateau.** World population will likely peak or be close to peaking (around 9.7 billion by 2050). Global fertility rates continue to fall, but life expectancy continues to rise.
- **Focus shifts from resource scarcity to wealth distribution** and managing aging populations.
- **Pensioner Boom in Developed/Middle-Income Nations.** Countries like Japan, China, and most of Europe will have significantly inverted age pyramids, with huge fiscal pressure on social security, healthcare systems, and a severe reduction in the working-age population.
- **Automated Elder Care** and a massive rise in the political power of older cohorts. Migration will become an essential, if contentious, policy tool to balance labor shortages.
- **The Mega-City Dominance.** Nearly two-thirds of the world's population will live in urban areas by 2040, with the vast majority of this growth occurring in Asia and Africa, leading to the proliferation of megacities (e.g., Lagos, Kinshasa, Mumbai).
- **Infrastructure Overload**, but also intense centers of innovation and economic activity. The rural-urban divide will be a key fault line.
- **Electric/Autonomous Fleets and eVTOLs.** Personal urban travel will be dominated by shared, autonomous, electric vehicles and the localized deployment of eVTOLs (electric Vertical Take-Off and Landing aircraft), especially in high-density megacities.
- **End of Mass Car Ownership** in major cities; reduced traffic congestion, but new challenges in airspace management and urban noise pollution.
- **Sustainable Aviation and Space Tourism.** A significant portion of commercial aviation will transition to more sustainable fuels (e.g., hydrogen, sustainable aviation fuels). Commercial suborbital travel and low-Earth orbit (LEO) tourism will be a niche market for the ultra-wealthy.
- **Increased Cost of Mass Air Travel** due to carbon pricing/sustainability mandates, alongside the creation of an entirely new ultra-luxury space economy.
- **Haptic and Sensory VR.** Advanced virtual and augmented reality (VR/AR) platforms will offer fully immersive, sensory work and leisure experiences, reducing the need for physical travel for business or casual interaction.
- **Decreased Business Travel** reliance and the creation of fully decentralized, "metaverse-centric" global workplaces.
- **The Rise of Digital Tribes and Contested Reality.** People will increasingly seek comfort and validation in online "identity silos," reinforcing belief systems and creating a deeply polarized media environment. Trust in major institutions (government, media, science) will continue to be highly variable.
- **Increased Political Instability** and greater difficulty achieving national consensus on complex issues like AI regulation or climate policy.
- **Climate Adaptation Dominates Policy.** Climate change impacts (extreme weather, resource stress) will be impossible to ignore. Climate migration—both internal and cross-border—will become a constant humanitarian and geopolitical challenge.
- **Massive Investment in climate-resilient infrastructure** (sea walls, smart grids, controlled-environment agriculture) and a global re-prioritization of resources.
- **The "Empathy Economy" and Meta-Skills.** Automation will eliminate many routine jobs. The highest-value human skills will be those AI cannot replicate: creativity, emotional intelligence, critical thinking, and complex communication (meta-skills).
- **Permanent Learning** becomes necessary. Education systems will scramble to pivot from fact-based learning to teaching adaptability and human-centric skills.
- **Emerging Markets Dominate GDP**. The global economic center will decisively shift. Emerging economies (E7) will significantly outpace the G7. By 2050, China and India are projected to be the 1st and 2nd largest economies, with the US likely 3rd.
- **Increased Geopolitical Competition** and challenges to the Western-led international rules-based order. Global governance becomes significantly more challenging.
- **Concentrated AI-Driven Wealth.** Economic growth will be driven by productivity gains from AI and automation. This wealth will concentrate among the owners of the AI capital, leading to extreme global and national inequality.
- **Maximalist Escapism:** Flying becomes part of the adventure, involving bold, sensory-rich travel and rejecting mediocrity.

- **Peak Fossil Fuel Demand and Circular Economy.** Fossil fuels will still be used, but global demand will peak due to massive deployment of renewables (solar, wind, advanced storage). The focus will shift to building a truly circular economy to manage resource scarcity.
- **Global competition over critical minerals** (lithium, rare earth metals) necessary for the renewable energy transition.
- **Quantum Supremacy and Encryption Wars:** The development of large-scale, fault-tolerant Quantum Computers will render all current public-key encryption obsolete, necessitating a global transition to Quantum-Resistant Cryptography (QRC) in all financial, military, and communications systems.
- **3D-Printed/On-Demand Organs:** Routine access to bio-printed organs and tissues (e.g., livers, kidneys) grown from a patient's own cells eliminates organ transplant waiting lists and the need for immunosuppressive drugs, fundamentally transforming long-term chronic care.
- **Advanced Materials Engineering (Nano-Design):** AI-driven design of meta-materials and nano-materials with engineered properties leads to breakthroughs in super-efficient energy storage, self-healing construction materials, and room-temperature superconductors for a highly efficient power grid.
- **Empathic/Hybrid Intelligence Systems:** The rise of "Empathic Robots" and sophisticated AI companions/ assistants that can interpret complex emotional cues to provide personalized psychological support, education, and elder care, moving beyond simple task automation.
- **Digital Twins and Synthetic Reality:** The creation of Digital Twins (detailed, real-time virtual models) of cities, supply chains, and even individuals (for personalized health modeling) for predictive simulation and high-stakes decision-making.
- **Hyperloop Network Deployment:** Initial inter-city or regional high-speed Hyperloop routes become operational, reducing travel times between major hubs (e.g., London-Paris, or US West Coast hubs) to under one hour, challenging short-haul air travel.
- **Containerized Freight Automation:** The logistics sector achieves near-full automation, utilizing autonomous, electric cargo ships, rail freight, and drone-delivery hubs, significantly reducing the cost and carbon footprint of global trade.
- **Active Modalities Dominance in Cities:** Urban planning aggressively shifts away from private cars. Shared electric bikes and scooters (Active Modalities) and seamless, integrated public transport become the fastest, most convenient, and often default method of inner-city travel.
- **Green Hydrogen Aviation:** Long-haul air travel begins a mandated transition to Green Hydrogen-powered aircraft, requiring the rapid development of new airport infrastructure for hydrogen production and fueling.
- **Subterranean Traffic Networks:** Major megacities, constrained by space, invest in underground tunnels and multi-layered transport systems (like those championed by The Boring Company) to route autonomous vehicle fleets and dedicated freight, relieving surface-level congestion.
- **Nigeria Becomes the World's Third Most Populous Country:** By around 2050, Nigeria is projected to surpass the US in population, becoming the third most populous nation, underscoring Africa's growing demographic and future economic importance.
- **Median Age Crisis in Asia:** Countries like Japan and South Korea will likely see their median age exceed 53 years by 2040, creating unprecedented fiscal strains on pension and healthcare systems and forcing radical policy solutions (e.g., mass robotics integration).
- **The Rise of the Global Refugee/Climate Migrant Class:** The number of people displaced by climate events, resource wars, and political instability will continue to surge, creating a permanent, large-scale Climate Migrant Class that requires new global governance and resettlement frameworks.
- **The Sovereignty Erosion by Non-State Actors:** Large, decentralized global technology and financial platforms (operating on blockchain and in the metaverse) and powerful non-state AI entities will challenge the traditional sovereignty of the nation-state, forcing new models of global regulation.
- **Human-Machine Symbiosis:** The boundaries between human intuition and machine intelligence blur into collaboration.
- **Community-Led Resilience Movements:** As trust in national institutions wanes, local communities will emphasize autonomy and resilience, focusing on local food supply (vertical farms), micro-grids for energy, and community-based disaster response in the face of frequent climate shocks.
- **The 4-Day Work Week Becomes a Normative Goal:** Driven by automation-led productivity gains and social demand for better work-life balance, the four-day work week (or its equivalent in output-based contracts) will become a primary policy objective and standard labor demand in many developed economies.

- **End of Control:** Humans oscillate between the desire to master complexity and the need to trust invisible systems. Automation, AI integration, and predictive systems taking over operations. Increasing data dependence and algorithmic decision-making.
- **Collective Journey:** Air travel as a shared moral act, where individual choices carry collective consequences. Climate impact awareness, sustainable aviation fuel, electric and hydrogen flight. Accessibility and inclusivity as social responsibilities. Growing public scrutiny of aviation's carbon footprint.
- **Hyperconnectivity:** The world is becoming a smaller place due to technological advancements. Number of connected devices increase. Rapidly evolving transportation modes. Increasing wealth stimulates exploration.
- **Quest for Belonging:** In transient, anonymous spaces, people search for identity, recognition, and connection. Personalization and adaptive services. Global mobility dissolving stable identity anchors. Social media shaping self-presentation. Group travel vs. individual solitude.
- **Pursuit for effortless living:** Modern life strives to eliminate friction, making smoothness a symbol of progress.Instant gratification culture and "on-demand everything." Predictive service systems (AI concierges, automated processes). Invisible technology promising simplicity but masking complexity.
- **Care as the New Luxury:** The highest form of comfort becomes being genuinely cared for (emotionally, ethically, physically). Travelers are willing to pay more for features they care about.
- **Battle between Efficiency and Interaction:** What we optimize for performance often costs us significance. Automation removing the human touch. Design trade-offs: every efficiency gain removes friction and character. Balance between utilitarian success and emotional depth.
- **Augmented Authenticity:** In a mediated world, authenticity becomes something we design, not discover. Are AI-generated humans disrupting the future of beauty?
- **Reclaiming Time:** In a world obsessed with acceleration, time itself becomes a form of luxury. Technological automation freeing time from tasks. Nostalgia for slower, more meaningful journeys.
- **Body in Motion:** Health, nutrition and micro-recovery are becoming more and more important for people. Physical and digital interfaces could be shaping bodily awareness.
- **Fluid Identities:** People shift between multiple selves (professional, personal, digital) more easily. Work resorts have further elevated into wellness sanctuaries and purpose-driven community hubs.
- **Transparency and Trust:** As systems grow invisible, people crave visibility & clarity becomes comfort. Design of legibility: showing how the system works. Trust as a new form of comfort currency.
- **Creating space for self development:** Spaces are being redefined to improve personal and societal environments. Upcoming technologies that take away everyday tasks. Redefining public spaces to create more living areas.
- **Population Growth and Aging:** The world's population is expected to reach approximately 9.2 billion by 2040. The global population will become older than ever before, with a projected 35% increase in the proportion of older individuals between 2000 and 2040. By 2050, the age group 65 or above is projected to account for 1 in 6 people globally.
- **Wealth Transfer:** Baby Boomers are projected to transfer over $70 trillion in wealth to younger generations by 2045, marking the largest intergenerational wealth transfer in history. By 2040, Gen X is projected to control over 50% of global wealth.

- **Health Crisis:** Noncommunicable Diseases (NCDs) are projected to cause 80% of deaths in low-income countries by 2040. Conversely, global life expectancy is projected to rise by approximately 8–10%, reaching an average of 77–78 years by 2040.
- **Urbanization:** Approximately 70% of the global population, or about 6.4 billion people, are projected to reside in urban areas by 2040. The number of mega-cities (populations exceeding 10 million) is expected to grow from 33 in 2020 to around 50 by 2040.
- **Hyper-Personalization and Emotional AI:** This trend involves environments responding intuitively to user needs through AI, Machine Learning (ML), and Natural Language Processing.
- **Data as a Strategic Asset and Trust Enabler:** Data ownership will redefine industries, requiring transparency and security.
- **A Shift Towards the Longevity Economy:** An aging and active population requires adaptable spaces and new services focused on vitality.
- **Effortless Integration and Interaction:** The focus shifts to streamlined, frustration-free experiences using seamless connectivity and simple technology.
- **A Shift Towards Non-Materialistic Luxury:** Luxury prioritizes meaningful, personalized experiences, exploration, and efficiency over material possessions. Experiential luxury is expected to capture more than 35% of the luxury market by 2040.
- **Blended Reality and Sensory Integration:** The boundary between physical and digital realities is expected to blur entirely by 2035.
- **Sustainability Beyond Materials:** Sustainability expands to include dynamic optimization of resources and resilience.
- **Air Travel Rise:** Global air-travel demand is expected to at least double by 2050. Extreme weather will cause at least 40% more flight delays by 2035.
- **E-commerce Dominance:** It is projected that 95% of all purchases will be conducted online by 2040, marking a substantial shift from traditional stores.
- **Physical Retail Evolution:** Physical stores are anticipated to transform into experiential hubs by 2040, focusing on immersive and personalized shopping experiences.
- **Hyperconnectivity/IoT:** The IoT is expected to reach hundreds of billions or even trillions of connected devices by 2040.
- **Digital Currency:** Due to blockchain technology, Bitcoin is expected to be adopted by 65% of the global population by 2040 and be an official currency by 2045.
- **Embedded Freedom:** A focus on fluid, adaptive cabins that move with the passenger, offering personalised, inclusive, and seamless experiences, particularly catering to the diverse mix of travelers, including older flyers and multi-generational groups.
- **Vital Rejuvenation:** Travel that prioritises health and resilience against environmental changes.
- **Secluded Sanctuary:** The commercialisation of solitude, offering digital privacy and disconnection as a premium offering in response to increasing surveillance and hyper-connectivity.
- **Playful Adventures:** Next-gen entertainment moving beyond passive viewing to deliver immersive, interactive, and social experiences tailored to digital natives, specifically Gen Alpha (aged 16-30 in 2040) and Gen Beta (born 2025–2039).
- **Digital Repression and Surveillance States:** Governments will use the Trillion-Sensor IoT environment and advanced AI to implement sophisticated, real-time Digital Repression strategies, creating highly controlled societies in many autocratic nations.

Clusters

CLUSTER 1

External power shapes a compliant, fluid self.

The individual self is constantly **formed by powerful external currents.** With our personal path rendered **fluid and changeable**, our choices are often dictated by the forces of **governments, corporations, and social peer pressure**. This leaves the individual feeling like a **negligible voice** among billions, struggling to assert agency against the vast, shifting tide of collective interest.

Factors

- **A Shift Towards Non-Materialistic Luxury:** Luxury prioritizes meaningful, personalized experiences, exploration, and efficiency over material possessions. Experiential luxury is expected to capture more than 35% of the luxury market by 2040.
- **End of Mass Car Ownership** in major cities; reduced traffic congestion, but new challenges in airspace management and urban noise pollution.
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- **Space Tourism.** Commercial suborbital travel and low-Earth orbit (LEO) tourism will be a niche market for the ultra-wealthy.

CLUSTER 2

Competition drives costly human progress.

The human species thrives under **inequality**, using the resulting **competition** as a powerful engine for **evolution**. This historical dynamic leads to the pervasive belief that we are always inherently better off than the last generation. Yet, we must continuously question the true cost of this progress and at whose expense this powerful, unequal system is maintained.

Factors

- **Increased Life Expectancy** in developed nations; growing ethical and economic divide between the "enhanced" and the rest of the population.
- **Permanent Learning** becomes necessary. Education systems will scramble to pivot from fact-based learning to teaching adaptability and human-centric skills.
- **Battle between Efficiency and Interaction:** What we optimize for performance often costs us significance. Automation removing the human touch. Design trade-offs: every efficiency gain removes friction and character. Balance between utilitarian success and emotional depth.
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- **Wealth Transfer:** Baby Boomers are projected to transfer over $70 trillion in wealth to younger generations by 2045, marking the largest intergenerational wealth transfer in history. By 2040, Gen X is projected to control over 50% of global wealth.
- **Health Crisis:** Noncommunicable Diseases (NCDs) are projected to cause 80% of deaths in low-income countries by 2040. Conversely, global life expectancy is projected to rise by approximately 8–10%, reaching an average of 77–78 years by 2040.
- **Emerging Markets Dominate GDP**. The global economic center will decisively shift. Emerging economies (E7) will significantly outpace the G7. By 2050, China and India are projected to be the 1st and 2nd largest economies, with the US likely 3rd.
- **Concentrated AI-Driven Wealth.** Economic growth will be driven by productivity gains from AI and automation. This wealth will concentrate among the owners of the AI capital, leading to extreme global and national inequality.
- **Economic Inequality:** As wealth gaps widen, collective political and social movements may gain strength as people organize to demand systemic change and fairer distribution of resources.
- **Population Growth and Aging:** The world's population is expected to reach approximately 9.2 billion by 2040. The global population will become older than ever before, with a projected 35% increase in the proportion of older individuals between 2000 and 2040. By 2050, the age group 65 or above is projected to account for 1 in 6 people globally.

CLUSTER 3

Connectivity requires centralized order.

Driven by **population growth** and **hyperconnectivity**, the world is fundamentally transforming into a single, vast **city-nation**. This necessitates an urgent shift toward thinking as **one society**, making **centralization** the inevitable future. Civilization must adapt to new, unified **regulations** to manage this singular global

Factors

- **Urbanization:** Approximately 70% of the global population, or about 6.4 billion people, are projected to reside in urban areas by 2040. The number of mega-cities (populations exceeding 10 million) is expected to grow from 33 in 2020 to around 50 by 2040.
- **Subterranean Traffic Networks:** Major megacities, constrained by space, invest in underground tunnels and multi-layered transport systems (like those championed by The Boring Company) to route autonomous vehicle fleets and dedicated freight, relieving surface-level congestion.
- **Nigeria Becomes the World's Third Most Populous Country:** By around 2050, Nigeria is projected to surpass the US in population, becoming the third most populous nation, underscoring Africa's growing demographic and future economic importance.
- **The Mega-City Dominance.** Nearly two-thirds of the world's population will live in urban areas by 2040, with the vast majority of this growth occurring in Asia and Africa, leading to the proliferation of megacities (e.g., Lagos, Kinshasa, Mumbai).
- **Infrastructure Overload**, but also intense centers of innovation and economic activity. The rural-urban divide will be a key fault line.
- **Hyperloop Network Deployment:** Initial inter-city or regional high-speed Hyperloop routes become operational, reducing travel times between major hubs (e.g., London-Paris, or US West Coast hubs) to under one hour, challenging short-haul air travel.
- **The Sovereignty Erosion by Non-State Actors:** Large, decentralized global technology and financial platforms (operating on blockchain and in the metaverse) and powerful non-state AI entities will challenge the traditional sovereignty of the nation-state, forcing new models of global regulation.
- **Global Peak/Plateau.** World population will likely peak or be close to peaking (around 9.7 billion by 2050). Global fertility rates continue to fall, but life expectancy continues to rise.

CLUSTER 4

Convenience sacrifices depth.

The pursuit of the most **convenient path** and **instant gratification** has led to a reliance on hyperconnectivity that encourages us to **think less** on our own. This outsourcing of thought erodes individual **authenticity** and ultimately causes a profound social **disconnection** behind a facade of constant contact.

Factors

- **Pursuit for effortless living:** Modern life strives to eliminate friction, making smoothness a symbol of progress. Instant gratification culture and "on-demand everything." Predictive service systems (AI concierges, automated processes). Invisible technology promising simplicity but masking complexity.
- **Hyper-Personalization and Emotional AI:** This trend involves environments responding intuitively to user needs through AI, Machine Learning (ML), and Natural Language Processing.
- **Technological Autonomy:** Technologies like ubiquitous personal devices, remote work, and personalized AI tools empower individuals with unprecedented control over their own lives, careers, and information consumption, potentially weakening dependence on traditional collective structures (like the office or local community).
- **Active Modalities Dominance in Cities:** Urban planning aggressively shifts away from private cars. Shared electric bikes and scooters (Active Modalities) and seamless, integrated public transport become the fastest, most convenient, and often default method of inner-city travel.
- **Haptic and Sensory VR.** Advanced virtual and augmented reality (VR/AR) platforms will offer fully immersive, sensory work and leisure experiences, reducing the need for physical travel for business or casual interaction.
- **E-commerce Dominance:** It is projected that 95% of all purchases will be conducted online by 2040, marking a substantial shift from traditional stores.
- **Physical Retail Evolution:** Physical stores are anticipated to transform into experiential hubs by 2040, focusing on immersive and personalized shopping experiences.
- **Effortless Integration and Interaction:** The focus shifts to streamlined, frustration-free experiences using seamless connectivity and simple technology.

CLUSTER 5

Freedom unlocks discovery, not fulfillment.

As automation eliminates **everyday tasks**, the resulting abundance of **free time** will profoundly challenge **traditional norms**. This new leisure allows people to embark on deeper **self-discovery**. While this era brings widespread **partial satisfaction**, the very nature of having everything leaves no one fully content or **completely fulfilled**.

Factors

- **Creating space for self development:** Spaces are being redefined to improve personal and societal environments. Upcoming technologies that take away everyday tasks. Redefining public spaces to create more living areas.
- **Embedded Freedom:** A focus on fluid, adaptive cabins that move with the passenger, offering personalised, inclusive, and seamless experiences, particularly catering to the diverse mix of travelers, including older flyers and multi-generational groups.
- **Secluded Sanctuary:** The commercialisation of solitude, offering digital privacy and disconnection as a premium offering in response to increasing surveillance and hyper-connectivity.
- **Reclaiming Time:** In a world obsessed with acceleration, time itself becomes a form of luxury. Technological automation freeing time from tasks. Nostalgia for slower, more meaningful journeys.
- **Fluid Identities:** People shift between multiple selves (professional, personal, digital) more easily. Work resorts have further elevated into wellness sanctuaries and purpose-driven community hubs.
- **Electric/Autonomous Fleets and eVTOLs.** Personal urban travel will be dominated by shared, autonomous, electric vehicles and the localized deployment of eVTOLs (electric Vertical Take-Off and Landing aircraft), especially in high-density megacities.
- **Decreased Business Travel** reliance and the creation of fully decentralized, "metaverse-centric" global workplaces.
- **Emphasis on Self-Expression:** Westernized cultural trends, heavily amplified by social media, continue to focus on personal identity, self-actualization, and challenging traditional norms.

CLUSTER 6

Techno-fixation on nature's solution.

Facing the inherent **flaw** of human mortality, and driven by the deep desire to avoid death and extinction, we continually turn to **new technologies**. These innovations are primarily tasked with correcting our imperfections, often drawing deep **inspiration from nature** itself to build systems capable of enduring.

Factors

- **Body in Motion:** Health, nutrition and micro-recovery are becoming more and more important for people. Physical and digital interfaces could be shaping bodily awareness.
- **Human-Machine Symbiosis:** The boundaries between human intuition and machine intelligence blur into collaboration.
- **Advanced Materials Engineering (Nano-Design):** AI-driven design of meta-materials and nano-materials with engineered properties leads to breakthroughs in super-efficient energy storage, self-healing construction materials, and room-temperature superconductors for a highly efficient power grid.
- **Green Hydrogen Aviation:** Long-haul air travel begins a mandated transition to Green Hydrogen-powered aircraft, requiring the rapid development of new airport infrastructure for hydrogen production and fueling.
- **Precision Medicine and Human Enhancement.** Genetic sequencing will be routine and inexpensive. Gene editing (CRISPR), advanced synthetic biology, and personalized RNA therapeutics will make many currently incurable diseases treatable. Human enhancement (cognitive and physical) will become accessible, though likely exacerbating wealth inequality.
- **Pensioner Boom in Developed/Middle-Income Nations.** Countries like Japan, China, and most of Europe will have significantly inverted age pyramids, with huge fiscal pressure on social security, healthcare systems, and a severe reduction in the working-age population.

CLUSTER 7

Digital alienation is healed by crisis-driven empathy.

Hyperconnectivity ironically fosters **individualism** and fuels widespread distrust, leading to an "us-against-the-world" stance. However, when faced with a **shared crisis**, this dynamic reverses. Humanity's most powerful asset, **empathy** and **emotional intelligence**, drives people to seek genuine **human touch** and **familiarity**, ultimately forging new, stronger ways of connecting.

Factors

- **Lack of solidarity:** Increased global connectivity, travel, and migration can weaken local, national, or familial ties, leading individuals to prioritize their own choices, careers, and personal networks over inherited collective identities.
- **Situational Prioritization:** People may be highly individualistic in their careers, consumption habits, and personal goals, yet strongly collectivistic when addressing a shared crisis (like a natural disaster or economic downturn).
- **Digital Tribes:** The rise of online communities and subcultures—often called "digital tribes"—will likely replace some traditional local collectives (like neighborhood groups or religious institutions).
- **Empathic/Hybrid Intelligence Systems:** The rise of "Empathic Robots" and sophisticated AI companions/assistants that can interpret complex emotional cues to provide personalized psychological support, education, and elder care, moving beyond simple task automation.
- **The Rise of the Global Refugee/Climate Migrant Class:** The number of people displaced by climate events, resource wars, and political instability will continue to surge, creating a permanent, large-scale Climate Migrant Class that requires new global governance and resettlement frameworks.
- **Community-Led Resilience Movements:** As trust in national institutions wanes, local communities will emphasize autonomy and resilience, focusing on local food supply (vertical farms), micro-grids for energy, and community-based disaster response in the face of frequent climate shocks.
- **Quest for Belonging:** In transient, anonymous spaces, people search for identity, recognition, and connection. Personalization and adaptive services. Global mobility dissolving stable identity anchors. Social media shaping self-presentation.
- **The Rise of Digital Tribes and Contested Reality.** People will increasingly seek comfort and validation in online "identity silos," reinforcing belief systems and creating a deeply polarized media environment. Trust in major institutions (government, media, science) will continue to be highly variable.
- **The "Empathy Economy" and Meta-Skills.** Automation will eliminate many routine jobs. The highest-value human skills will be those AI cannot replicate: creativity, emotional intelligence, critical thinking, and complex communication (meta-skills).

CLUSTER 8

Irrelevance yields social connection.

As **automation** makes us feel **irrelevant** and **replaceable**, we inevitably grow lazy regarding traditional work. Paradoxically, this freedom from everyday tasks grants us much more time for friends and family, thereby accelerating our evolution into a more **socially advanced** and deeply **collective society**.

Factors

- **The 4-Day Work Week Becomes a Normative Goal:** Driven by automation-led productivity gains and social demand for better work-life balance, the four-day work week (or its equivalent in output-based contracts) will become a primary policy objective and standard labor demand in many developed economies.
- **Containerized Freight Automation:** The logistics sector achieves near-full automation, utilizing autonomous, electric cargo ships, rail freight, and drone-delivery hubs, significantly reducing the cost and carbon footprint of global trade.
- **AGI Proximity and Ubiquitous Automation.** AI will move from assisting to autonomously managing most white-collar and specialized technical tasks (e.g., legal discovery, financial analysis, software development).
- **Massive Job Disruption** and the potential necessity of new economic models (e.g., Universal Basic Income) to manage structural unemployment.
- **Blended Reality and Sensory Integration:** The boundary between physical and digital realities is expected to blur entirely by 2035.
- **3D-Printed/On-Demand Organs:** Routine access to bio-printed organs and tissues (e.g., livers, kidneys) grown from a patient's own cells eliminates organ transplant waiting lists and the need for immunosuppressive drugs, fundamentally transforming long-term chronic care.

Frameworks

CLUSTER 9

The desire for data-driven control erodes trust.

The universal desire for **control** creates an intense struggle where **trust** is the most vital asset. In a **hyper-surveilled** environment where "Big Brother is watching," **data** becomes the ultimate source of intelligence and power. This dynamic pushes society toward a kind of **digital communism**, raising constant ethical questions about the nature and influence of propaganda, and fostering a deep **collective fear of losing autonomy**.

Factors

- **End of Control:** Humans oscillate between the desire to master complexity and the need to trust invisible systems. Automation, AI integration, and predictive systems taking over operations. Increasing data dependence and algorithmic decision-making.
- **The Trillion-Sensor World.** The Internet of Things (IoT) will explode into trillions of connected devices, with every physical asset monitored and managed by AI in real-time. The "digital space" will be a central economic zone, transacting in sovereign and decentralized digital currencies.
- **Zero Privacy** by modern standards, highly efficient resource management (smart cities/grids), and immense power vested in the entities that control the data.
- **Augmented Authenticity:** In a mediated world, authenticity becomes something we design, not discover. Are AI-generated humans disrupting the future of beauty?
- **Transparency and Trust:** As systems grow invisible, people crave visibility & clarity becomes comfort. Design of legibility: showing how the system works. Trust as a new form of comfort currency.
- **Digital Twins and Synthetic Reality:** The creation of Digital Twins (detailed, real-time virtual models) of cities, supply chains, and even individuals (for personalized health modeling) for predictive simulation and high-stakes decision-making.
- **Digital Repression and Surveillance States:** Governments will use the Trillion-Sensor IoT environment and advanced AI to implement sophisticated, real-time Digital Repression strategies, creating highly controlled societies in many autocratic nations.
- **Quantum Supremacy and Encryption Wars:** The development of large-scale, fault-tolerant Quantum Computers will render all current public-key encryption obsolete, necessitating a global transition to Quantum-Resistant Cryptography (QRC) in all financial, military, and communications systems.
- **Data as a Strategic Asset and Trust Enabler:** Data ownership will redefine industries, requiring transparency and security.

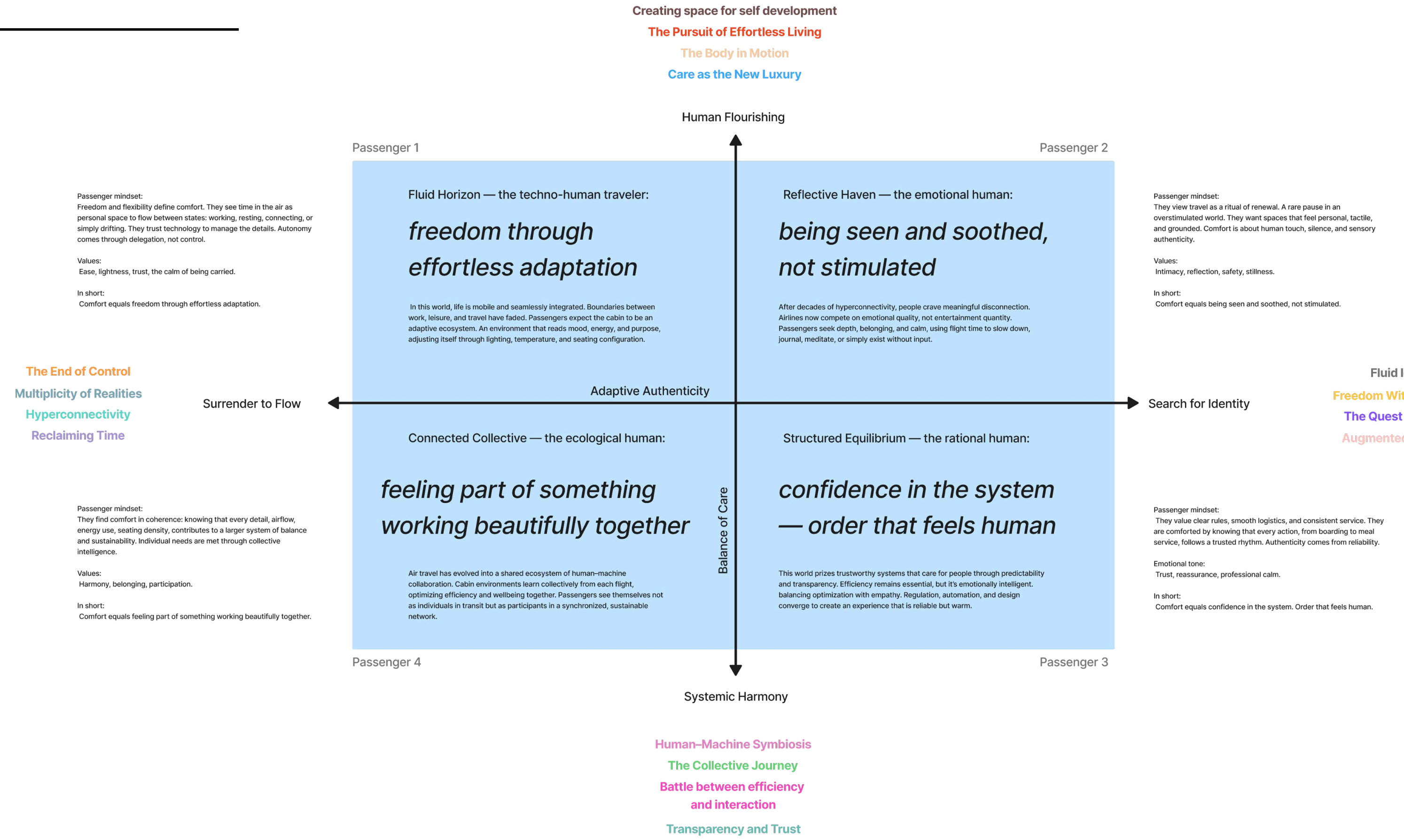
CLUSTER 10

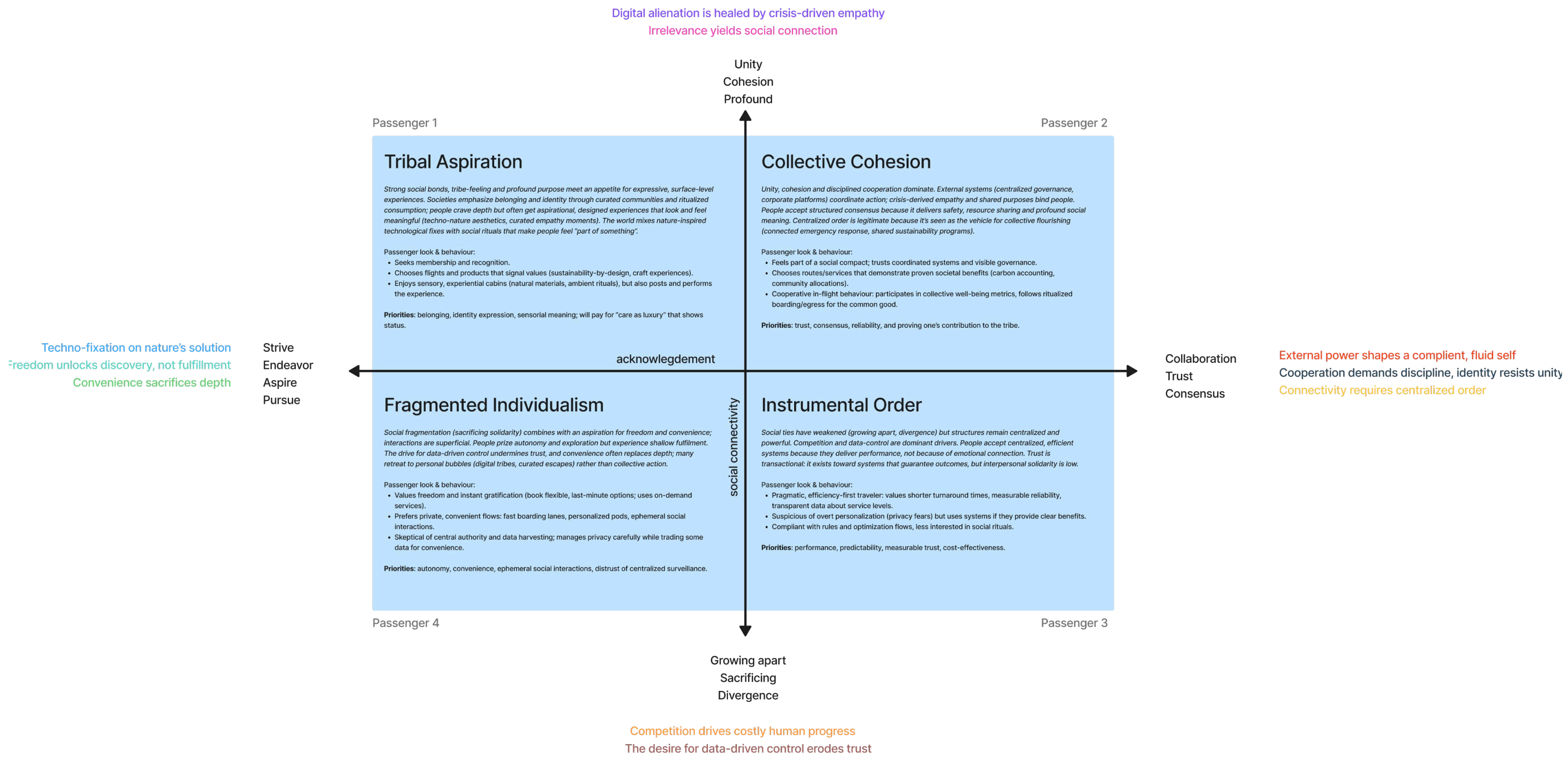
Cooperation demands discipline, identity resists unity.

Our very nature is a paradox: **competition** is rooted in our DNA, yet survival at this pivotal moment demands **cooperation**. While we cherish our **unique identities** and seek to avoid blame, working together requires **respect and discipline**. This is the challenge humanity faces as the risk of **losing control** to advanced AI forces us to finally embrace unity.

Factors

- **Organized Cooperation:** Problems like climate change, pandemics, and complex global supply chains require coordinated, collective action at national and international levels. Individual solutions are inadequate.
- **Rise of Authoritarianism/Nationalism:** In many parts of the world, there's been a resurgence of strong national identities and state-centric ideologies, where the needs of the nation or state are explicitly prioritized over the rights or desires of the individual.
- **Regional Splits:** Societies with strong state control (like China or Russia) are likely to remain firmly rooted in collectivism (or state-centric nationalism), while many Western and Northern European countries may lean more heavily toward liberal individualism.
- **Collective Journey:** Air travel as a shared moral act, where individual choices carry collective consequences. Climate impact awareness, sustainable aviation fuel, electric and hydrogen flight. Accessibility and inclusivity as social responsibilities. Growing public scrutiny of aviation's carbon footprint.
- **Increased Geopolitical Competition** and challenges to the Western-led international rules-based order. Global governance becomes significantly more challenging.
- **Peak Fossil Fuel Demand and Circular Economy.** Fossil fuels will still be used, but global demand will peak due to massive deployment of renewables (solar, wind, advanced storage). The focus will shift to building a truly circular economy to manage resource scarcity.
- **Global competition over critical minerals** (lithium, rare earth metals) necessary for the renewable energy transition.
- **Increased Political Instability** and greater difficulty achieving national consensus on complex issues like AI regulation or climate policy.
- **Climate Adaptation Dominates Policy.** Climate change impacts (extreme weather, resource stress) will be impossible to ignore. Climate migration—both internal and cross-border—will become a constant humanitarian and geopolitical challenge.
- **Massive Investment in climate-resilient infrastructure** (sea walls, smart grids, controlled-environment agriculture) and a global re-prioritization of resources.

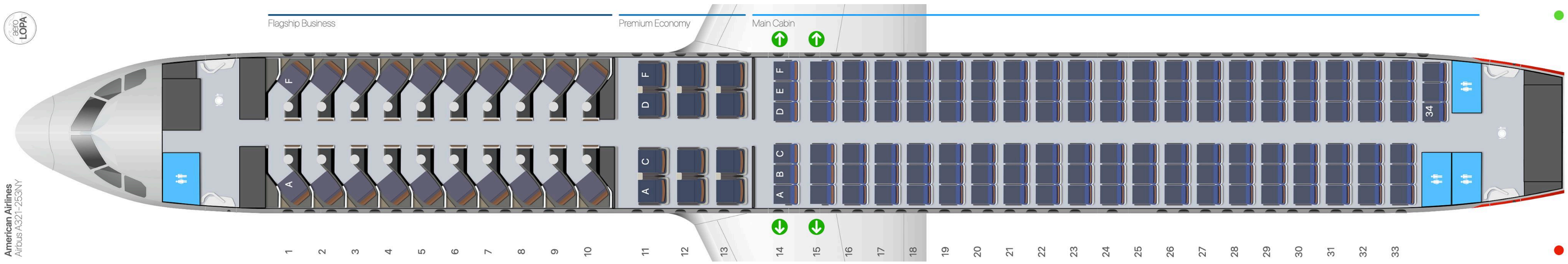


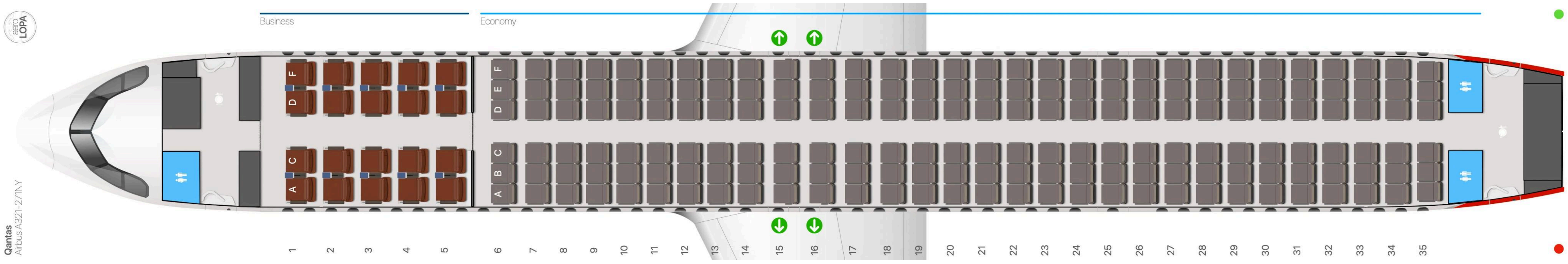


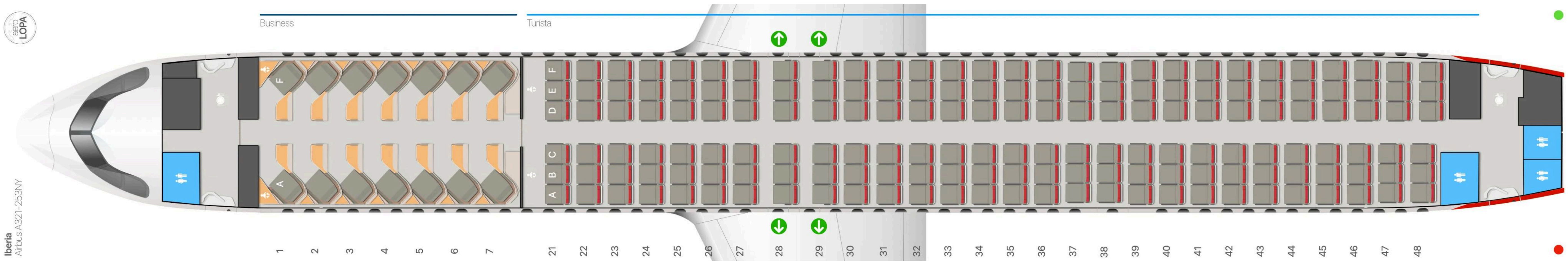
Appendix F

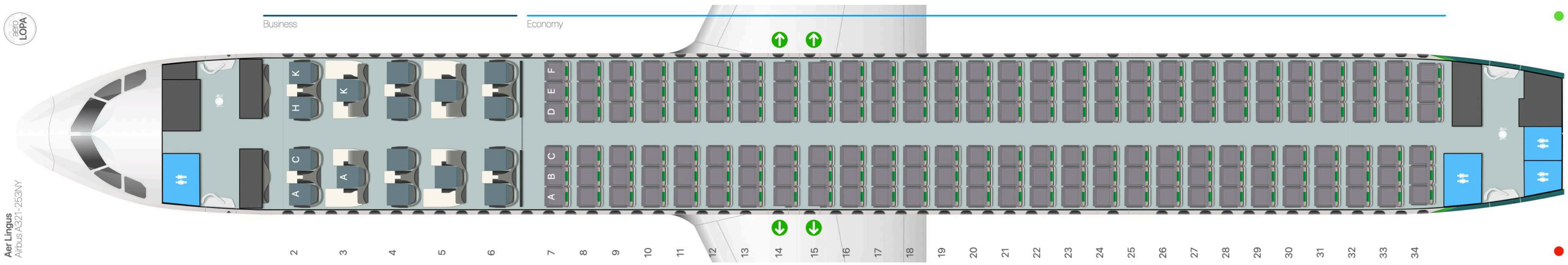
Airlines LOPA

This appendix provides a comparative analysis of the Layout of Passenger Accommodations (LOPA) for American Airlines, Qantas, Iberia, and Aer Lingus, which represent the primary current operators of the Airbus A321XLR. These configurations served as essential industry benchmarks to validate the volumetric feasibility of the 2040 cabin vision against real-world narrowbody long-haul standards.




aero LOPA
Qantas
Airbus A321-271NY
Business
Economy
A C D F
A B C D E F
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

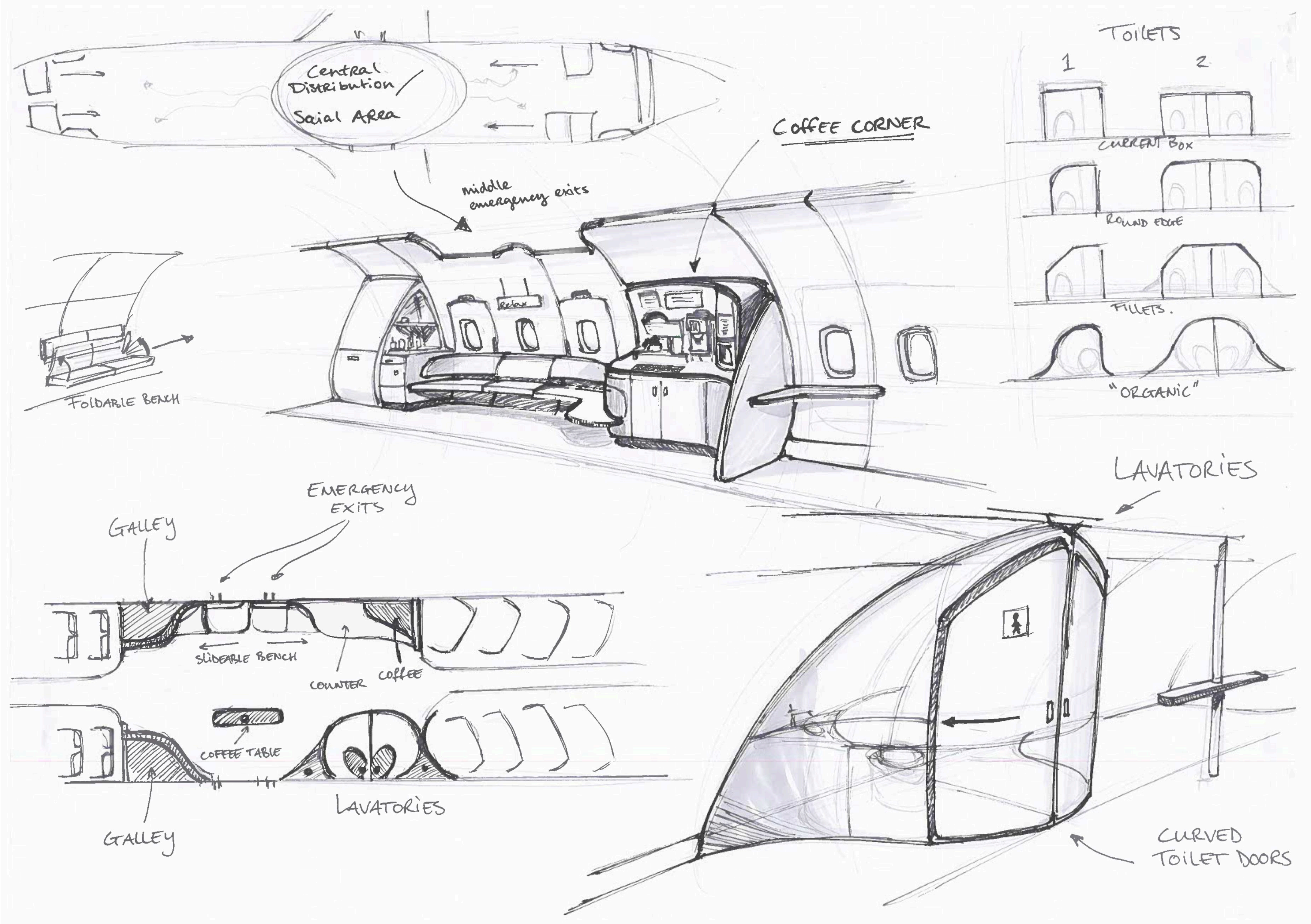

aero LOPA
Iberia
Airbus A321-253NY
Business
Turista
A F
A B C D E F
1 2 3 4 5 6 7 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

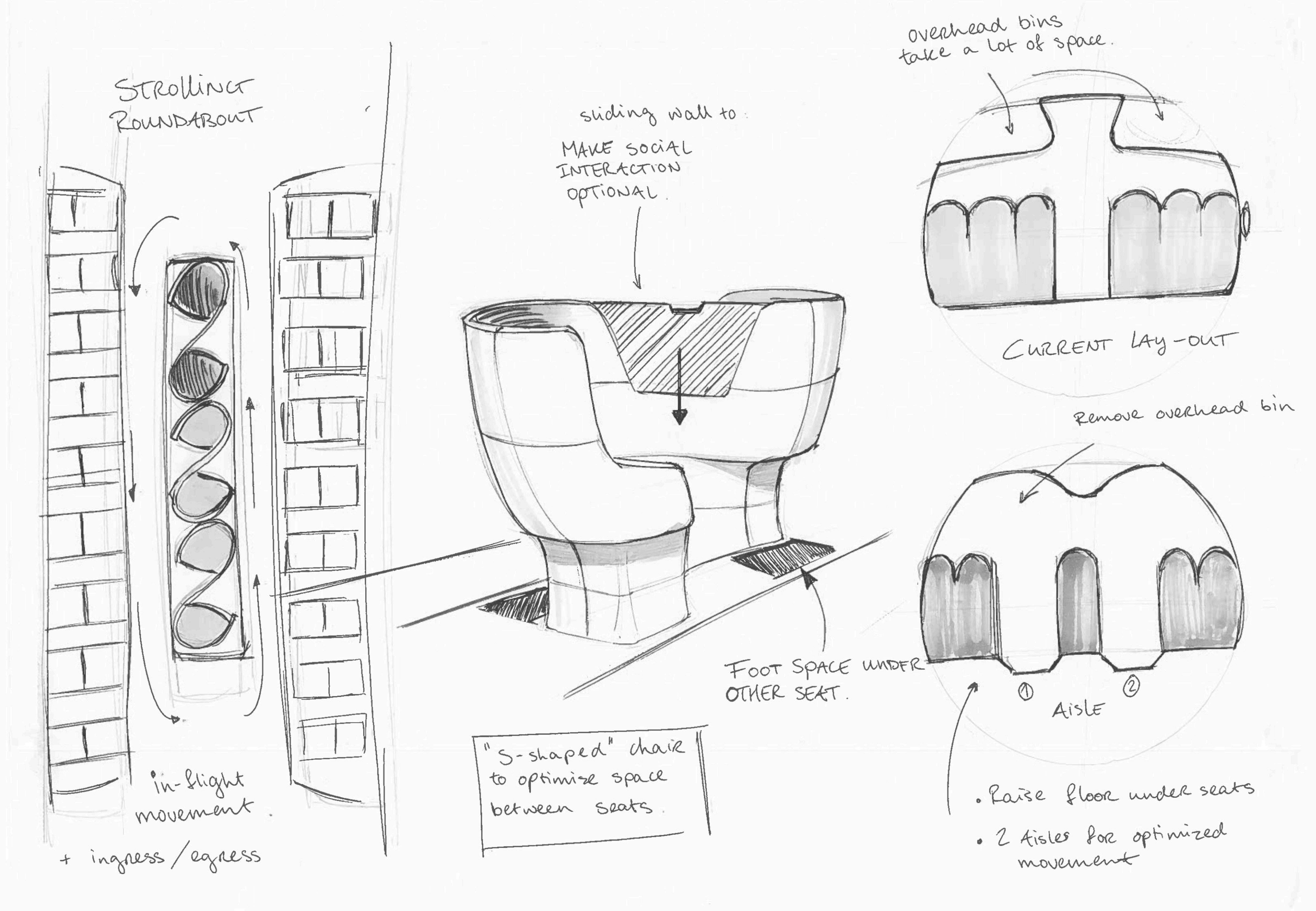

aero LOPA
Aer Lingus
Airbus A321-253NY
Business
Economy
A C H K
A K
A B C D E F
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

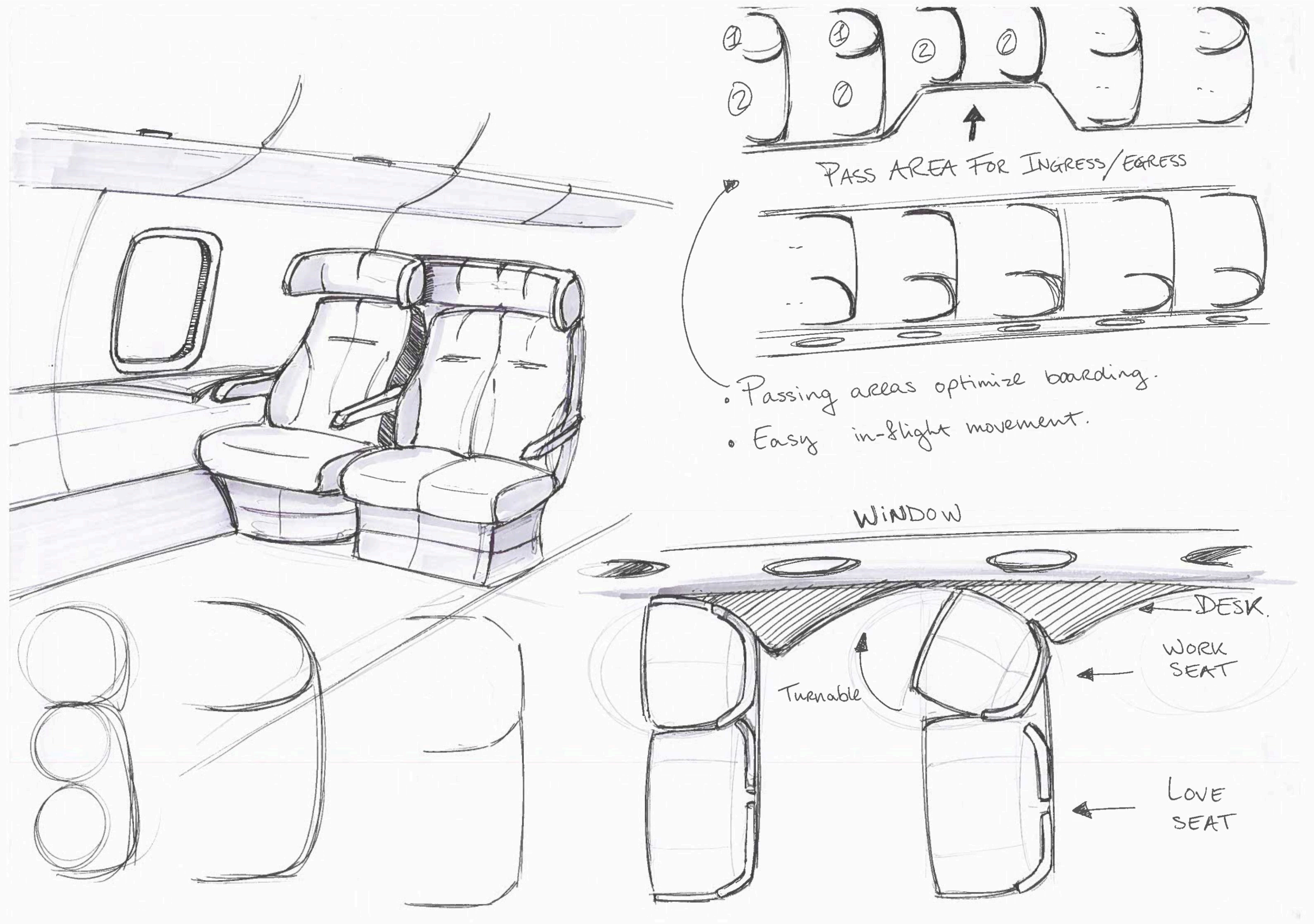
Appendix G

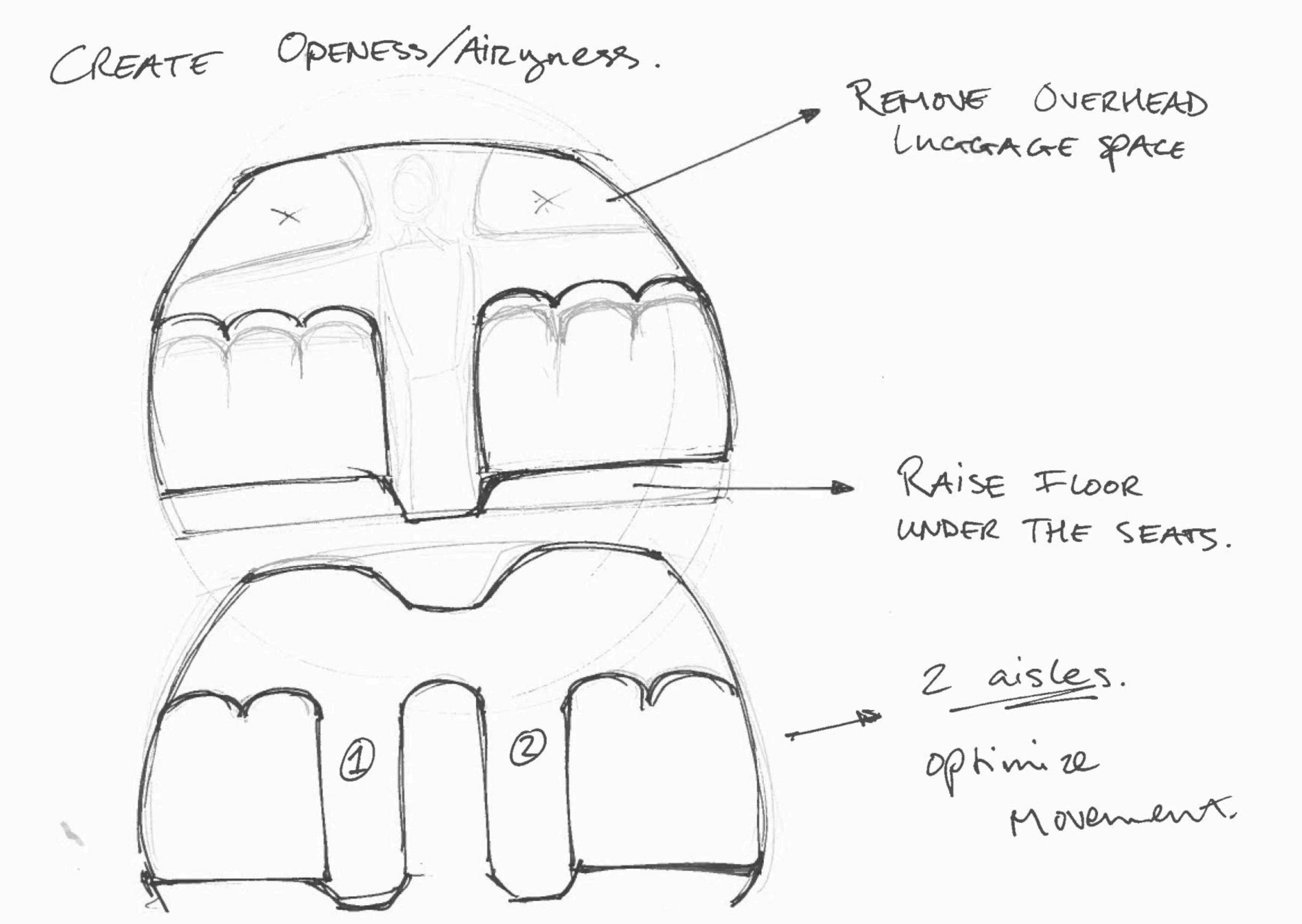
Exploration Sketches

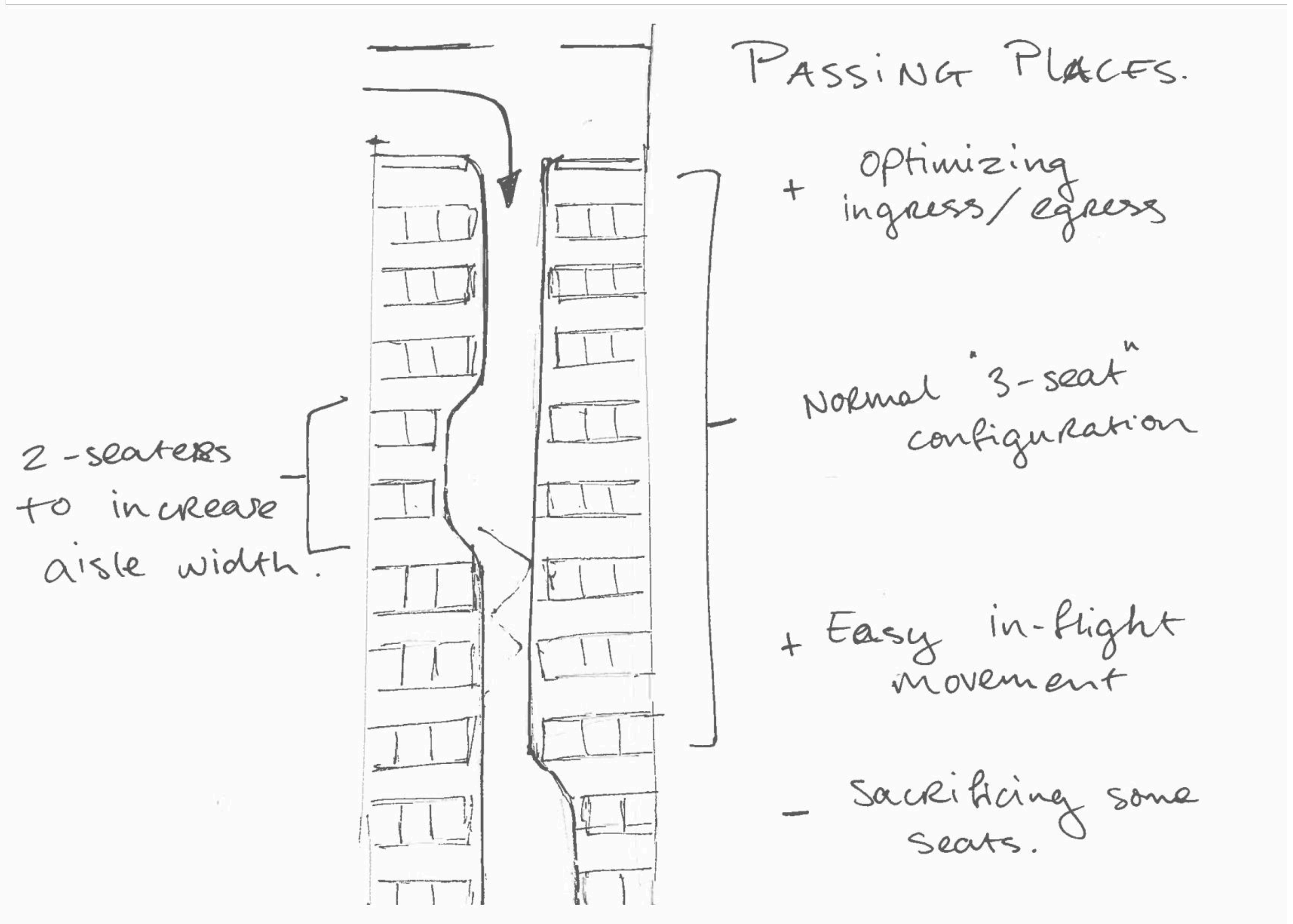
This appendix presents a comprehensive collection of the Exploration Sketches generated during the project's iterative ideation phase. These visual studies document the transition from abstract future scenarios to tangible interior geometries, showcasing the design thinking required to translate the "Zen Mountain Lodge" vision into concrete architectural and ergonomic solutions.

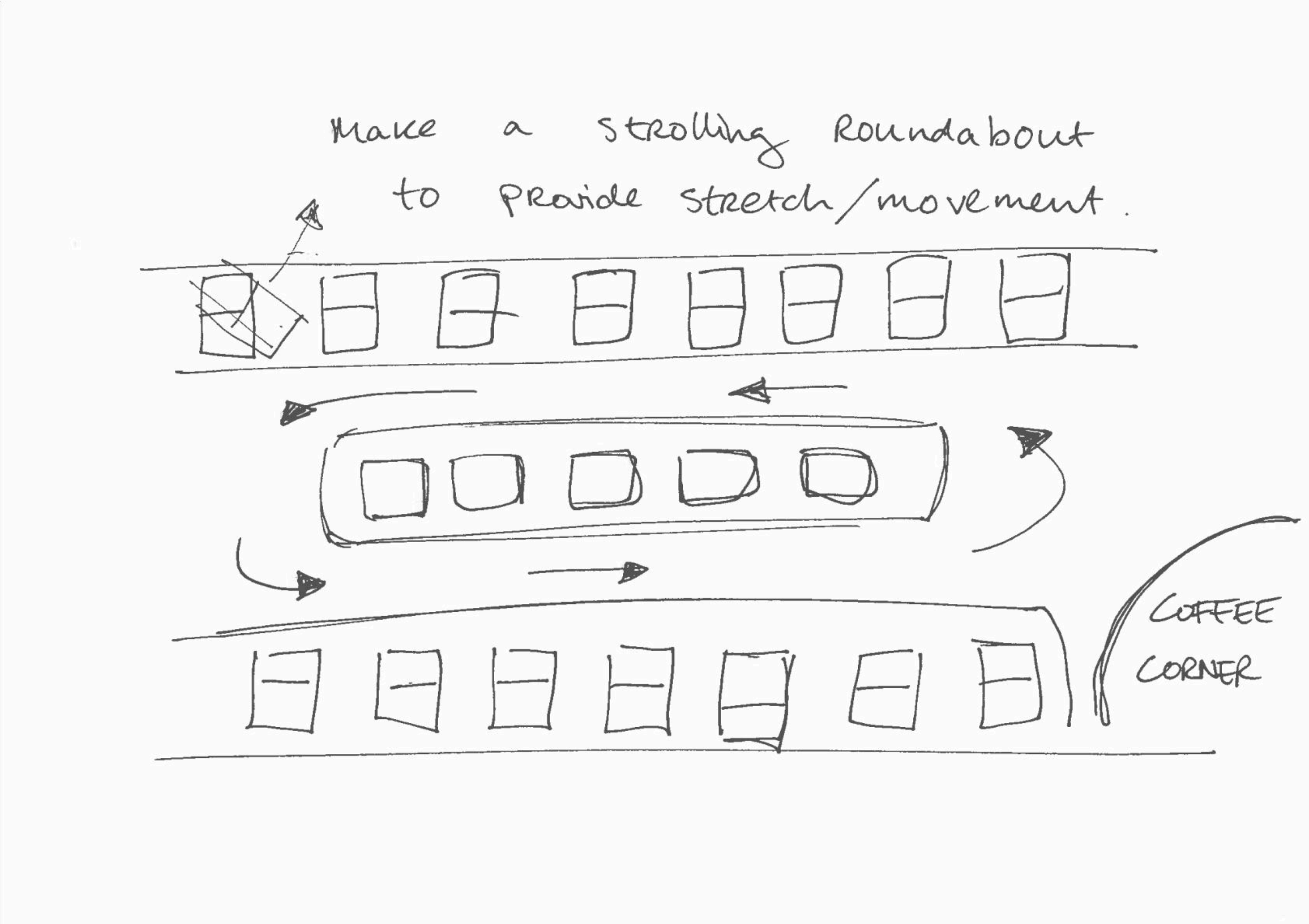


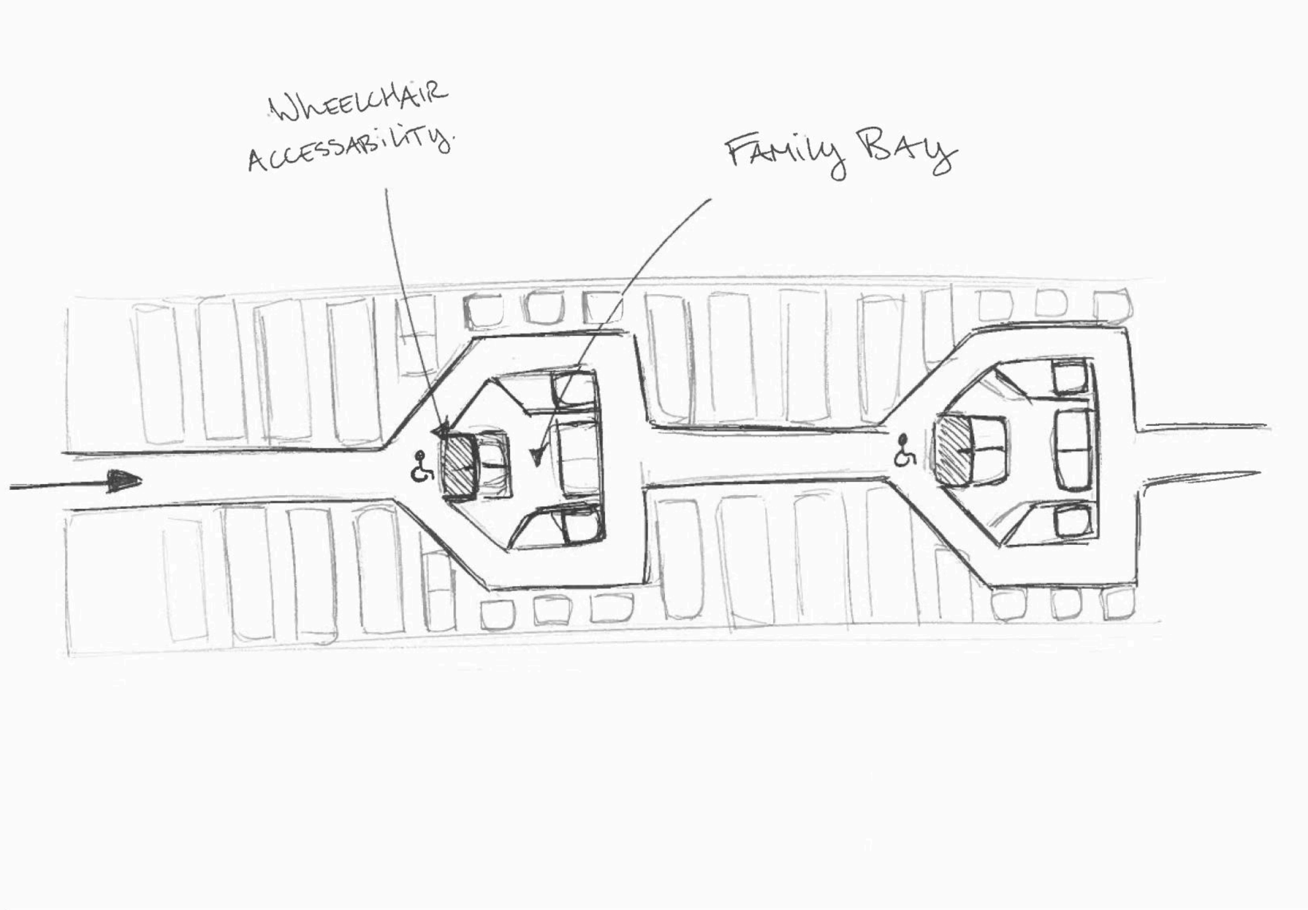

STROLLING ROUNDABOUT
in-flight movement
+ ingress / egress
sliding wall to:
MAKE SOCIAL INTERACTION OPTIONAL
FOOT SPACE UNDER OTHER SEAT.
"S-shaped" chair to optimise space between seats
overhead bins take a lot of space.
CURRENT LAY-OUT
Remove overhead bin
1
2
AISLE
• Raise floor under seats
• 2 Aisles for optimized movement

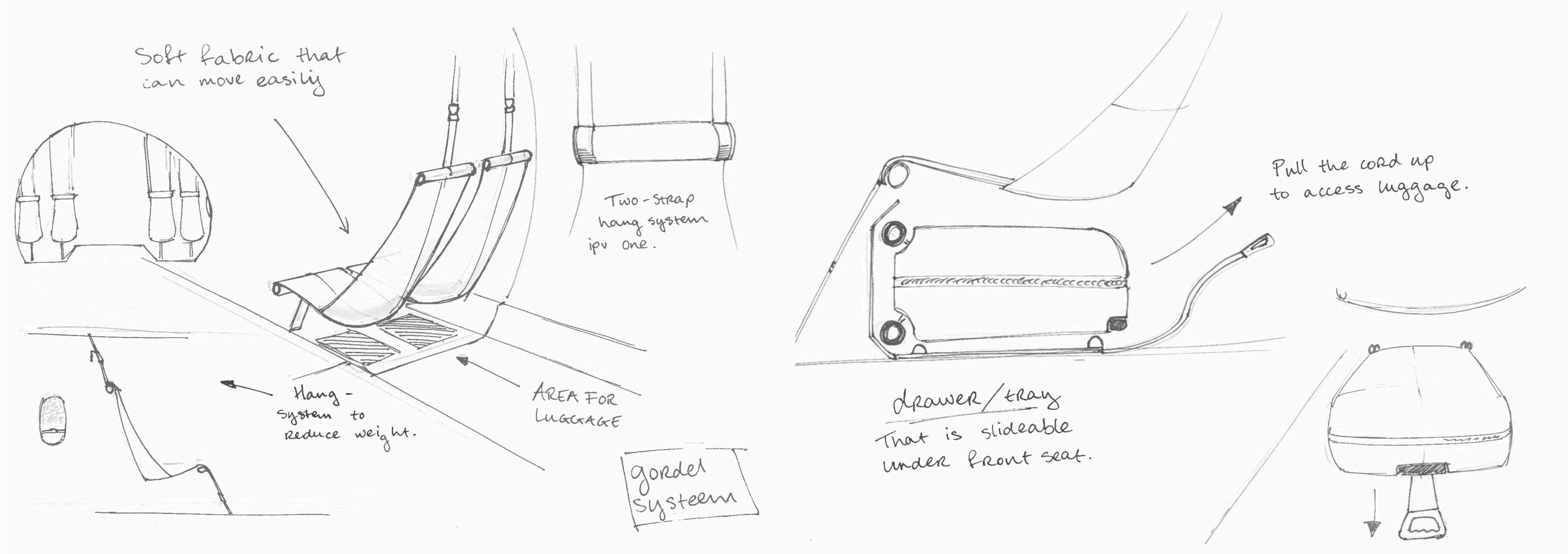

PASS AREA FOR INGRESS/EGRESS
• Passing areas optimize boarding.
• Easy in-flight movement.
WINDOW
DESK.
WORK SEAT
Turnable
LOVE SEAT

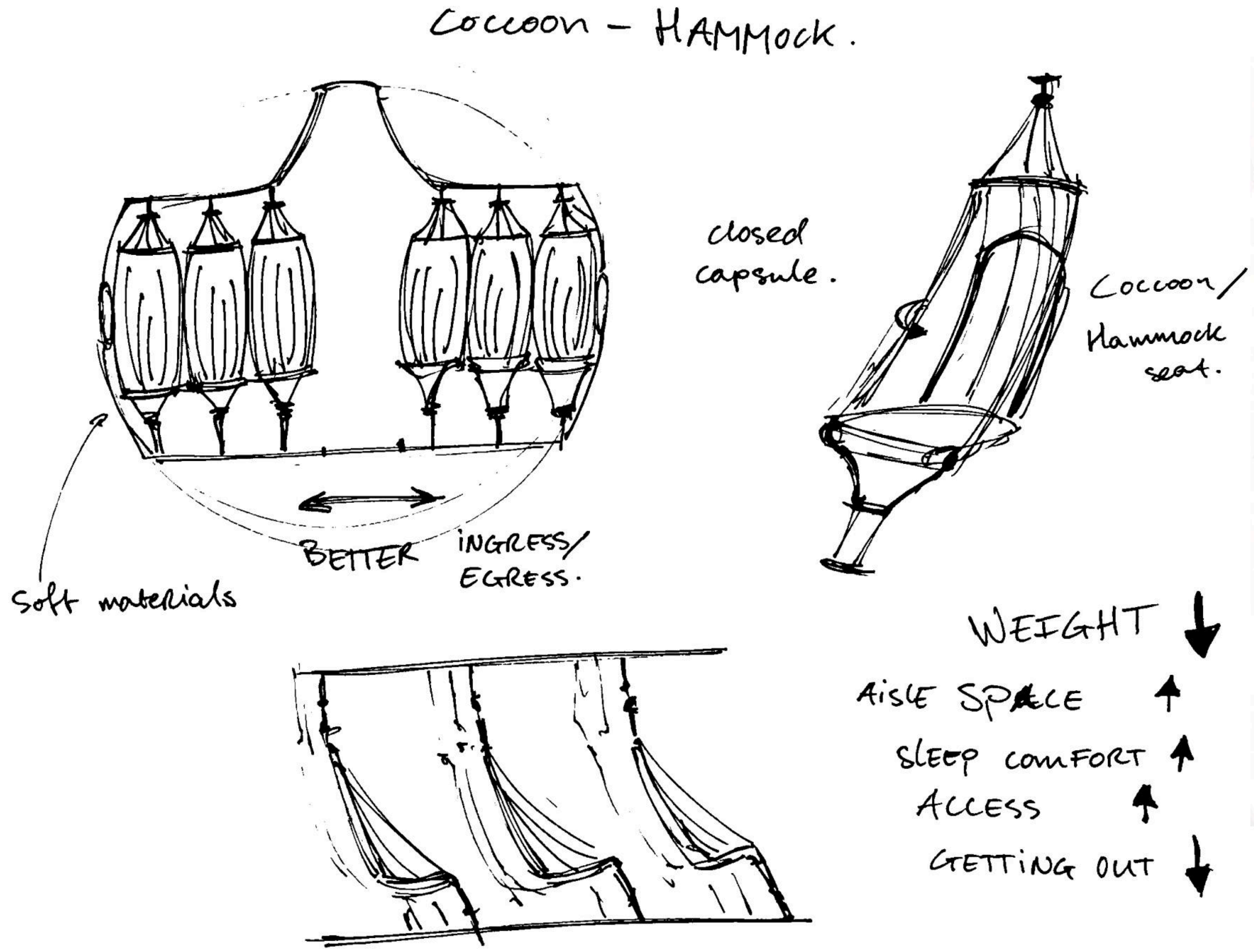

CREATE OPENESS/AIRYNESS.
REMOVE OVERHEAD LUGGAGE SPACE
RAISE FLOOR UNDER THE SEATS.
2 aisles.
optimize Movement.

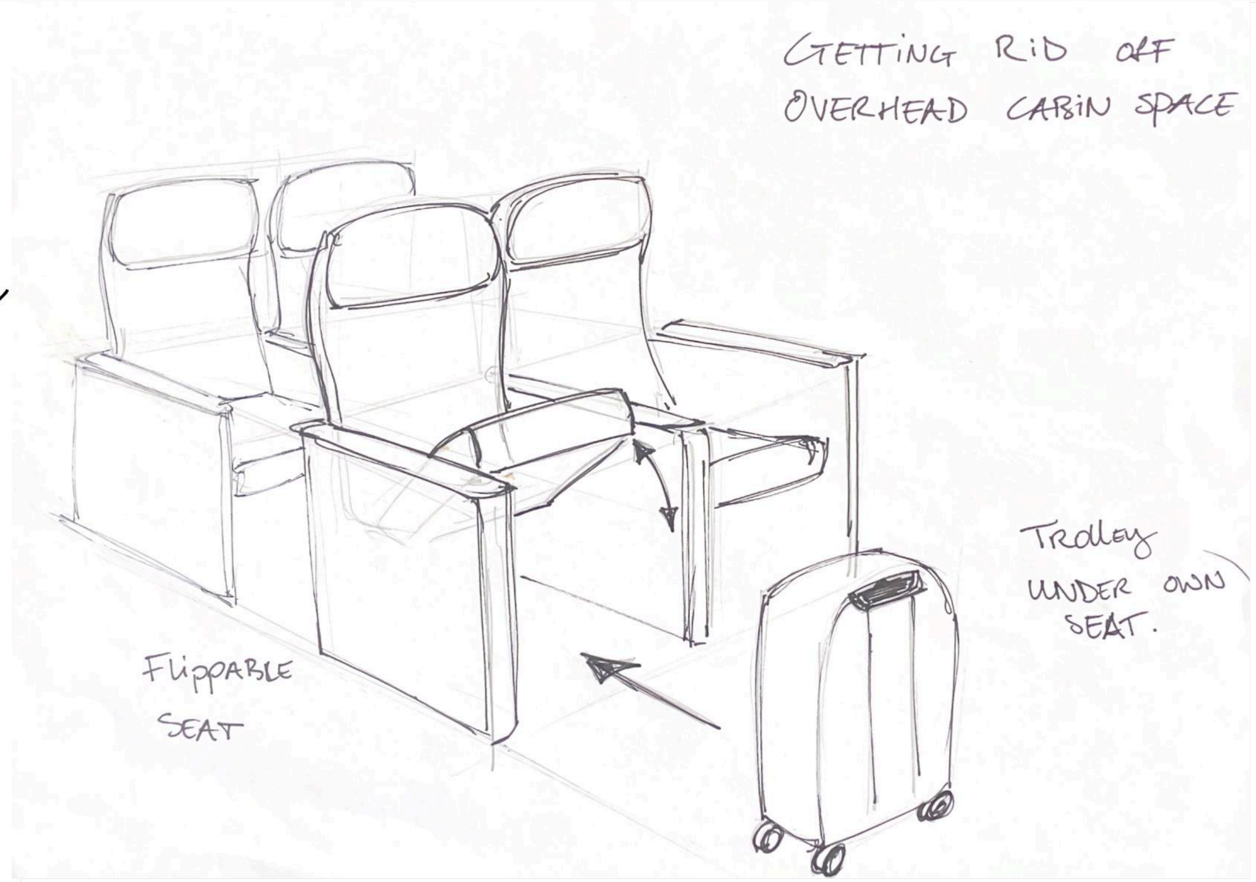

PASSING PLACES.
+ optimizing ingress/egress
Normal "3-seat" configuration
2-seaters to increase aisle width.
+ Easy in-flight movement
- sacrificing some seats.

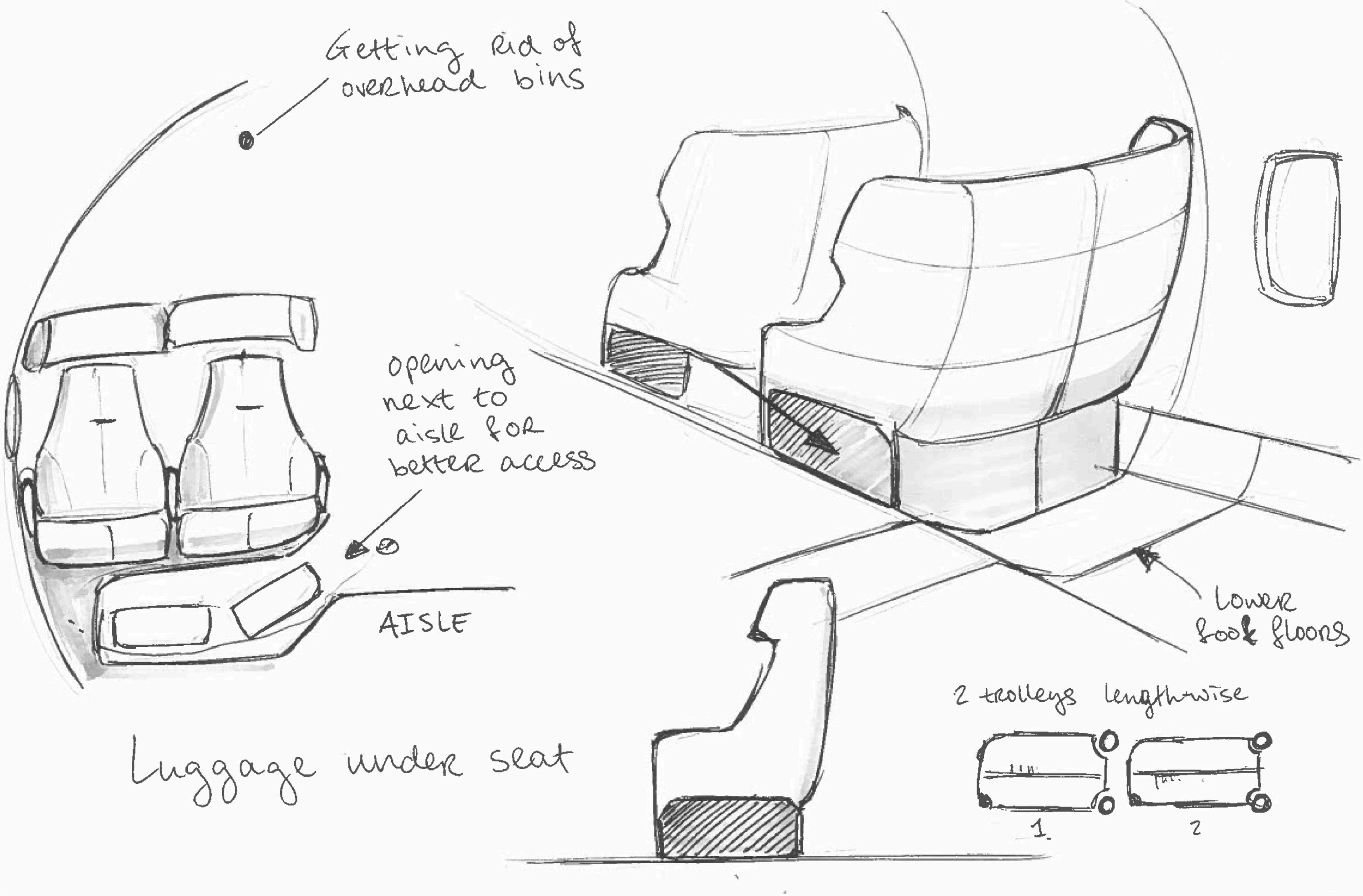

Make a strolling Roundabout to provide stretch/movement.
COFFEE CORNER


WHEELCHAIR ACCESSABILITY
FAMILY BAY

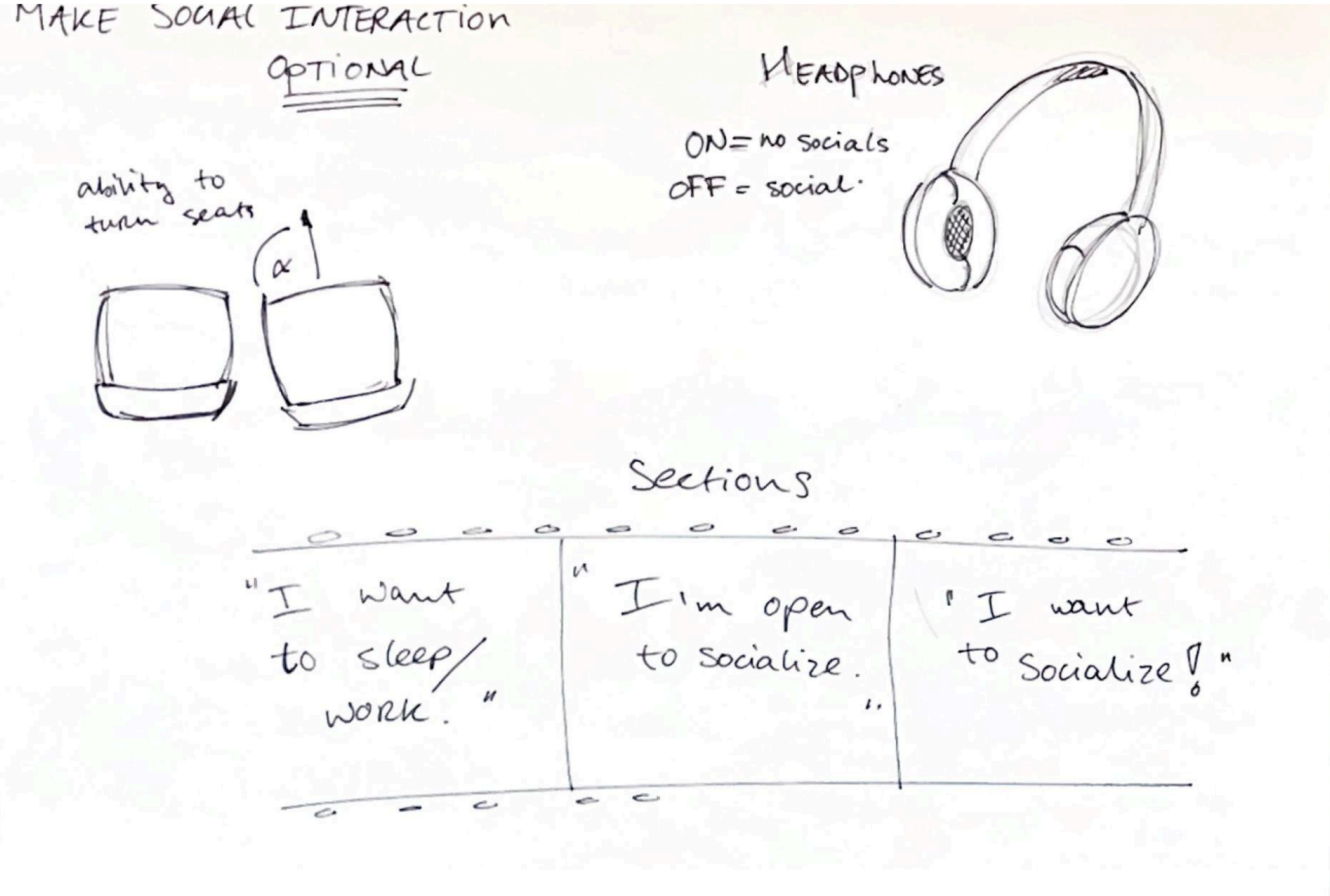

Soft fabric that can move easily
Two-strap hang system ipv one.
Hang-system to reduce weight.
AREA FOR LUGGAGE
gordel systeem
Pull the cord up to access luggage.
drawer/tray
That is slideable under front seat.

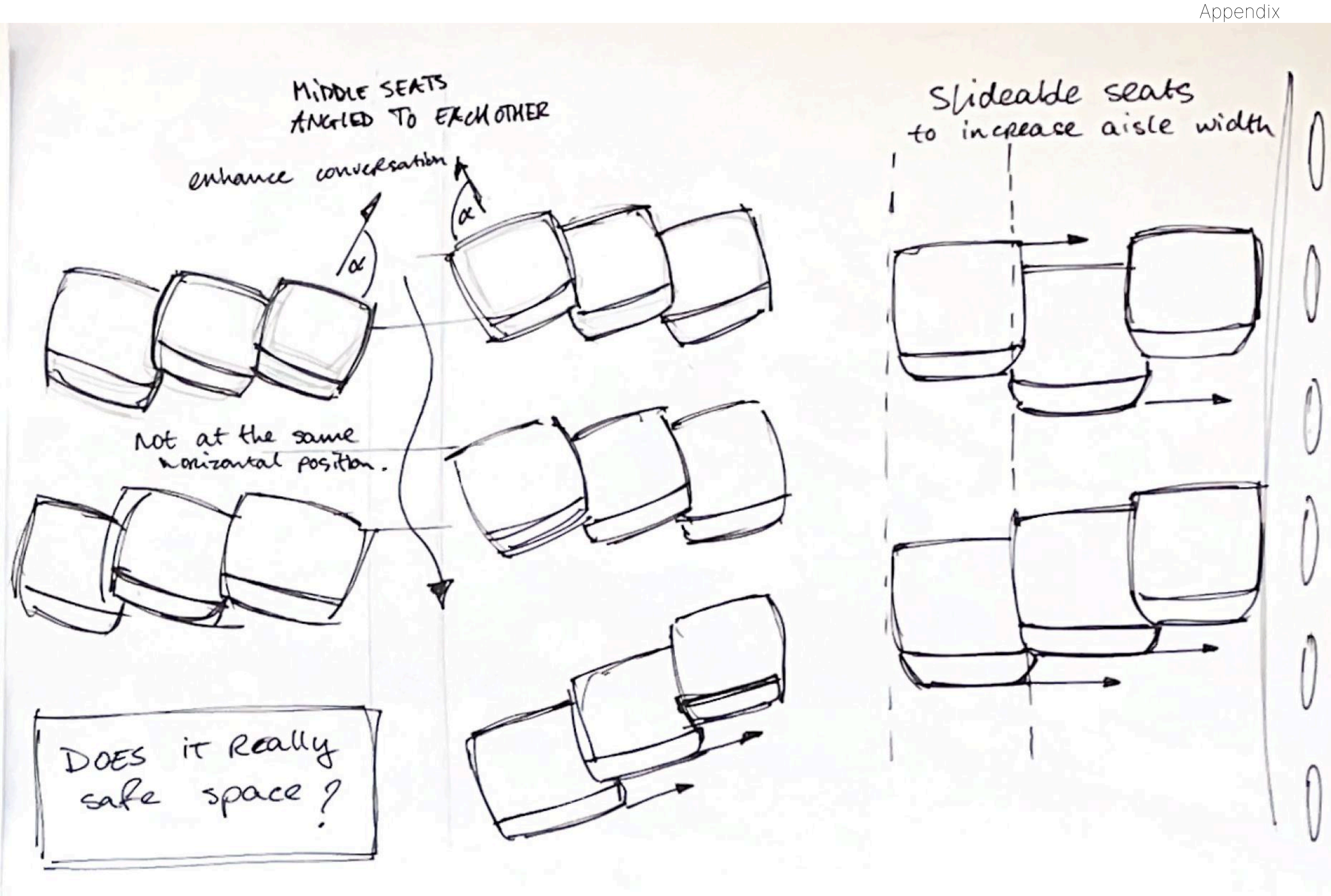

COCOON – HAMMOCK.
closed capsule.
Cocoon/ Hammock seat.
Soft materials
BETTER
INGRESS/ EGRESS.
WEIGHT
AISLE SPACE
SLEEP COMFORT
ACCESS
GETTING OUT

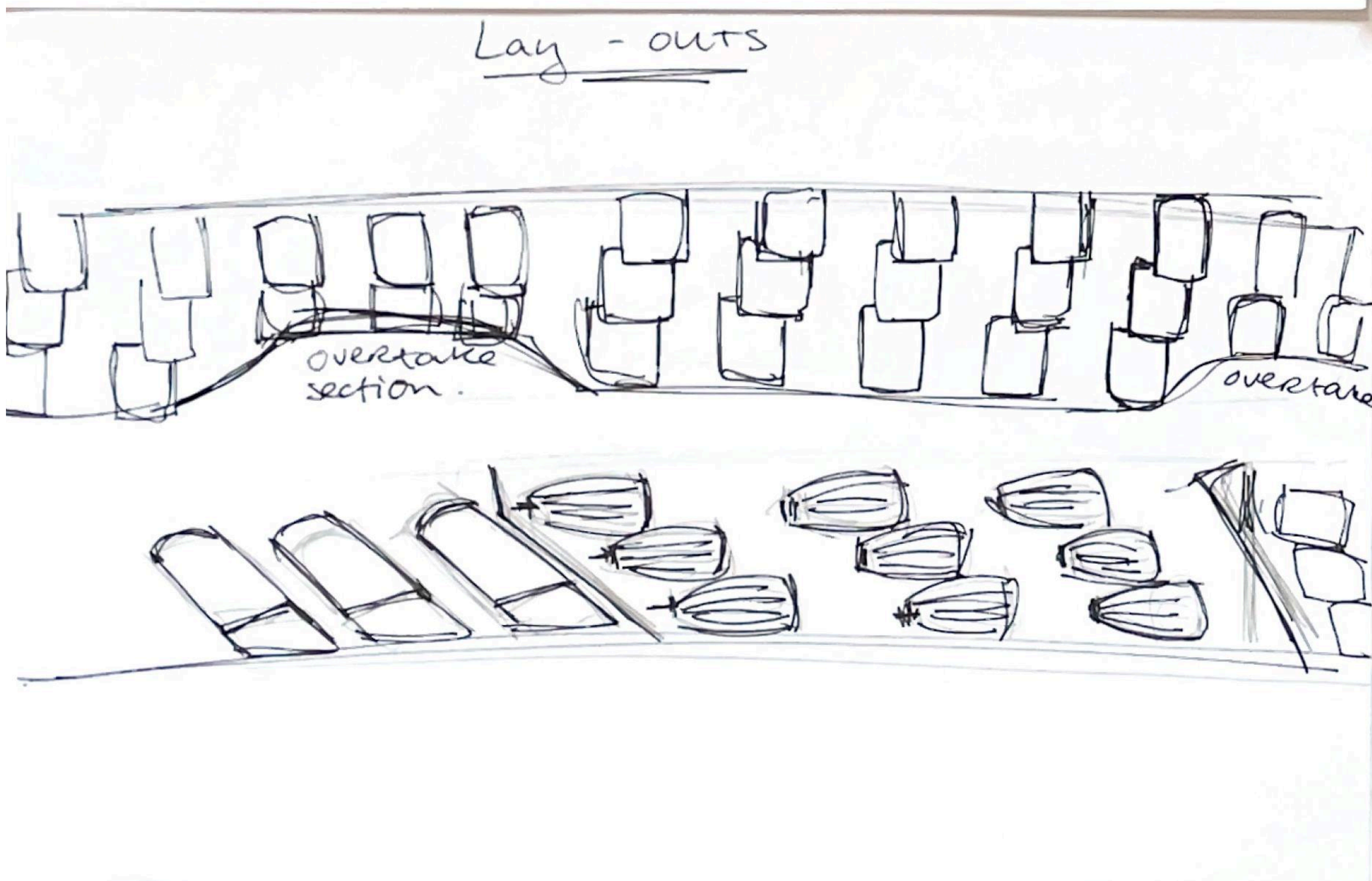

GETTING RID OFF OVERHEAD CABIN SPACE
Trolley UNDER OWN SEAT.
Flippable SEAT

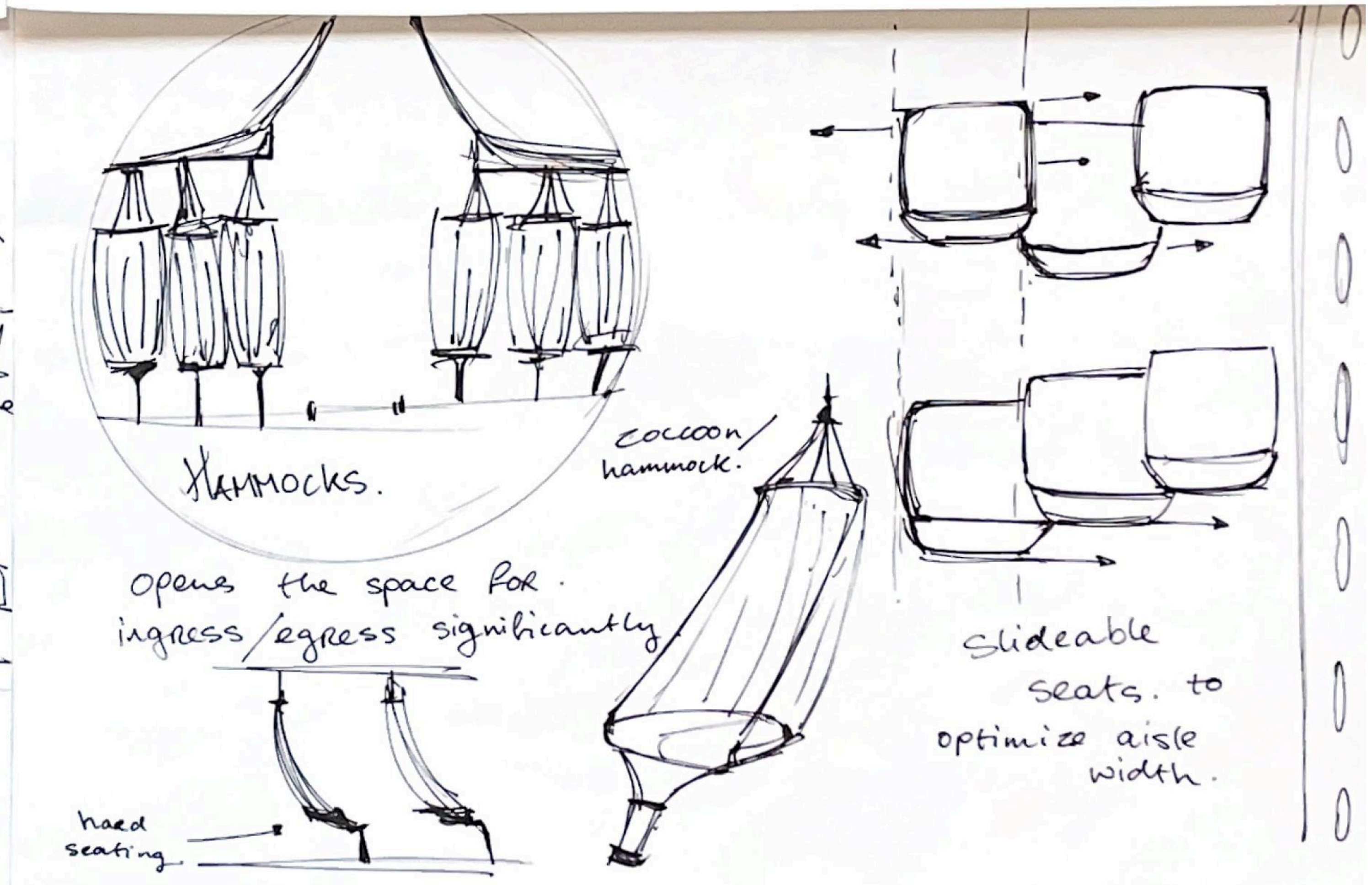


Getting rid of overhead bins
opening next to aisle for better access
AISLE
Luggage under seat
Lower foot floors
2 trolleys lengthwise
1
2


MAKE SOCIAL INTERACTION OPTIONAL
HEADPHONES
ON = no socials
OFF = social.
ability to turn seats
α
Sections
"I want to sleep/ work."
"I'm open to socialize."
"I want to socialize!"


MIDDLE SEATS ANGLED TO EACH OTHER
enhance conversation
α
Not at the same horizontal position.
DOES IT Really safe space?
Slideable seats to increase aisle width


Lay - outs
overtake section.
overtake


HAMMOCKS.
cocoon/ hammock.
Opens the space for ingress/egress significantly
hard seating
Slideable seats. to optimize aisle width.

Appendix H

Moodboard

This appendix presents the Moodboards and CMF (Color, Material, and Finish) strategy that defines the visual and tactile identity of the 2040 cabin. These curated selections translate the "Zen Mountain Lodge" vision into a tangible palette of sustainable, residential-inspired materials designed to prioritize passenger well-being and emotional calm.