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Interior Design of an Urban Air Mobility Vehicle for Use in Prehospital Medical Emergencies

Developing a Concept to Complement Today's Ambulance Vehicles

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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MASTER'S THESIS 2025

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Cover: The final interior design concept.

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Abstract

Urban Air Mobility (UAM) is a rapidly emerging field focused on creating aerial traffic systems in urban cities and utilising the air for transportation of passengers and cargo, to ease arising issues with traffic congestion and increased travel times.

The research project Airmobility Emergency System (AMES) at Chalmers aims to develop a UAM vehicle for implementation within emergency medical services in the near future, with focus on the Region Västra Götaland (VGR) in Sweden. UAM will serve as a complement when neither road ambulances nor helicopters are suitable options. This ensures that public emergency services can access accident sites regardless of ground conditions.

This project is part of AMES and focuses on developing a comfortable, functional, and user-friendly interior concept that meets the needs of ambulance personnel, enhancing their ability to provide care with effectiveness and efficiency.

Based on literature, a survey and field studies conducted at the ambulance helicopter base and a road ambulance station in VGR, an interior design concept was developed and evaluated through 1:1 scale prototyping and CAD modelling. A final evaluation with paramedics in the full-scale prototype, followed by refinements, resulted in a user-centred interior solution.

The primary project deliverables consist of a visualisation of the concept through a comprehensive CAD model, supported by a detailed product specification and an equipment list. Together, these deliverables propose a recommended interior design for an Urban Air Mobility (UAM) vehicle intended for future implementation in emergency medical services.

The proposed interior design concept features a seat-stretcher configuration with one stretcher positioned centrally. A seat is placed on each side of the stretcher, with an additional seat behind the patient's head. Storage solutions are integrated at the back of the cabin to accommodate items not needed during flight. Additional storage is positioned along the ceiling. Loose equipment and bags can also be secured to the floor, enabled by the built-in L-tracks. In situations where the autonomous system would require human intervention, essential manoeuvring hardware such as stop buttons, displays and a dashboard, is incorporated into the design.

KEYWORDS
Urban Air Mobility • eVTOL • Cabin Interior Design • Emergency Medical Service (EMS) • Air Ambulance • Industrial Design Engineering • User-Centered Design

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Our sincere appreciation goes to the exterior design team, Yu-Han Hua and David Gustafsson. Working closely together played a key role in delivering a concept with genuine potential for future implementation in emergency medical services. Thank you for your commitment, collaborative efforts and for making our weekly meetings so enjoyable. We are deeply grateful, as our joint effort resulted in the successful exhibition of our concept at EVS38 in Gothenburg on June 16, which was a memorable experience.

We are also grateful to Anders Almqvist, a nurse anaesthetist at the helicopter emergency medical service in VGR, for repeatedly offering his time, sharing his expertise, and providing us with a detailed tour of the ambulance helicopter, which gave us invaluable insights into the prehospital organisation.

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Matilda Nevelius Wernholm & Linnéa Westberg, June 2025

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Abbreviations

UAM	Urban Air Mobility
VTOL	Vertical Take-Off and Landing
eVTOL	Electric Vertical Take-off and Landing
EMS	Emergency Medical Services
HEMS	Helicopter Emergency Medical Services
VGR	Region Västra Götaland
SvLc	Sjukvårdens Larmcentral (Swedish Medical Emergency Dispatch Centre, responsible for receiving and assessing medical emergency calls)
AH	Ambulance Helicopter (air ambulance)
RA	Road Ambulance
Paramedics	Prehospital EMS personnel, including specialist nurses and doctors within anesthesiology

1 Introduction

Urban Air Mobility (UAM) is a rapidly emerging field focused on creating aerial traffic systems in urban cities consisting of un-/manned electric vertical take-off and landing (eVTOL) aircrafts, that enable shorter distance transportation of passengers and cargo on a lower altitude than conventional air traffic (Cohen & Shaheen, 2021; EASA, 2021; K. Wang & Qu, 2023; L. Wang et al., 2023).

By utilising the third dimension of space and moving parts of the transportation away from the roads, traffic congestion is eased so that travel times are shortened and current delays caused by heavy traffic can be avoided (EASA, 2021; K. Wang & Qu, 2023; L. Wang et al., 2023).

For the emergency medical service (EMS) in Västra Götalandsregionen, the average response times have been steadily increasing in the past ten years (Edenström, 2024). This may cause serious consequences for people in emergencies where every second matters. One factor is congested traffic within urban areas, including Gothenburg, which hinders ambulances from reaching the accident sites in time.

Figure 1.1: A future urban city with an implemented aerial traffic system including autonomous UAM vehicles (Created with ChatGPT with the prompt "An urban city with UAM flying around between vertiports").

There are a multitude of road ambulances, but they are slower than the helicopter and are affected by traffic congestion and road conditions. While the helicopter is fast, it is also expensive and therefore only one exists within VGR. UAM could be a more efficient, accessible, and sustainable alternative for medical emergency responses when neither road ambulances nor helicopters are suitable options. This ensures that public emergency services can access accident sites regardless of road blockages or severe ground conditions.

The client in this Master's thesis project is the research project Airmobility Emergency System (AMES) at Chalmers University of Technology, whose logo is shown in Figure 1.2. AMES aims to bridge the gap between current ambulance vehicles by developing a UAM vehicle, designed for implementation in EMS (Chalmers, 2024). The UAM vehicle is hereafter referred to as simply as UAM.

Airmobility
Emergency
System

Figure 1.2: Logo of the AMES research project at Chalmers

AMES is funded by Vinnova and Västra Götalandsregionen (VGR) (Chalmers, 2024). VGR is responsible for the prehospital emergency service in the region. The UAM developed in the AMES project will serve as a complement to the current helicopter and road ambulance. It will be electric and fly autonomously and unmanned. The UAM provides a middle ground with medium cost, which brings the possibility of having multiple UAMs within the region.

This thesis project is part of the AMES project and is focused on developing a comfortable, functional, and user-friendly UAM vehicle interior that meets the specific needs of ambulance personnel and enhances their ability to provide care with effectiveness and efficiency. In parallel with this project, another thesis team developed the exterior design. To ensure a coherent end product that meets shared project requirements, the interior and exterior teams worked in close collaboration throughout the project.

During the exploratory phase of the project, four main missions that the future UAM may encounter were identified. Use Case A involves treating the patient from arrival on-site until arrival at the hospital, where the hospital staff takes over the care. Use Cases B-D primarily involve support at accident scenes where healthcare is already underway, typically by road ambulances or helicopters. In these missions, the UAM supplements the EMS with additional resources, but is not the primary vehicle for transporting critically ill patients. This project focuses on Use Case A, as that is most critical since it involves the most interaction with the patient and vehicle.

A – Treat a patient during the flight to the hospital

The UAM is dispatched and arrives at the scene. The paramedics locate the patient, begin treatment, and load the patient onto the stretcher for transport. Treatment continues during the flight to the hospital. The patient's condition is life-threatening, and every minute is critical.

B – Transport paramedics to the accident site

When paramedics working on-site require additional support, a UAM is dispatched with personnel to assist the ongoing operation.

C – Deliver supplies to the accident site

When additional equipment is required, a UAM is deployed to deliver the necessary resources to support the paramedics already operating on-site.

D – Remove patients from the accident site

When it is determined that a road ambulance is a less suitable way of removing patients from an accident site. Examples include remote areas or traffic accidents with limited accessibility.

1.1 Aim

This project aims to explore the integration of advanced technologies, functionality, and passenger experience within the design of an autonomous Urban Air Mobility (UAM)I vehicle, tailored to serve as an emergency response unit. The focus lies on developing a comfortable, functional, and user-friendly interior that meets the specific needs of ambulance personnel and enhances their ability to provide care with effectiveness and efficiency.

To support achieving the project's aim, the following research questions have been formulated:

R1: What equipment should be implemented in the interior?

R2: What interior features fulfil the EMS paramedics' needs and expectations, in terms of functionality and user experience?

R3: How should the interior be designed to be effectively integrated with the UAM's exterior while supporting the paramedics' workflow?

1.2 Objectives

To support fulfilling the project's aim and answer the research questions, the following objectives have been established:

- Conduct extensive research on current emergency vehicles and other relevant products on the market.
- Conduct user research and combine the results with theoretical background to address user needs and technical aspects.
- Define requirements for the interior design.
- Develop a concept for interior design, represented by a medium-fidelity CAD model.
- Deliver an equipment list and product specification for the concept.
- Build a 1:1 scale low-fidelity prototype of the concept.

1.3 Initial Requirements

The following requirements were provided by the client (AMES) and are applicable to both the exterior and interior team, see Table 1.1. They were outlined at the beginning of the project and are based on previous research and findings in the AMES project. In addition, a list of the minimum medical equipment required for prehospital care was provided, see Table 1.2.

Table 1.1

Initial Client Requirements for the UAM Interior Design

Transport Compatibility	The UAM must fit within a 20' standard shipping container with internal dimensions of: W235 cm × L571 cm × H238 cm.
Access and Doors	The UAM should have three entrances: one rear door and two side doors.
Stretcher Access	The stretcher should enter through the rear door. The Scoop stretcher must fit through both rear and side doors, in case one entrance is blocked.
Battery Integration	Reserve 30 cm between interior and exterior walls for battery cell integration.
Ground Clearance	Minimum 50 cm from the ground to the UAM's undercarriage.
Stretcher Loading Height	The desired distance from the ground to the stretcher handles is 100 cm, for ergonomic loading of the stretcher into the UAM.
Weight Distribution	The default layout should support a balanced weight distribution. The UAM system automatically compensates for dynamic weight shifts during flight, such as moving equipment and paramedics.

Table 1.2
Initial List of Required Medical Equipment

Corpuls	Defibrillator, monitor vital signs.
Emergency bag	Primary bag including medical drugs, catheters, and equipment for treatment.
Paediatric bag	Treatment for children.
Woundcare bag	Treatment of wounds.
Respiratory bag	Respiratory bag including 1 flask of oxygen 3 L. If full, one flask will last 60 minutes with a flow of 10 L/min.
LUCAS	Automatic cardiopulmonary compressions in cardiac arrest.
Ringer-Acetat 1L	Fluids for resuscitation, including a heated bag connected to the ambulance electrical circuit (2x1 kg + 1 kg for the bag).
Scoop stretcher	Retractable stretcher for immobilisation of trauma victims as well as carrying patients from the scene to the ambulance.
Personal items	Helmet, communication radio, protective clothing, flashlight, scissors, knives, boots, belt.

1.4 Delimitations

This project has the following delimitations:

- The interior design is developed at a conceptual level, focusing on representing functionality. Detailed design and construction are beyond the scope of this project.
- Design of medical equipment is not considered. The interior rather adapts to the equipment currently used for providing prehospital care.
- The interior of the UAM is designed to align with the exterior. However, the exterior design lies outside the scope of this project. As the interior was developed in parallel with the exterior, collaboration between the two teams allowed for influence over certain aspects of the exterior that directly impacted the interior.
- When designing the interior, the electrical installation, such as routing of cords, placement of outlets, and installation of equipment, was not taken into consideration.
- The interfaces for manoeuvring and monitoring the vehicle are not within the design scope. However, the physical placement of related hardware such as screens, buttons, and controls is included. The design does not address the operation of the vehicle when it comes to the interface and experience of these systems.
- The focus is on paramedics working in the UAM, not on patient experience. Since patients are typically critically ill and unconscious, the design prioritises supporting paramedics effectively.

1.5 Outline of Thesis / Reader's Guide

The report has eleven sections starting with Introduction, followed by Background, Methods, User Research, Design Requirements, Concept Development, Final Concept Evaluation, Presentation of Deliverables, Discussion, Conclusion and Appendices.

Introduction introduces the project, its aim and its cause, based on the literature review further described in the Methods section.

Background outlines the theoretical foundation of Urban Air Mobility (UAM), including current development in this field. Background is also provided on emergency medical services in Sweden and VGR. The background is based on the literature review, further described in the Methods section.

Methods include the methods used during the project, while the execution of these is presented in later sections.

User Research includes the research execution and key findings, organised into design modules of the UAM vehicle.

Design Requirements similarly explains the rationale behind design decisions, based on theory, client directives and research insights.

Concept Development explains the development process of the UAM concept and the outcome, organised according to the design modules.

Final Concept Evaluation presents the outcomes of the final evaluation of the digital 3D model and the prototype, including strengths and areas of improvement.

Presentation of Deliverables presents the refined final concept.

Discussion concludes the report by discussing project process and results and suggesting areas of further development.

Conclusion summarises the outcomes and confirms goal fulfilment.

Appendices include additional material with details for the interested.

2 Background

This section introduces the concept of Urban Air Mobility (UAM) and outlines its potential benefits in terms of sustainability, accessibility, and emergency response. It presents current technologies, use cases, and development trends, including examples of existing and conceptual UAM solutions in emergency medical services. Finally, it highlights important design considerations such as hygiene, equipment weight and user needs, that were mentioned in industry reports and academic work.

2.1 Urban Air Mobility

Characteristic of UAM is the advanced technology of electric aircraft that brings advantages in terms of safety, convenience, affordability, accessibility and sustainability (Cohen & Shaheen, 2021; EASA, 2021; K. Wang & Qu, 2023; L. Wang et al., 2023). Use cases for UAM include commuting and travel, cargo transport, goods delivery and emergency and rescue services. The decreased fossil fuel consumption and urban air pollution can transform urban transportation to become more sustainable. Figure 2.1 shows an example of a UAM dispatch sequence within emergency services.

Figure 2.1: A UAM mission sequence, from dispatch to arrival at the site and coordination with other cooperation with other emergency units, ending with arrival at the hospital, or return to base.

The social acceptance of UAMs is rather high as advancements in emergency services directly impact the general population (ADAC Luftrettung, 2020; EASA, 2021). There is a certain scepticism towards commercialisation of the new technology but implementation in EMS can be the first starting point for further implementation.

2.1.1 Current and previous UAM concepts

The concepts of today's eVTOLs are both piloted and unmanned, to be used in various different fields like passenger transportation and emergency services. There are three different types of eVTOLS, where different techniques are used for lifting and cruising (EASA, 2021). Traditional drones are of the type wingless Multicopters, and a large-scale version of this design will be developed in the AMES project, which is called UAM. Examples of this type of vehicle are Volocopter's VoloCity and EHang's 216 AAV with multiple rotors for lift and cruise, seen in Figure 2.2 (Volocopter, n.d.; EHang, n.d.). Both concepts are designed for fully autonomous flights but will be piloted in the early stages of implementation.

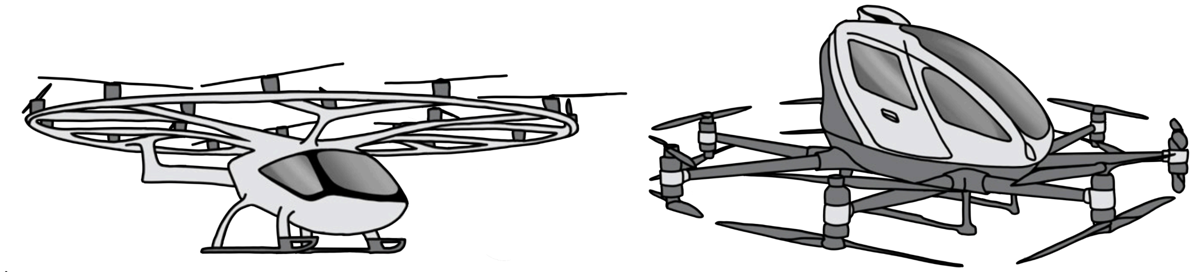


Figure 2.2: UAMs VoloCity by Volocopter and EHang 216 AAV by EHang. Illustration by Linnéa Westberg.

2.1.2 Vertiports and the UAM network

A vertiport is a landing pad used for vertical take-off and landing, very space-efficient compared to landing runways and thus a suitable alternative in cities (L. Wang et al., 2023). There are various suitable vertiport locations. Rooftops and airports are currently used by helicopters for take-off and landing and could be extended in size and number (EASA, 2021; L. Wang et al., 2023). Other alternatives are building new landing sites on ground, both in urban, suburban and rural areas. Figure 2.3 sets the scene for a potential future urban city with implemented UAM.

Figure 2.3: A UAM standing on a Vertiport on a rooftop in a large city. (Created with ChatGPT with the prompt "A futuristic eVTOL aircraft landing on a rooftop helipad, seen from above, in a modern cityscape at dusk. Other eVTOL aircraft are nearby").

2.1.3 Current development and future prospects

Urban Air Mobility is rapidly advancing, and eVTOLs have already been implemented for commercial use around the globe. An example is Voom (an Airbus company) that offered a manned eVTOL commuting service in metropolitan São Paulo, Mexico City and San Francisco during 2018–2020 to circumvent the saturated infrastructure and road traffic congestion (Airbus, 2018; Subramanian, 2018).

The use case of drone delivery of supplies such as food, consumer products, and medical supplies is already in operation across the globe (EASA, 2021). Amazon operates its own drone service, while Walmart uses Zipline and Wing, both of which, along with Matternet, collaborate with partners in various countries and industries (Amazon Staff, 2024; Matternet, 2024; Team Zipline, 2024; Walmart, 2024).

In 2021, the European Union Aviation Safety Agency (EASA) estimated UAM to become commercial in 2025 (EASA, 2021). The market is well underway in Europe with many companies driving pilot eVTOL projects while also undergoing certification processes, which take them closer to a future launch. EASA estimates the European UAM market to reach EUR 4.2 billion by 2030, generating 90,000 jobs, while the forecast for the global market is to grow from EUR 4 billion in 2025 to EUR 14 billion in 2030 (EASA, 2021; Fortune Business Insights, 2025).

The future prospects for eVTOL development indicate that in the next five years, piloted passenger eVTOLs and cargo eVTOLs will start to become commercialised, and infrastructure, traffic management and safety will improve (Lineberger et al., 2019). From 2030, autonomous eVTOLs will emerge following successful pilot projects, while costs drop and battery capacity increases.

2.1.4 UAM can Improve Emergency Services

A big field of application within UAM is emergency responses like medical emergencies, search and rescue, fire fighting and to aid in disasters (Cohen & Shaheen, 2021). This includes drones carrying cargo and large UAMs that can load people.

For smaller UAVs (drones), it could be both the delivery of medical supplies and equipment such as defibrillators, as well as surveillance and assessment of locations. In 2021, Sweden had its first successful case of saving a man's life as a result of a defibrillator being sent out by the Medical Emergency Dispatch Centre (Järnerot, 2021). Another example is dispatching a drone to investigate and assess the accident scene to help decide whether to send further assistance, and what type (L. Wang et al., 2023). VGR is currently running a large-scale project focused on this technology and is progressively implementing drones for surveillance and logistics (Innovationsplattformen VGR, 2024).

Multicopter for Germany's EMS ADAC Luftrettung – feasibility study

An example of a large UAM is the project between Germany's prehospital Helicopter Emergency Medical Services (HEMS), ADAC Luftrettung, and Volocopter where they adapt their multicopter VeloCity for use in medical services (ADAC Luftrettung, 2020). The aim of the project is to investigate how the Multicopter can be implemented to extend the reach of emergency doctors, addressing current issues such as long travel times and a shortage of personnel. It is currently being piloted, with only personnel onboard and no patient transport, due to weight limitations.

The expected benefits of implementing this UAM into the EMS are that it will provide additional resources in a more efficient way than today, where they're dependent on road ambulances (ADAC Luftrettung, 2020). With the implementation of UAM, a larger geographical area is covered, and prehospital care can be provided quicker due to the shorter travel times.

Their feasibility study highlights the importance of hygiene (ADAC Luftrettung, 2020). Surfaces must be fully disinfectable without residue and all materials must be chemically resistant. All-around visibility is also crucial, especially downward, to ensure safe landings on uneven terrain.

In Germany, the estimated weight of required medical equipment, including respiratory, intubation and diagnostic equipment as well as infusion treatment and medical supplies, is 125kg (ADAC Luftrettung, 2020). In addition, technical equipment constitutes 12kg. Due to the multicopter's weight limitations, it was necessary to reduce the load by removing non-essential items, balancing the need for adequate care with staying within the weight constraint of 200kg.

Ambulance UAM in the Netherlands – concept design

A concept design for a UAM vehicle was developed by a master's student in the Netherlands, covering both the interior and exterior of the aircraft (Dielemans, 2021). This project provides valuable background on UAM and outlines the specific requirements and needs associated with a UAM when used within the context of prehospital emergency medical services. The vision for this concept was that the functions must effectively support the paramedics and that the design should reflect the profession and evoke trust. Medical equipment that was considered to be needed ina future UAM include … The project result in a concept covering both the exterior and interior design.

Design and analysis of an autonomous air ambulance – concept design

A concept design for a UAM vehicle for implementation in medical emergencies was done by researchers in India (Pagare et al., 2024). The UAM was aimed to carry one paramedic and one patient, weighing in total 170kg. Additionally, all equipment was estimated to a total weight of 403,5kg, including furnishing such as seats, storage and stretcher, resulting in a total payload of 573,5kg.

Design of an ambulance module for a drone – concept design

A bachelor's thesis in Sweden explored the development of an ambulance module designed for attachment to a drone (Ramn & Mulder, 2019). The project involved field studies with the air ambulance service where user needs and challenges associated with current helicopter-based solutions were identified. The team defined requirements where paramedics considered safety, ergonomics, vibration and turbulence, storage and hygiene to be of high importance in a prehospital environment. The project outcome was a proposed design concept for both the interior and exterior of the ambulance module.

2.2 Prehospital Emergency Care in VGR

Region Västra Götaland (VGR) is a regional government located in Västra Götaland and is responsible for healthcare and development within the region (Västra Götalandsregionen, 2024a, 2024b). This includes primary healthcare, specialised medical care, emergency care and dental services.

In VGR's plan for prehospital care from 2021, it is stated that "VGR shall offer equitable, efficient, integrated, and accessible healthcare provided with the highest quality and patient safety, based on the individual's needs and experiences. The prehospital care should provide evidence-based and advanced healthcare with the aim of creating value for both residents and the rest of the healthcare system in Västra Götaland" (Västra Götalandsregionen, 2021a).

Since 1996, 112 has been the emergency number in Sweden (Högstedt, 2022, pp. 17–18). SOS Alarm is responsible, assigned by the state, to respond to these calls. The goal with healthcare is to promote good health which in prehospital settings, can be translated to adopting measures that promote continued good health, achieved both by life-supporting measures or good attitude towards patients resulting in positive psychological well-being (Sandman & Bremer, 2022).

2.3 The Emergency Call Sequence in VGR

In emergencies, individuals in need of assistance call 112, and SOS Alarm responds to the call (Högstedt, 2022, p. 18). Some regions, including VGR, have their own regional triage, prioritisation, and ambulance dispatch systems. For medical emergencies in VGR, a nurse at the Sjukvårdens Larmcentral (SvLc) joins the call, triages the patient's condition, assigns a priority grade and dispatches the nearest ambulance accordingly (Västra Götalandsregionen, 2021b).

There are four prioritisation grades emergencies can be classified as. The prioritisation grade depends on how serious and emergent it is, with Prio 1 being the most urgent and Prio 4 the least (Edenström, 2024b; Högstedt, 2022, p. 22). Both Prio 1 and Prio 2 are further divided into A and B, with A being slightly more urgent than B. The prioritisation grades 1-4 are explained in Table 2.1. As more information is gathered, the priority is reassessed, potentially lowering or increasing the ambulance's urgency (Högstedt, 2022, pp. 22–24). The highest grade is always prioritised which means ambulances en route to lower-prio calls can be redirected to higher-prio missions if needed.

Table 2.1

Description of Prioritisation Grades

Prioritisation grade	Emergency level
Prio 1	Extremely urgent, life-threatening situations. The ambulance is immediately dispatched.
Prio 2	Urgent, but not life-threatening. The ambulance is dispatched.
Prio 3	Non-urgent, but medical needs exist. It is assessed that a reasonable waiting time will not impact the patient's condition. Ambulance is dispatched.
Prio 4	Non-urgent, the patient does not require medical care during transport. Patient is directed to medical transport.

A particularity of VGR is that SvLc has a HEMS-coordinator in addition to the nurse, who listens in on calls where a life-threatening condition is suspected, as well as traffic accidents and drownings (Högstedt, 2022, p. 21; Holtze, 2022b, p. 123). A helicopter is dispatched when a patient's condition is life-threatening or time-critical, requiring immediate medical care and this decision is influenced by factors including the helicopter's transport time, advanced medical capabilities onboard, and the ability to access remote locations (Västra Götalandsregionen, 2018). The HEMS-coordinator monitors the entire flight mission and oversees other missions in the geographical area to assure the most critical case is prioritised (Högstedt, 2022, p. 21; Holtze, 2022b, p. 123).

2.3.1 Response times

In 2023, Prio 1 constituted 39% and Prio 2 54% of all Prio 1-3, excluding helicopter missions (Edenström, 2024a). The same year, the helicopter received 1668 calls, on average 4,5 calls per day, corresponding to 0.8% of all ambulance calls in VGR (P. Arnell, personal communication, 31 March 2025; Edenström, 2024a). Figure 2.4 displays the total calls in year 2023 as well as distribution of prio within VGR road ambulance, to the road ambulance and ambulance helicopter, respectively.

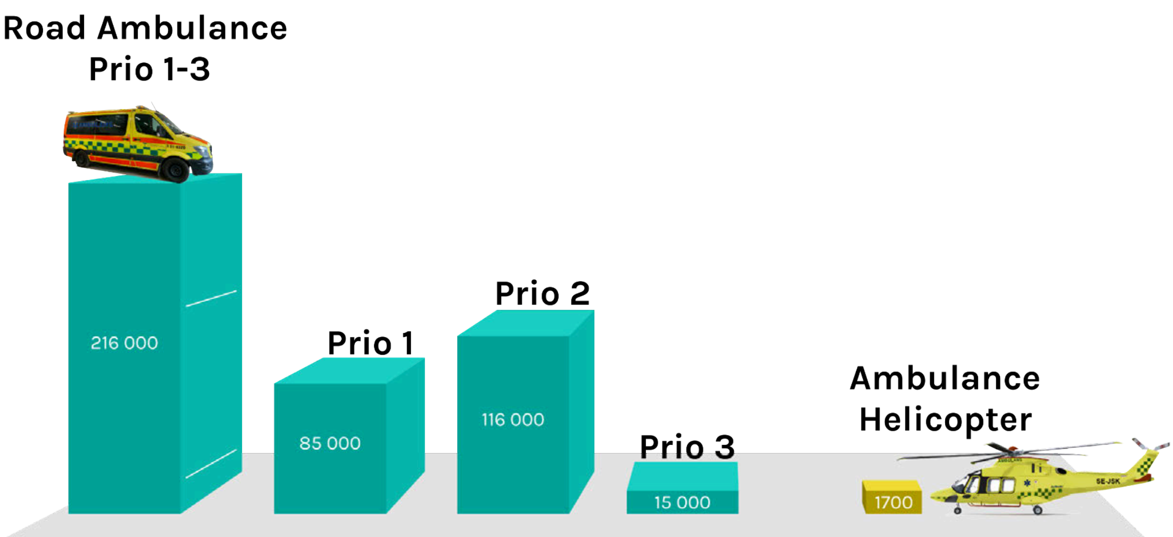


Figure 2.4: Total road ambulance and ambulance helicopter calls in VGR year 2023, and road ambulance priority distribution (P. Arnell, personal communication, 31 March 2025; Edenström, 2024a). Illustration by Linnéa Westberg.

VGR has a goal fulfilment of approximately 72% when it comes to reaching 90% of prio 1 calls within 20 minutes of SOS Alarm answering the call (Edenström, 2024). The large geographical area results in varying response times between cities and the countryside. The average time has been steadily increasing over the past ten years, moving further away from the 12-minute median goal. The increasing response times, from 11,75 min in 2013 to 15,43 min in 2023, are alarming as each second impacts the patient's chances of survival (Edenström, 2024a; Radio, 2024).

2.4 The Ambulance Helicopter

Sweden has eleven ambulance helicopters across nine regions (Holtze, 2022b, p. 121). Region Stockholm operates three of them, while the others are based in cities Gällivare, Lycksele, Östersund, Mora, Uppsala, Karlstad, Gothenburg, and Visby, see Figure 2.5. Gothenburg is the southernmost helicopter base. One reason behind or the limited number of helicopters is cost, where expenses include pilot salaries, fuel, the purchase and maintenance.

Helicopters are mainly used for the most severe primary missions, for instance cardiac arrest, respiratory arrest, strokes and traumatic injuries, but can also be dispatched for secondary missions where critically ill patients are transported between hospitals (Holtze, 2022b, p. 123; Region Dalarna, n.d.; Västra Götalandsregionen, 2018). The critical status of the patients places high demands on the EMS personnel, especially in combination with challenging circumstances like a traffic accident on a highway or difficult terrain (Holtze, 2022b, pp. 122–123; Svensk Luftambulans, n.d.). Apart from the pilot(s), the helicopter crew consists of one Certified Registered Nurse Anesthetist (CRNA) and in some regions, including VGR, also an anesthesiologist (ANES) (Holtze, 2022b, p. 121; Västra Götalandsregionen, 2021a). From now on, the CRNA will be referred to as nurse, the ANES as doctor, and the general term for both will be paramedics.

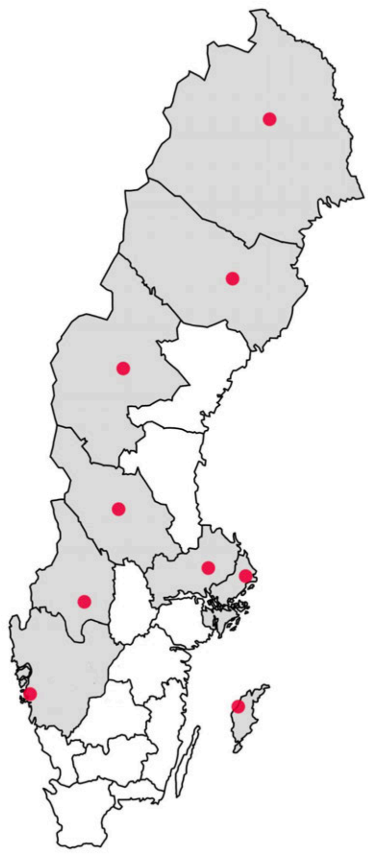


Figure 2.5: Nine ambulance helicopter bases distributed across nine Regions in Sweden (Holtze, 2022b, p. 121). Illustration by Linnéa Westberg.

With expert knowledge of the human body, medical conditions, injuries, and the use of medical equipment and procedures, the paramedics also demonstrate a strong understanding of helicopter-specific work routines. The paramedic views the ambulance helicopter as a treatment-focused environment where the patient's health is the central concern. These paramedics value high standards of quality, safety, function, and hygiene, and likely conceptualise the workflow as a structured sequence in which every tool has a designated place in the cabin. The paramedics are working on a weekly basis, typically working long shifts. They mainly engage within the ambulance helicopter organisation, but collaborate with other ambulance vehicles and emergency services.

Based on Janhager's theory on User Profile (2005), the paramedics' influence on the choice of medical devices is low, given that equipment and interior design are determined at the organisational level. However, they have a moderate influence on how this equipment is used. The paramedic is responsible for ensuring patient safety, adapting measures to the situation within the constraints of the available equipment, and adhering to strict safety protocols. They are also expected to monitor and be prepared to take over the operation of the UAM when required.

Given the paramedics' limited influence over the work environment while having great responsibility for the patient, the importance of the eVTOL to be reliable and to support confident and efficient use increases (Janhanger, 2005). Good physical ergonomics is also essential, as they have minimal ability to adjust their surroundings. Furthermore, the vehicle must accommodate a diverse group of users, placing high demands on adaptability in design.

The ambulance helicopter is operated by two paramedics who work in close collaboration. Each team of two establishes their own preferred way of working and divides responsibility in line with their preferences. This means that the way of working varies somewhat across teams.

The patient is considered a secondary user, as they do not actively interact with the vehicle. If conscious, they may perceive the environment and the paramedics but do not engage with the vehicle itself (Janhager, 2005). Communication between paramedic and patient is often limited either because the patient is too ill to speak or due to the high noise levels in the helicopter, which make verbal communication difficult. Sign language is used for the basic communication needs such as indicating pain levels.

In 2023, the ambulance helicopter in VGR received approxiamtely 1668 calls in total, see Figure 2.6. Of these, 825 were completed with a patient onboard, and of these, 76% were primary missions (P. Arnell, personal communication, 31 March 2025).

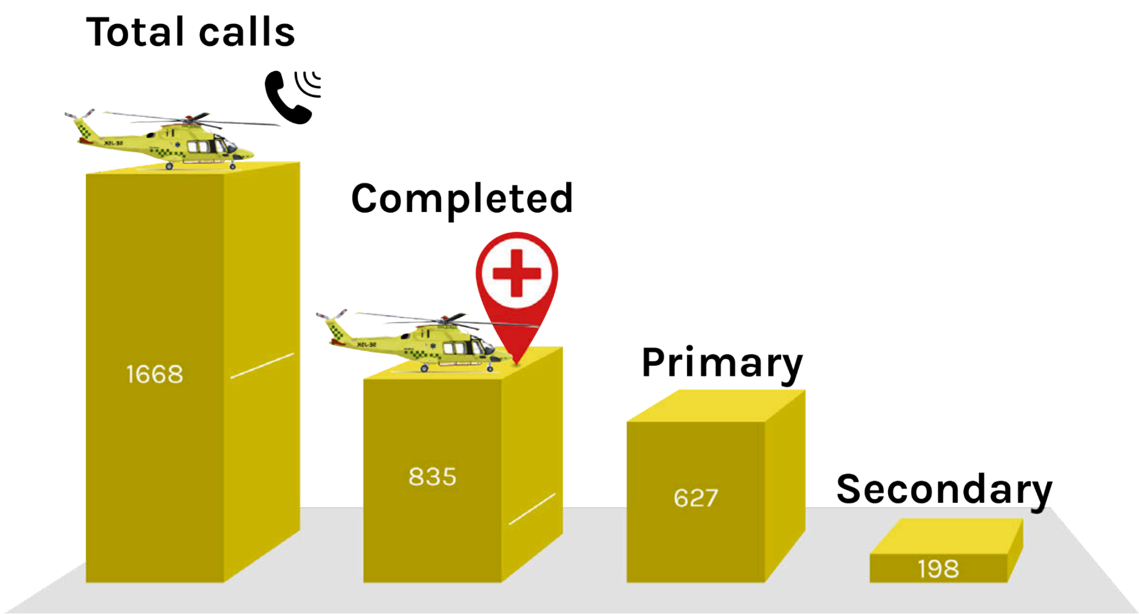


Figure 2.6: Distribution of road ambulance and ambulance helicopter missions in VGR year 2023 (P. Arnell, personal communication, 31 March 2025; Edenström, 2024a). Illustration by Linnéa Westberg.

2.4.1 At VGR's helicopter base

All ambulance vehicles and their status are seen on a map that is accessed from both the helicopter base, the helicopter and the emergency call center. For urgent calls, the operators dispatch the nearest road ambulance(s) and the helicopter. Typically, a road ambulance arrives first as it is closer to the patient, and begins treatment. The helicopter then takes over during transport to the hospital, significantly reducing the total time from the emergency call to hospital arrival. A one-way flight from Åmål in northern VGR to Sahlgrenska Hospital in Gothenburg takes approximately 30 minutes, compared to 2–2,5 hours by road ambulance (Google Maps).

2.4.2 Ambulance helicopter models used in Sweden

Leonardo AW169

The helicopter currently used in VGR is Leonardo AW169, see Figure 2.8. The stretcher is entered through one of the side doors (W160 cm x H120 cm) and rotated 90 degrees into position aligned with the flying direction (Leonardo Helicopters, 2019). The cabin volume of 6,3 m³ is rather large with measurements W200 cm x L280 cm x H130 cm (Avincis, n.d.-b). The large width makes it possible for paramedics to sit on both sides of the stretcher, see Figure 2.7. The total storage volume is 1,75 m³, of which the exterior compartment constitutes 1,4 m³ (Avincis, n.d.-b; Leonardo Helicopters, 2019).

Figure 2.7: Cabin layout of Swedish ambulance helicopter Leonardo AW169 (Avincis, n.d.-b). Reprinted with permission.

Figure 2.8: Swedish Ambulance Helicopter Leonardo AW169 (Avincis, n.d.-b). Reprinted with permission.

Airbus H145

In most other Swedish regions, the smaller Airbus H145 helicopter is used, where the stretcher is loaded through the rear doors and placed along the inside wall, which means there is only space for a paramedic on one side of the stretcher, see Figure 2.9. The cabin width is approximately 150 cm and the height is 130 cm alike Leonardo AW169 (Avincis, n.d.-a).

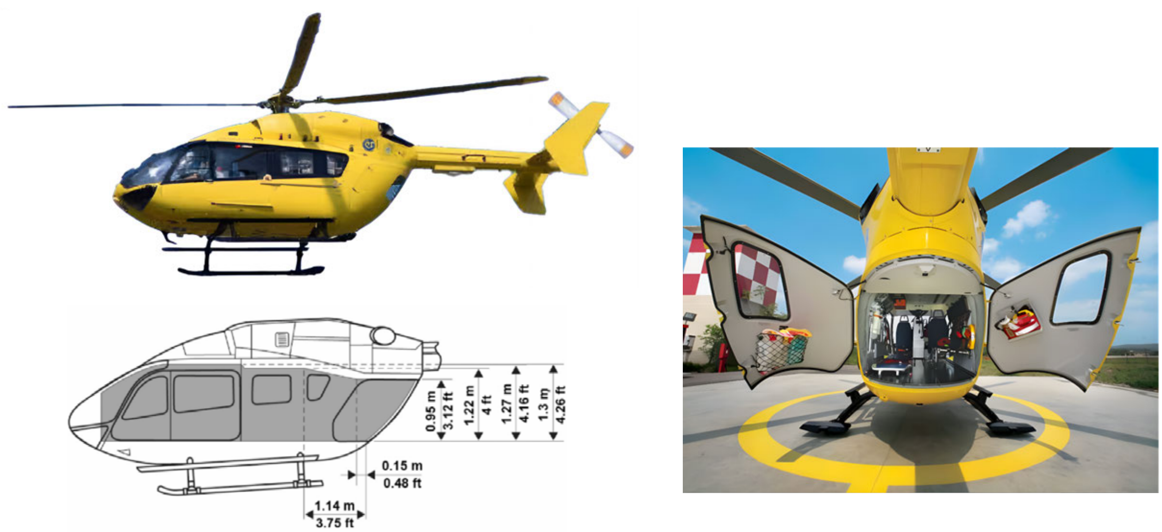


Figure 2.9: Swedish Ambulance Helicopter Airbus H145 (Avincis, n.d.-a). Reprinted with permission

3 Methods

This project has had a User-Centered Design (UCD) Process characterised by regular iterations of the design phases. Figure 3.1 shows the phases in the process and their proportion to the overall project. The UCD Process starts with exploring the usage and the context, followed by identifying user needs and continuing with iteratively developing and evaluating designs (Reale et al., 2018). The final two stages of the UCD process (implementation and post-deployment review) were excluded due to the thesis project's limited time and are not included in the figure.

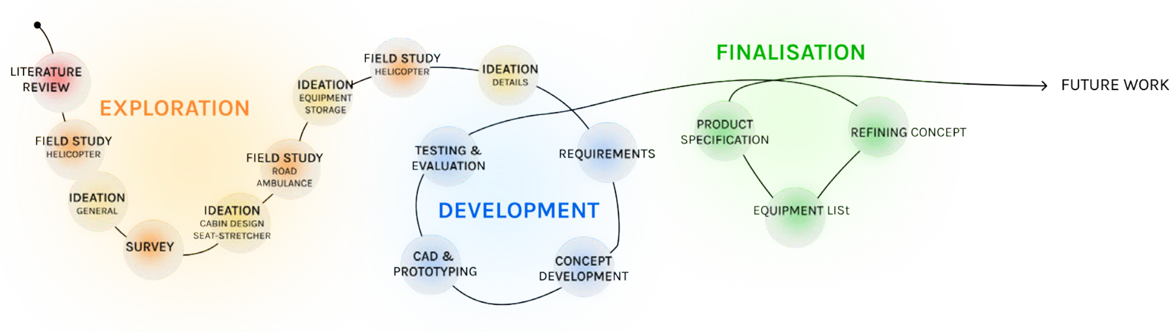


Figure 3.1: Illustration of the project process from framing the problem to delivering a finished solution.

3.1 Literature review

An overall literature review was conducted to support the project's background understanding and help define the problem, users, and potential solutions. The reviewed topics can be grouped into three main areas:

- Prehospital healthcare, emergency missions, and helicopter ambulances
- UAM and eVTOLs and the emergence of the technology
- EMS eVTOLs, including current and past concepts

Background information on the healthcare system was retrieved from authoritative websites and official EMS sources. In addition, Google Scholar was used to find academic literature on emergency medical services and Urban Air Mobility. Common search terms included *ambulance, eVTOL, UAM, drone, EMS,* and *HEMS*. These were combined in various ways to collect relevant research.

Due to the explorative nature of the study in combination with limited literature on UAM in emergency medical services, an unstructured review approach was conducted. Gathered information was thematically analysed, and relevant information was printed and pinned on a board to enable quick review of the material throughout the project.

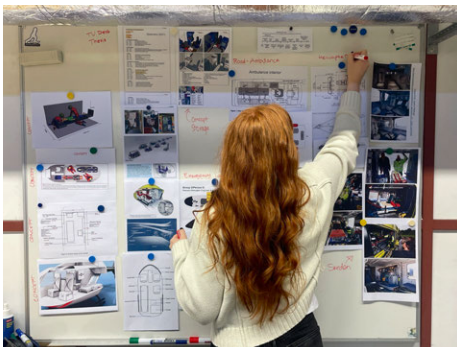


Figure 3.2: Overview of reviewed literature, to which own comments are added

3.2 User research

The user research included field studies at the VGR ambulance helicopter and road ambulance base, as well as a survey, which will be further detailed in this section.

Field study – VGR ambulance helicopter

In total, two field studies were conducted, first during the User Research phase to gain a comprehensive understanding for the helicopter interior, equipment and prehospital work. The second time was during the concept development phase with the aim to dive deeper into specific aspects of the interior and included equipment.

The first visit was structured into an interview part and an observation part with the aim of gaining an understanding of the ambulance helicopter organisation and the helicopter in which they work, as well as identifying challenges related to the work. The interview was semi-structured, following a brief interview guide with general questions about the organisation and air ambulance mission, as well as specific questions about equipment, the work inside of the cabin and challenges related to this, see *Appendix A - AH Field Studies*.

To aid the observation of the current helicopter Leonardo AW169, an observation guide was prepared with topics related to workflow, measurements, equipment and storage, aesthetics and cabin layout, see *Appendix A - AH Field Studies*.

The second field study covered topics that were missed during the first visit, and also included questions related to the early ideas during concept development, see *Appendix B - RA Field Studies*.

Field study – VGR road ambulance

A field study was arranged at the road ambulance to study the interior design and storage solutions of ambulance vans, see *Appendix C - Survey*. This way, a broader understanding of the ambulance organisation was gathered, as the UAM will also to some extent handle cases that today's road ambulances are dispatched on. This study was semi-structured with a combined observation and interview guide. The visit provided valuable insights into storage solutions and what requirements paramedics put on the interior in terms of functionality, range of reach etc.

Survey

A survey was distributed to all regions operating ambulance helicopters to gather comprehensive data supporting decisions on the cabin layout, see *Appendix C - Survey*. The survey consisted of four sections related to the cabin layout, equipment, storage and aesthetics, respectively. The questions were both free answers and multiple-choice as there was interest in both quantitative data/statistics and qualitative elaborated answers to provide understanding for their mental model and requirements/needs.

3.3 Data analysis

To analyse data, different methods were used. These methods are explained in this section.

KJ analysis

The KJ-analysis is a bottom-up method where each piece of data is written on an individual note (Bligård, 2015, p. 106). The notes are then compared and grouped together, gradually forming identifiable categories. This bottom-up process creates a network of data that is visually grouped based on their connection, which enables general conclusions to be formed.. The analysis included data from the Field Studies and qualitative responses from the survey. The method was employed digitally and each note was colour-coded based on source of information (type of study and user group).

Tables and diagrams

The quantitative data derived from the survey was structured into tables, where each user group was separated for comparison and identification of similarities and differences in attitudes and opinions between the groups. The data was also visualised in diagrams for analysis and to support decision-making of requirements on the interior.

3.4 Framing the Problem

The following methods were used when framing the problem.

User Profile and User Relations

The relevant user groups were categorised based on Janhager's (2005) framework where the primary user is defined as the one interacting with the system while side users are individuals that are affected without actively interacting. Thereafter, the user groups' characteristics were further analysed using on Janhager's User Profile template. The section about Influence on and Responsibility of Use were particularly insightful, as it highlighted the key aspects of the actions performed in the UAM. Janhanger's theory on User Relations then served as a basis for defining the interrelations between the users.

Use cases and scenarios

Four main Use Cases were defined to understand the various contexts in which the future UAM may be used, and which types of situations the paramedics might encounter. This clarified the diversity of situations that the UAM may encounter, and supported ideation towards a design that is adapted to a broad range of uses.

Different scenarios serve different purposes throughout a project (Reale et al., 2018). To accommodate for variations within each Use Case and concretise how the UAM would be used by paramedics, the most relevant use case was further elaborated by exemplifying specific parts of the response sequence through sub-scenarios. The aim was to support the entire project process by clarifying the context of use and paramedics' needs as well as enabling analysis of key stages and challenges.

To support evaluation, a main scenario was defined based on critical events. The aim was to set a realistic scene for participants in the evaluation and support testing of key design aspects by performing a task sequence, as suggested by Reale et al. (2018).

The scenarios were based on insights from the field studies, where paramedics described various situations they may encounter and explained how their work is carried out in practice. The main scenario's relevance was validated by people with experience in emergency healthcare.

Requirement list

The list of requirements was continuously updated throughout the entire data collection phase as new insights emerged, as well as in later stages of the project. Included in the list is the requirement description, the measured value such as weight, dimension or number, whether the requirement is necessary or desired to be achieved, and the source of the requirement to ensure traceability.

3.5 Ideation

In the ideation stage of the project, the methods were employed with the the aim to generate a broad solution space for each of the different parts of the interior, exploring both standard solutions and more radical ones.

Brainstorming

Brainstorming is an ideation method where participants generate ideas and express spontaneous thoughts on different topics together (Wikberg Nilsson et al., 2019, p. 125).

Braindrawing

Braindrawing is an ideation method where all participants, unlike during brainstorming sessions, sketch ideas on a given topic individually within a set time (Wikberg Nilsson et al., 2019, p. 129). When time is up, the papers are exchanged, and participants add to or develop each other's ideas. This encourages idea-building and fosters solutions that individuals might not generate on their own. The session ends with going over the ideas and discussing them within the group.

Scale modelling

Scale modelling was employed to facilitate idea generation by providing a three-dimensional representation of the space that was designed for. A 1:10 scale model was made using cardboard and paper. The equipment that was known to be used by the paramedics was also

Figure 3.3: The 1:10 scale model, with 3D-printed equipment, seats and a sitting manikin.

3D-printed in scale, see Figure 3.3. This allowed for quick, hands-on exploration of layouts by physically moving elements, which ultimately removed the need to spend time with CAD or drawing every part by hand. The model provided a clearer sense of the space and constituted a shared reference point, which enabled discussions and testing of what ideas would work in practice.

Rendering images with AI

To produce rapid images of the interior, and potentially spark new ideas, some basic sketches were imported into the softwares Vizcom, Adobe Firefly and Canva, to rapidly render realistic images of the interior with AI. These images served as inspiration for aesthetics and, to some extent, functionality. The results were not used entirely but rather as a tool for taking the sketches to the next level and a way to give a rough feeling for the characteristics of the ideas. These images were used to communicate ideas to the client and the users for evaluation.

Figma

Figma is a digital design and prototyping tool used to create wireframes, mockups, and interactive interfaces. In this project, Figma was utilised not only for visual design and prototyping but also as a tool to summarise research data and support the ideation process. Its collaborative features made it easier to organise insights, explore concepts, and communicate ideas effectively within the team.

3.6 Concept Development

The following methods and tools were used during concept development.

Morphological matrix

To handle the complexity of the interior, variations of the cabin design parts such as windows, doors and cabin shape, were ideated individually. It was then used in the morphological matrix, used to generate various concepts to keep a large solution space. A morphological matrix is a table where all ideas related to the same requirement share one row. By selecting one idea from each row a unique solution is generated. (Wikberg Nilsson et al., 2019, p. 147).

CAD

The concepts were progressively visualised in the CAD using CATIA V5, Autodesk Alias and Autodesk VRED, as these were considered the most efficient visualisation tools for achieving a realistic representation of the cabin and its included components. The 3D modelling phase extended over a significant period and was continuously refined. The different phases can be divided into the subphases: cabin layout ideation, placement of equipment, storage ideation, and finally, detailed development of individual parts, from larger equipment to smaller elements.

Full-scale prototyping

A low-fidelity prototype of the interior was gradually built in full-scale to confirm that decisions, such as measurements and placement, met the requirements. A platform was built so that the UAM body was elevated in height, making it more similar to reality. The platform was built together with the exterior team, using aluminium profiles.

Apart from physically implementing design decisions, there was a lot of rapid prototyping of ideas, using cardboard. This method enabled more realistic and reliable testing of solutions inside the cabin as there was a better understanding of the context.

To build the interior, cardboard boxes, plastics, textiles and other items about to be thrown away, were gathered from bulky waste and reused. This brought strong economic and environmental benefits.

3.7 Evaluation

The following methods and tools were used for evaluation during the project.

Ergonomic evaluation using Siemens Jack Software

Jack is a software developed by Siemens that is used for ergonomic evaluation of a product or system. A model of the product is imported, and in the software, manikins can be inserted. Settings are made for the manikins, for example, to follow certain percentile measurements.

When performing the analysis, the 5th percentile female to 95th percentile male was used, in accordance with the standard recommendation for performing these analyses (Hägg et al., 2025). This way the extremities are taken into account, as it is assumed that all people within this range of measurements will be adapted for, where the smallest person will be able to reach necessary items, and the largest person will be able to fit within the space.

The specific analyses performed with this software was range of reach, fitting in the space, and view angle. This was to ensure that all equipment is close enough to the paramedics, that they have sufficient seating space alongside the patient, and that they have a visual overview of important parts of the UAM such as screens and monitor devices.

User test

User testing was conducted in two stages: a pilot test and a main evaluation. The pilot test, involving one participant with a medical background, helped validate the evaluation method and provided initial feedback.

The main evaluation was carried out with two paramedics from the road ambulance service. After a concept presentation, participants interacted with a full-scale, low-fidelity prototype based on a scenario. Scenario (Wikberg Nilsson et al., 2019). Feedback was gathered through open-ended questions, see *Appendix F - Evaluation Guide*. Most participants were also asked to place stop buttons and handles where they found them most suitable.

4. User Research

This section describes the execution of the user research conducted in the project and the results. As described in the methodology, data was collected through field studies at the ambulance helicopter base and at a road ambulance station in VGR, and supplemented by a survey to research further on specific topics.

4.1 User Research Execution

The execution of the user research is explained in this section.

4.1.1 Field Study – VGR Ambulance Helicopter

First visit

One paramedic participated during the first visit, as the others were on duty at the time. The visit was initiated with an interview, followed by an exploration of the Leonardo AW169 helicopter. The helicopter worked as a mediating object and supported the paramedics to show specific functions, talk about the placement of items and illustrate how equipment is being used inside. This really helped to understand the space of the helicopter.

Second visit

During the second field study, four paramedics participated to varying degrees. One throughout the entire visit, and the others during parts of it. Their involvement included observing the helicopter, as well as providing feedback and discussing early concepts developed during the initial design phase. Time was also spent on measuring current equipment and furniture, to ensure realistic dimensioning of all parts included in the concept.

4.1.2 Field Study – VGR Road Ambulance

The field study for the VGR Road ambulance was semi-structured with a combined observation and interview guide. It was conducted with one paramedic, who showed the ambulance and its features. The visit provided valuable insights into storage solutions and what requirements paramedics put on the interior in terms of functionality, range of reach etc. The ambulance worked as a mediating object and made it easier to come up with questions on site, which also made it possible for the paramedic to explain specific routines and equipment functions.

4.1.3 Survey

The survey was distributed to all Swedish regions that have an ambulance helicopter base. The aim was to get a broad range of answers and to cover opinions from paramedics working in different organisations, and especially in different helicopter types. The reason was to identify differences and similarities in their attitudes.

To keep anonymity for the respondents, but still enable mapping out which region each paramedic who answers the survey is working in, one survey was created for each region. This also made it easier to compare answers from different regions, and the answers might be affected by what helicopter the paramedic is working in.

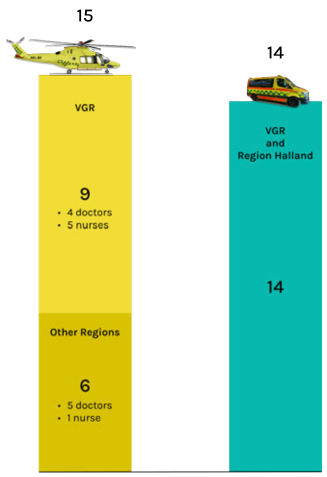
Not all regions responded to the survey, but answers were received from paramedics working with both Leonardo AW169 and Airbus H145, which gave a broader perspective since they have different sizes and seat configurations.

To complement the perspective of paramedics working in ambulance helicopters, the survey was adapted and distributed to the road ambulance in VGR and Region Halland. Only two regions were asked due the large number of a road ambulance bases in Sweden and that the main user target group for the UAM is paramedics specialised in anesthesia, and they work today within the helicopter.

In Table 4.1, the distribution of responses is presented, showing the number of responses from each region. The survey was distributed to eight regions, of which responses were retrieved from four. For the road ambulance, both asked regions responded. The responses were evenly distributed between nurses and doctors among helicopter personnel in VGR, while the majority of responses from other regions were from doctors.

Table 4.1

Table of Survey Responses, Showing the Number of Respondents by Region and Job Title



4.1.4 Data Analysis

The data from each field study was incorporated into a KJ analysis. Answers received from the survey with open questions where the respondents could answer freely were also added to the KJ analysis. The data was structured and organised into different categories.

The multiple-choice questions from the survey were analysed using diagrams and statistics.

Some open-ended questions were analysed using diagrams as a complement to the KJ-analysis. The answers were simplified into categories. To ensure fair interpretation, categorisation was based on the respondents' actual wording rather than inferred meaning.

4.2 User Research Result

This section presents insights from the field study and survey, and clarifies needs and requirements that paramedics have related to their current situation and and the future UAM. The results are organised into six design modules: Workflow and Cabin Layout, Cabin Design, Seat and Stretcher, Equipment, Storage, and Details.

Due to secrecy reasons, pictures taken inside the helicopter are not displayed in this report, while permission was given to use pictures taken inside the road ambulance.

4.2.1 Workflow and Cabin Layout

In the current AH work setup, supported by the configuration of seats, stretcher and equipment, the nurse sits on the left side and the doctor on the right. If intubation is required during flight, the doctor moves to a position behind the patient's head to perform the procedure. This happens very seldom, as intubations are preferably performed on-site before departure. The nurse typically holds primary responsibility for monitoring medical devices, which is why the monitors are positioned on the left side in existing helicopter configurations, see Figure 4.1.

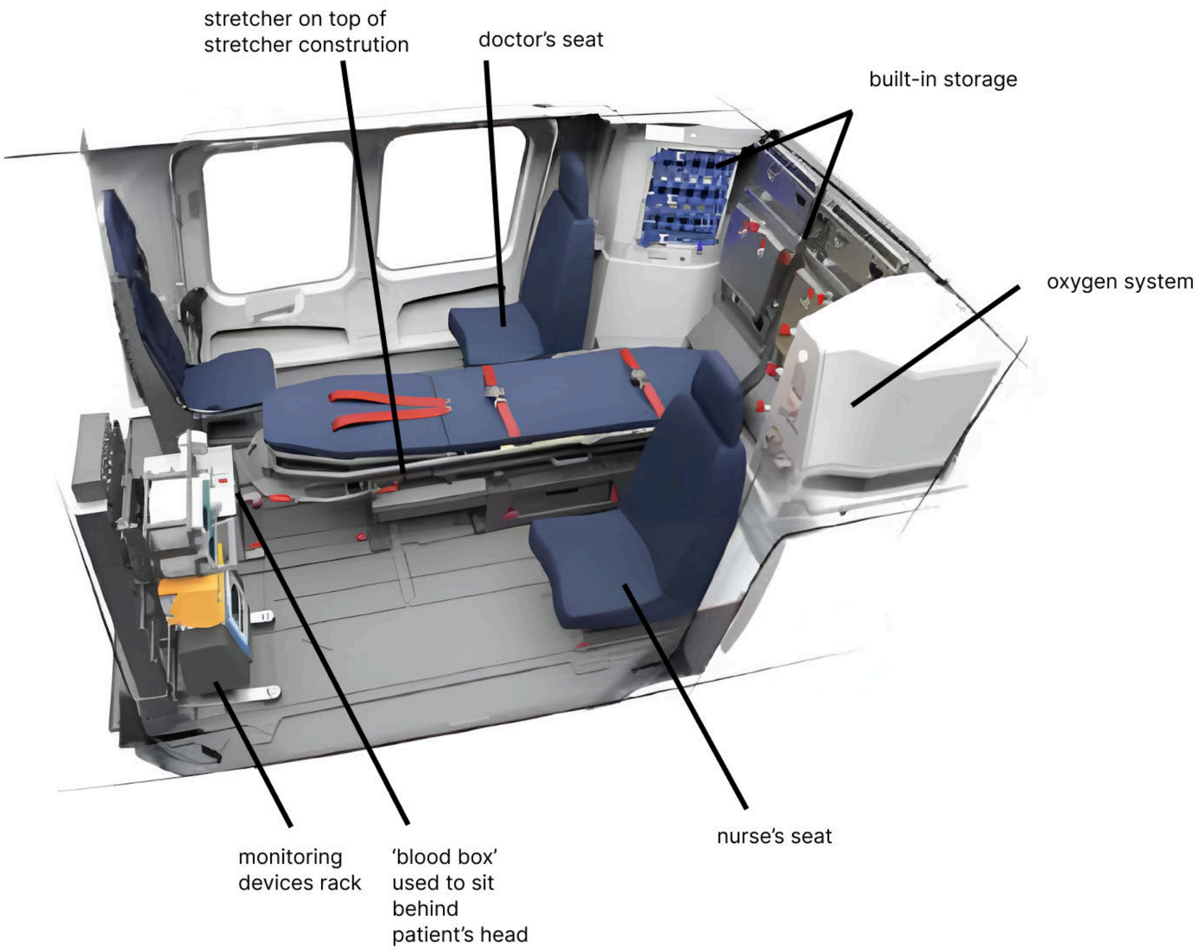


Figure 4.1: Overall layout of the current helicopter Leonardo AW169 used in VGR, with added explanations (Avincis, n.d.-a). Edited with permission.

During take-off, both personnel must be secured and seated. Once in the air, they can unbuckle and move freely within the cabin. Medical procedures are sometimes performed while kneeling on the floor. According to a participant in the first AH field study, this doesn't bring any discomfort since it only occurs for short periods, and their protective gear includes knee padding. Adjusting the seats was considered too cumbersome and slow.

Regarding weight balance, paramedics usually inform the pilots before doing any sudden movements, since they have to compensate for this manually. There are no restrictions on the paramedics' weight or length, while the maximum patient weight is 150kg.

For the road ambulance, typically only one paramedic treats the patient since the other has to drive the van. Depending on the need for treatment, there is one seat on the side and one at the head, see Figure 4.2. A monitor device rack is placed near the entrance, in front of the seat beside the stretcher, which is loaded through the rear entrance.

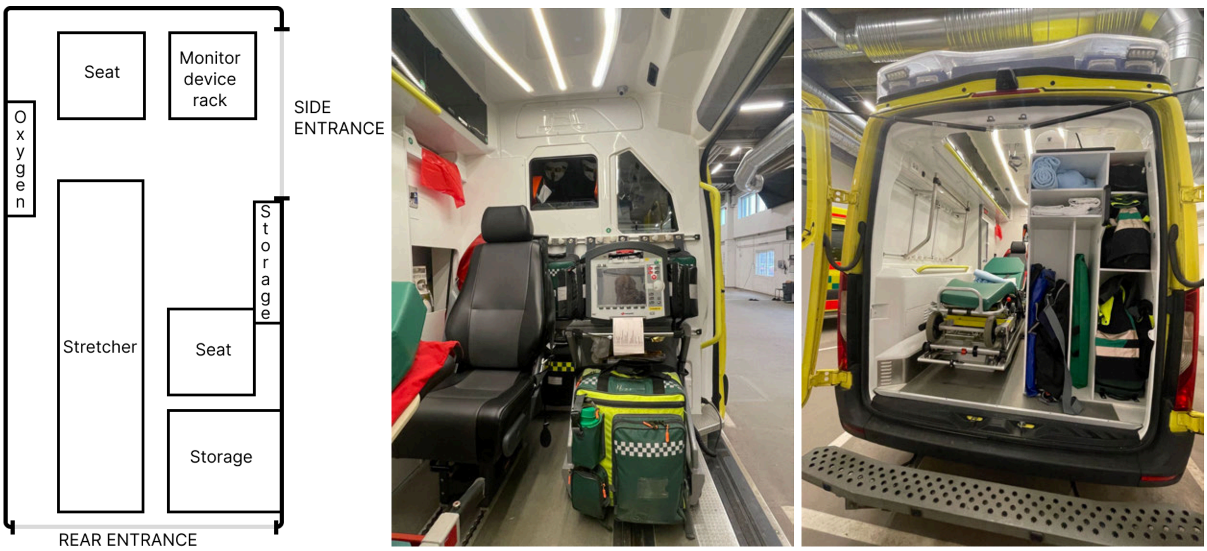


Figure 4.2: Overall layout of a road ambulance van used in VGR. The second image shows a view from the seat beside the stretcher, and the third image a view of the rear entrance, from the outside.

4.2.2 Cabin Design

Dimensions

Cabin Width

The AH paramedics in VGR like their current width of 200 cm, and have a negative attitude towards a narrower cabin as that would sacrifice the space on both sides of the stretcher, which they perceive is crucial for providing good care. The AH paramedics in other regions, working in the Airbus H145 with a width of 140 cm, claim it works well but are in general positive towards a larger cabin.

Cabin Height

The majority of survey respondents working in the AH, both within VGR and other regions with a cabin height of 1.3 m, find the space acceptable or satisfactory, see Figure 4.3. However, many mention that their helmet sometimes touches the ceiling. Especially those over 180 cm may struggle and need to bend. VGR personnel consider the height sufficient but acknowledge the same issue. One respondent working in the Airbus H145 helicopter with the same height suggested increasing the height by 10–15 cm. During the AH field study, it was observed that a 190 cm tall paramedic would have 5 cm clearance with a helmet.

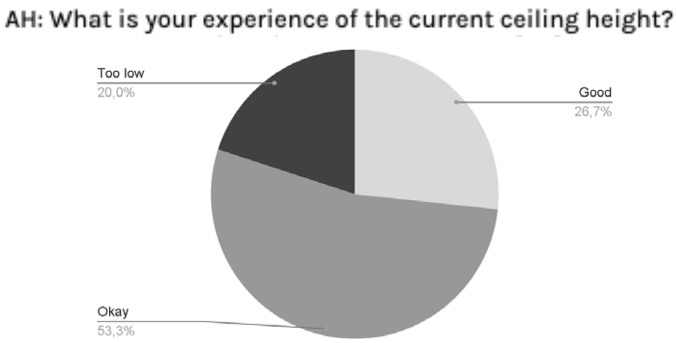


Figure 4.3: Distribution of responses on the current cabin ceiling height, among AH paramedics.

RA paramedics appreciate vehicles where they can stand upright, and like the AH paramedics, find lower ceiling heights insufficient. During the RA field study, one participant pointed out that an overly high ceiling can also be problematic, as it reduces reachability within the cabin.

Another aspect of the ceiling height is that the patient should be able to sit upright at a 90 degree angle. Therefore, no equipment should be mounted in the ceiling in a way that hinders this movement path.

Entrances

The responses from AH paramedics include those working in the Airbus H145, in which the stretcher is loaded through the rear entrance, and those in the Leonardo AW169, which only has side doors. This variation may influence their answers, as they are accustomed to loading stretchers through different types of doors with varying widths—just as RA paramedics typically load patients through the back of the ambulance.

Rear entrance

During both the AH and RA field studies, it was mentioned that all doors should be openable with one hand, for efficient handling of patients and equipment as well as during a potential evacuation. It was also desired to enter through the rear entrance together with the patient, which was confirmed by the survey responses, see Figure 4.4. The majority believed that both paramedics can use the side doors while the patient is being loaded through the rear entrance. However, nearly as many consider it most appropriate for one paramedic to accompany the patient during loading.

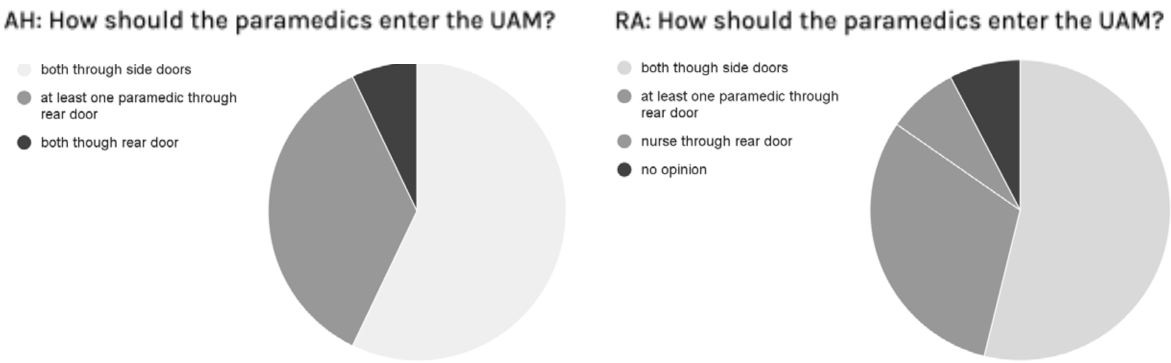


Figure 4.4: Responses regarding the smallest acceptable rear door width, among AH and RA paramedics, respectively.

To the question what is the smallest possible width of the rear door, given that one paramedic should enter beside the patient, the responses show a wide variation, indicating a lack of clear consensus among respondents. It is clear that their responses are influenced by their experience with different vehicle types, see Figure 4.5. AH paramedics most commonly consider 120 cm as the minimum acceptable width (29%), with 21% requesting even wider. The RA responses are divided, with many preferring 100 cm, 120 cm, and 160 cm, respectively. A width of 120 cm would accommodate the opinions of 57% of paramedics among both AH and RA, while 140 cm would accommodate 71% among AH and 6% among RA.

What is the smallest possible rear door width?

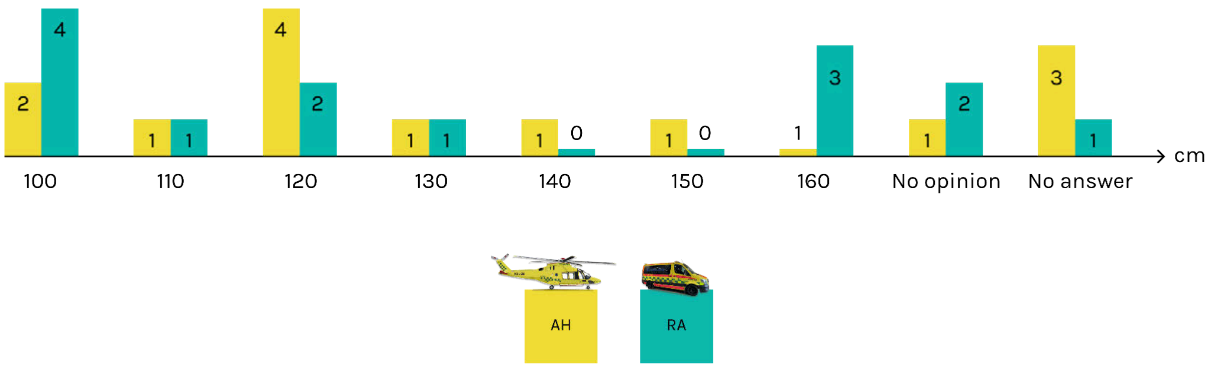


Figure 4.5: Responses regarding the smallest acceptable rear door width, among AH and RA paramedics, respectively.

Side entrance

Regarding the side entrances, considering that paramedics must be able to enter with the scoop stretcher and place it on top of the stretcher construction in case the rear entrance is blocked, responses from both AH and RA paramedics cluster around 100 cm, see Figure 4.6. Generally, AH paramedics tend to prefer a wider entrance, with some suggesting up to 120 cm, although 90 cm is also a common response.

What is the smallest possible side door width?

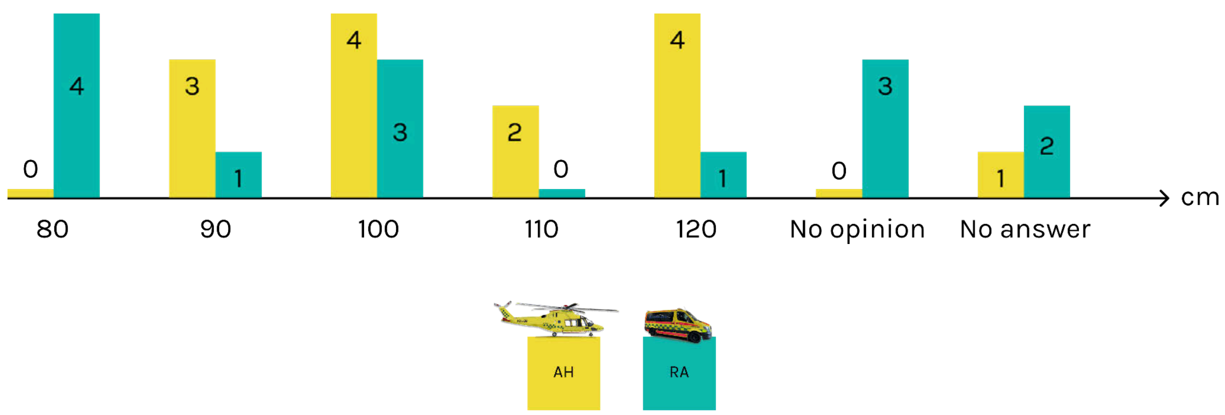


Figure 4.6: Responses regarding the smallest acceptable side door width, among AH and RA paramedics, respectively.

Windows

An HA field study participant highlighted that the windows must be large enough to function as emergency exits and be placed near the seats, for instance, during an emergency landing in water. Windows help reduce motion sickness for both patients and paramedics while also supporting situational awareness. Visibility in all directions was requested, whether provided through windows or via screens displaying the surroundings.

4.3 Seats and Stretcher

This section presents the results from the user research regarding the seats and the stretcher. The findings are divided into two parts: the functionalities and design preferences expressed by the paramedics, and the preferred configuration between the seats and the stretcher.

4.3.1 Functionality and Design

Seats

In the survey, the respondents got to decide what functions they desired from the seats. Looking at the answers from the AH respondents, all of them desired longitudinal translation functionality, i.e. translation along the stretcher's side, see Table 4.2. 92% of the AH respondents wanted rotation. It was clear that most AH respondents didn't desire any other functions than longitudinal translation and rotation. However, the RA respondents answered quite differently.

Table 4.2

Survey Result Regarding Seat Functionality

Respondent type	Percentage of respondents desiring the function				
	Longitudinal movement	Transversal movement	Rotation	Adjustable height	Adjustable backrest
AH respondents	100%	0%	92%	8%	17%
RA respondents	57%	21%	57%	36%	7%
All respondents	77%	12%	73%	23%	12%

In total, 77% of the respondents answering the survey desired longitudinal translation and 73% desired rotation. The other functions were obviously less desirable

The two helicopter seats on each side of the stretcher were observed during the AH field studies. They could rotate 360 degrees and translate longitudinally along the stretcher. However, the function was somewhat difficult to apply in practice, which led paramedics to avoid using it and instead kneel when an alternative working position was required.

During the RA Field study, the interviewed paramedic suggested having a regular seat on one side of the stretcher and a foldable seat on the other side. This would allow access to the patient from both sides while still saving space when the foldable seat isn't in use.

Stretcher

In the survey, respondents were asked whether or not they would like the stretcher to have an adjustable height function. 21,4% of AH respondents and 25% of RA respondents stated that this function is strongly desired, see Figure 4.7. 21%,4 of the AH respondents and 25% of the RA respondents thought this feature might be useful, and lastly, 57,1% of the AH respondents and 33,1% of the RA Respondents did not see any need for this function. Based on this data, a total of 21% strongly desired the function, 29% thought it might be useful, 43% didn't perceive any need

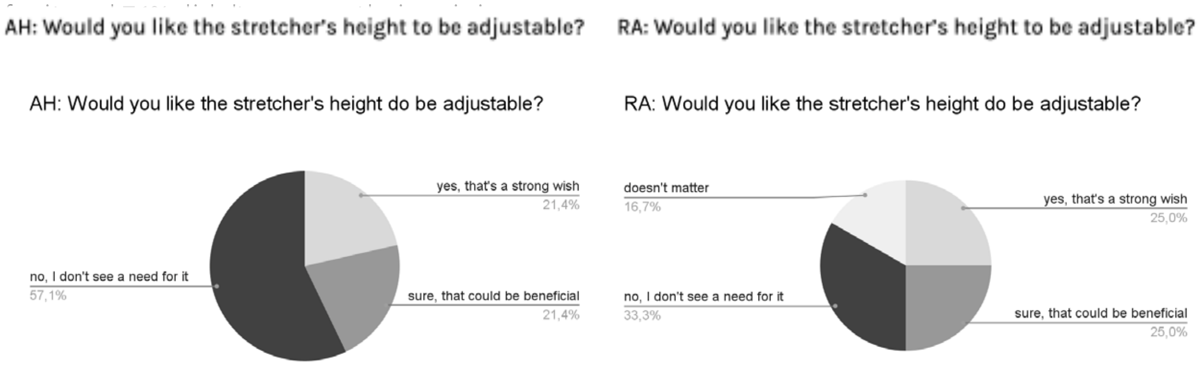


Figure 4.7: Responses to the suggestion of having an adjustable stretcher height, showing RA, AH and combined RA and AH responses, respectively.

During the AH field study, the stretcher design of Leonardo AW169 was examined. This stretcher has a fixed height, but the backrest can be adjusted to a sitting position. The stretcher is mounted in tracks integrated in the floor, but can be translated longitudinally to adjust its positioning. The paramedics expressed that this feature is useful for gaining access to the patient and achieving a more ergonomic working position during specific procedures. The stretcher is also rotatable, as it is loaded through the side doors.

4.3.2 Seat-stretcher Configuration

From the field studies at the VGR helicopter ambulance, the paramedics stated that they need access from the patient's knees and up as well as some sort of seat possibility at the patient's head when intubating. This seat possibility at the end of the stretcher, i.e. the patient's head, will be referred to as *head seat*.

The field study at the VGR RA also gave a lot of valuable insights, since the road ambulance that was displayed during the field study had a different seat-stretcher configuration than the AH. The road ambulance had a seat at only one side of the stretcher, not both sides. The paramedic interviewed in the study was positive towards having one seat on each side of the stretcher. One quote from the interview is **"There should definitely be access to both sides of the patient.**" Having access from both sides make it easier to take care of a broader type of inquiries, especially in the case of trauma patients. One respondent stated that **"to examine and treat the patient, we need to have good access to the pelvis, abdomen, chest, and head"**. When asked if there is any case where switching sides during flight would be beneficial, AH paramedics agreed there is no such case as they have constant access from both sides.

In the survey, the respondents got to give their opinions on two different seat configurations: Middle and Side. They were asked to describe advantages and disadvantages with each. One configuration was with the stretcher being placed in the middle, with two seats on each side and one head seat, see Figure 4.8a. In the other configuration, the stretcher was placed next to the wall, only having a seat at one of its sides and at the head, see Figure 4.8b.

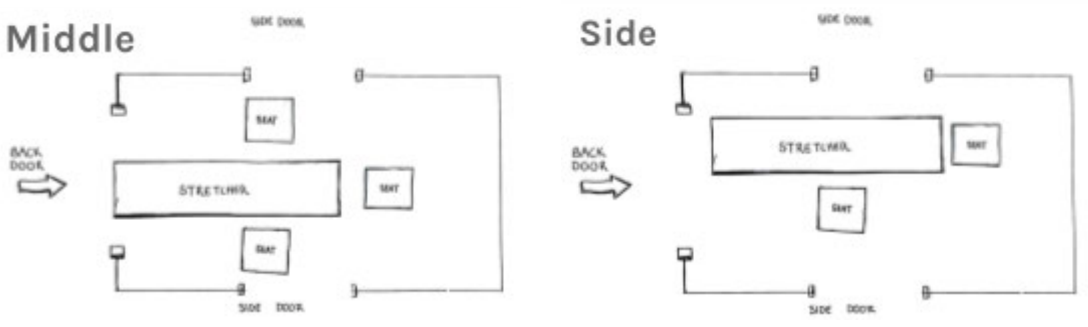


Figure 4.8: Two seat configuration Middle and Side, that paramedics were asked to evaluate in the survey.

They were asked to describe advantages and disadvantages with each. Everyone that works in AW169 preferred the Middle-configuration, while the respondents that workedin H145 were somewhat more neutral, even if leaning toward the Middle-configuration

The respondents identified several advantages of the Middle-configuration. This setup allows access to the patient from all sides, which facilitates medical interventions regardless of the patient's injury condition. It enables two paramedics to work simultaneously without obstructing each other, thereby improving workflow and efficiency. Additionally, it supports more effective airway management during flight. The configuration also allows for the use of multiple resources at the same time, further enhancing the quality of care provided.

Disadvantages identified by respondents for the Middle-configuration were that it takes up a lot of space compared to the Side-configuration. Since equipment must be accessible from both seats at all times, having the Middle-configuration might raise a concern among a couple of respondents.

For the Side-configuration, there were no specific advantages identified. One identified disadvantage with the Side-configuration was that it is more difficult to access the patient from all angles, which makes it challenging to perform certain injections and medical procedures. One AH respondent wrote: **“We have tried this in the H145. It's problematic as access is lacking on one side for procedures such as inserting a needle, ultrasound, thoracotomy, etc.”**

Another issue with the Side-configuration is that the paramedics might interfere with each other’s work. Another AH respondent wrote: **“Not acceptable for the management of critically ill patients, as half of the patient is inaccessible, and there is competition for the same space.”.** A RA respondent agreed that the configuration implies a **“reduced ability to collaborate effectively”.**

4.4 Equipment and Placement

Ideally, most equipment should be accessible from inside the cabin and within reach from the seat. Paramedics emphasise that the care depends highly on the patient’s condition, making it a difficult question to say definitively what equipment is most important to have within reach. The specific tools and equipment required can vary significantly based on the situation. Even equipment that is used rarely cannot be excluded, as it becomes crucial when such cases occur.

To determine the importance of access to different equipment, paramedics participating in the field studies or the survey, were asked to describe what they need to reach while fastened in their seat and what can be out of reach.

One survey respondent **“generally advocates for having access to the majority of equipment during transport, as the patient's condition can change rapidly and new differential diagnoses may arise that require further diagnostics and intervention”**. These items should be within the yellow area, see Figure 4.9. But paramedics can also unbuckle themselves to access items within the white area. Things that don’t have to be reached from the inside, for example, seldom-use equipment and immobilisation devices, are currently stored in the ambulance helicopter’s exterior compartment, and can therefore be stored in the grey area at the back of the UAM.

For details about each equipment and the importance of it being within reach, see *Appendix G - Equipment List*. Below are the summarised results.

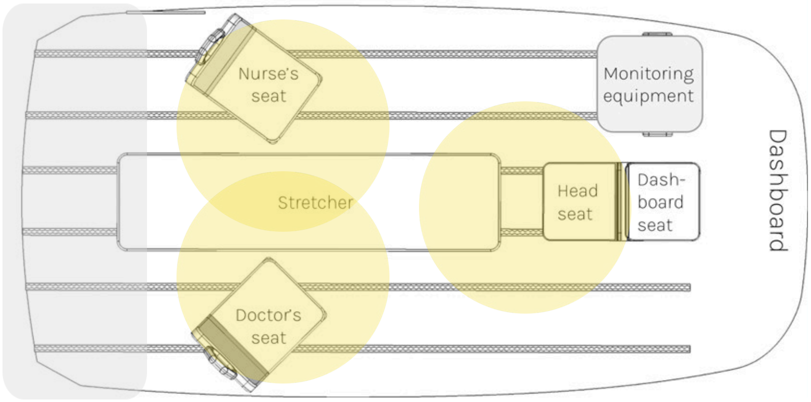


Figure 4.9: Illustration of the range-of-reach areas in the UAM. Yellow represents 'within reach from seat, white represents 'reachable inside cabin', and grey represents 'outside of reach.

4.4.1 Reachable inside the cabin

In general, equipment needed to treat acute or emerging conditions must be stored inside the cabin for constant access during flight. One survey respondent stated that equipment related to controlling A-B-C (Airway, Breathing, Circulation) is of high importance and should be kept within close reach.

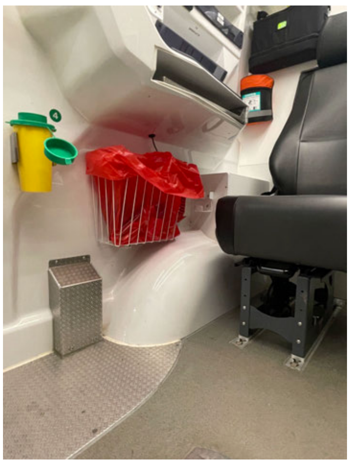


Figure 4.10: Sharps disposal box and waste bag in front of the side seat in one of VGR's road ambulances.

Many AH survey respondents indicated that they have no issue unbuckling to access items when needed, which is currently standard practice, even though most equipment is within reach. Their emergency bag, which they take to the patient on site, is always used in the helicopter and contains most of the necessary tools. Of highest importance is access to medical supplies such as medications, syringes and needles, respiratory equipment and monitoring devices.

Some AH respondents also highlighted the need for quick access to equipment like intravenous line access tools, ultrasound, and radio communication devices. In addition to this, a paramedic at the RA considered waste bags, the sharps disposal box, vomit bags and paper towels as essential to reach quickly. Figure 4.10 shows the placement of sharps disposable box and waste bag in one of the road ambulances.

Equipment that must be inside the cabin but can be out of reach from the seat and fetched if needed, are according to some respondents seldom-used medication, blood and infusion and the LUCAS device used for automatic chest compressions during cardiac arrest.

4.4.2 Reachable only from outside

For patient conditions that are apparent upon arrival, such as trauma injuries, necessary equipment can be retrieved from the outside via a separate exterior storage, used on-site and then brought into the cabin during flight if necessary. This includes rarely used items for specific situations but also frequently used equipment that can be bulky or heavy to lift out of the vehicle.

An example of what is stored is the scoop stretcher that can be accessed from outside the cabin when needed. A scoop stretcher is used to transport injured individuals, especially those with suspected spinal injuries. It consists of two halves that are joined around the patient to lift them with minimal movement. If used, it is placed on top of the stretcher inside the ambulance.

Participants in both AH and RA field studies confirmed that the scoop stretcher most often is retrieved after an initial assessment of the patient's condition, meaning that it is not necessary to store it inside for bringing it on the way out. Additionally, the survey respondents answered the question **"How would you like to access the scoop stretcher?"**. The respondents were given different predefined options accompanied by explanatory images to support their choice, see *Appendix C – Survey*. Although survey responses varied, see Figure 4.11, the key takeaway is that the scoop stretcher does not need to be accessed from inside the cabin. It can be stored externally or reached through the rear entrance when needed. Many of AH respondents preferred access via the side doors, see Figure 4.10a.

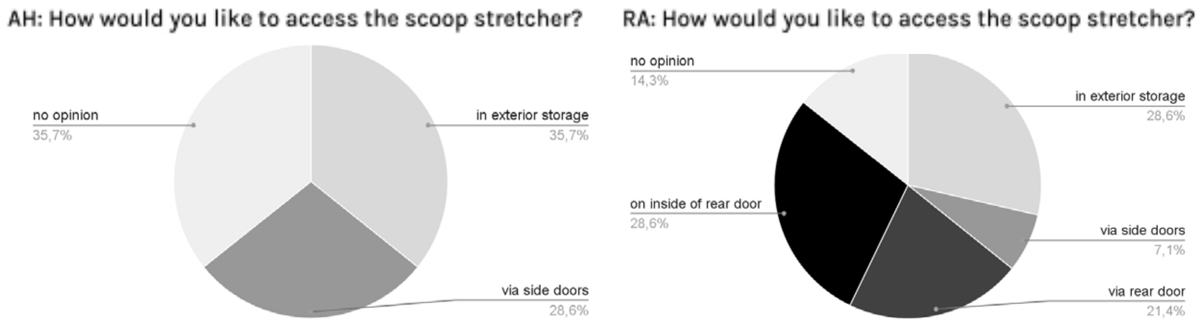


Figure 4.11: Responses regarding the smallest acceptable rear door width, among AH and RA paramedics, respectively.

More equipment mentioned during field studies and in the survey are immobilisation devices, a mini-stretcher, thermal heating bag, seldom-used medical supplies and equipment used during crisis situations as well as for preventing hypothermia.

When asked whether any interior equipment should also be accessible from the outside, the answer was no. Instead, necessary items can be brought outside from within the cabin, meaning storage solutions do not need to allow access from multiple directions.

4.5 Storage

Storage was explored during both the field studies and the survey. During observations in Leonardo AW169, all storage solutions, like fixed boxes, cabinets, drawers, etc., were measured. It was evident that all storage, especially the exterior storage, was not used.

4.5.1 Storage Type

According to responses from the survey, cabinets and drawers were the most popular storage options, with many participants emphasising the importance of easy access and quick opening. One respondent noted the benefit of not having to open an entire box to retrieve an item. Drawers, in particular, were appreciated for their ability to organise and present contents clearly.

Feedback on nets to store equipment was mixed; one respondent rejected nets entirely without giving a reason, while another suggested they could be useful for non-emergency items, such as vomit bags and trauma oxygen masks.

One participant recommended using the ceiling to place medical equipment to maximise space. In addition, several respondents liked hatches with touch-latch mechanisms, which open with a push, highlighting their convenience and speed during critical situations. AH respondents also brought up the aspect of safety when flying, including that it must be airproof.

However, most respondents stated that they prefer different types of storage depending on what is being stored inside. Some items must be easily accessible, while some don't. Equipment that needs to be carried from the ambulance to the patient or injury scene is often best stored in bags, while loose equipment is better organised and secured in boxes. A lot of respondents in the survey didn't mind that much about what type or storage solution the ambulance had, and highlighted that different equipment works best with different storage types.

During the field study at the RA station, when asked about storage preferences, the interviewed RA paramedic preferred a storage solution with compartments similar to those in the current road ambulance, with sections for bags, similar to binders on a bookshelf, allowing them to be easily pulled out, see Figure 4.12. The storage solution for the scoop stretcher was also observed, where the scoop is pushed vertically into a narrow compartment in the exterior storage.

During the first AH field study, it was brought up that an important aspect of storage design is that boxes, hatches, and all types of compartments should be easy to open with one hand. Hatches with double-finger locks were considered difficult to use one-handed, while touch-latch hatches were preferred, as they open easily with a simple push. VGR's road ambulances are equipped with touch-latch hatches as seen in Figure 4.13.

Figure 4.12: Rear entrance storage in a road ambulance van currently used in VGR, reached from the outside.

Figure 4.13: Storage design with touch-latch hatches that open automatically when pushed.

For the survey question **“Would you like any compartments or boxes to be transparent so that the contents are visible?”** 61,5% of all respondents, both AH and RA, answered “Yes, 7,7% answered “No”, and 30,8% answered that it doesn't matter, see Figure 4.14. In the survey, respondents generally indicated a preference for transparent hatches on boxes and drawers, as this helps them identify what is inside more easily, even though they already know where items are stored. One AH survey respondent who considered this feature unnecessary implied that it is essential to know where your belongings are, regardless.

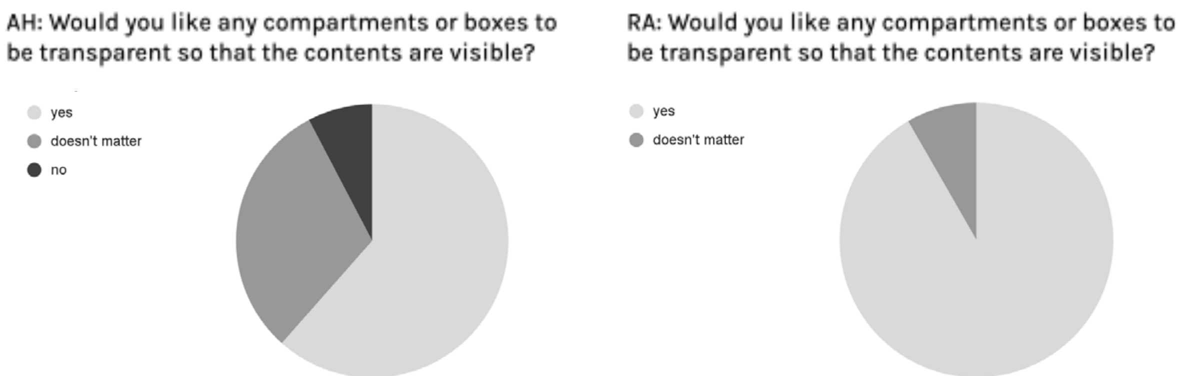


Figure 4.14: Responses regarding transparent storage solutions, among AH and RA paramedics, respectively.

4.5.2 Storage Placement

As explained in *Section 4.4 - Equipment and Placement*, equipment that was not used that often, or not needed to be accessible from the inside, was stored in the exterior storage in the back of the helicopter.

Regarding storage placement, it was highlighted that drawers are more suitable at lower heights for easier access, while placing them closer to the ceiling makes it difficult to

grab and see their contents. For higher or ceiling-level storage, shelves with hatches were preferred. It was also pointed out that drawers directly behind the seats were difficult to reach, as the paramedics would need to unfasten themselves to access them.

At the AH field study, boxes that were placed quite high in connection with the ceiling were identified. The paramedics said it was a bit difficult to grab the things in those drawers due to their placement, but since they contain equipment that isn't often needed, they don't have to access it very often. This aligns with what was conducted in the survey.

4.6 Other

During the field studies and survey, a few other aspects regarding hygiene and aesthetics were explored or brought up, which are presented in this section.

4.6.1 Hygiene

As the ambulance interior is a place for medical operations and performances, hygiene is an important factor to keep in mind when designing. In the survey, having an interior design that facilitates hygiene was brought up by many respondents. It was mentioned that bodily fluids can spread easily and must be removable without difficulty to ensure patient safety and maintain cleanliness.

The importance of smooth surfaces was also emphasised, specifically avoiding corners, holes, or indentations that could collect dirt or bodily fluids. Every seam or crease presents a potential hygiene risk, as they can trap contaminants and are difficult to clean thoroughly.

During the first AH field study, floor drains in the helicopter were identified. These drains enabled efficient cleaning, as paramedics could simply flush the area with water to rinse away dirt and bodily fluids. The paramedics stated that they perform a thorough cleaning every week, in addition to cleaning as needed. The stretcher surface and frequently used equipment are always disinfected with alcohol between patients.

4.6.2 Aesthetics

It was evident that aesthetics were less important for the paramedics, both from the field studies and survey answers. The most important attribute that was highlighted was functionality, and that the aesthetics should support that to improve the workflow, rather than being good-looking and aesthetically pleasing. Hygiene was brought up again regarding aesthetic considerations. It was emphasised that the aesthetics should support easy cleaning, and many respondents expressed that the cabin's colour palette should be light so bodily fluids can be easily detected.

Sufficient lighting to assess skin colour and blood circulation was also desired, and therefore, colourful lighting in the cabin was considered very unsuitable. Adaptable lighting was also emphasised as important; it should be dimmable and capable of providing daylight-level brightness when required.

As presented in *Appendix C - Survey*, survey respondents were asked to select their top three aesthetic preferences from several different design profiles. The answers varied among the respondents, with the most popular aesthetics being a natural background complemented by orange or green interior details. The preferences are illustrated in Figure 4.15.

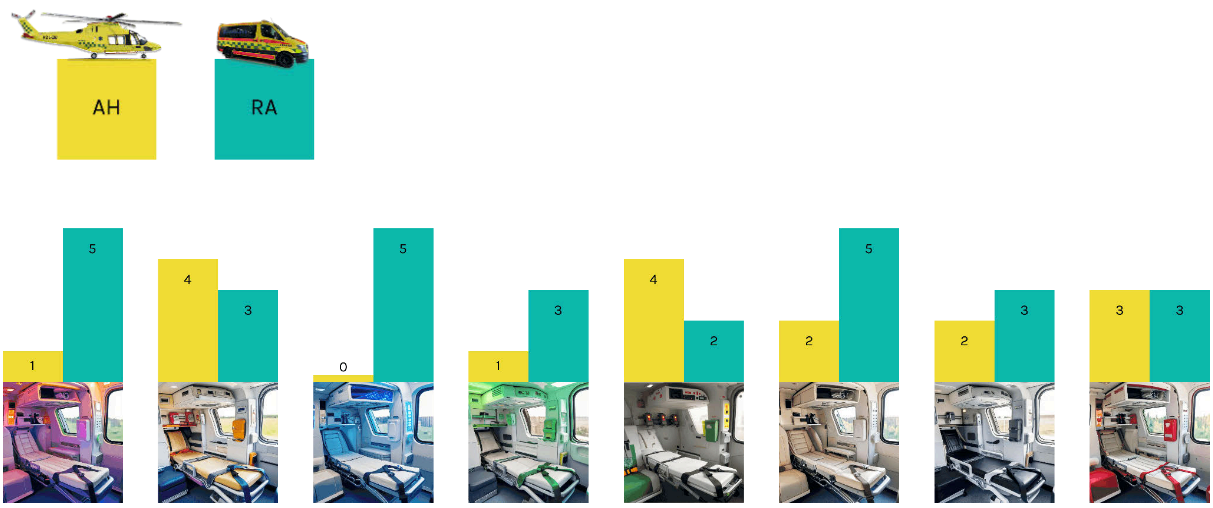


Figure 4.15: Aesthetic preferences among AH and RA paramedics

The comments regarding the respondents' aesthetic choices generally indicated a consensus that appearance is of low importance compared to functionality, as mentioned before. Many respondents stated that aesthetics had little to no significance in their decision. The attributes most frequently mentioned as desirable included professionalism, neutrality, comfort, simplicity, trustworthiness, calmness, and safety.

5 Design Requirements

This section presents the requirements for future UAM design, outlining the requirements, needs and technical criteria that will shape its development. The framework is a result of information derived from the literature review, requirements from the client and user studies. The requirements are divided into the six design modules: Workflow, Cabin Design, Seat and Stretcher, Equipment, Storage and Details. A comprehensive requirements list is available in *Appendix D – Requirement List*, and below are the requirements in summary.

For this project, the same configuration and division of responsibilities as in the current AH in VGR were chosen. This means the nurse sits on the left side, with the main responsibility for the monitoring equipment. The doctor sits on the right side with the main responsibility for treating the patient.

In the UAM, the task of overriding the autonomous system for manual manoeuvring is introduced, adding a new responsibility for the paramedics. Both paramedics must be capable of performing this task in case the other is hindered. Both must be able to access the front, to control the vehicle manually via the dashboard if needed. Additionally, the client emphasised to keep the doctor's side free of obstruction to enable full translation of the seat all the way to the front.

To simplify reading throughout the report, the terms 'nurse's side' and 'doctor's side' will be used to refer to the left and right side of the cabin, respectively, see Figure 5.1. Of course, the nurse and doctor can decide on their task division internally and choose to switch places.

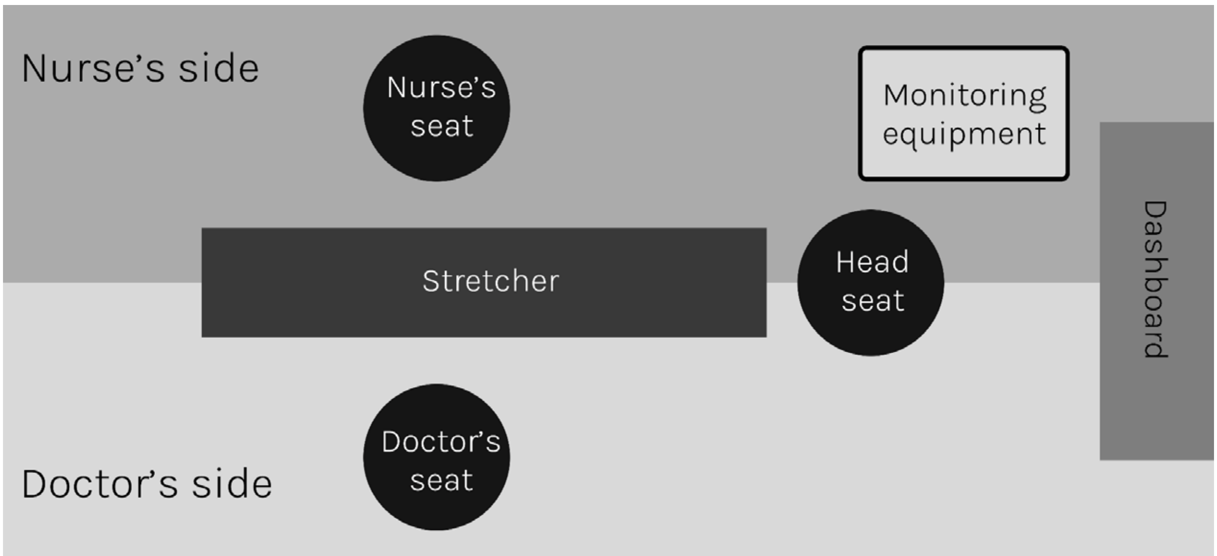


Figure 5.1: Overview of UAM layout and

5.1 Requirements on Cabin Design

The cabin design includes the overall shape, dimensions, and layout, including windows and entrances. Measurements were determined in collaboration with the exterior team to meet initial dimensional requirements and in consultation with the client.

Measurements

Since the main constraint of the UAM cabin is space, it is more likely that larger body sizes will have a hard time fitting in, while smaller individuals will benefit. However, they may face issues with reaching equipment in their surroundings instead. As mentioned in *Section 4.2.1, Workflow and Cabin Layout*, there are no height restrictions for paramedics. Therefore, it is essential to design a solution that accommodates a wide range of body sizes. This is achieved by taking anthropometric data into account, which is a prerequisite for ensuring good ergonomics for diverse body sizes. The design solution should therefore accommodate the 5th percentile female to the 95th percentile male in accordance with Holtze's recommendation (2022a, pp. 56–57). The critical anthropometrics used as reference are based on the Swedish workforce (Hanson et al., 2009). Some measurements are illustrated in Figure 5.2.

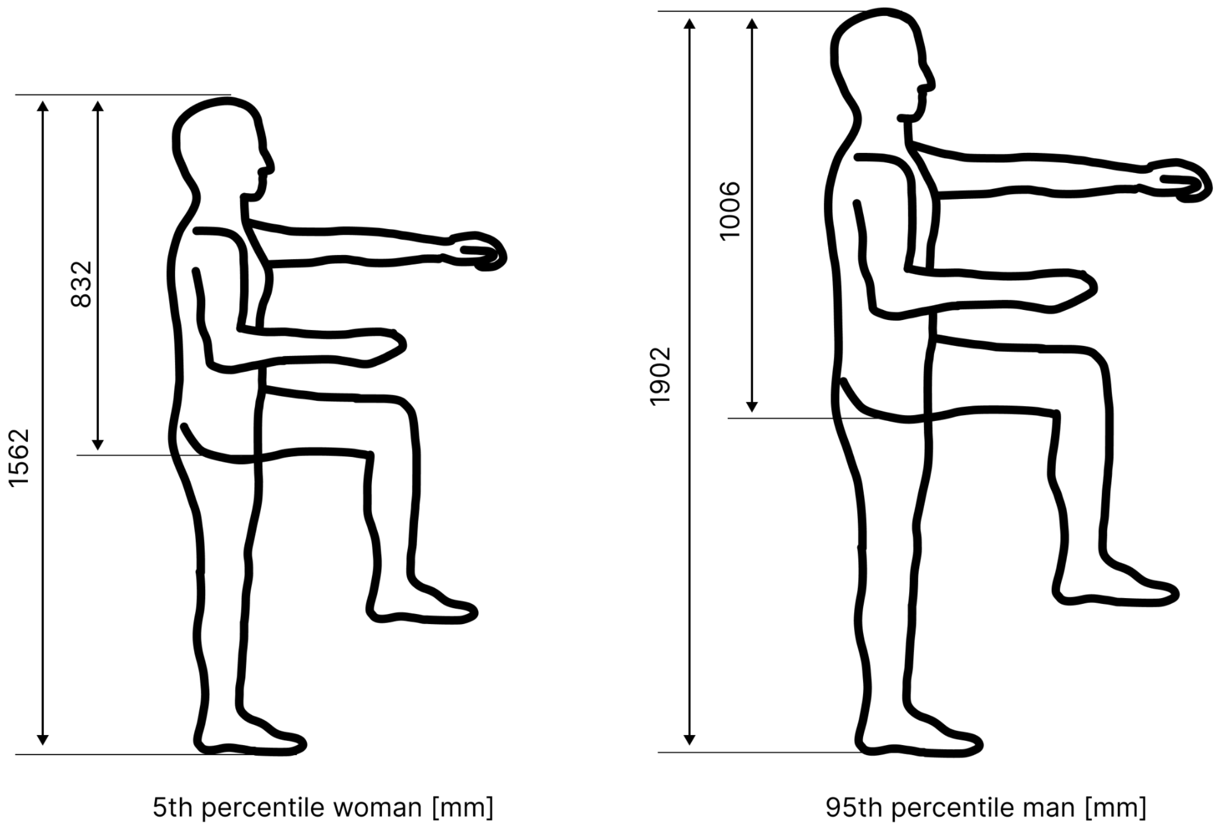


Figure 5.2: Anthropometric data for a 5th percentile female and a 95th percentile male, based on Hanson et al. (2009).

Cabin Width

The interior width was set to 200 cm to allow for approximately 15 cm of space on each side between the interior and exterior walls, including wall thickness. This results in a total height of around 230 cm, which remains within the maximum allowed height of 235 cm, see *Section 1.3 - Initial Requirements*. 200 cm ensures that the dimensions remain the same for AH paramedics in VGR (working in the Leonardo AW169 helicopter)

Cabin Length

To fit the stretcher, head seat and dashboard, a length of at least 350 cm was deemed necessary. The upper limit of 600 cm, see *Section 1.3 - Initial Requirements*, was not of any concern.

Cabin Height

Although opinions about the current helicopter cabin height were scattered, the conclusion is that it is desirable to increase the height to solve the issue with helmets touching the roof and people having to bend. This would allow the 95th percentile male to fit inside the UAM cabin. However, an excessive increase would reduce the possibility of reaching ceiling-mounted equipment, resulting in a requirement of 140-150 cm, which is within the UAM's maximum dimensions, see *Section 1.3 - Initial Requirements*.

Entrances

To enable loading of the stretcher through the rear entrance, the minimum required width was set to 140-160 cm.

For the side entrance, an initial requirement of 100-120 cm was set as this corresponds well with user research, where the majority requested a minimum width between 90 and 120 cm.

Common for both entrances is that they must enable loading of equipment from the outside into the cabin without obstructing the entrance, as well as provide sufficient space for personnel entering while carrying equipment.

Windows

Windows with minimum dimensions 60x60 (as in the current helicopter) must be placed next to the seats so that paramedics can use them as exit routes in case of emergency. The windows should offer 180-degree external visibility to enhance situational awareness, reduce motion sickness, and contribute to a more pleasant flight experience. These requirements were communicated to the exterior team, which was responsible for the window placement and design. Windows were consequently excluded from this project's concept development phase.

Tracks

To ensure air safety, tracks must be mounted in the floor, ceiling and along the walls for securing equipment, seats, the stretcher and storage. These tracks should support the intended workflow by enabling attachment of included parts in a way that supports paramedics in performing their tasks effectively.

5.2 Requirements on Seats and Stretcher

This section brings up the important aspects and requirements regarding the seats and stretcher. This includes its configuration as well as design.

5.2.1 Seat-stretcher Configuration

To create a UAM solution that will align with the paramedic opinions, the input and answers from the field study and interview were the ground for the seat configuration decision. The two alternatives were Middle, see Figure 4.8a and Side, see Figure 4.8b.

Even though the Middle-configuration is used in Leonardo AW169 and the Side-configuration is used in Airbus H145 and in the road ambulances, it was clear that the respondents preferred the Middle-configuration, regardless of previous experience. The reason was the improved access to treat the patient. A couple of respondents expressed that they had worked with both helicopters, and preferred the Middle-configurations.

It was therefore decided to continue with the Middle-configuration, having one seat on each side of the stretcher as well as behind the patient's head. The primary reason behind this was to enable 360-degree patient access. This also aligns with what Holtze states regarding that 360-degree access to the patient allows for more efficient treatment, as multiple personnel can work simultaneously from different angles (2022a, pp. 56–57). Adequate space also supports better ergonomics by reducing physical constraints on movement and posture.

Although paramedics saw no need for switching sides during flight, the introduction of a new vehicle may lead to unforeseen practices. Therefore, the interior should support this flexibility, as emphasised by the client.

5.2.2 Seats and Stretcher Design

Seats

The survey results clearly pointed to a preference for seats that are both rotatable and capable of longitudinal movement along the stretcher. It was therefore decided that at least one seat on the stretcher's side will have these functions. How the seat on the other side of the stretcher should be designed will be explored during concept development.

Regarding other functionalities like adjustable height, backrest and transversal translation, i.e. translation towards the stretcher, was not found as necessary. Some respondents even pointed out that they didn't find any need for these features. One reason for this might be that the seats in Leonardo AW169 don't include these features and therefore, the paramedics working there are used to not having them. The RA respondents were generally more positive towards functions such as adjustable height. Keeping in mind that the stretcher will have an adjustable height, it was decided to fix the seat height. The seat height was set to 35 cm, similar to what it is in Leonardo AW169. The suitability of this height was validated by testing it with the stretcher in the full-scale prototype.

Stretcher

It was decided that the stretcher would be translatable to make it easier to take it in and out of the back door. In Leonardo AW169, the stretcher is rotatable since it is loaded from the side doors. However, this function is not needed for the UAM, as the stretcher will be loaded through the rear door.

Respondents' opinions about whether or not the stretcher's height should be adjustable were very divided. After consultation with the Exterior team, the distance between the UAM's skids and the floor was set to 80 cm. The reason for the distance is to ensure a ground clearance of 50 cm and to leave room for the battery.

In the Leonardo AW169, the stretcher loading height is 110 cm. As presented in *Section 1.3 – Initial Requirements*, the desired loading height is 100 cm. Since the UAM will have a higher floor level, the loading height will naturally exceed 110 cm. Therefore, it was decided to implement an adjustable-height stretcher construction to enable lowering the loading height when needed.

5.3 Requirements on Equipment

A separate list of medical equipment for the UAM was created, excluding basic fixtures like windows, chairs, and the stretcher. Smaller mounted devices used by paramedics, such as radios, were included. The importance of each item was evaluated, prioritised on a three-tier scale based on the importance of proximity to the paramedic. The detailed Equipment List is found in *Appendix G – Equipment List*.

The trade-off between weight and feasibility was challenging, as the most critical emergencies require a wide range of equipment. Therefore, the UAM must be well-equipped to handle such cases. As no initial requirement on maximum weight for the interior was given, it was concluded that as little equipment as possible should be excluded compared to current ambulance vehicles. This ensures that the UAM is adequately equipped to handle a wide range of injuries and illnesses. At the same time, the layout should not feel excessive or overcrowded.

Equipment should be placed where paramedics intuitively would reach to support efficient treatment and help them stay aware of each item's location, which one survey respondent has emphasised as important, see *Section 4.5.1 – Storage Type*. For example, a paramedic may instinctively reach for paediatric equipment in the monitoring devices rack, as they would in a helicopter, despite knowing it is stored in the rear compartment. Errors during routine tasks, referred to as skill-based performance, can occur when users fail to shift to rule-based behaviour (Lehto et al., 2012). In such cases, the automatic response overrides the conscious application of known rules (Lehto et al., 2012). Routine-based behaviour should therefore be considered in the placement strategy.

Additionally, placement should reflect the division of responsibilities between the nurse and the doctor, and be close to the positions where the corresponding treatment is typically performed. This ensures that both have easy access to the tools and equipment relevant to their tasks. An example is having the monitoring devices on the nurse's side of the UAM, and respiratory equipment close to the patient's head and the seat behind it.

Excluded equipment

After going over the list with paramedics working in VGR, equipment that is rarely used and not aligned with the use cases for the UAM was excluded. These excluded items are also found in detail in *Appendix G - Equipment List*. Examples are medication for smoke poisoning and extra equipment sets. Since the UAM will complement and not replace the helicopter, the helicopter can provide this equipment in case such accident occurs.

5.4 Requirements on Storage

Based on the results of the user research, it was clear that the preferred storage type depended on what was stored inside. Therefore, no specific storage type was decided on as a requirement. Instead, the guideline was to have a variety of storage solutions, both simple storage for bags and equipment that isn't needed inside the UAM, and storage for small, loose medical equipment and items.

To effectively store all desired equipment, it was decided to set at requirement for a storage volume of at least 0,388 m^3. This is equal to the current interior storage volume of 0,35 m^3 plus the volume of 0,038 m^3 that is required for the scoop stretcher. In general, the goal was to incorporate as much storage capacity as possible.

Since the majority of respondents from the survey wanted transparent hatches and boxes, it was decided to implement this for the concept. Another requirement identified through user research was to avoid placing drawers high up on the walls, near the ceiling. For storage located higher up, hatches, preferably touch-latch hatches, were recommended instead. Drawers are more suitable for lower storage, as this placement makes it easier to get an overview and access the contents. One respondent emphasised the importance of not having to open an entire drawer to see what's inside, which is also a valuable insight to carry forward in the concept development.

Another guideline for concept development is not to have any drawers directly behind the side seats, as they are difficult to access and open when seated facing forward.

The UAM will not feature any separate exterior storage. This decision was made in collaboration with the exterior team as the exclusion of an extra compartment benefits the exterior design, while the spacious cabin allows for storing all necessary equipment inside. Consequently, it is relevant to explore what interior storage solutions are suitable for items currently stored in the exterior compartment, such as the scoop stretcher. Survey responses showed diverse preferences regarding the scoop stretcher's placement, so no specific requirement was set, except that it must be easily accessible from the outside via one of the entrances.

5.5 Requirements on Details

This section addresses additional details that need to be considered or included in the development of the concept. These elements are generally features that should be incorporated, but due to time constraints, they were not prioritised during the iteration and evaluation process.

5.5.1 Manoeuvring System

The paramedics working in the UAM must be able to take over control of the vehicle in case of an emergency or if something unplanned happens. This is a new feature compared to the ambulance helicopter, which has pilots manoeuvring the vehicle. This results in new responsibilities for the UAM crew and a new practice in the workflow.

To facilitate this, certain functions must be included in the interior. There needs to be a dashboard in the front of the UAM, where paramedics can take over control of it if needed. This dashboard must have a seating option.

The interior must include display screens, with cameras monitoring the surroundings. As the paramedics must be able to get an overview of the situation, these screens need to be displayed so they can be seen from the side seats without obstructing the forward view. Based on the client's recommendations, it was decided to have the following six displays:

- Front view, angled 45 degrees downward
- Right view, angled 45 degrees downward
- Left view, angled 45 degrees downward
- Back view, angled 45 degrees downward
- Ground view, angled 90 degrees downward
- GPS

The monitoring cameras' angles are visualised in Figure 5.3.

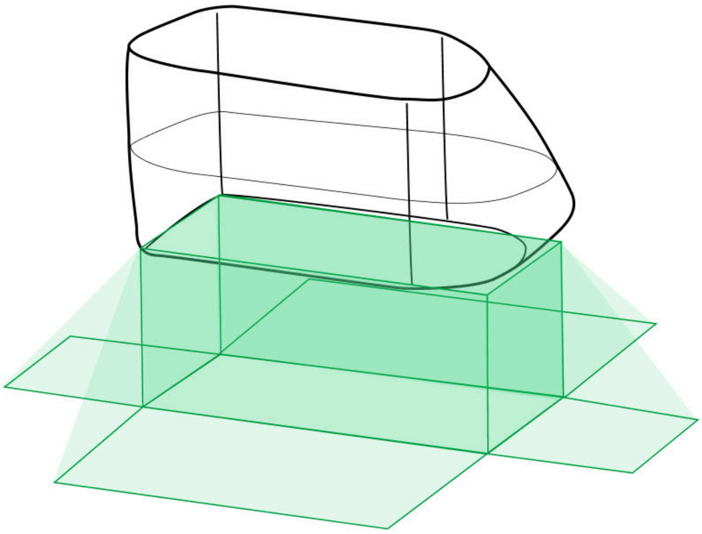


Figure 5.3: Visualisation of the monitor cameras' coverage area. Illustration by Matilda Nevelius Wernholm.

Another feature to be included in the interior is stop buttons, which allow the UAM to stop in the air and hover. This enables the paramedic to move to the dashboard and manually provide new instructions for how the UAM should proceed. This feature was defined as an initial requirement and is considered important in case of emergencies or if the paramedic realises that landing at a specific location is not possible. A stop button must be within reach from wherever the paramedic is sitting. The stop buttons must be visible from all positions within the cabin and designed to be intuitive, ensuring that paramedics can quickly locate and activate them in emergencies. Additionally, the buttons should be positioned to prevent accidental activation; for instance, they should not be placed on the floor or inside the doors.

5.5.2 Hygiene

To support a hygienic working environment and ensure patient safety, the interior should feature smooth surfaces and floor drains to facilitate easy cleaning. Design elements such as creases, corners, and holes that could collect dust or bodily fluids should be avoided, as revealed in the survey as well as in user research conducted by Ramn and Mulder (2019). Additionally, all materials must be chemical resistant to allow proper sanitation (ADAC Luftrettung, 2020).

5.5.3 Aesthetics

The interior should generally feature light, greyscale, or natural colours. Colourful accents may be added in shades of green or orange, identified as the most preferred options in the survey, but overall, the design should maintain a clean and minimalistic appearance, where functionality is prioritised over aesthetics.

6 Concept Development

This section outlines the development of the concept, including design and evaluation, with the execution description embedded in the presentation of results. The concept development process can be divided into different phases, starting with a broader perspective and then moving into specific details. Each phase had its own iteration cycle, with a new focus in each. First, the workflow and cabin design were investigated, then the seat configuration, equipment, storage and lastly the details of the interior. The process is visualised in Figure 6.1.

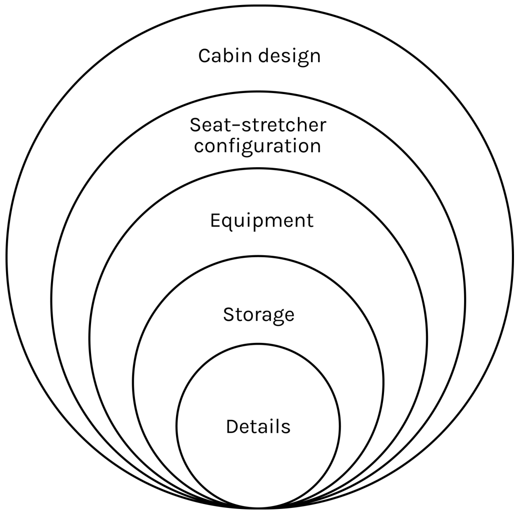


Figure 6.1: Representation of the concept development process, from the overall layout and attributes, to detailed design.

Throughout the entire design process, a full-scale prototype was used to measure, test, and evaluate ideas. This prototype was developed alongside the design process, with each design module contributing to its gradual construction until it was eventually completed.

The process began with the construction of a shared platform in collaboration with the exterior team, based on predefined dimensions. Seats and a stretcher were then built and tested, with a focus on seat height, stretcher translation, and overall ergonomics. Adjustability of the stretcher was incorporated and tested in the prototype. To better get a better spatial understanding, the most important medical equipment was built, which informed the development of storage solutions. Storage concepts were built and evaluated with a focus on feasibility and reachability. Finally, detailed elements such as the dashboard and panic button were integrated and tested during a final evaluation with paramedics.

6.1 Scenario – UAM Dispatch Mission

There are a range of scenarios where traditional emergency response may be challenged. These include urgent medical cases, difficult-to-reach locations, environmental obstacles, and potential system malfunctions. To support the design process, a scenario was defined to highlight the different stages of an ambulance mission and to ensure that the most critical aspects were considered in the development of the interior. The scenario below presents a narrative of a possible sequence of events, which is based on Use Case A – Pickup patient and treat during flight to hospital, as described in *Section 1 – Introduction*.

1. Dispatch and Arrival at Inaccessible Site

An accident occurs in a remote deforested area, where an individual falls, hurts their leg and hits their head hard against a stump. Due to the absence of accessible roads and the lack of space for a helicopter to land, an Urban Air Mobility (UAM) vehicle is dispatched to the site to provide emergency assistance.

Figure 6.2: Paramedics preparing patients for boarding the UAM. (Created with ChatGPT with the prompt "The patient on the stretcher, two paramedics. The UAM stands in the background, on the deforestation area", 2025).

2. Patient is Located

Upon arrival, the paramedics locate the patient, who is in great pain. The paramedics suspect internal bleeding and initiate on-site treatment immediately. They also connect the patient to monitoring devices. One paramedic retrieves the scoop stretcher from the UAM, and together they secure the patient.

3. Boarding and Departure

The stretcher, with the patient secured, is lifted onto the stretcher construction inside the UAM. One paramedic enters through the rear door alongside the patient, while the other closes the rear door and re-enters via the side door.

4. Medical Emergency During Flight

During the flight towards the hospital, the patient becomes unconscious. To ensure free airways, the doctor moves to a position behind the patient's head to perform intubation. Meanwhile, blood circulation decreases and the patient eventually goes into cardiac arrest. The nurse initiates chest compressions with the LUCAS device and manages intravenous medications. The doctor joins in, switching back to their seat beside the stretcher.

Figure 6.3: Paramedic overriding autonomous manoeuvring. (Created with ChatGPT with the prompt "Paramedic overrides autonomous manoeuvring", 2025).

5. UAM System Failure Management and Arrival at Hospital

As the UAM approaches the hospital vertiport, it encounters strong winds, causing difficulties with autonomous manoeuvring. The doctor detects the issue and presses the stop button, shifting control to manual override. Moving to the front operator's seat, the doctor manually inputs landing commands on the dashboard, where the UAM navigates the turbulence successfully.

Upon landing, hospital personnel meet the paramedics and take over care of the patient for further treatment.

Figure 6.4: Paramedic overrides autonomous manoeuvring. (Created with ChatGPT with the prompt "Paramedic overrides autonomous manoeuvring and lands manually on Vertiport in stormy weather", 2025

6.2 Design

In this section is the concept development process is presented, describing how five different design modules Cabin Design, Seats and Stretcher, Equipment, Storage and Details evolved throughout the project.

In parallel with defining requirements and conducting user studies, early idea generation was carried out to gain a broader understanding of the problem and explore a wide range of potential solutions. This phase also allowed for the rapid elimination of unfeasible concepts. As the ideation took place at a very early stage, most of the ideas did not directly inform the final development process based on the defined requirements. Therefore, the focus of this report is not on the initial ideation phase. However, sketches from this stage can be found in *Appendix E - Ideation*. The following section will instead address one design module at a time, covering the process from requirement definition to the final concept.

6.2.1 Cabin design

The chosen dimensions for the interior are W200 cm x L400 cm x H150 cm, which falls within the boundaries outlined in the initial requirements and aligns with paramedics' wishes.

The width was set to 200 cm, which matches the dimensions of the current AH Leonardo AW169, resulting in minimal change to paramedics' working conditions.

The minimum requirement on the length was first set to 350 cm, as that was considered suitable for fitting all furnishings. With both the exterior team wanting a longer nose and the head seat being made into two seats, thus being longer than expected, a decision was made to extend the length to 400 cm.

The prototype platform was built with a width of 200 cm and a length of 400 cm, see Figure 6.5. Due to construction limitations, the platform floor was built at 75 cm above the ground.

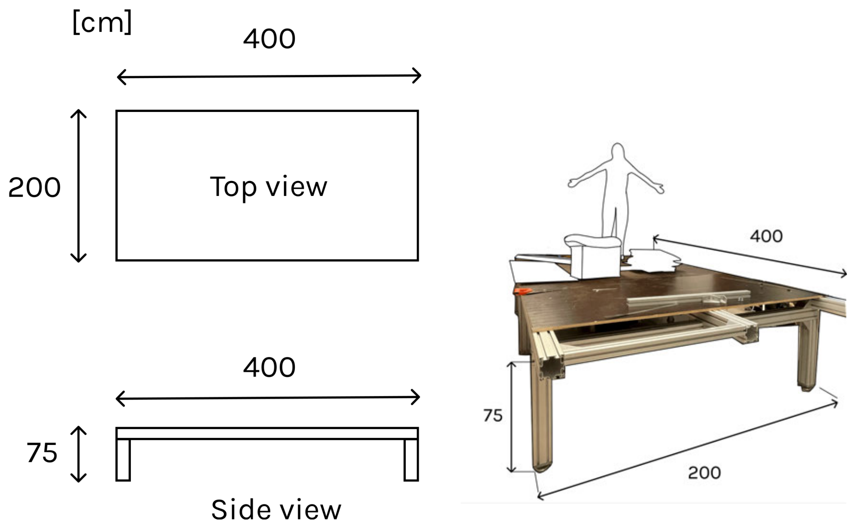


Figure 6.5: Sketch of the prototype platform's dimensions. The image shows the platform and a person standing on top, at the back.

The height was increased to 150 cm, which was appreciated by the AMES. The ceiling height of 150 cm means an increase of 20 cm, which solves the issue with paramedics' helmets touching the roof, ultimately removing the need to bend. The increased height brings more space over the patient, which ensures the patient can sit up straight, and it improves the ergonomics as paramedics have more space to perform manual CPR.

Furthermore, a floor height of 80 cm from the ground was established in collaboration with the exterior team, based on initial requirements regarding ground clearance and battery cell thickness.

Entrances

Rear entrance
The client emphasised the importance of maximising the use of the rear space. Combined with insights from user research and the constraints of the exterior design, a width of 160 cm was selected, being the only option that satisfies all stakeholder requirements. This results in 20 cm of clearance between the stretcher entrance and each side wall.

Side entrances
For the side door, a width of 120 cm was set after confirming successful loading of the scoop stretcher through testing of widths between 100 and 140 cm. This decision aligns well with user research, where the majority requested a minimum width between 90 and 120 cm. A limitation of the door width is that it will open by sliding it towards the back, which requires 120 cm of clearance backwards. Designing a larger door would create challenges for the exterior design.

Tracks

There will be six floor-mounted tracks, each 3.4 meters long from the back edge of the floor almost to the front, leaving 60 cm for the built-in dashboard. These tracks are arranged into three lanes, each consisting of two tracks: one lane for each side and one for the middle. The models used are airline-style L-tracks, which are standard in aircraft, including the current helicopter Leonardo AW169. See *Appendix H - Product Specification* for details.

A potential issue with using tracks is that they could be more difficult to clean thoroughly compared to if components were mounted directly to the floor (Ramn & Mulder, 2019). However, not using tracks would reduce the flexibility in use. Since the current helicopter has tracks, it was decided to delimit further analysis in this area and adopt the standard solution, as that aligns with current safety and hygiene regulations.

Everything, including seats, stretcher, storage and monitoring devices rack, is mounted in these tracks to ensure air safety. With the tracks already in place, future configurations of the UAM can be adjusted to suit the needs of different ambulance stations, for example, allowing a nurse to move freely to the front and place monitoring devices on the right side instead. This aligns with the requirements regarding workflow.

In the prototype, the tracks were represented by duct tape attached to the floor, which served as a reference when specifying the exact distance between them.

6.2.2 Seat and Stretcher

Stretcher design

For the stretcher design, the length and width dimensions were kept as in the Leonardo AW169. Different height ranges were tested in the 1:1 prototype. A quick CAD model of the stretcher was made to also evaluate the existing height with the 5th percentile female and 95th percentile male in Siemens Jack.

During the field study, it was observed that the paramedics could not place their knees under the stretcher, as the construction didn't allow enough space. This made it impossible for the paramedics to sit at a 90 degree angle towards the stretcher. The client requested to fix this issue, and different stretcher constructions were explored where the paramedics could place their knees under it. In the AW169, two drawers were placed under the stretcher. This storage feature was considered important to retain, but conflicted with the idea of an adjustable stretcher, as the drawers are fixed at the bottom of the structure. To solve this, the new stretcher includes small drawers in the fixed lower part of the construction while still allowing height adjustment, see Figure 6.6.

Figure 6.6: Stretcher fixed construction design and functions

The drawers can be removed if the paramedics rather would use the space to rest their feet, or to store other equipment. The construction design allows paramedics to place their knees under the stretcher and even stretch out their legs, due to the gap between the two height-adjustable pillars, as shown in Figure 6.6.

To adjust the stretchers' placement, as well as making it easier to load and unload, the top part of the construction is not fixed but can translate. First, there is a plate on top of the fixed construction that can translate longitudinally. Then, the stretcher itself can also translate to maximise the possible translation movement. This is visualised in Figure 6.7.

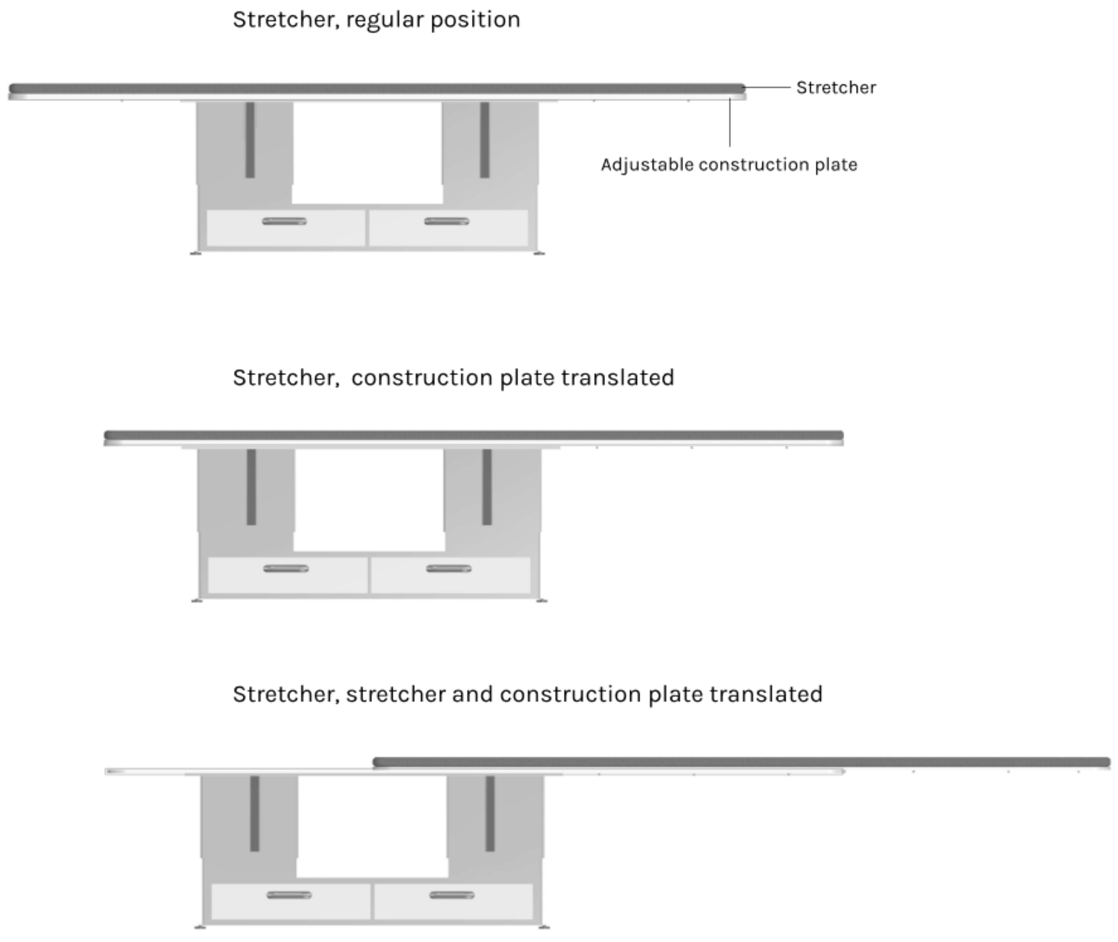


Figure 6.7: Stretcher translation

It was a requirement that the height could be adjusted to 55 cm, matching the current height in Leonardo AW169. With the proposed construction, the maximum height is 60 cm and the minimum is 40 cm. Allowing a lower minimum height could be beneficial for easier loading and unloading of the UAM. To achieve the desired loading height of 100 cm, the stretcher would need to be lowered to a minimum of 20 cm. This could be made possible by removing the drawers and redesigning the structure with three extendable pillars instead of two. However, for this concept, the decision was made to retain the current construction. Another feature is the ability to fold the stretcher into a seated position, making it possible to have the patient sitting up.

Seat design and seat-stretcher configuration

For the seat-stretcher configuration, multiple ideation and concept development methods were used to identify different types of configurations. First, the brainstorming and brain drawing methods explained in *Section 3 - Methods* were used to explore possible solutions for the seating. It was already decided to have a seat solution on each side of the stretcher as well as at its head, but what kind of seat was not yet decided. The main ideas were having one regular helicopter seat, one foldable seat, and one sort of stool seat. A Morphological matrix was used to create different configurations with these ideas, see *Appendix E - Ideation*. The stretcher placement was also explored, whether it should be placed in the middle of the UAM or closer to one of the walls.

During ideation, multiple different seat configurations were explored. It was established that the seat configuration and seat design were interconnected; regular helicopter seats require more space, which means the stretcher must be placed in the middle to allow enough room, see Figure 6.8a. In contrast, for a foldable seat that is attached to a wall or object, the stretcher needs to be mounted closer to it so the paramedic can reach the patient effectively, see Figure 6.8b.

Two main ideas were taken further into ideation, one having three helicopter seats; one at each side of the stretcher and one head seat, and the other one having two helicopter seats and one third seat being foldable. Having a foldable seat would have certain advantages and disadvantages. For instance, it would take up less space, as it can fold and it has to be attached to something, preferably the UAM inner wall. It would not be able to translate or rotate, and it would be smaller and probably less comfortable, which would be a disadvantage. Having the foldable seat at one of the stretcher sides would make it possible to have the stretcher closer to that side and therefore more space on the other side. These two ideas were visualised, named Seater and Folder, respectively, see Figure 6.8.

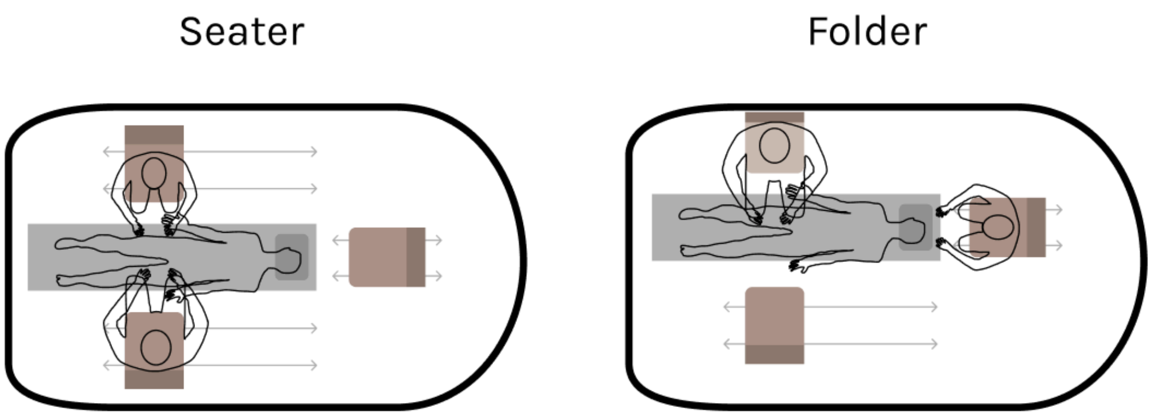


Figure 6.8: Seater and Folder concepts visualised.

As visualised in the picture, Seater has three helicopter seats that can translate and rotate 360 degrees. Folder has two helicopter seats, one at the side of the stretcher and one at the head. Both of these can translate and rotate 360 degrees. However, the third seat is a foldable one, and therefore, its placement is fixed.

Seater and Folder was evaluated with the AH paramedics during the second field study there. They explained that they mostly sit on each side of the patient and rarely at the head, and therefore want comfortable seats at the side. They only sit at the head when intubating, something that happens very rarely, and therefore, they didn't mind what kind of seat it was as long as they could sit there. The intubation also takes place only for a short amount of time, so in total, they spend very little time sitting at the head. Another reason why they preferred Seater was that they liked to work with a 45 degree angle towards the patient. This makes it easier for them to place intravenous lines.

Due to this, it was decided to continue with a concept that has two translatable and foldable helicopter seats on each side of the stretcher, and therefore, having the stretcher placed in the middle so each side gets the same amount of space. Both seats will be translatable using tracks attached to the floor.

However, it was time to investigate what kind of solution should be used for the head seat. The paramedics said a box is almost preferable, as they can store things as well as use it as a seat. As they rarely sit at the patient's head, they didn't see the need for a helicopter seat.

For the UAM, a dashboard will be placed at the front, and according to the client, it must include a seat equipped with a 5-point harness to ensure safety when controlling the vehicle. This led to a new ideation session, focusing on the head and dashboard seat, which was decided to call the front seat. To further understand the spatial restrictions, the 1:1 scale prototype was used.

The solution for the front seat is a longer box, with two seat pads, one being foldable to act as a backrest when sitting at the dashboard, see Figure 6.9. This way, the seat provides storage without obstructing the view from the stretcher-side seats to the front.

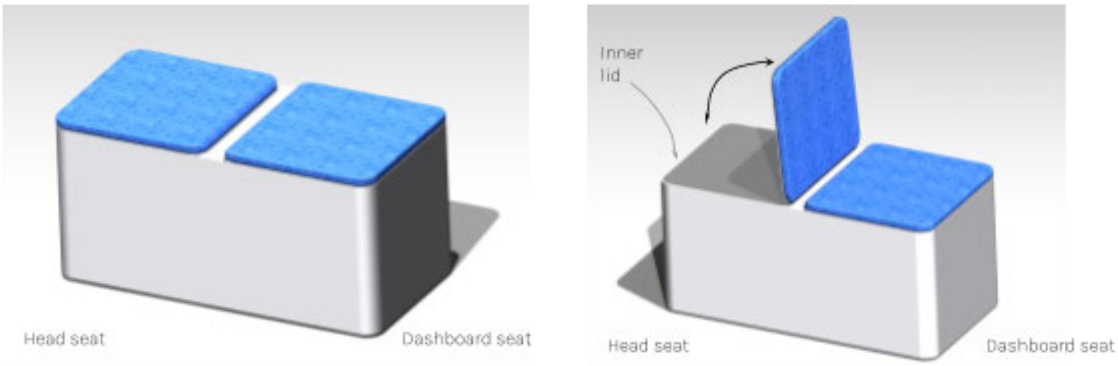


Figure 6.9: Front seat

The front seat, consisting of a head seat and a dashboard seat, features seat pads that serve as lids for storage compartments. Since the dashboard seat must allow for a 5-point harness and a backrest, the head seat pad can be folded up and secured in an upright position with the harness behind the pad. To ensure that the contents of the box remain stored even when the head seat pad is folded up into a backrest, an inner lid is included. This makes it possible to sit on the head seat and perform intubation, even while the folded-up seat is being used as a backrest by the paramedic sitting on the dashboard seat, see Figure 6.10.

Figure 6.10: Both paramedics are sitting on the front seat, treating the patient and controlling the UAM simultaneously.

The seats and stretcher will be mounted to tracks on the floor. The stretcher and front seat will have a fixed position, but the side seats will utilise the tracks to enable longitudinal translation along the stretcher. The doctor's seat will be translatable to the front, allowing it to be positioned next to the front seat so that both paramedics can sit together when travelling without a patient.

The final seat configuration, including the new front seat, is displayed in Figure 6.11. To meet the requirement for a flexible workflow where paramedics can switch sides in the UAM during flight, as explained in *Section 5.2.1 - Seat-stretcher Configuration*, the stretcher is placed 30 cm in from the back to create a passage between the rear door and the stretcher.

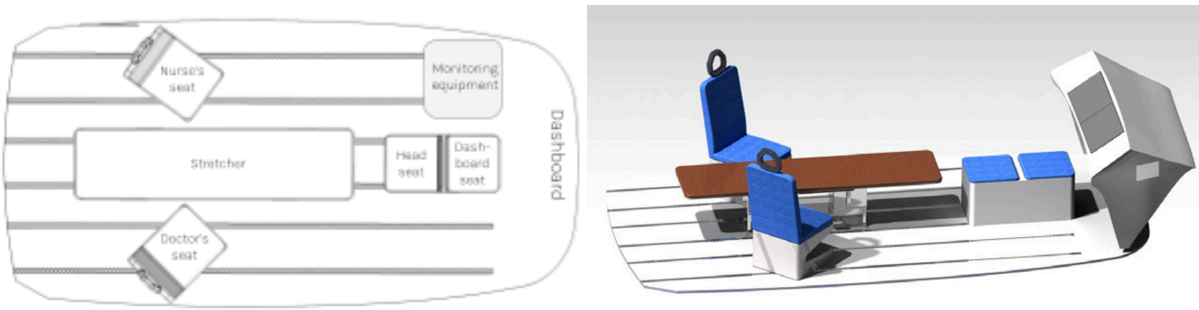


Figure 6.11: Final seat-stretcher configuration.

Basic models of the seats using cardboard were placed in the full-scale prototype, and the stretcher was built using cardboard. To allow for adjustable height, it was attached to an aluminium profile, see Figure 6.12. One seat was later redesigned by incorporating wheels to enable both translational and rotational movement. This enabled quick testing and validation, especially in terms of size and distance between items.

Figure 6.12: Building the seats and the stretcher and testing the seat-stretcher configuration in the full-scale.

6.2.3 Equipment

A list of all equipment was developed from the initial list of minimum required equipment. When it was evident that weight limitations didn't restrict adding more equipment, the list was elaborated. Based on user research, more equipment was added to the list. Much equipment in the current helicopter was suspected to be excessive, and a quick evaluation by going over this list was done with paramedics during the second AH field study. They explained what was needed and when, and what could be removed from the list. This resulted in a final equipment list. For details, see *Appendix D - Requirement List*, where the list of excluded equipment is also provided.

Monitoring devices rack

Detailed construction of the monitoring devices' rack is out of the project scope, but desirable functions are added so that it can be moved along the tracks (on the nurse's side) and rotated. This enables a high degree of flexibility and ensures visibility of the monitors regardless of where the paramedics are seated. A quick test of the functionality was done in the full-scale prototype, where a tester (in the interior team) was seated at the head seat, with the stretcher at the lowest level of 40 cm, see Figure 6.13. The visibility of the monitoring devices was considered good in this configuration.

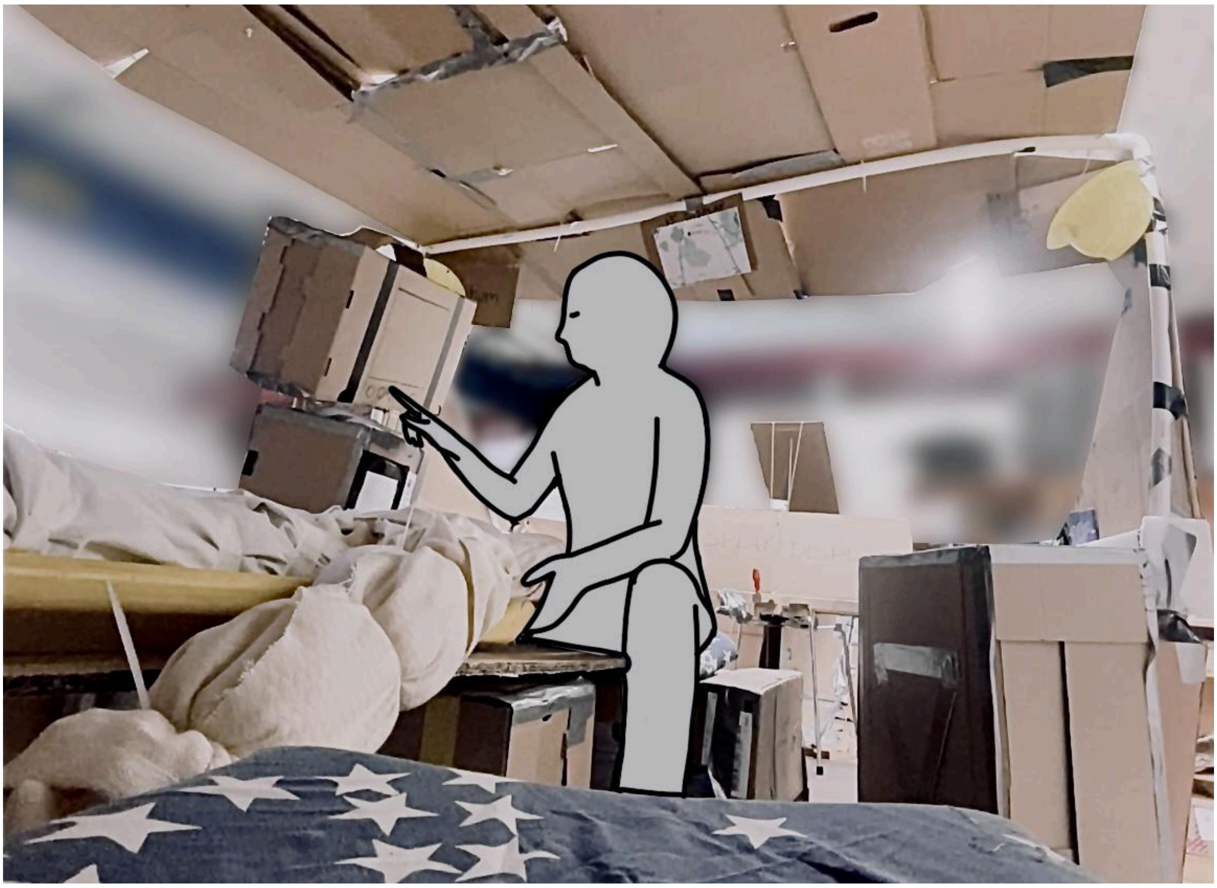


Figure 6.13: Own testing of prototype, seated on head seat for intubation, while monitoring vital parameters on the Corpuls monitoring device. The rack has been moved towards the back and rotated 90 degrees. The tester is 168 cm tall.

6.2.4 Storage

With the general cabin design and seat configuration decided, the remaining space could be assessed to see if it could be used for storage. The UAM's layout was printed and used during ideation, where empty spaces were explored with various types of storage solutions.

Rear entrance storage

To fulfil the design requirement that one paramedic must be able to enter through the rear entrance with the stretcher, one side of the rear opening must remain free of storage. The other side, however, can be utilised for storing equipment that is not needed from inside the cabin, as its position behind the side seat makes it difficult to access during flight. Since some equipment, such as the scoop stretcher, is not used inside the cabin but instead taken out after the UAM has landed, this space can still be used as a valuable storage function. It can also store medical equipment that is currently usually stored in Leonardo AW169's exterior storage.

It was decided to keep the nurse's side free from storage and to place storage on the doctor's side. During the ideation session, sketches were created to explore potential storage solutions. The main ideas included drawers and shelves for bags, oriented in various directions. These concepts were tested in the full-scale 1:1 prototype. It became clear that drawers would not be functional, as they could not be opened due to space restrictions near the floor, and it had already been decided not to place drawers higher up, as they become difficult to access. Similarly, shelves would not be practical if they were oriented facing forward or towards the stretcher.

It was decided to implement a combination of shelves and compartments, see Figure 6.14. The shelves face towards the rear and are accessible through the rear entrance, see Figure 6.15. There is approximately 30 cm of space between the rear door and the shelving unit, making it possible to reach around and grab equipment even during flight. The bottom of the shelf includes a roll-up door, allowing loose items to be securely stored. The scoop stretcher was given a dedicated compartment, similar to the compartment that was observed in current RAs in VGR, where it can be placed securely. Additionally, there was unused space at the top of the storage area, which was used to install a small compartment accessible from the seat, see Figure 6.16. This space is intended for items that are used less frequently, as accessing it requires the user to turn in their seat. The compartment has a transparent touch-latch hatch for easy access, with a hasp for extra security when needed. Finally, the shelves are provided with straps that can be fastened for security. The configuration was tested by us to ensure the reachability on the highest shelf, see Figure 6.17.

Figure 6.14: The rear entrance storage.

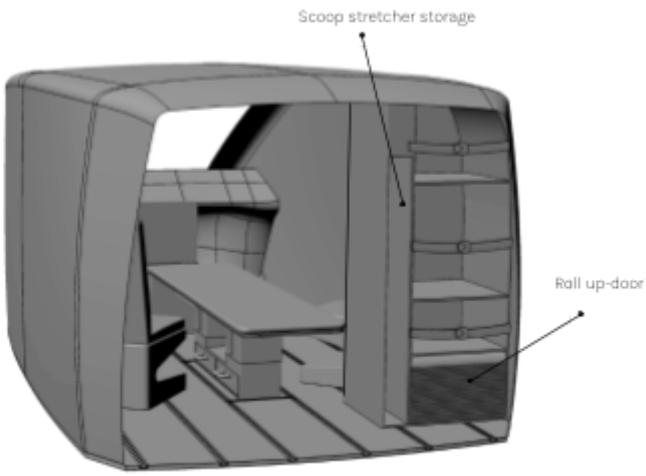


Figure 6.15: The rear entrance storage in context.

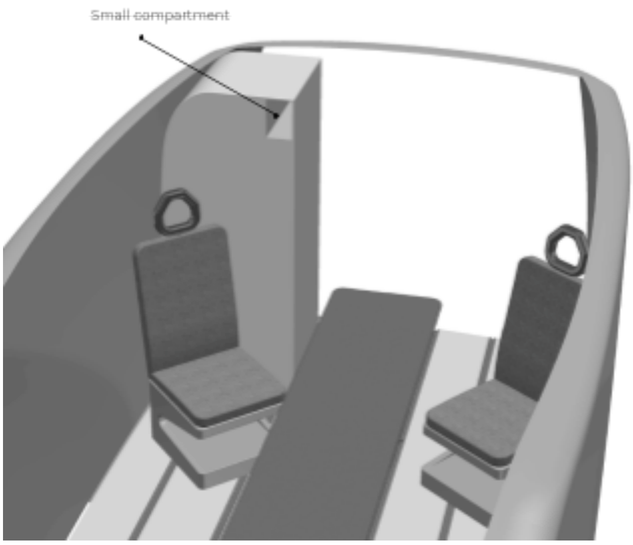


Figure 6.16: Small compartment detail, with touch-latch hatch that opens automatically when pushed.

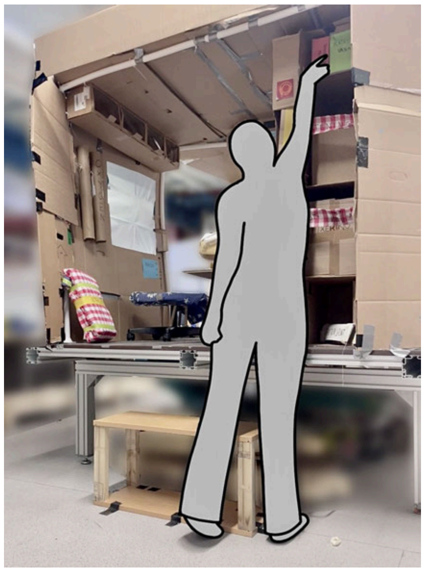


Figure 6.17: Own testing of the height of the highest shelf in the rear entrance storage, to ensure the reachability from the ground. The tester is 168 cm tall.

Ceiling-storage

To utilise the ceiling space, storage compartments were added on each side at the rear of the UAM cabin. For ease of access to medical items, touch-latch hatches were also used for this storage. The transparent hatches allow for quick identification of the contents, and the compartments are integrated into the ceiling design to ensure a seamless finish, see Figure 6.18. The height was tested to ensure the reachability of items inside the storage, see Figure 6.19.

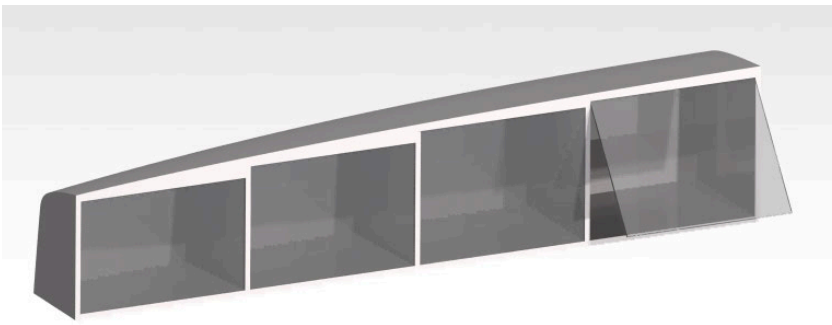


Figure 6.18: The left-side ceiling-storage, with transparent touch-latch hatches that open automatically when pushed.

Figure 6.19: Own testing of the ceiling-storage, to ensure reachability of items inside. The tester is 168 cm tall.

Other storage

As the walls and ceiling are equipped with tracks, bags and medical equipment can be stored in almost any location. Using hooks and securing straps, the items can be easily fastened and kept in place during flight. The stretcher construction's two integrated drawers also provide additional storage, particularly useful for equipment that needs to be accessible near the patient.

6.2.5 Details

Manoeuvring system - dashboard and displays

During iterations, multiple placements of screens were tested, see Figure 6.20.

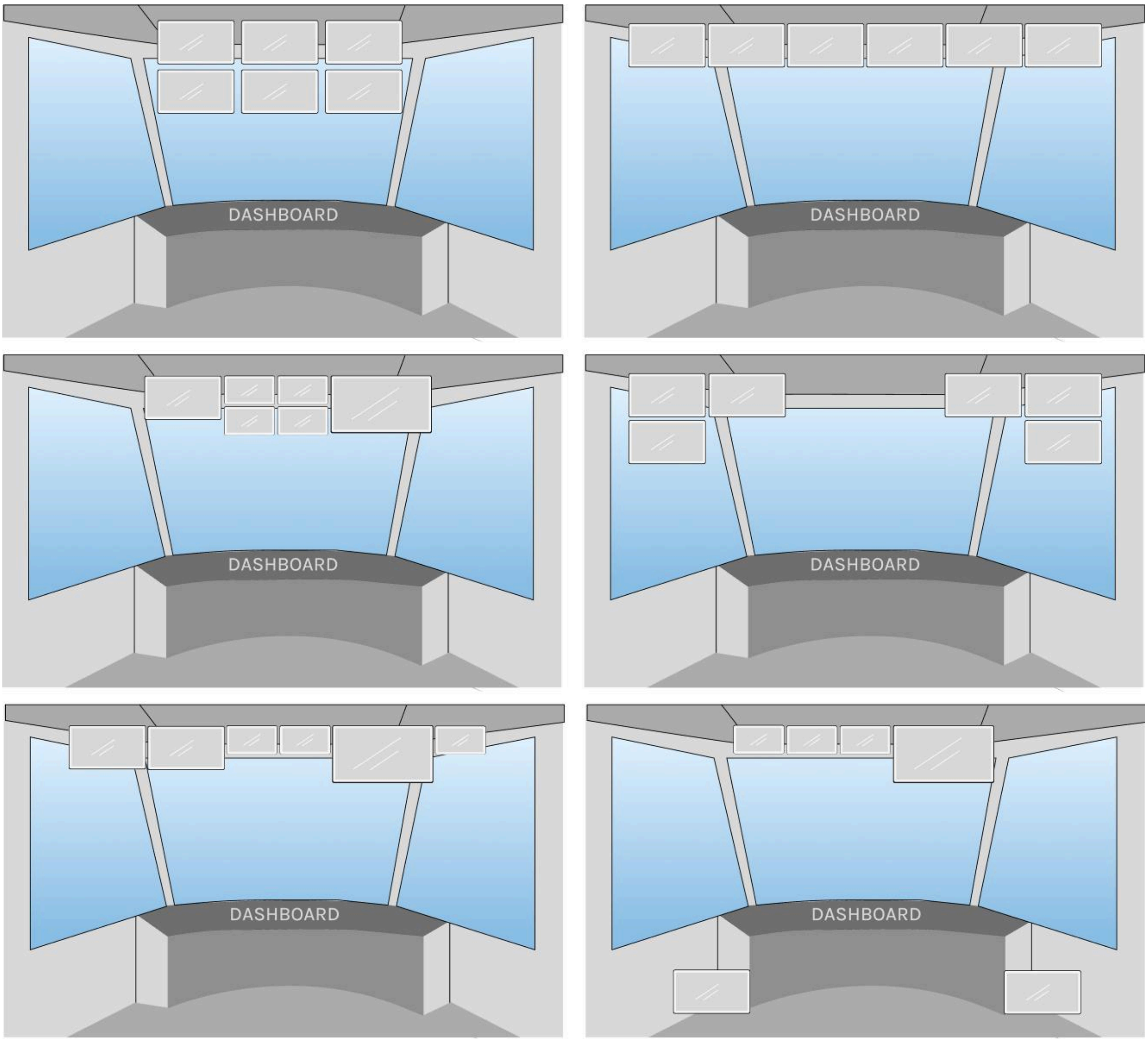


Figure 6.20: Display placement tested.

Screen placement was also tested in the 1:1 prototype to evaluate visibility and assess whether the screens obstructed the front window and blocked too much of the forward view. Screens positioned in the lower corner next to the dashboard were found to be highly unsuitable, as they were obstructed by other components and blocked the possibility of placing equipment there. It was evident that big screens would cover too much of the window if they were placed directly over it. Tilting the screens slightly improved their visibility while minimising obstruction of the forward view. The screens were added to the CAD model and later evaluated using Siemens Jack. Figure 6.21 illustrates the setup in Siemens Jack, showing a 95th percentile male seated on the nurse's side looking forward. The eye cones represent his field of vision, and the image on the right displays his actual view.

Figure 6.21: Setup in Siemens Jack. The right image shows a 95th percentile male seated on the nurse's side, with the grey cone representing his field of vision. The left image displays what he sees from that position.

The screens were set to the dimensions 295 × 210 mm. With this size, only five screens could be accommodated in the front ceiling area, as illustrated in Figure 6.20. However, it is possible to include foldable displays positioned closer to the side seats. All camera angles and the GPS will also be displayed on the dashboard, ensuring good visibility when manoeuvring the UAM.

A dashboard was positioned at the front of the cabin. However, the design of the screen layout and control panel will not be developed within the scope of this project due to time constraints. In the CAD model, the dashboard was left empty. Some ideas regarding the dashboard's displays included giving each camera angle its own dedicated screen, alternatively integrating all views into a single screen that allows the user to switch between them. Additionally, a joystick could be implemented for steering the UAM.

Manoeuvring system - stop button

Inclusion of a system for manual override was an initial requirement. However, its design has not been extensively explored or iterated due to time constraints. To ensure it is easy to locate, recognise, and understand, a simple and classic stop button design was implemented, see Figure 6.22. The placement of stop buttons was postponed until after the final evaluation to ensure compliance with the paramedics' requirements.

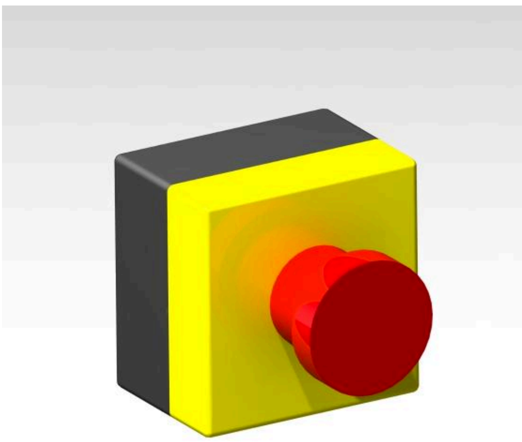


Figure 6.22: Stop button design.

Radio communication device

For the radio communication device, also including cabin lighting control, three concepts were developed. The first is to place the radio in the ceiling, similar to the design in the Leonardo AW169, see Figure 6.23a. The second concept is to integrate a fold-out radio in the roof, above each side seat, see Figure 6.23b. The third and last concept is to incorporate a fold-out radio on each of the side walls, see Figure 6.23c.

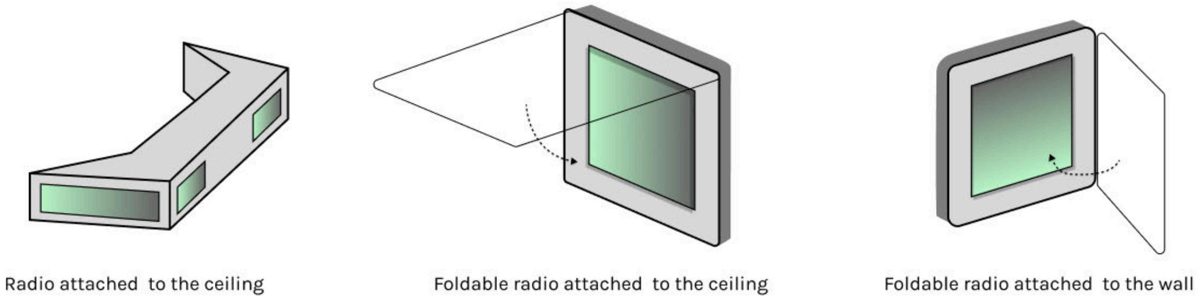


Figure 6.23: The three concepts for the radio communication device.

These ideas will be tested in the final concept evaluation. One important aspect is that the patient can be able to sit up without touching the radio if it is directly above.

Other details

To support the paramedics when boarding the UAM, and working inside, handles were placed inside the cabin. The handles are placed next to the entrances as well as the ceiling. When designing the handles, the only requirement was that it should work for both the 5th percentile female and 95th percentile male. However, due to time constraints, much research was not done on this topic. Instead, similar dimensions to existing solutions were used. The handles design is shown in Figure 6.24.

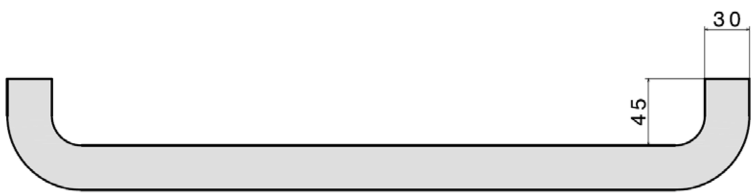


Figure 6.24: Drawing of the handle

Drains will be placed on the cabin floor, to facilitate easy cleaning. In the project, the design and specific location of these drains has not been decided. However, it is something that should be included in the final UAM.

7 Final Concept Evaluation

The Concept Development phase was concluded with a final evaluation aimed at identifying areas for improvement to be addressed in the Final Design, as well as validating the concept and understanding paramedics' experiences and attitudes towards it.

This section begins with a description of how the evaluation session was conducted, followed by a presentation of the evaluation results.

7.1 Execution

A pilot test was conducted with one participant within the medical field (but not in prehospital care) to validate the evaluation method and gain initial insights on the concept.

The evaluation session began with a presentation of the concept, including exterior and interior. Participants were encouraged to ask questions and share their thoughts. They were presented with the main scenario and thereafter experienced the physical prototype, see Figure 7.1.

The physical prototype evaluation mainly followed the scenario sequence, with feedback gathered through open-ended, probing questions, see *Appendix F - Evaluation Guide*. The test also included an assignment to place stop buttons and handles where desired. The prototype was tested by two paramedics from the road ambulance; one tested the whole prototype and one tested the cabin dimensions and seat and stretcher configuration.

Figure 7.1: The full-scale prototype used during evaluation, seen from the back and from the right side.

7.2 Evaluation Results

In this section, the opinions and feedback gathered from the pilot test and final evaluation are summarised. The result is divided into what opinions were brought up during the pilot test and the final evaluation. The data is divided into the categories of the UAM and differs between the pilot test and final evaluation, as both participants highlighted different subjects and put more emphasis on certain aspects of the prototype.

7.2.1 Pilot test

This section presents the aspects of the concept and prototype that were highlighted by the participants during the pilot test.

Cabin Design

In general, the participant emphasised the benefit of preserving the layouts in the current helicopter and ambulances, particularly regarding equipment placement. They said that **"in time-critical situations, you instinctively reach towards where you are used to, and there is no opportunity to search for items"**.

The participant considered that they had sufficient space to perform manual CPR, see Figure 7.2. Handles were suggested in the ceiling and along the sides of the entrances to support effective and safe entry into the UAM, see Figure 7.3.

Figure 7.2: Participant evaluating cabin space and height during manual CPR.

Figure 7.3: Participant's proposed handle placement at side entrance.

Seat and Stretcher

The adjustable stretcher height was appreciated as it allowed the legs to fit underneath. However, it is important that the patient is not positioned too high above the floor as this limits access during procedures like intubation.

The task of lifting the scoop stretcher out from the rear entrance storage was appreciated and considered to be at an acceptable height, see Figure 7.4. Loading the scoop stretcher was perceived as somewhat difficult to evaluate due to the absence of a realistic patient weight. While the height was considered acceptable given the circumstances and the imagined weight, a lower loading height would likely be more beneficial from an ergonomic perspective.

Figure 7.4: Participant lifting the scoop stretcher out from the rear entrance storage.

Equipment and Storage

The possibility to move and rotate the monitoring devices' rack was appreciated as it enables a good overview regardless of seating position. The ceiling-storage was considered to be within a good range of reach from both seats.

Details

Ceiling-mounted equipment

It was suggested to place the ceiling-mounted radio communication device near the patient's hips or further back in the cabin to avoid hindering the patient from sitting up. If this would compromise functionality, an idea was to allow adjustable positioning.

Stop button

Similar concerns applied to stop button placement, where positioning near the ceiling and floor entails a higher risk of accidental activation. In addition, high placement may be out of the natural field of vision, thus being difficult to locate during emergencies. Preferred locations were further away from the patient but within immediate reach, see Figure 7.5.

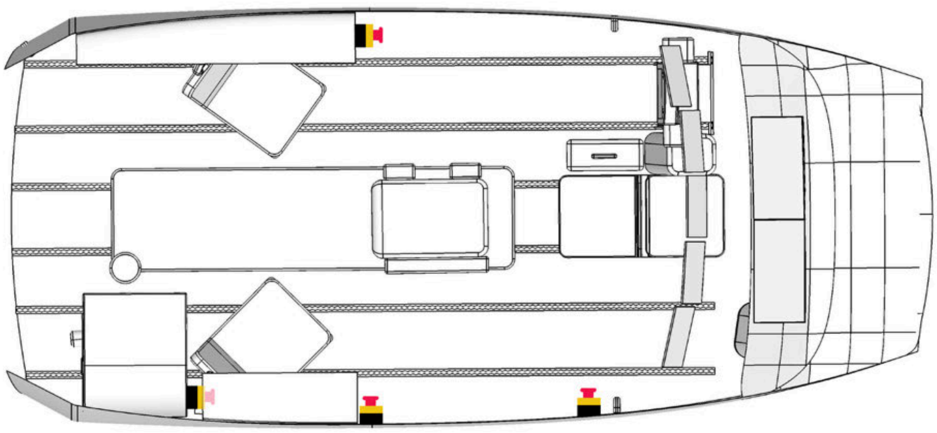


Figure 7.5: The partcipant's preferred placement of stop buttons, when asked to freely place stickers as they liked.

Displays

A concern raised regarding placing external view-displays in the front floor corners was the risk of stepping on them, as well as limited visibility unless seated at the dashboard. It was suggested that external view displays should match the camera angle to support spatial orientation.

7.2.2 Final Evaluation

In this section are the aspects of the concept and prototype presented that were brought up by the participants during the evaluation.

Cabin Design

Overall impression

The overall experience was that the UAM is luxurious. One participant was positively surprised by the spacious interior and the amount of equipment, which exceeded their expectations.

The abundance of equipment was exemplified by the inclusion of a ventilator device. During primary missions, manual ventilation using a resuscitation bag is often preferred, given the short travel times between the accident site and the hospital. Syringe pumps were also not considered necessary.

Entering the UAM through the rear door

In addition to the extra step outside the UAM, support during entry was considered important. A handle on the left side of the rear opening was suggested to assist paramedics entering through the rear door.

Seat and Stretcher

Loading of the scoop stretcher

One participant tried to load the scoop stretcher into the main stretcher as they would if a real patient were lying on it. The stretcher was positioned at the standard height of 50 cm, resulting in a total loading height of 125 cm, which was considered acceptable. It was mentioned that the option to lower the stretcher height would be beneficial during loading.

Seat-stretcher configuration

When the scoop stretcher was placed on the main stretcher at its position of 55 cm, the overall height was perceived as somewhat too high relative to the seat, which resulted in poor access to the patient, see Figure 7.6. Lowering the stretcher to 40 cm was appreciated as it enabled better access to the patient's arms and provided a good angle for intubation.

Regarding height adjustability, it was concluded that adjustment is not essential. While not disadvantageous, the feature could be omitted if it significantly increases the UAM's weight. However, adjustable height may be beneficial during loading. An adaptable stretcher shape allowing upright, inclined and declined positions was desired.

The stretcher's built-in arm support was appreciated for facilitating access to intravenous lines. Adjustability of the seats' height was not considered to be needed.

Figure 7.6: Participants evaluating the cabin space, seat and stretcher height as well as the seat-stretcher-configuration.

Equipment

The participant mentioned the need for paper towels, after which the proposed placement on the side of the rear storage was shown. This location was immediately accepted and considered optimal due to its quick accessibility.

The placement of the sharps disposal box near the seats was regarded as appropriate, for example, under the stretcher.

The placement of the radio communication device in the ceiling was considered acceptable. However, having a device on each side wall, next to the windows, was also seen as a suitable alternative. The current ceiling placement was considered feasible, and the idea of a foldable, ceiling-mounted device that can be lowered when needed was likewise viewed as a practical solution.

Storage

The ceiling-storage was considered suitable for both frequently used equipment that needs to be within close reach, as well as items used more rarely. The first equipment mentioned for this space included various respiratory devices and IV fluids.

Details

Manual override

The overall visibility of the UAM's front area, including the dashboard, windows, and ceiling-mounted displays, was described as "really good", see Figure 7.7. The size of the ceiling-displays was considered appropriate. Regarding the dashboard, a request was made for a screen displaying technical measurement data, for paramedics to get a glance at and quickly assess the situation.

Figure 7.7: View of the displays and monitoring devices from the doctor's seat.

A need was expressed for the UAM system to actively communicate its status. A light near the dashboard that blinks or changes colour would contribute to a sense of safety and control. It was noted that it can be difficult to remain continuously vigilant, and that the system itself should contribute to situational awareness by clearly signalling when human interaction or intervention is required.

A question was raised about the division of roles between the nurse and the doctor. The nurse typically monitors medical devices while the doctor focuses on treatment. In a situation requiring manual control of the UAM, it was seen as more reasonable for the nurse to be seated at the dashboard, especially if the doctor is performing tasks like intubation. In some countries, however, both paramedics are nurses which makes the seating arrangement less relevant.

Stop button

The paramedic emphasised the risk of accidentally hitting the head on the stop button if placed in the ceiling. Another aspect is reduced sight, which is worsened in stressed situations since it is not in the natural field of vision. When seated behind the patient's head, the participant's preferred placement of the stop button was either at the dashboard or to the left, as seen in Figure 7.8. Excessive use of buttons could make the UAM feel less secure, raising the question, "Why would I need to interfere?". Additionally, being able to stop the system from the rear door would enhance control and trust, even though failure is unlikely.

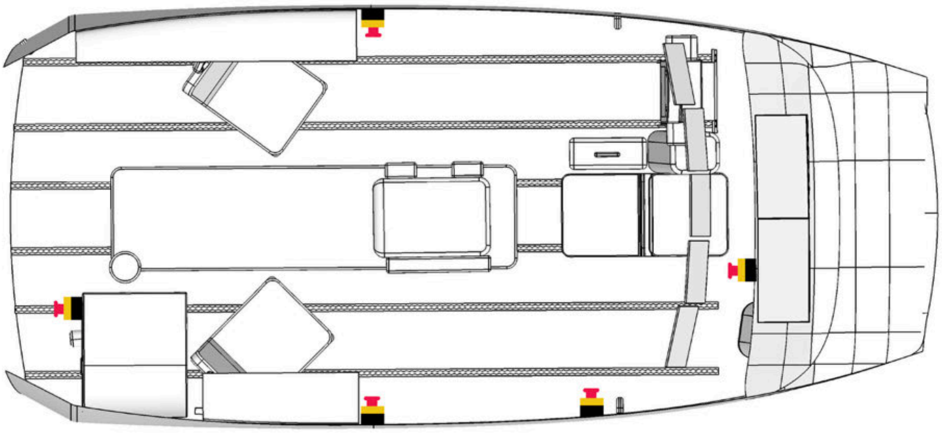


Figure 7.8: The partcipant's preferred placement of stop buttons, when asked to freely place stickers as they liked.

After the evaluation, stop buttons and handles were implemented. This is further described in *Section 8.1.1 – Features Implemented After Evaluation.*

8. Presentation of Deliverables

This section presents the final concept design with images and descriptions. The layout follows the main scenario presented in *Section 6.1 - UAM Dispatch Mission*, to give a clear, step-by-step understanding of how the UAM interior has been adapted for different situations. All details on equipment and interior components are listed in the Equipment List and the Product Specification, which are also project deliverables introduced in this section.

8.1 Final Interior Design

This section presents the final design shown in Figures 8.1 and 8.2. For an explanation of each equipment included in the interior CAD model, see Figure 8.17 in *Section 8.2 - Equipment List*.

Figure 8.1: Side view of the interior, showing ceiling-storage, seat-stretcher configuration and monitoring devices rack.

Figure 8.2: Back view of the interior, showing the rear entrance storage, stretcher and seats.

8.1.1 Features Implemented After Evaluation

The stop buttons and handles were implemented accordingly with the requests from participants in the final concept evaluation. An overview of the placement on the nurse's side is shown in Figure 8.3, including also radio communication devices.

Stop buttons

Participants in the evaluation had similar opinions regarding placement of stop buttons, see Figures 7.5 and 7.8. The final placement gives both nurse and doctor access to a stop button regardless of position in the UAM to ensure safety at all times, see Figure 8.1. A stop button is also located at the rear storage to ensure safety and give paramedics control in case of system failure while the UAM is on the ground.

Figure 8.3: Radio communication device, stop button, handle and on the nurse's side of the UAM.

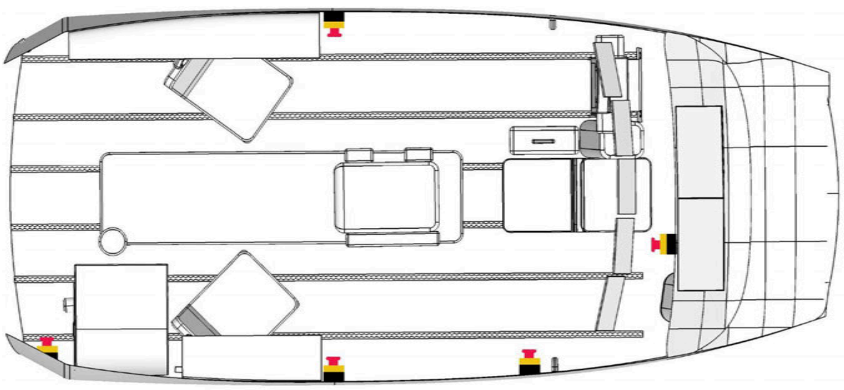


Figure 8.4: Final positions of stop buttons, in total 5 pcs, based on participants' preferred placement.

Handles

Handles are placed along both sides of the side entrances as well as on the left side of the rear entrance, where one paramedic enters together with the patient. Additionally, handles in the ceiling are incorporated to provide further support when entering and exiting the cabin as well as moving inside. Figure 8.5 shows the vertical and horizontal handle placement.

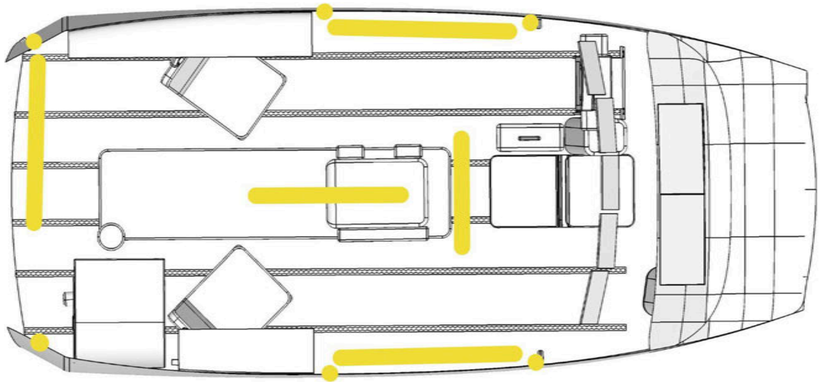


Figure 8.5: Placement of handles. Dots indicate vertical handles (mounted along the walls), and lines indicate horizontal handles (positioned along the floor and walls).

8.1.2 Fulfilment of Requirements

How well the UAM interior design fulfils the requirement list found in *Appendix D - Requirement List*, will be determined in the following section.

The final inner cabin is 400 cm long, 200 cm wide and 150 cm high. This fulfils requirement 1.1.2-1.1.3. With a height of 150 cm and a stretcher height of 40-60 cm, a patient can sit up, and paramedics can lean over the patient based on anthropometrics from Hanson et al. (2009). The sitting height from buttocks to head for a 95th percentile man sitting upright is 100,4 cm. Combined with the lowest possible stretcher height, this results in a total height of 140,4 cm, which is less than the cabin height of 150 cm. This fulfils requirements 1.2 and 1.3.

The distance from the ground to the floor is 80 cm, which fulfils the requirement 1.6. The rear entrance is 160 cm, fulfilling requirement 1.7. The two side entrances are 120 cm wide and 145 cm high. Their width makes it possible to load with equipment from the outside and still enter the UAM without equipment blocking the entrance. It's also wide enough to carry equipment into the cabin. This makes the UAM interior design fulfil requirement 1.8.1-1.8.4.

As described in *Section 6.2.1 - Cabin Design*, tracks are distributed across the floor, walls, and ceiling. This allows equipment and interior components to be securely mounted and fastened. It also makes the entire interior design modular, as furniture and equipment can be easily rearranged or removed when needed.

When designing the interior, dimensions have been tested and adjusted using anthropometric measurements from the 5th percentile female and 95th percentile male to include a large user group.

The seat design was excluded from the Concept Development phase, as it already fulfilled all needed requirements. This includes the two side seats which can rotate 360 degrees, and their translation ranges are shown in the Product specification, see *Appendix H - Product Specification*. As mentioned in *Section 6.2.2 - Seat and Stretcher*, the front seat includes a five-point harness mounted behind the head seat pad lid. This lid can be folded up to function as a backrest for the dashboard seat.

Regarding the stretcher design, one additional feature was incorporated during the concept development phase. Based on insights from the pilot study, it was highlighted that having arm support for establishing intravenous access is very helpful. As a result, an armrest feature was added to the stretcher. As noted in *Section 6.2.2 - Seat and Stretcher,* the final stretcher assembly has a higher stretcher-loading height than the desired height of 100 cm. The proposed stretcher construction has a minimum height of 40 cm, and given an 80 cm clearance from the ground to the UAM floor, the lowest achievable loading height is 120 cm.

Requirement 2.5.8 from the requirement list, *Enable securing scoop stretcher onto stretcher*, has not yet been addressed. However, this is an important aspect to consider in future development.

Routine actions, such as retrieving supplies from a specific storage unit, can be disrupted if placement changes, as highlighted during the evaluation pilot test. To support compatibility between vehicles and allow paramedics to act intuitively based on prior experience, regardless of which vehicle they work in, equipment placement has been established to be as consistent as possible with existing layouts to support routine-based behaviour. Therefore, the final design reflects the current AH and RA layout to a fair extent.

There are many different storage solutions for medical equipment. Equipment in bags can be mounted using straps in the tracks. As explained in *Section 6.2.4 - Storage*, equipment not used often or not needed from the inside can be stored in the rear entrance storage. Loose medical equipment can be stored on the stretcher's drawers or in one of the two ceiling-storage. The front seat also provides great storage possibilities.

The storage volume in the UAM is 0,67368 m^3 in total, which fulfils the set requirement of having at least 0,388 m^3 storage.

The requirements related to details of the concept, for instance 5.1.1, 5.1.3 and 5.1.4, are addressed to a limited extent, and further development is needed before a valid assessment of their fulfilment can be made. However, the incorporation of a physical stop button, displays, and a dashboard provides the necessary prerequisites for meeting these requirements once the functionality has been fully developed.

8.1.3 Scenario

The final interior design will now be described through a narrative, based on the scenario explained in *Section 6.1 – UAM Dispatch Mission*.

1. Dispatch and arrival at Inaccessible Site
An accident has occurred in a remote deforested area, and an Urban Air Mobility (UAM) vehicle has been dispatched to the site to provide emergency assistance. The paramedics board the UAM awaiting them at the Vertiport. Since it is a sunny day, they choose to sit together at the front to enjoy the view during the 20-minute flight to the accident site. The nurse takes the dashboard seat, while the doctor moves their seat from its position beside the stretcher all the way to the front. Before departure, both press their respective buttons to signal to the system that they are ready for takeoff, whereafter the UAM lifts off and starts flying towards the accident site, see Figure 8.6.

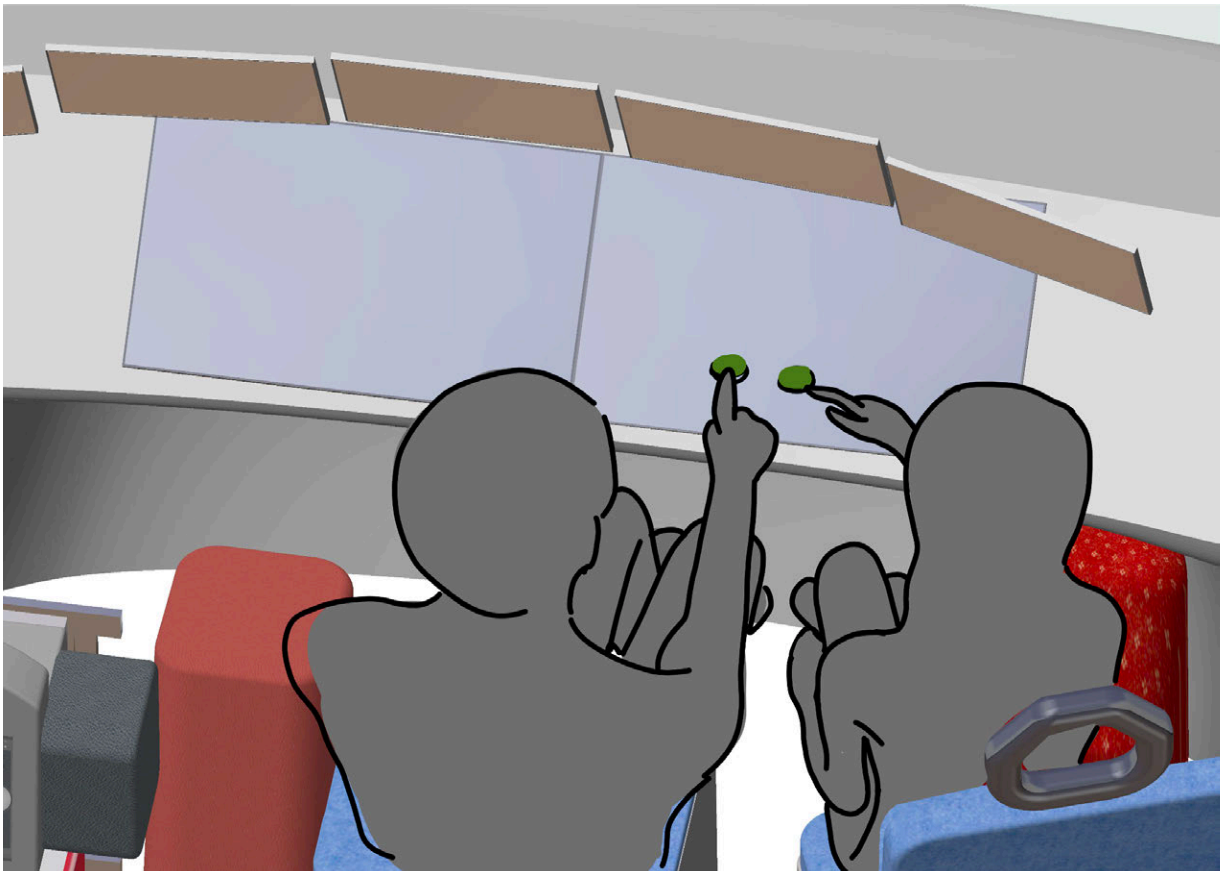


Figure 8.6: Paramedics sitting at the front, pushing each button to confirm to the UAM that they're ready for departure.

2. UAM approaches the accident site
A few minutes before landing, the doctor moves the seat back to its original position, preparing to treat the patient. The UAM approaches the accident site and prepares for landing. The person who made the call accompanies the patient, see Figure 8.7.

Figure 8.7: UAM approaches the patient at the accident site and prepares for landing.

3. The patient is located

After landing, the paramedics exit on each side of the UAM and retrieve their equipment. The nurse brings the Corpuls device to monitor the patient's vital parameters, while the doctor takes the emergency bag containing essential medical supplies. Figure 8.8 illustrates the doctor unloading the emergency bag. They step out first, then reach for the equipment stored inside the UAM at an ergonomic, waist-height level.

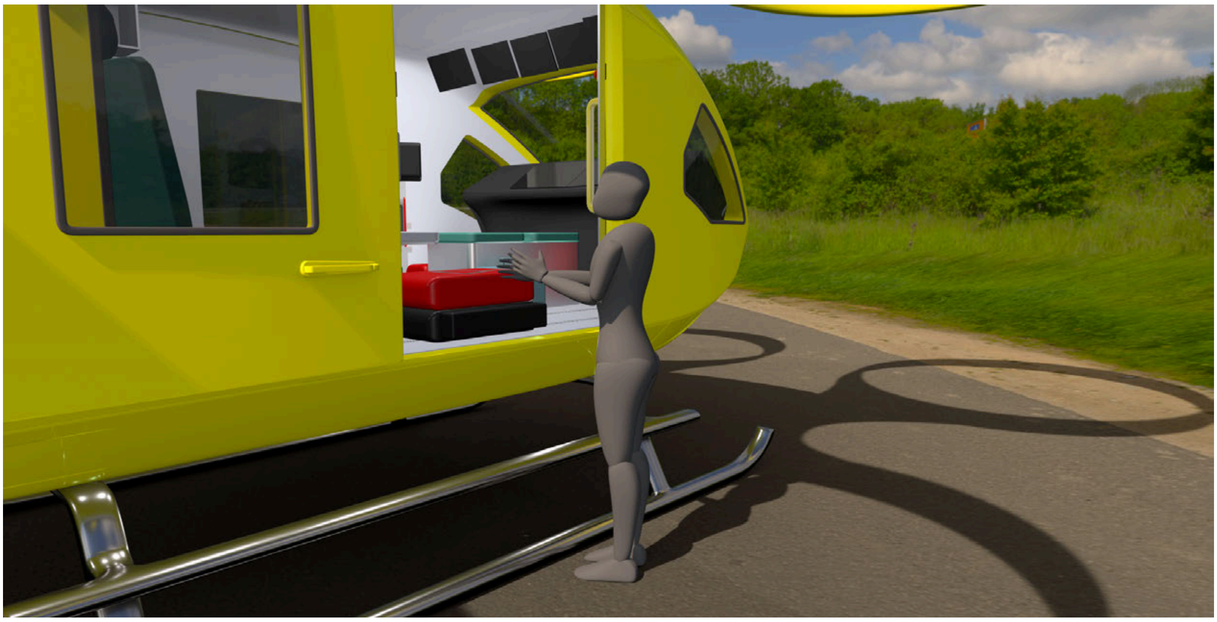


Figure 8.8: The doctor unloads the emergency bag and brings it on the way to the patient.

After having initiated treatment of the patient, placed intravenous lines in the arms, and administered pain medication, the nurse goes back to the UAM to retrieve the scoop stretcher since the patient must be carried. The scoop stretcher is easily retrieved by pulling it out from its compartment in the rear entrance storage, accessed through the rear entrance, see Figure 8.9.

Figure 8.9: Nurse unloads the scoop stretcher.

3. Boarding and departure

The paramedics load the patient into the UAM together, see Figure 8.10, and they are assisted by the ability to lower the stretcher height to 40 cm, resulting in a total loading height of 120 cm. Although the patient is heavy, the large entrance and the possibility to rest the scoop stretcher on the UAM floor edge allow one paramedic to step inside before completing the lift. The nurse follows the patient into the UAM on their left side, while the doctor closes the rear door behind them and enters through the right-side entrance.

Figure 8.10: Paramedics loading the patient into the UAM.

Once seated beside the patient as seen in Figure 8.11, both paramedics fasten their seatbelts and again press their respective buttons to confirm to the UAM system that they are ready for departure. A green light and the message **"UAM is departing"** appear on the dashboard at the front. After lift-off and starting to fly forward, the message changes to **"UAM is cruising, arrival expected in 20 minutes."**.

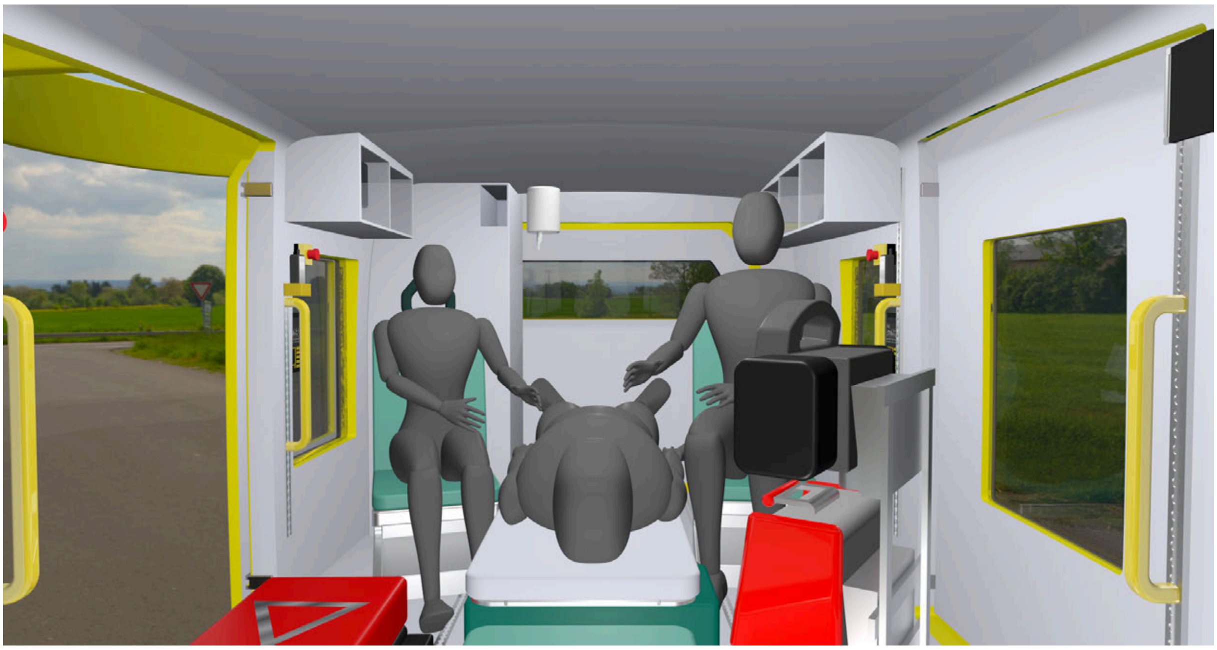


Figure 8.11: The paramedics sit on the side seats and treat the patient.

4. Medical emergency during flight

Halfway through the journey, the patient becomes unconscious. To ensure free airways, the doctor changes to sit at the head seat behind the patient's head to sedate and intubate them, while the nurse manages intravenous medications, see Figure 8.12. The respiratory equipment is right beside the head seat for quick access within immediate reach. To enable both paramedics to monitor the patient's condition, the nurse moves the monitoring devices' rack closer towards the stretcher and rotates it more towards the doctor.

Meanwhile, blood circulation decreases, and the patient eventually goes into cardiac arrest. The nurse initiates mechanical chest compressions with the LUCAS device while managing intravenous medications, see Figure 8.9. The doctor joins in, switching back to their seat beside the stretcher, see Figure 8.13.

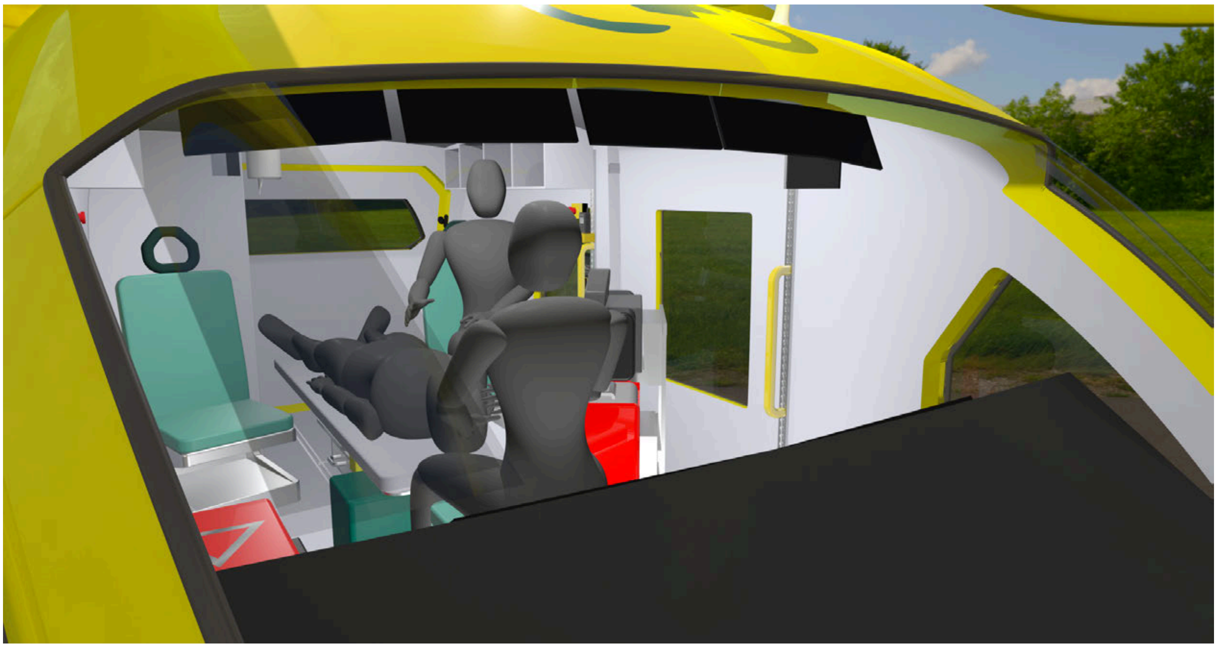


Figure 8.12: Doctor sedates and intubates the unconscious patient while the nurse manages IV medications.

Figure 8.13: The nurse initiates CPR with LUCAS and manages IV medication together with the doctor who has switched back to sit on the side seat.

In a scenario where the LUCAS wouldn't work or be suitable, manual chest compression would be possible thanks to the increased ceiling height. In another scenario, for example, when infusion is needed, the nurse can reasonably retrieve Ringer-Acetate solution from the ceiling-mounted storage on the left side, see Figure 8.14.

Figure 8.14: Nurse taking out medical supplies from the ceiling storage.

5. UAM System Failure Management and Arrival at Hospital

As the UAM approaches the hospital vertiport, it encounters strong winds, causing difficulties with autonomous manoeuvring. In this case, the nurse detects the issue and presses the stop button, shifting control to manual override, see Figure 8.15.

Figure 8.15: Nurse pushes the stop button on the wall next to the right-side entrance, to override the autonomous system, making the UAM top and hover in the air.

The doctor moves to the dashboard seat and manually inputs the landing commands via the dashboard, after which the UAM successfully navigates the turbulence, see Figure 8.16. It would be possible for the nurse to do it as well, either by passing between the stretcher and head seat, or if the doctor sits on the front seat, by moving the monitoring devices' rack all the way to the front and passing between the rack and dashboard seat. However, it is very unlikely that intubation of the patient during flight simultaneously as an emergency stop occurs. Besides, in these cases, intubation can be completed before giving new commands via the dashboard since the UAM will just stay still in the air. Upon landing, hospital personnel meet the paramedics and take over care of the patient for further treatment.

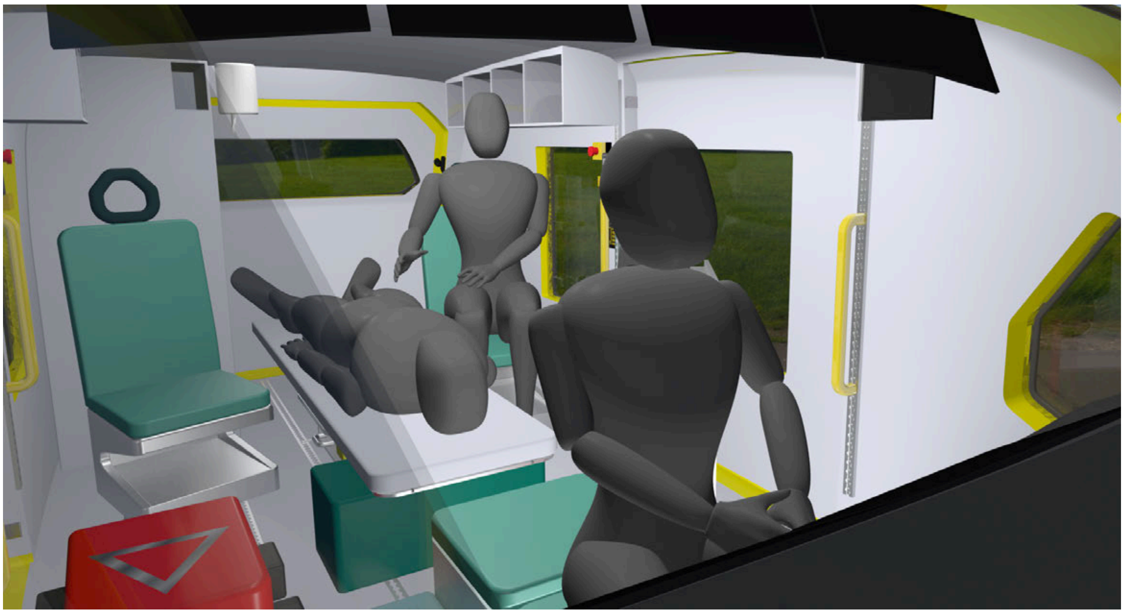


Figure 8.16: Doctor moves to the dashboard seat to manually input landing commands during turbulence.

8.2 Equipment List

The second delivery of this project is a complete list of all equipment that is recommended to include in the future UAM, see *Appendix G - Equipment List*. Below is the most important equipment that is included in the CAD model of the UAM interior, see Figure 8.17. Certain small-volume supplies and seldom-used equipment have been excluded from the CAD model, but are detailed in the Equipment List.

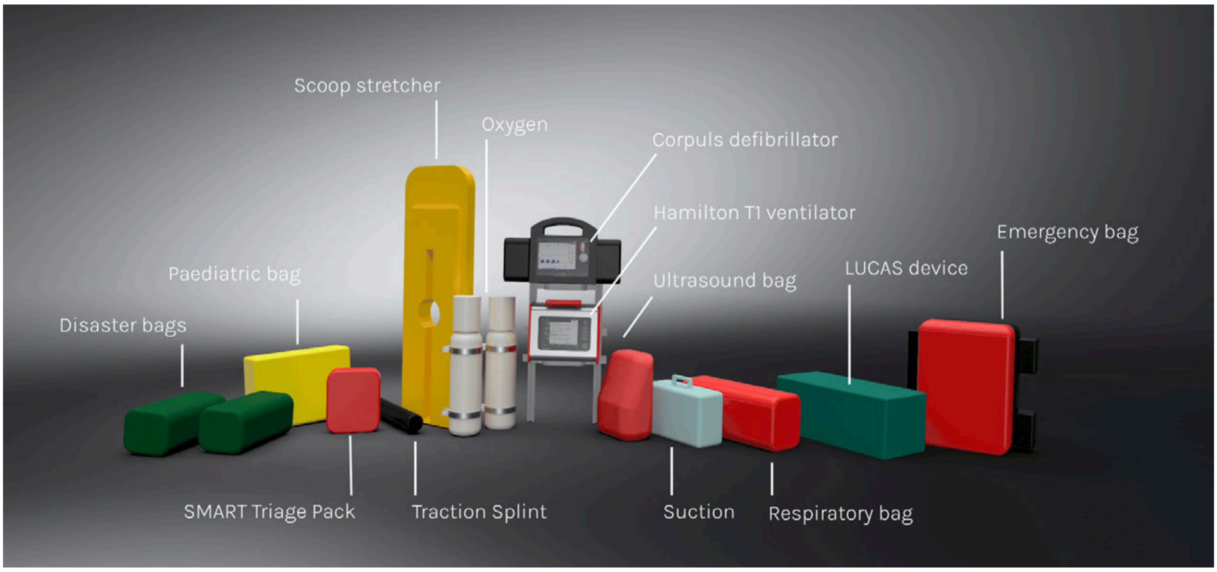


Figure 8.17: All equipment included in the CAD model visualising the concept design.

8.3 Product Specification

This deliverable presents a comprehensive specification of the final concept, detailing all components and their attributes, organised according to the defined design modules. The complete specification is available in *Appendix H – Product Specification*. It includes precise measurements such as dimensions, weights, and volumes and the functionality for all parts is stated. Additionally, the product specification contains technical drawings and visualisations to support the understanding of the CAD model.

9 Discussion

The strengths and limitations of the methods, their execution, and results are presented in each of the sections: User Research, Concept Development, and Final Result.

9.1 User Research

This section discusses the methodology, execution and results of the user research.

9.1.1 Methods and Execution

During the research phase, the involvement of paramedics working in prehospital care was central. Much of the reasoning behind the final design is based directly on insights gained from the users themselves. As we initially had limited knowledge about prehospital emergency care services, conducting research and learning from experts was a high priority.

Regarding the target users, both RA and AH paramedics within the prehospital field were included in the user research. This was essential, as the UAM is intended to function as an intermediate solution between a road ambulance and an air ambulance. While RA and AH paramedics sometimes shared similar preferences, there were also notable differences in certain aspects. Including the perspectives of both groups contributed to a more comprehensive understanding and strengthened the foundation for the design process.

During the AH field studies, only one type of helicopter, Leonardo AW169, was observed. Since the Airbus H145 is also commonly used for prehospital dispatches in Sweden, investigating the solutions implemented in that model could have enhanced our understanding of existing designs and broadened our perspective. However, the client did not consider it necessary to visit helicopters from other regions, as the final concept is intended specifically for VGR, making it most important to ensure their satisfaction. Another reason for not including other helicopter types was that the Leonardo AW169 served as a suitable reference for spatial dimensions, while the Airbus H145 is smaller than desired. Travelling to observe other helicopter types would also have required significant time and a logistical effort.

Regarding the survey, it was distributed to all regions operating a helicopter ambulance. However, not all regions responded and aside from VGR and Region Värmland, very few AH paramedics participated. Involving a larger number of paramedics, both AH and RA, would have strengthened the user research. In particular, including more AH paramedics from additional regions could have improved the reliability and representativeness of the findings. Future research could benefit from incorporating co-creation or design sessions in collaboration with paramedics to gain deeper insights. It is also worth noting that AH paramedics particularly had limited availability. As each region typically operates only one helicopter, and its crew must be ready for dispatch at any time, scheduling meetings proved to be a significant challenge.

A key area where a deeper understanding would be beneficial is the use of medical equipment during helicopter missions. One example of a misunderstanding that arose during the research was the assumption that AH paramedics typically perform intubation at the head of the patient during flight. In reality, this is rarely the case, as such procedures are usually completed before departure. This highlights a broader gap in our understanding of how equipment is used in practice, particularly in the constrained environment of the helicopter. Gaining more detailed insights into equipment handling, usage routines, and spatial limitations would strengthen the design process and ensure better alignment with real-world practices.

Another potential improvement to the user research would be conducting a contextual inquiry by observing paramedics during actual dispatch missions. However, due to strict weight limitations in the helicopter, it was not feasible for researchers to accompany the crew. An alternative approach could involve recording missions to allow for later observation and analysis. This method would require careful ethical consideration to ensure that patient privacy and data protection are fully maintained. If handled appropriately, such recordings would provide valuable contextual data and support a deeper understanding of the work environment and workflows.

9.1.2 Result

When analysing the results from the user research, it became evident that the responses were quite biased. In general, paramedics tended to favour the solution already implemented in their Region, particularly concerning storage solutions. For instance, AH paramedics working in the Leonardo AW169 preferred having access to the scoop stretcher via the side doors or an exterior storage, whereas RA paramedics preferred access via the rear door. It was also notable that paramedics who worked in vehicles with transparent storage hatches advocated for this, while other were more neutral. This was something we noticed and remained aware of throughout the design process. In cases where opinions differed, the VGR paramedics were generally prioritised since the UAM is intended for use in VGR.

It was also observed that the AH paramedics were strongly focused on the solutions currently in use, and it was evident that they had rarely considered alternative design ideas. Since their opinions and ideas aligned with their existing solutions, this might have affected the final design, as most decisions were based on the paramedic's input.

Overall, the survey results aligned with the literature review, increasing the reliability. The same goes for field studies.

An important aspect to consider when analysing the results from the user research is that the role of paramedics within the UAM will differ from their current responsibilities. When questions regarding interior design, equipment, and workflow were posed, the responses reflected today's prehospital paramedic role. Notably, AH paramedics do not perform tasks related to monitoring and controlling the vehicle, as these responsibilities lie one the pilots. Designing for a role that does not yet exist is challenging, as there are no existing experts to consult. Therefore, we had to listen carefully to the paramedics' insights, consider their perspectives, and make several assumptions. If the UAM paramedic role was already established, gathering input from those individuals would undoubtedly be very valuable.

The user research, along with an analysis of current emergency vehicles and other relevant products on the market, greatly contributed to understanding both user needs and technical aspects. This research played a crucial role in defining the requirements list, as it addressed key user perspectives, technical constraints, and other essential factors. Since one of the main aims of this project was to develop a solution that aligns with the paramedics' needs and expectations, the emphasis on user research provided a strong foundation when setting the requirements.

9.2 Concept Development Process

The design process presented in this report is more linear than the actual process that took place. This structure was chosen to make the report easier for the reader to follow. In practice, the design work was still divided into the design modules that had been presented; however, the process was significantly more iterative, and sometimes several modules were developed simultaneously. As most components and parts in the UAM interior are interconnected, a change in one area often requires adjustments in others. Despite this complexity, the design process effectively supported the goal of developing the interior layout.

We worked closely with the exterior team throughout the entire project, particularly during the concept development phase. While both teams had their ideas, goals, and requirements, the designs needed to align to form a coherent overall concept. This required continuous adaptation and, at times, prioritisation when conflicting requirements arose. This collaborative dynamic was one of the key reasons behind the many iterations in the process. As new requirements emerged on both sides during the project, continuous communication, regular updates, and validation of design decisions were essential to ensure alignment and feasibility across the teams.

This project marked our first experience designing an entire interior space, rather than a single object, interface, or workflow. To ensure we focused on the right aspects, we began with a broader perspective, starting with the overall cabin layout before gradually refining individual elements such as seating, stretcher placement, storage solutions, and finally, the smaller design details. This approach proved valuable in creating a concept that meets the identified requirements.

At the beginning of the concept development phase, using scale modelling with cardboard and 3D printed objects helped to iterate ideas and quickly test them. Having seats, a stretcher and equipment loose made it possible to rearrange them to try new configurations. It also allowed quick modifications. The scale model also worked well as a mediating object when discussing ideas with the exterior team and client.

Building a 1:1-scale prototype greatly supported the design process. The hands-on approach enhanced ideation, as the design and functionality of each component evolved alongside its physical construction. It enabled us to better understand the spatial constraints, test various layout solutions, and conduct a more reliable user re-evaluation. The prototype also facilitated ergonomic analysis, assessment of reachability, and evaluation of the forward visibility from different seating positions.

Using CAD programs as an aid to visualise the interior design and functionality helped us understand the design, evaluate it and present it to others. CATIA was mostly used, but some complex surfaces were made using Autodesk Alias. During the concept development phase, CAD proved to be both effective and efficient, allowing the rapid creation of low and medium-fidelity models of furniture, storage, and equipment. These models were used to test and explore different spatial configurations and design options quickly.

The final concept draws inspiration from the design of current road ambulances and helicopter cabins. However, there is a risk in simply replicating existing solutions that may soon become outdated, rather than using the opportunity to develop a more innovative layout. This concern is partly addressed through the integration of modular tracks in the floor, ceiling, and walls, which allow interior components to be updated or reconfigured as needed. This flexibility also supports adaptation to various use cases, such as transportation of medical equipment and personnel to accident sites, as in the ADAC Luftrettung Multicopter project (ADAC Luftrettung, 2020).

Furthermore, findings from user research and evaluation indicate a high level of satisfaction with the current configurations, particularly the Leonardo AW169 helicopter and road ambulance vans. The paramedics participating in the final evaluation were also positive towards the proposed UAM interior. As experts in prehospital care, paramedics have the in-depth knowledge of how to provide effective treatment and what environmental factors best support their work. This implies that prioritising highly innovative or futuristic redesigns over proven layouts is not justified at this stage.

9.3 Deliverables

The final interior design fulfils the key requirements, as explained in *Section 8.1.2 - Fulfilment of Requirements.*

Regarding the stretcher's loading height, it is 120 cm at its lowest, which doesn't meet the desired 100 cm, as also brought up in *Section 8.1.2 - Fulfilment of Requirements.* This results in a loading distance that is 20 cm above the desired level. To address this discrepancy, *Section 6.2.2 - Seat and Stretcher*, proposes to modify the stretcher design by either adopting three extendable support pillars instead of two or eliminating the under-stretcher drawers. If the minimum stretcher loading height can be reduced to 100 cm, it would offer ergonomic advantages for the paramedics working in the UAM. To determine the most ergonomic loading height more precisely, further investigation using ergonomic data and analysis would be beneficial.

During concept development, various solutions for the stretcher construction were explored to ease stretcher loading. Unfortunately, none of them proved feasible within the UAM's constraints. A deployable ramp would obstruct interior space and could not reliably accommodate variable ground conditions or elevation changes. An electric stretcher lift would be too heavy.

Using CAD to visualise the final concept was extremely valuable. In Autodesk Alias, complex surfaces for the interior cabin and dashboard were modelled with precision. These surfaces were then integrated into Catia V5, where additional components such as storage solutions, seats, the stretcher, equipment, and details were developed. The use of constraints ensured that each item was placed accurately within the space. To demonstrate the functionality of key elements, mechanisms were incorporated to simulate real-world movements such as the translation of the side seat and the adjustable height of the stretcher. This approach not only enhanced the realism of the design but also made the final interior concept easier to present and explain.

Regarding the equipment list, it is important to keep in mind that it is only a proposal based on user research, development, and evaluation. However, we want to point out that we are not experts in this field, and the final decision on what equipment to include is up to the AMES project, including VGR. That said, the proposed list is something we actively used throughout the design process to make sure that all the equipment included can be efficiently and safely stored in the UAM.

Of the 46 included pieces of equipment, the weights of 15 are known, totalling 90 kg, see *Appendix G - Equipment List*. However, the total interior weight remains uncertain due to the unknown weight of the furnishing and detailed components, which lie outside the scope of this project. Additionally, it was noted that paramedics perceive the current layout as spacious and well equipped. This indicates a potential for reducing the amount of equipment if the total weight turns out to be too high.

The product specification was made to provide the opportunity to see final dimensioning, specific placement and illustration of key functionalities. The specification only includes the interior solution developed in this project, and makes it easier to continue developing the concept in the future.

9.4 Evaluation

The evaluation is discussed regarding both methodology and execution, as well as the outcome and what might have affected the results.

9.4.1 Methodology and Execution

Field study insights were gathered from both AH paramedics and one RA paramedic. Their complementary perspectives contributed to a deeper understanding of the prehospital care system and helped identify both shared and differing needs, which informed the development of solutions suitable for both user groups.

The project benefited from spontaneous user feedback on ideas during the project process, which enabled rapid iterations and continuous refinement of the concept without spending excessive time on infeasible ideas.

A limitation of the evaluation session, however, was that no AH paramedics were able to participate, meaning their perspectives were missing at this stage. The perspectives of the RA paramedics were of great value as it may differ from AH paramedics, as reflected in the survey responses. For future evaluations with users, we suggest scheduling sessions at least one month in advance to ensure a high number of participants and thus achieve a stronger basis for drawing conclusions and making decisions that impact the solution. It is especially important to complement the current insights with the perspectives of AH paramedics as they are the target user group of the future UAM.

Being inside the prototype offered a highly tangible and immersive experience for the participants of the evaluation. A limitation of the pilot test was that the participant was a medical student without experience in prehospital care. While this provided useful insights, it cannot fully represent the perspective of paramedics.

There were plans to distribute an evaluation survey via mail to paramedics that participated in the first survey and shared their contact information. Due to time constraints, it was unfortunately not possible to conduct at that moment. This would be a great opportunity to involve more users, from many regions, and overcome the challenge of conducting a physical evaluation.

9.4.2 Result

The results of the final evaluation may have been influenced by the fact that the 1:1 mockup was made out of cardboard and had low fidelity. This also applies to the functionality of the interior elements, while some features could be simulated, the mockup did not fully convey the intended experience. As a result, the mockup may have negatively affected the outcome, since it did not accurately represent the final design. On the other hand, the low-fidelity nature of the prototype might have had a positive impact. Because it appeared unfinished, respondents may have felt more encouraged to provide feedback and critique, as it signalled that changes were still possible. This openness can lead to more honest and constructive input during the evaluation process.

One source of error that may have had, even if minor, an impact on the results is the fact that not all dimensions were entirely accurate. Some elements appeared either larger or smaller than intended, which could have influenced the experience of being inside the UAM and interacting with the interior.

9.5 Ethical considerations

The ethics of taking EMS personnel's time to support the project have been considered. User studies have been conducted without affecting the EMS personnel's work, as we adapted the studies to when they were free and not engaged with patients. For instance, the second field study had to be rescheduled due to a dispatch mission.

Furthermore, contact details have not been collected unless necessary, and the use of photos taken during field studies has been handled in concern of confidentiality. Photos of paramedics were avoided and all personal data has been managed in accordance with GDPR, following Chalmers' guidelines. Survey respondents also had the option to provide their contact information for potential future participation in evaluations, where personal data was handled in the same way.

It is important that the UAM interior is designed so that paramedics can continue to work in line with prehospital care practices. Changes should not be made without reason, since that poses a risk of deteriorating their working environment. The design should reflect their profession and be suit their needs. While a futuristic interior is not a problem, it should not compromise the paramedics' ability to provide care. The primary goal is for the design to serve their needs and enhance their work.

The selection of equipment is a significant responsibility of engineers, as it is crucial that EMS personnel have the necessary tools to treat patients effectively. Therefore, it was essential for us to develop a thorough understanding of the scenarios in which the UAM will be used. This ensures that the equipment can be chosen appropriately and thoughtfully, based on the correct assumptions and requirements. Furthermore, involving the paramedics in the decision-making process is crucial to ensure the solution is adapted to reality.

Involving the paramedics is also a way of respecting their competence and ability to contribute to the design that they rely on to perform their work. When further developing the proposed concept of this project, paramedics should be involved in the design process to a broader extent, to give them the chance to influence their working environment. A challenge is finding a form of participation that includes them effectively, as they would likely need to sacrifice their free time.

9.6 Sustainable development

To minimise resource use, materials such as plastic, textiles, and cardboard from discarded packaging, as well as items from bulky waste, were collected and reused for prototyping. This approach supported a sustainable development process, both economically and ecologically, as the resources were almost exclusively reused.

This meant a limited range of materials, as we used what we found, which forced us to think innovatively and find clever solutions with the resources available. The scarce resources posed a challenge but also strengthened our creativity. The threshold for experimentation was reduced as mistakes resulting in having to rebuild components had minor consequences.

The sustainability of the interior solution itself depends highly on further development of the construction in terms of material use and material selection. One aspect considered during the development was modularity, where the use of tracks allows interior components to be transferred between vehicles, ultimately reducing the need for new production when UAM vehicles are updated.

However, the most significant environmental and economic impact will likely stem from the development of the autonomous system and vehicle itself, rather than the interior components. Economically, the UAM will be cheaper than a helicopter, and it has great potential from a social sustainability perspective, as described in *Section 1 - Introduction* and *Section 2 - Background*.

9.7 Future work

The next step for the AMES project to take on the development process of this concept is to design each component in detail. This includes defining the detailed design of each component, construction in CAD, prototyping and testing, and material selection. In parallel, established components such as tracks and helicopter seats can be purchased and incorporated into a high-fidelity prototype. Validation of the concept by engineers from different fields is recommended to ensure feasibility and air safety. The solution and prototype should be iteratively evaluated with personnel working within EMS.

As part of further development and construction of the proposed solution, the weight should be established to determine whether the amount of equipment must be reduced. To support this assessment, comparing with the weight limits of other UAM projects, such as the ones described in *Section 2.1.4 - UAM can Improve Emergency Services*. In such cases, equipment categorised with importance levels 1 and 2 in the Equipment List should generally be prioritised.

We recommend involving other regions in the development process since the perspectives of paramedics following other work routines in other helicopter models would provide invaluable insights for improving the solution. This approach would bring the possibility of extending the future implementation of UAM to multiple regions and eventually countries, as it is adapted to a wider user base.

Components related to the human-machine interaction need further development, including stop buttons, dashboard, displays and radio communication devices, to establish an intuitive and user-friendly interface that is adapted to the emerging role of combining patient treatment and vehicle monitoring. Furthermore, it should be assessed whether the stop-button functionality should be realised through a physical stop button or if alternative technologies could be employed.

To cover a broad range of missions, the characteristics of priority 3 missions should be further investigated to validate that the UAM concept meets the specific needs associated with these scenarios. What has been revealed so far is that paramedics are experts at adapting to a wide variety of situations. As long as they have access to essential equipment, they are creative and resourceful in solving the situations they are facing.

In the long term, the expansion of the use of UAM within EMS in VGR should be explored to investigate how an extended network of UAM vehicles could address a variety of use cases. These may range from patient treatment to the rapid delivery of additional personnel or equipment to accident sites. UAM could also be used to evacuate people from disaster areas where roads are blocked.

10 Conclusion

This project has explored how the interior of a future UAM vehicle for prehospital emergencies should look to support the medical unit, enhancing a user-friendly and ergonomic design that fulfils the medical personnel's needs and desires. At the beginning of the project, the following research questions were formulated to support achieving this aim:

R1: What equipment should be implemented in the interior?

R2: What interior features fulfil the EMS paramedics' needs and expectations, in terms of functionality and user experience?

R3: How should the interior be designed to be effectively integrated with the UAM's exterior while supporting the paramedics' workflow?

Regarding R1, the equipment list, see *Appendix G - Equipment List*, is a proposal of what should be included in the UAM, based on user research and iteration.

For R2, the final design meets nearly all of the identified needs and expectations of EMS paramedics. Naturally, this is somewhat subjective, as needs, expectations, and preferences vary between individuals. This variation was evident in the user research, where different paramedics expressed differing preferences for various solutions. However, with a focus on paramedics working in VGR, the final design supports the key needs that were identified. These include seating arrangements, stretcher functionality, storage capacity, entrance dimensions, and window placement. One requirement that is not fully met in the current design is the stretcher-loading height, which is mentioned. Additionally, several detail-level functions require further development.

Overall, the evaluation indicated that the paramedics were both pleased and impressed with the final design. Ergonomics has been considered throughout the interior layout and iteration process, but further specific analysis is recommended to verify that the interior accommodates good ergonomics conditions. Currently, the stretcher represents the primary ergonomic improvement. Its design enables paramedics to sit comfortably with adequate legroom beneath it. Furthermore, the adjustable height feature helps ensure an optimal working position. While the final design may not address every single need or expectation, it provides a strong foundation and direction for future development and iterations.

Regarding R3, the final design is explained in *Section 8.1 - Final Interior Design*. The Product specification presents dimensions and key functions, see *Appendix H - Product Specification*. To summarise, the interior cabin design is well integrated with the exterior design. As a result of close collaboration with the exterior team, the final UAM design fulfils the paramedics' key needs and desires. Placement of entrances and windows fulfils the requirements regarding workflow, desires and safety. The interior features the stretcher positioned centrally, with one seat on each side. At the front of the cabin, the front seat serves as both the head seat and the dashboard seat. This configuration allows all necessary elements to fit within the cabin without disrupting the workflow. The interior also has great storage possibilities.

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Appendix A – AH Field Studies

A.1 Field Study I Guide

Interview

Scenarios

- What is your attitude towards an EMS UAM?
  think about different contexts, environments, accident types, injuries
- Can you think of any cases where an emergency UAM would be the most suitable option?
- How much time does an emergency response/call usually take?
    - How are they seated when in the air?
    - Do they feel tired after sitting like that?
    - Can you move during flight? when in the air

Storage

- What type of storage solution do you prefer?
- Modularity - what do you want to be able to move? how much movement is needed?
- Is the current equipment placement effective?
- Can items be accessed with one or both hands?
- What's the priority order in terms of accessibility?
- Should storage solutions be transparent or opaque?
- Is it important for personnel to see the contents of drawers at a glance?

Equipment

- Are there any equipment that need to be accessible both from inside and outside?
- Which equipment is used most often and the least?

Aesthetics

- Can the lighting be adjusted?
- When and why is lighting changed?
- Is there any colour-coding and if so, what's the rationale behind?

Observation

- Measure and document storage volume
- Note dimensions, weight, and mounting of all equipment, furniture, and power outlets.
- Measure headroom and estimate comfortable clearance above personnel's heads.
- Observe staff movement: note any awkward reaching or stretching.
- Identify equipment that must be within easy reach and assess current mounting security.

A.2 Field Study II Guide

Observations

- Measure and document storage volume missed in Field Study I
- Measure and document equipment missed in Field Study I

Interview

Workflow

- Are there situations where you would want to switch places?
    - Is the ability to switch seats a desired function in the UAM?
    - If yes, how would you like to switch places?
- In how many cases, and for how long, does the doctor sit behind the patient's head?

Retrieval of Scoop Stretcher

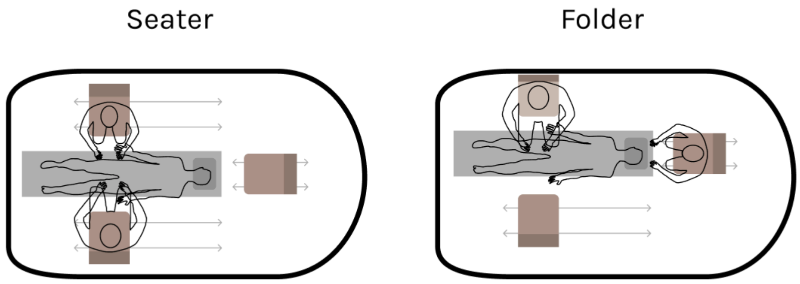
- Where in the UAM would it be suitable to store the scoop stretcher?
- At what point in the process is the scoop stretcher typically retrieved from the AH?
- Do you leave any doors open during treatment or transport?

Patient integrity

- Are there any patient integrity concerns with having many windows?
- How much visibility should the windows allow to maintain patient privacy?

Evaluation of seat-stretcher configuration

- What are the advantages and disadvantages with each seat-stretcher configuration?
- Which one do you prefer and why?
- Which problems may arise with these configurations?
- What's your attitude towards having a foldable seat?
    - What are the advantages and disadvantages?
    - What would you like to have under the seat?
    - Should the seat be on the doctor's or nurse's side? Who needs the most space?



Appendix B – RA Field Study

Observations

- Measure and document storage volume
- Measure and document equipment

Interview

Workflow

- Is it generally easy to do things correctly, or are there aspects that make tasks difficult, cumbersome, hard to see, or hard to locate?
- Have you made any custom modifications or adjustments to the ambulance since receiving it from the manufacturer?
- How do you typically exit the ambulance? In what order do you bring out or collect equipment?

Seats and stretcher

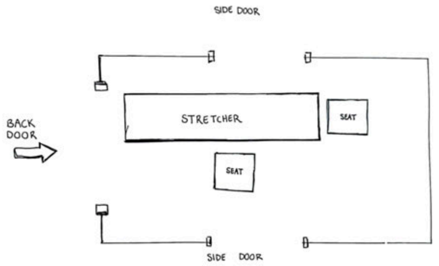
- How do fixed seats affect your work? Have you had to adapt your working methods as a result?

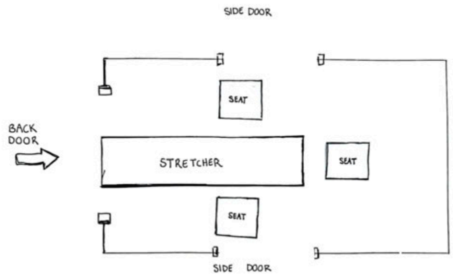
Storage

- Should storage solutions be transparent or opaque?
- Is it important for personnel to see the contents of drawers at a glance?
- Are there any problems related to the current placement of equipment?

Evaluation of seat-stretcher configuration

- What are the advantages and disadvantages with each seat-stretcher configuration?
- Which one do you prefer and why?
- Which problems may arise with these configurations?
- What's your attitude towards having a foldable seat?





Appendix C – Survey

1. What's your job title?

The work in the helicopter

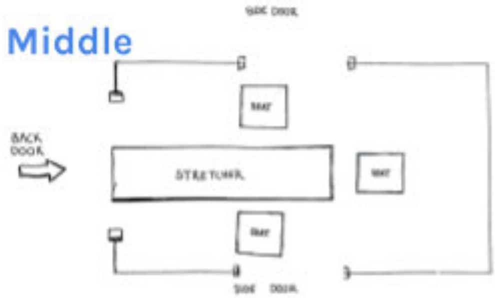
This section covers questions related to the work in the helicopter.

2. **What's your experience with the current ceiling height? Please include your height in your response.**
   free text answer

3. **What equipment do you <u>need</u> to have within reach while seated with your seatbelt fastened?**
   free text answer

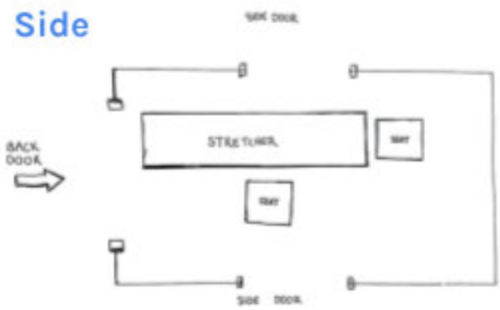
4. **What equipment do you <u>not need</u> to have within reach while seated with your seatbelt fastened?**
   free text answer

5. **What advantages/disadvantages do you see with this layout for the placement of the stretcher and seats?**



   free text answer

6. **What advantages/disadvantages do you see with this layout for the placement of the stretcher and seats?**



   free text answer

The furnishing

This section covers questions related to the helicopter's layout and interior.

7. **What functions would you like the seat to have?**
   free text answer

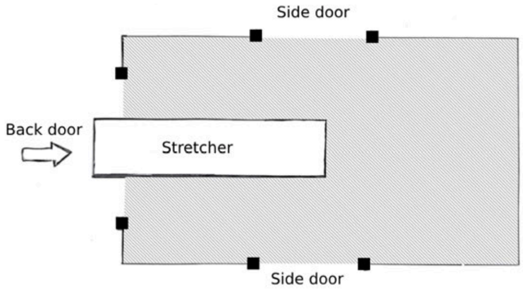
8. **What type of built-in storage solution do you prefer?**
   free text answer

9. **Would you like the stretcher's height do be adjustable?**
   - ☐ yes, that is a strong wish
   - ☐ sure, that could be beneficial
   - ☐ no, don't see a need for it
   - ☐ doesn't matter
   - ☐ *free text answer*

10. **Do you want any compartments or drawers to be transparent so that the contents are visible?**
    - ☐ yes
    - ☐ no
    - ☐ doesn't matter
    - ☐ *free text answer*

The UAM doors

The UAM will have a rear door through which the stretcher is loaded in and out. There will also be a door on each side for personnel to enter and exit. If needed, the scoop stretcher can be brought in through a side door and placed on top of the main stretcher, for example in difficult terrain where the rear door is blocked.

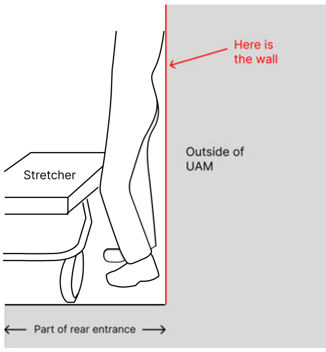


11. **How should the paramedics enter the UAM?**
    - ☐ both paramedics though rear door
    - ☐ at least one paramedic through rear door, doesn't matter who
    - ☐ doctor thorough rear door, nurse through side door
    - ☐ nurse through rear door, doctor through side door

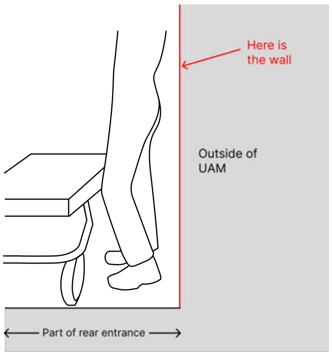
☐ both through side doors

12. What's the smallest possible width of the rear door?

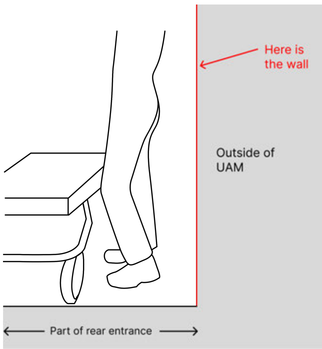
The stretcher is always brought in through the rear door. The images below show the clearance between the stretcher and the wall, which is the same on both sides of the stretcher.



120 cm



130 cm



140 cm

- ☐ 100 cm
- ☐ 110 cm
- ☐ 120 cm
- ☐ 130 cm
- ☐ 140 cm
- ☐ 150 cm
- ☐ 160 cm
- ☐ no opinion
- ☐ *free text answer*

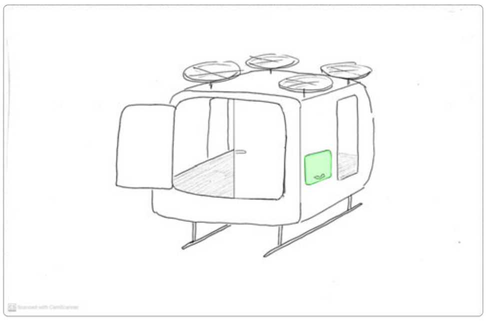
13. What's the smallest possible width of the side door?

Sidodörren används för in- och utstigning av personal, och vid behov inlastning av skopbår.

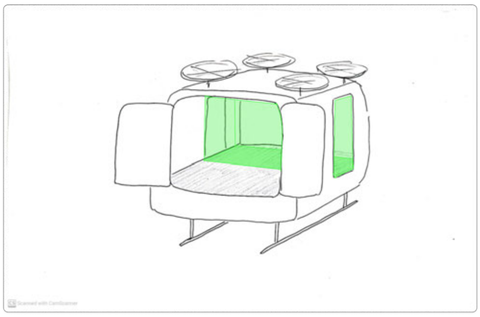
- ☐ 80 cm
- ☐ 90 cm
- ☐ 100 cm
- ☐ 110 cm
- ☐ 120 cm
- ☐ 130 cm
- ☐ 140 cm
- ☐ no opinion
- ☐ *free text answer*

14. How would you like to access the scoop stretcher?

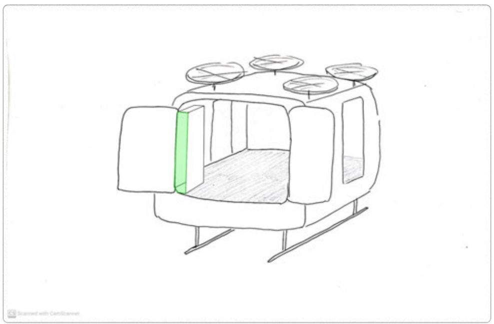
- ☐ in exterior storage



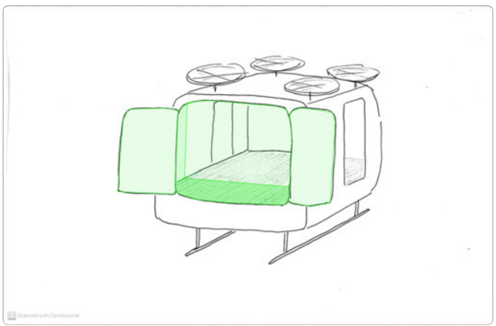
- ☐ via side doors



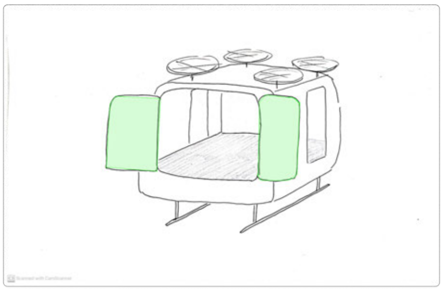
- ☐ via rear door, only accessed from outside



- ☐ from inside and from outside via rear door



- [ ] on inside of rear door



- [ ] no opinion
- [ ] *free text answer*

Aesthetics

15. Select your <u>favourites (maximum 3)</u> based on the aesthetic experience.
Focus on colour, lighting, and materials, as well as the overall atmosphere the style conveys, without considering the interior layout or equipment.

1

2

3

4

5

6

7

8

multiple choice answers between 1-8

All images were rendered using AI softwares Vizcom and Adobe Firefly.

16. Please elaborate what you liked/disliked with the different images
free text answer

17. Do you have any other thoughts, ideas, or suggestions regarding the interior? Is there anything specific you think we should consider?
free text answer

Appendix D – Requirement List

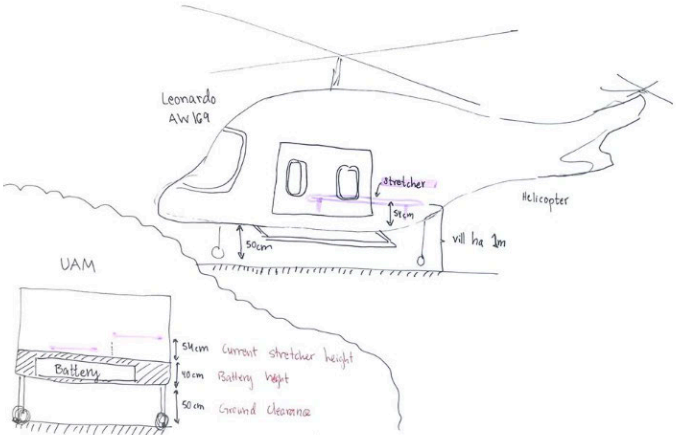
Importance
N – Necessary
D – Desired

No.	Requirement	Description	Measurements Other	 Weight (kg)	 Dimensions (cm) Width x Length x Height	Importance
1	**Cabin Design**					
1.1	Dimensions					-
1.1.1	• Max. outer dimensions				235x571x238	N
1.1.2	• Width				200	N
1.1.3	• Length				≥350	D
1.1.4	• Height				150	D
1.2	Clearance stretcher – ceiling	Patient must be able to sit up and parademics must be able to lean over patient			1000	D
1.3	Clearance head – ceiling	Paramedics can sit up straight			10-20	D
1.4	Battery cell thickness				20	N
1.5	Ground clearance				50	N
1.6	Distance from ground – floor level	ergonomic height			50 ≤ x ≤ 90	D
1.7	1 rear entrance				140 ≤ x ≤ 200	N
1.8	2 side entrances					N
1.8.1	• Width				100 ≤ x ≤ 120	N
1.8.2	• Height				145	N
1.8.3	• Enable equipment to be loaded from the outside into the cabin without obstructing the entrance					D
1.8.4	• Provide sufficicent space for personnel entering while carrying equipment bags					D
1.9	Doors must be openable with one hand					N
1.10	Windows must provide a clear view of outside					~~N~~
1.10.1	• of sides					N
1.10.2	• of front					D
1.10.3	• of the ground					D
1.11	Window on each door	For good sight	1		B: 40-70 H: 40x70	D
1.12	Windows next to each seat	For escape and sight	1 ≤		60x60	N
1.13	Accomodate for anthropometric measurements	5% female to 95% male				D
1.13.1	• 5% female			50	1562	D
1.13.2	• 95% male			103	1902	D
	Tracks					N
1.14	• in ceiling, along walls and floor for attatchment of components					N
1.14.1	• to ecuring furnishing, storage and equipment					N
1.14.2	• allow translation along tracks					N
2	**Seats and Stretcher**					
2.1	2 helicopter seats	One certified helicopterseat on each side of the stretcher				N
2.1.1	• five-point harness					N
2.1.2	• fixed headrest					D
2.1.3	• fixed backrest					D
2.1.4	• fixed seat-floor height				35	D
2.1.5	• enable translation along L-tracks	along stretcher				N
2.1.6	• enable rotation		360°			N
2.2	Allow access to patient's both sides					N
2.3	Possibility of sitting behind patient's head					N
2.3.1	• provide storage possibilites	increase the amount of equipment within reach				D
2.4	Possibility of sitting at the dashboard					N
2.4.1	• five-point harness					N
2.4.2	• backrest					N

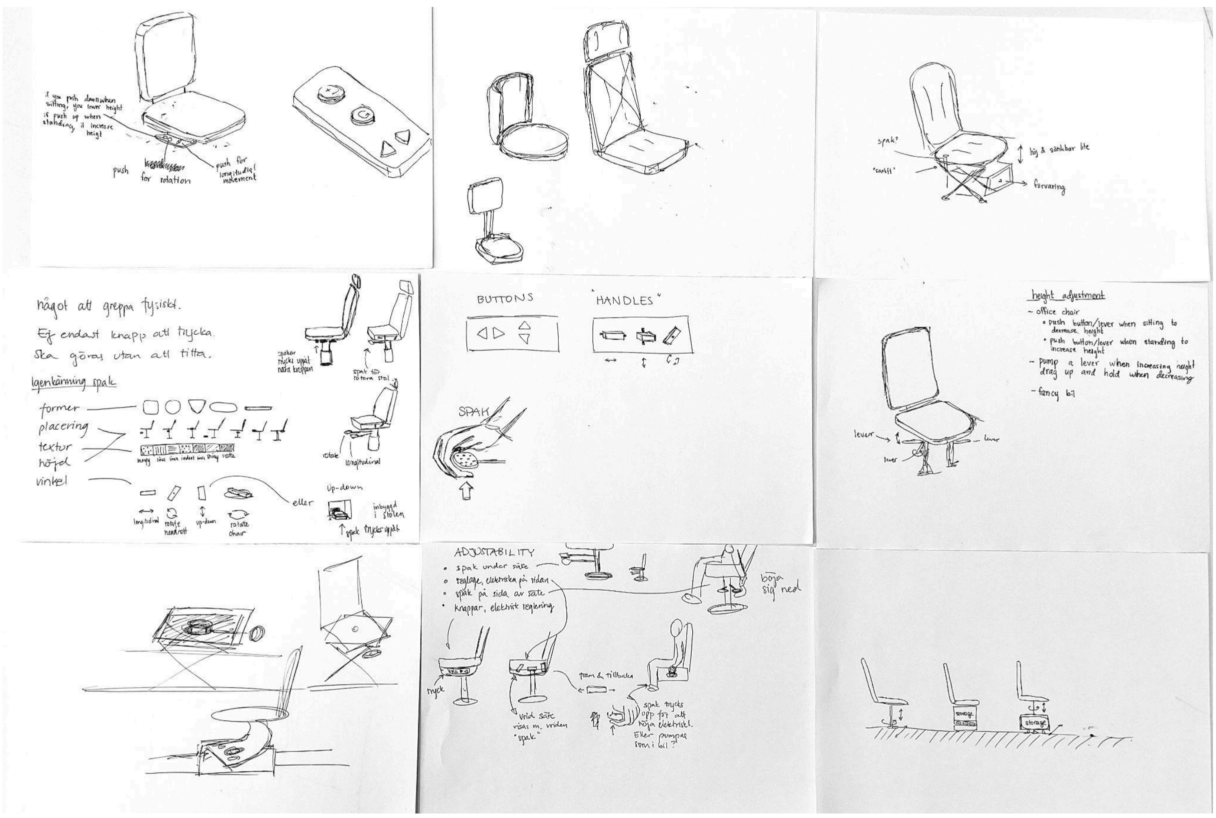
2.5	1 stretcher					N
2.5.1	• standard height				55	N
2.5.2	• adjustable height	provides better ergonomic prerequisites , when seated and when loading/unloading			40-55	D
2.5.3	• distance ground - stretcher handles provides ergonomic loading/ unloading	currently 110cm in helicopter			100	D
2.5.4	• width				50	N
2.5.5	• length				≥195	N
2.5.6	• adjustable backrest	for patient situp	70°			N
2.5.7	• enable longitudinal movement	out of rear entrance				N
2.5.8	• Enable securing scoop stretcher onto stretcher					N
3	**Equipment**					
3.1	Placement of equipment in intuitive location	where paramedics naturally would reach				D
3.2	Equipment should be placed in accordance with desired proximity of reach	stated in the Equipment List				D
3.3	Placement of equipment aligned with work repsonsibilty					D
3.3.1	• Respiratory equipment close to head seat					D
3.3.2	• Monitoring devices on nurse's side					D
3.4	Equip the UAM to support a range of mission types within its intended medical application					N
4	**Storage**					
4.1	Scoop stretcher accessible from outside					N
4.2	Provide storage for bags and loose medical equipment					N
4.3	All medical equipment stored with access from inside the UAM must be accessible with one hand					D
4.4	All stored equipment must be secured	To prevent unintentional opening of storage compartments and to ensure that no items fall out during operation				N
4.5	Hatches should be transparent	to provide overview of stored contents				D
4.6	Drawers should only be placed at lower height	to provide overview of stored contents				D
4.7	Allow quick access to items inside the storage solutions	avoid e.g. behind the seat				D
4.8	Minimum total storage volume	scoop stretcher storage volume + interior storage in AW169	≥0,388 m^3			N
5	**Details**					
5.1	**Maneuvering**					
5.1.1	Allow manual override of autonomous maneuvering.	vehicle hovers at safe height				N
5.1.2	Stop buttons and control interface accessible to both paramedics	to ensure safety				N
5.1.2.1	• Stop buttons reached from every seat					
5.1.2.2	• Stop buttons visible from all angles					
5.1.3	Prevent control violations	to ensure safety				D
5.1.4	No official training needed	only basic maneuvering				N
5.1.5	Displays		6			N
5.1.5.1	• showing camea views of surrounding environment	Front view, angled 45° downward Right view, angled 45° downward Left view, angled 45° downward Back view, angled 45° downward Ground view, angled 90° downward	5			D
5.1.5.2	• GPS map	trip progress, location	1			N
5.1.5.3	• Visible to both paramedics when seated beside the stretcher					N
5.1.6	Dashboard at front with control interface	provide the same infomation as the displays				N
5.2	**Hygiene**					
5.2.1	Smooth surfaces to avoid accumulation of bacteria					D
5.2.2	Chemical resistant materials	to withstand sanitation chemicals				N
5.2.3	Drains in floor	for easy cleaning				N
5.3	**Aesthetics**					
5.3.1	Lighting					-
5.3.1.1	• Night vision support	for sufficient lighting when dark outside				N
5.3.1.2	• Dimmable lights					N
5.3.1.3	• Adjustable colour within white spectrum					D
5.3.1.4	• Provide sufficient lighting when loading and unloading equipment					N
5.3.1.5	• Both paramedics should have access to light control panel					N
5.3.7	Colour					-
5.3.7.1	• Use colours that help distinguish equipment, blood, and dirt from the environment					N
5.3.7.2	• light, greyscale, or natural colors					N
5.3.7.3	• orange or green accent colours					D
6	**Other**					
6.1	Ensure patient integrity and privacy					N
6.2	Electric sockets		2			D

Appendix E – Ideation

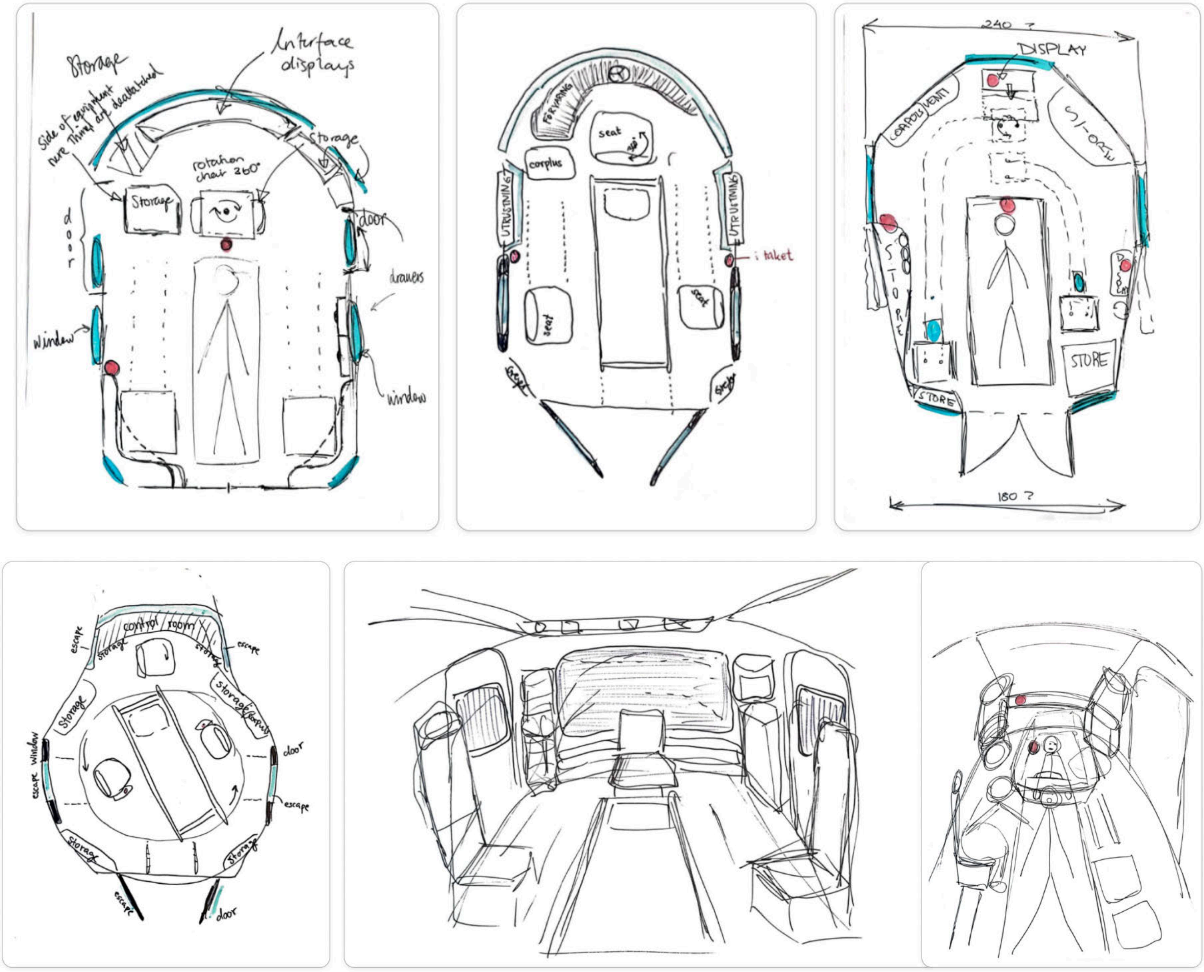
Sketch that supported the decision-making of cabin dimensions, ground clearance and floor-level height.



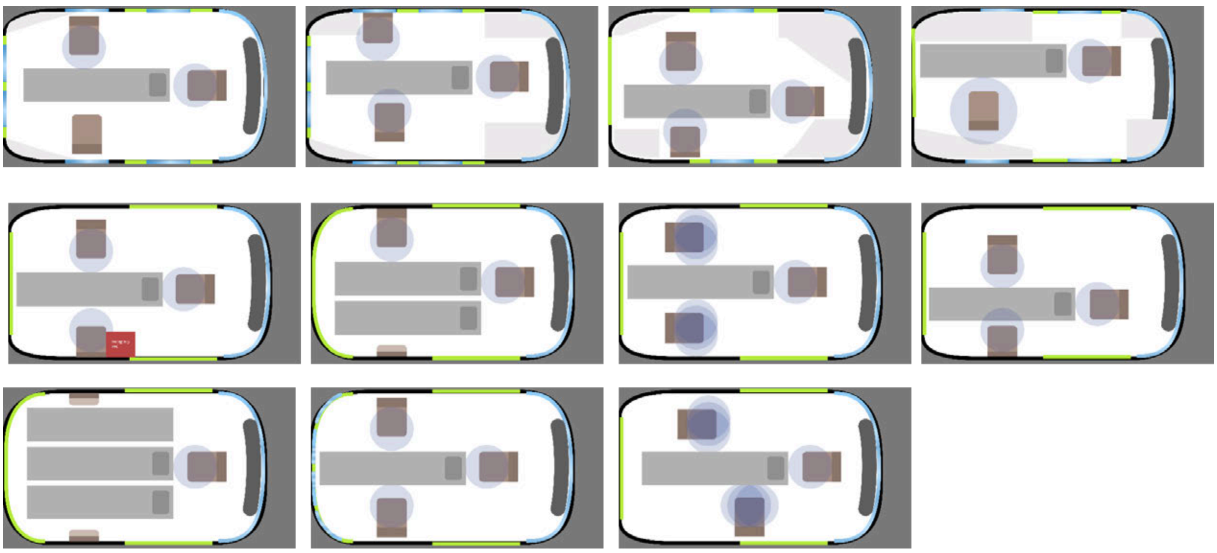
Early ideation on seat functionality, before the survey was distributed. The mechanisms enabling the functionalities, were not part of the project scope and therefore not explored further.



Results of Braindrawing session exploring cabin layouts, both traditional and innovative shapes.

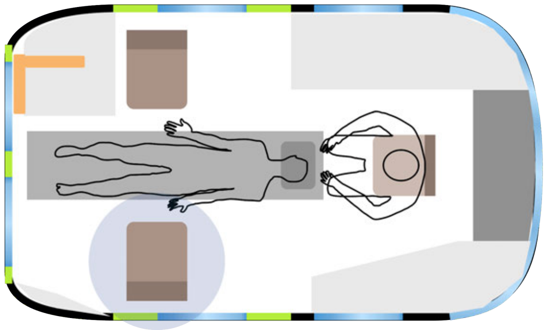


Results of digital Braindrawing session in Figma, exploring seat-stretcher configuration for Use Case A – Treat patient during flight to hospital and to some extent Use Case D – Remove patients from accident site.

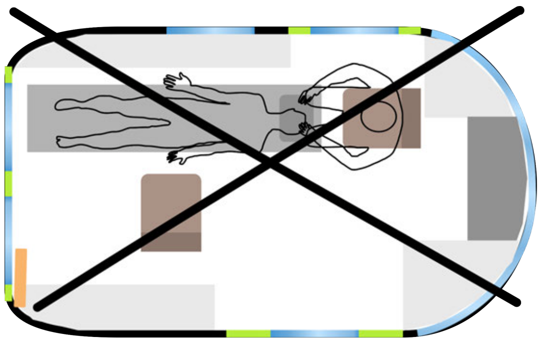


Results of concept generation using a Morphological Matrix

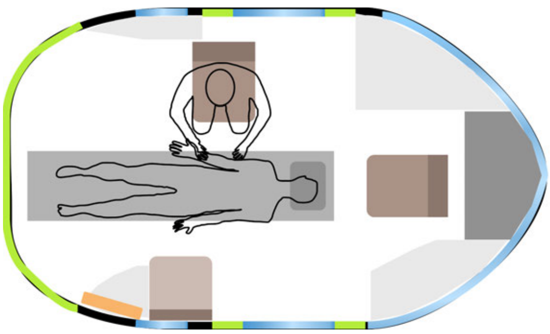
1. Two helicopter seats, one on each side, and a foldable seat behind the head. Scoop stretcher accessed via rear entrance.



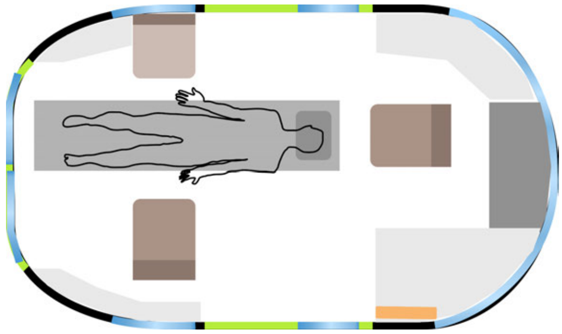
2. One helicopter seat on side and one behind the head. Scoop stretcher accessed via rear entrance. Concept discarded, after requirement regarding access to both sides was established.



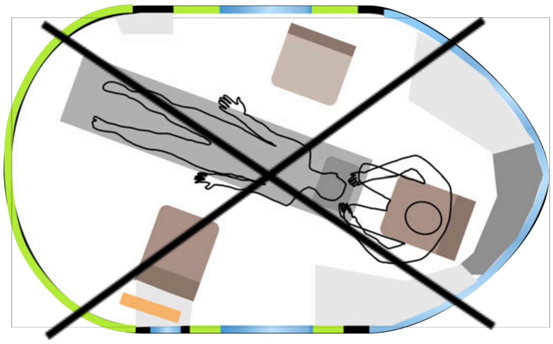
3. Foldable seat on doctor's side. Scoop stretcher accessed via rear entrance.



4. Foldable seat on nurse's side. Scoop stretcher accessed via rear entrance.



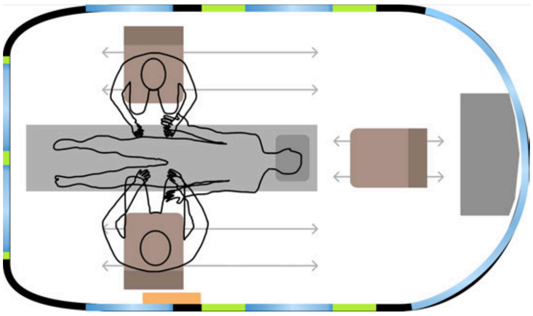
5. Skewed configuration, with foldable seat on the nurse's side. Scoop stretcher accessed via rear and/or side entrance.



First iteration of the concepts generated through morphological matrix

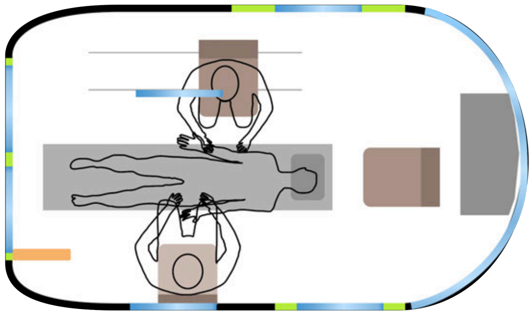
Concept 1 Seater

right side: normal seat
left side: normal seat
at head: normal seat



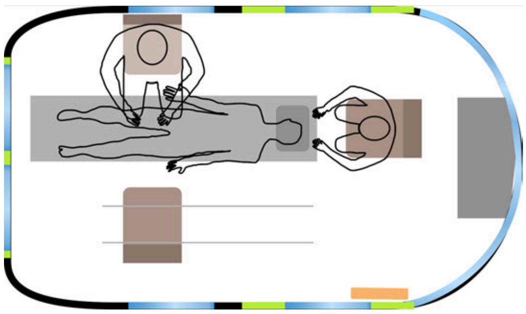
Concept 3 fold right

right side: foldable seat
left side: normal seat
at head: normal seat



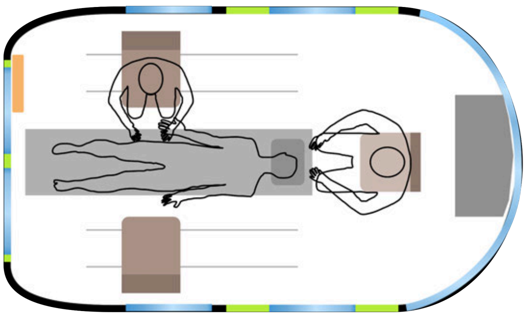
Concept 4 fold left

right side: normal seat
left side: foldable seat
at head: normal seat



Concept 2 fold head

right side: normal seat
left side: normal seat
at head: foldable seat



Appendix F – Evaluation Guide

Scenario Sequence

Below are the aspects of the Main Scenario to be covered during the physical prototype evaluation. The full scenario can be read in *Section 6.1 – UAM Dispatch Mission*.

1. **Dispatch and Arrival at Inaccessible Site**
   - Accident at a clear-cut area
   - Patient has fallen, sustained injuries to leg and head
   - No roads available; UAM is dispatched

2. **Patient is Located**
   - Patient is in severe pain; suspected internal bleeding
   - Patient is placed on the scoop stretcher

3. **Boarding and Departure**
   - Patient is loaded into the UAM through the rear door
   - Nurse enters together with the patient

4. **Medical Emergency During Flight**
   - Doctor changes position to perform intubation
   - After intubation, the doctor also manages IV access

5. **UAM System Failure Management & Arrival at Hospital**
   - Strong winds make autonomous landing difficult
   - Doctor presses the stop button to activate manual mode

Questions and Tasks

Probing questions after testing each feature

- How did you experience this? How did you feel?
- Did something work well?
- Did you experience any issues?
- How did you experience the space in terms of height, width and range of reach?

Assignment – placement of details

- Place stop buttons where desired, no restriction on number
- Place handles where desired, no restriction on number
- Explain the best option for placement of communication radio.
  - in the ceiling, in the center, over the stretcher
  - in the ceiling, in front of each seat
  - on the wall, next to each seat

Appendix G – Equipment List

Importance
1 – Reachable inside while buckled
2 – Reachable inside only while unbuckled
3 – Reachable from outside

Included Equipment	Measurements			Importance
	X	Weight (kg)	Dimensions (cm) Width x Depth x Height	
Bags				
Emergency bag inluding medical drugs, catheters, equipment for treatment		10,2	53x26x56	1
Paediatric bag		3	46x33x13	3
Bag with LUCAS CPR device		12,3	62x31x23	2
Disaster bag	2 pcs		39x20x18	3
Ultrasound bag			27x10x38	2
Respiratory bag oxygen, repspiratory equipment, thoracotomy devices		9,4	56x20x24	1
Head fixation bag			24x35x23	3
Medical equipment				
Corpuls 3 defibrillator device		8,7	54x30x19	1
Hamilton T1 ventilator device		6,5	32x22x27	1
Heating device				2
Weinmann Accuvac suction device		4,5	37x15x28	2
Loose items				
Scoop stretcher		9	120x40x8	3
Mini-stretcher		2		3
child harness		1,6	40x50	3
"Spindel" till scoop				3
Personal items		5		
• Helmet			18x22x18	1
• Walkie Talkie			8x6x22	1
• Protective Clothing				1
• Flashlight				1
• Scissors, knives				1
• Boots, belt				1

Radio communication equipment			77x20x9,5*	1
Immobilisation devices				3
Rescue rope Hansalina				3
Emergency flare				3
Slishman Traction Splint		0,5	51x8	3
Rack for monitoring equipment on scoop			52x38x68	3
head fixation bag			24x35x23	3
Neonatal/child set				3
Other equipment, good to have			33x17x6	3
Less Thermal bag			65x40x3	3
Reimplantationsset			28x23x9	3
SMART Triage Pack			18x9x22	3
Blanket				3
Loose medical supplies				
Blood				2
Plasma				2
Oxygen, CONOXIA 5L, 200 bar	2 pcs	7,7	D14,2xH61,6	1
Ringer-Acetat, 1L	2 pcs	1	35x25x12	2
Drugs				1
Paper towel bag storage			R15x20	1
Vomit bag bag			15x10x5	1
Trashbag				1
Sharps disposable box				1
Small orange bag			≈10x5x15	2
Total weight of known items		**90**		
Nr. of items with known weight		15		
Nr. of items with unknown (but low) weight		31		

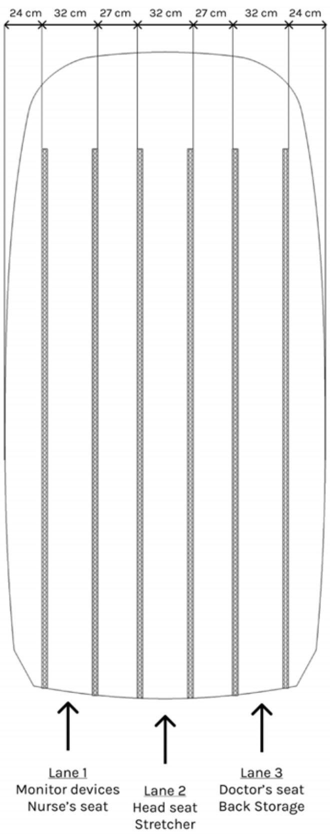
Excluded Equipment	Measurements		Reason for exclusion
	Weight (kg)	Dimensions (cm) Width x Depth x Height	
Woundcare bag	1	32x35x10	There is no such bag in the helicopter ambulance. Wound care is currently in the helicopter emergency bag. Necessary equipment is also found in the distaster bag. A seperate bag is not needed according to AH paramedics.
Complete tubing set for Hamilton T1 ventilator			duplicate of what's already inside
Round kneepillow			replaced by blanket
Pressure bag for arterial pressure			can be provided by hospital, AH & RA
"Blood cooling bag" containing powder for infusion fluids etc.			duplicate of what's already inside
Personal chemical/contamination protection kit			seldom-use, very specific
Autoinjectons for nerve agent poisoning			seldom-use, very specific
Body bag			can be handled by other part of EMS
Vacuum mattress	10,5	208x130x4,5 can be folded	very heavy. decreases access to patiient, must remove many harnesses which is time-consuming and not desirable in urgent scenario. Will be used in road ambulance soon.
Rack for monitoring equipment on scoop		52x38x68	only used during secondary missions

Appendix H – Product Specification

Specification	Description	Measurements		
		Other	Weight (kg)	Dimensions (cm) Width x Length x Height
Cabin design				
Cabin dimensions				200x400x150
Ground clearance				50
Distance from ground – floor level				80
Entrances				
• Side entrance		2		120x145
• rear entrance		1		160x145
Tracks	Airline-style L-tracks, MS33601		0,77 kg/cm	W3,5xH1,15
• in the ceiling	2 transversal 2 longitudinal for ceiling-mounted equipment, hooks	4	1,00	L100
• on walls	2 longitudinal 4 transversal for storage, handles, oxygen	6	0,44 0,77	L50 L100
• in floor	for chairs, stretcher, straps for cargo	6	2,70	L350
for placement, see Drawing 1				
Seats and Stretcher				
2 helicopter seats				
• five-point harness				
• fixed headrest				
• fixed backrest				
• fixed seat-floor height				35
• enabled translation along tracks				
1 front seat	including head seat and dashboard seat			80x40x35
• storage possibilities	accessed by folding up seat pad			
• fixed seat-floor height				35
• fixed position in tracks	behind patient's head/ in front of dashboard			
for placement and design, see Figure 6.11				
Stretcher				
• width				50
• length				200
• adjustable height				40-60
• distance ground – stretcher handles				120
• width				50
• adjustable backrest	patient situp	70°		
• enabled translation along tracks				
• enabled placement of scoop on top				
Equipment				
See Appendix H – Equipment List				
Storage		**Storage Volume**		**External dimensions of the storage unit**
Ceiling-storage: Nurse's side		0,0325 m³		125x30x30
Ceiling-storage: Doctor's side		0,0702 m³		70x30x30
Rear entrance storage		0,435 m³		60x50x150
• Scoop stretcher storage compartment		0,038 m³		13x50x130
Stretcher drawer		2x0,00798 m³		20x9,5x42
Front seat		0,128 m³		40x80x40
Total		0,68166 m³		

Details				
Stop buttons *for placement, see Figure 8.4*		5		
Handles *for placement, see Figure 8.5*		11		
Displays • roof displays • foldable side display		 5 1		
Radio communication • RAKEL Walkie Talkie • radio display	 one one each side one on each side	 2 2		

Drawing 1 – Tracks



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