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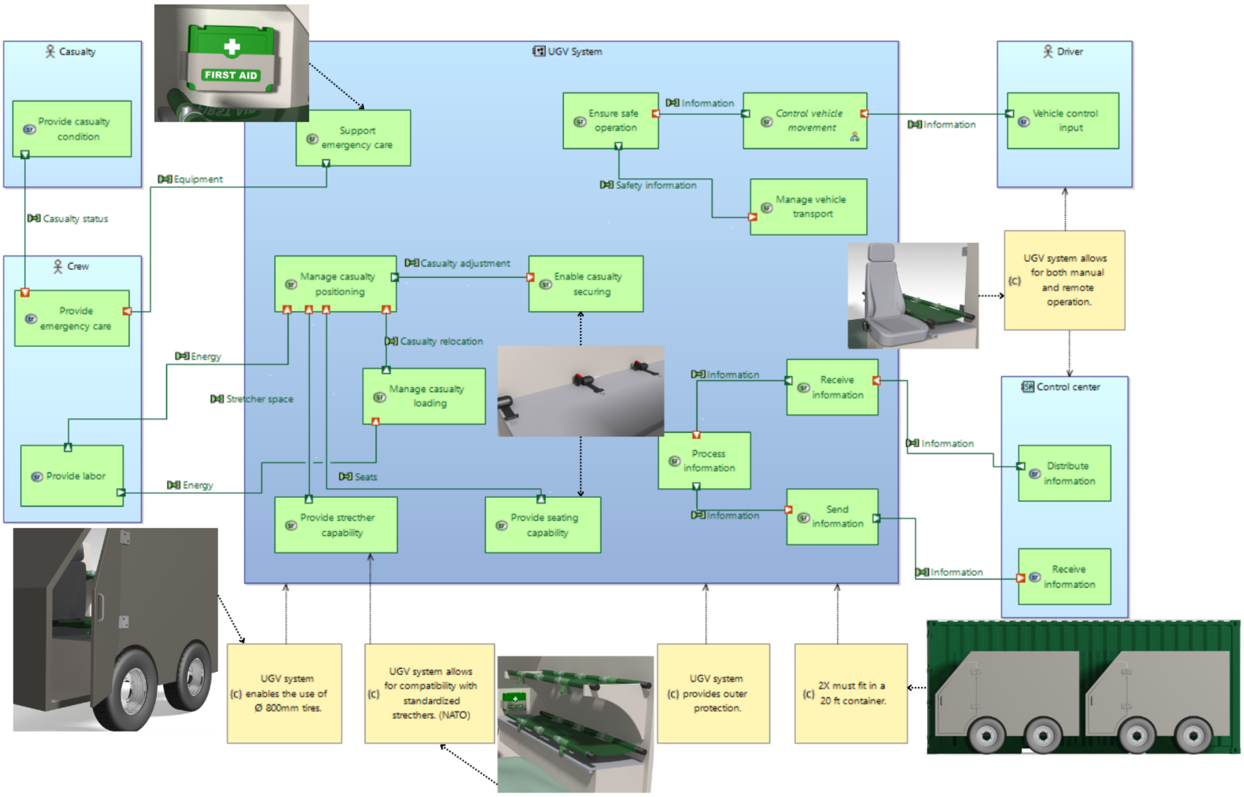

Concept Development of Unmanned Ground Vehicles in Dual-Use Operations

Applying and Evaluating Systems Engineering Methods to Conceptual System Design

Master’s thesis in Product Development

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Cover: Illustration of Model-Based Systems Engineering diagram with 3D modeled concept proposal

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Abstract

Unmanned Ground Vehicles (UGVs) are becoming increasingly relevant in military and dual-use operations due to their ability to reduce risks for personnel and support missions in high-risk environments. Recent conflicts have demonstrated the growing need for resilient autonomous and remotely operated systems capable of supporting casualty evacuation, medical evacuation, and logistics close to the frontline. Despite rapid technological development, there remains a need for structured methods to support early-stage concept development of such systems. This thesis investigates how Systems Engineering (SE) methods can support early product development and conceptual system-level design of UGVs for dual-use and near-front operations. The study aims to identify stakeholder and user needs, define relevant operational scenarios, and develop concept proposals adapted for CasEvac, MedEvac, and logistics missions. The project was conducted through theory research, market and competitor analyses, and semi-structured interviews with stakeholders, users, and experts. A Systems Engineering approach was applied using Concept of Operations (ConOps) and Model-Based Systems Engineering (MBSE) methods to structure operational and system-level analysis. Identified requirements and operational scenarios were translated into functional system models and visualized through CAD-based concept development. The results show that modularity, adaptability, compact dimensions, and safe patient transport are key design considerations for UGVs operating in high-risk environments. Three mission-oriented concept proposals were developed and evaluated based on identified operational needs. Furthermore, the study demonstrates that Systems Engineering methods support traceability, communication, and structured decision-making during early product development. The thesis contributes with a conceptual framework and design approach for future development of resilient dual-use UGVs in evacuation and logistics operations.

Keywords: Unmanned Ground Vehicles (UGV), Dual-Use Operations, CasEvac, MedEvac, Logistics, Systems Engineering (SE), Concept of Operations (ConOps)

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Sofia Larsson & Julia Tinghall, Gothenburg, June 2026

Contents

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AXP	Ambulance Exchange Point
CAD	Computer-Aided Design
CasEvac	Casualty Evacuation
CCP	Casualty Collection Point
ConOps	Concept of Operations
GVW	Gross Vehicle Weight
LCV	Light Commercial Vehicle
MBSE	Model-Based Systems Engineering
MedEvac	Medical Evacuation
PCC	Patient Casualty Care
POI	Point Of Injury
SE	Systems Engineering
TCCC	Tactical Combat Casualty Care
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle

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1

Introduction

The introduction presents the background and context of the thesis and introduces the investigated topic. It includes a presentation of the research project Eira X and the identified stakeholders, customers, and users. Furthermore, the chapter outlines the aim and goal of the thesis, the research questions, and the delimitations, including the initial requirements considered in the study. Finally, an overview of the report structure is provided.

1.1 Background & Context

Unmanned ground vehicles (UGVs) are land-based vehicles and their main purpose is to move risk and workload away from personnel and onto technology in military or civilian settings. UGVs can be remotely controlled or autonomous, which means an operator can navigate the vehicle from a distance, but the vehicle can also follow a planned route or task. This makes the UGVs especially useful for missions where terrain or threat level make manned options too costly or dangerous.

One of the main advantages of autonomous evacuation systems lies in their ability to preserve critical medical personnel while simultaneously minimizing their exposure to danger. This benefit is particularly important in the light of recent events in Ukraine, where violations of the Geneva Conventions have included deliberate attacks on wounded individuals and medical responders. In such an environment, UGVs are likely to assume an essential role in future evacuation operations (Procházka et al., 2025).

A notable aspect of the state in Ukraine is that the use of UGV is closely related to immediate battlefield needs and fast improvement cycles. In areas with heavy drone activity and strong electronic interference, normal resupply and evacuation can be extremely dangerous, so unmanned transport and casualty evacuation become very valuable rather than optional. This drives practical innovation, such as better ability to move in rough terrain, and modular vehicles that can be adapted for different tasks like casualty evacuation (CasEvac), medical evacuation (MedEvac) and deliveries. These new innovations help units continue to operate, while lowering the risk for soldiers and maintaining operational speed (Jamestown, 2026).

In a military context, UGVs can act as logistical support by transporting necessities from base to a unit in the field, reducing the load on soldiers by transporting heavier equipment or reducing the risk of casualties in dangerous areas (Försvarets Materielverk FMV, 2025). Beyond pure transport, UGVs can also be used as a mobile sensor platform to check areas or obstacles from a distance, for example by carrying sensors to detect hazardous substances (Försvarets Materielverk FMV, 2025).

In addition to these roles, UGVs can contribute to sustaining electrical power and energy logistics in the field. By transporting batteries, fuel cells, or portable generators, UGVs help ensure that units maintain access to critical power for communication systems, sensors, and other electronic equipment. This reduces the need for staff to carry heavy supplies and minimizes their exposure when resupplying in dangerous environments (Serowik & Szulczyk, 2026).

1.1.1 Research Project Eira X

In response to the challenges and emerging needs described above, the research project Eira X *Forward Logistics on the Transparent Battlefield* seeks to develop a concept for an UGV capable of delivering critical supplies. The project is funded by the Swedish innovation agency Vinnova and conducted through a collaboration between industry and academia, including the Swedish Defense University, Chalmers University of Technology, Halmstad University, and Volvo Construction Equipment (Swedish Defense University, 2025).

This master thesis is a part of the Eira X research project and contributes to the product development aspect and exploration and development of interior concept proposals for UGVs within evacuation and logistics operations.

1.1.2 Stakeholders, Customers & Users

The main stakeholders of a resilient UGV are the manufacturer, the buyer, and the end users, who are most influenced by whether the product succeeds or fails. Other stakeholders include defense contractors, system integrators, and retailers, as well as internal stakeholders such as Eira Systems AB, the sales team, service department, and production organization.

The primary users of the product are military and civilian personnel who operate UGVs in their daily work. In the military, this includes soldiers and operators who use UGVs for tasks such as transporting supplies, evacuating injured personnel, and inspecting dangerous areas. In civilian use, primary users may include emergency responders and security staff who use UGVs to reduce risk and physical workload. These users interact with the vehicle through remote control or manually, and they are strongly affected by how easy, reliable, and safe the vehicle is to use.

The secondary users are the people responsible for assembling and maintaining the UGVs. This group includes military and civil technicians, and third-party service providers or authorized partners of the manufacturer. Their interaction with the product mainly involves maintenance, repairs, transport, and software updates rather than operational use. Therefore, design aspects such as easy access to components, modularity, and clear interfaces are important for this user group.

1.2 Master Thesis Aim & Goal

This master's thesis aims to investigate how Systems Engineering methods can support early product development, applied to the conceptual system-level design of unmanned ground vehicles in dual-use and near-front operations.

The goal of this report is to conduct a market and competitor analysis to understand existing solutions and identify relevant opportunities. The report also focuses on defining customer and user needs and translating them into technical requirements, while considering constraints related to internal implementation, layout, passengers, and equipment. Furthermore, the work includes analyzing the use of Systems Engineering methods, such as Concept of Operations documentation and system models, for early concept development, as well as creating 3D modeled layouts to illustrate potential functions and interior configurations.

1.3 Research Questions

The research questions were formulated to guide the product development process and to ensure that the final UGV concept aligns with stakeholder, customer, and user needs, while also addressing operational requirements, market expectations, and the need for innovation within the UGV domain. The questions further support the evaluation of both the developed concept proposals and the contribution of Systems Engineering during the early phases of product development.

RQ1: What are the needs among the user, customer, and stakeholder segments for the UGVs?

RQ2: In which scenarios does the UGV concept offer the highest operational value?

RQ3: To what extent do the final UGV concept proposals address stakeholder and operational needs?

RQ4: To what extent has Systems Engineering contributed to the early product development phases?

1.4 Delimitations

The project has focused on the operational functionality of dual-use UGVs and the early conceptual development of its interior, rather than the development of a complete vehicle platform. The project will not include real-scale manufacturing and cost analysis of the final concept proposals.

To guide the project and establish clear boundaries at an early stage, a set of initial requirements was defined in collaboration with Eira Systems. These requirements formed the foundation for the concept development and ensured alignment with both operational objectives and project scope.

Lastly, CBRN (chemical, biological, radiological, and nuclear) conditions are not considered within the scope of this thesis. Consequently, the design considerations and operational analysis presented in this work do not include requirements related to operating in contaminated or hazardous CBRN environments.

1.4.1 Initial Requirements

Several initial requirements and viewpoints define the framework for the vehicle concept investigated in this thesis. First, the UGV is intended to operate within the size and operational context of a light commercial vehicle (LCV). This ensures that the vehicle remains within class B Swedish driving license. The system is also required to support both manual and remote operation, allowing flexibility in deployment depending on mission requirements and safety considerations.

In addition, certain design parameters are predetermined. The vehicle is required to utilize a 14.00 R20 truck wheel ($\sim \varnothing 1200mm$), which further constrains aspects of the chassis design and inner vehicle geometry. Furthermore, the maximum vehicle width is limited to 2280 mm, the maximum height is limited to 2300 mm, and the maximum length is limited to 5900 mm in order to ensure compatibility with the internal width of a standard 20 ft. shipping container, thereby enabling efficient transportation and logistical deployment.

As a result of the report's purpose and target area of medical evacuation, a portable stretcher is standard equipment that must fit in the vehicle. The dimensions used in this project are based on established NATO standard AMedP-2.1 with an overall width of 584 mm and overall length of 2290 mm. These measurements are used as a foundational reference during the development process to support the creation of a generalized and adaptable concept that aligns with widely recognized specifications (NATO, 2013).

1.5 Outline of the Thesis

The final report of this thesis is structured into eleven chapters, followed by appendices, as described below.

Chapter 2 - Theory
This chapter presents the theoretical background relevant to the thesis. It introduces topics related to product development processes, systems engineering, tactical operational methods, and key design principles. Furthermore, insights from NATO Safe

Ride standards are presented.

Chapter 3 - Methodology
The methodology chapter describes the methods and approaches applied throughout the thesis, as well as the declaration of artificial intelligence usage.

Chapter 4 - Market & Competitor Analysis
This chapter presents the conducted market and competitor analysis of related vehicle categories. The chapter concludes with identified findings and gaps from the analysis.

Chapter 5 - Customer & User Needs Analysis
This chapter presents the customer and user needs analysis based on the conducted interviews. Statements and functional needs are derived and summarized into key takeaways.

Chapter 6 - Scenarios & Missions from Research Findings
The sixth chapter introduces the operational scenarios and missions identified through the research findings. Different missions are presented together with their associated operational requirements and key insights.

Chapter 7 - Implementing Systems Engineering for Early Product Development
This chapter describes how systems engineering methods were implemented during the early product development process. Operational and system analyses are presented using Model-Based Systems Engineering (MBSE) approaches.

Chapter 8 - Modeling of Concept Proposals
This chapter presents the modeling of the developed concept proposals based on selected missions. The resulting concepts and associated findings are described and evaluated.

Chapter 9 - Discussion
The discussion chapter analyzes and evaluates the findings and results of the thesis. It includes discussions related to the research questions, and lastly ethical, societal, and ecological aspects.

Chapter 10 - Conclusion
This chapter presents the conclusions of the thesis and evaluates the research questions based on the obtained results and findings.

Chapter 11 - Recommendations of Future Work
The final chapter provides recommendations for future work and identifies potential areas for further development and research.

2

Theory

This chapter outlines the theoretical foundation of the project, including relevant methods, key concepts, and systems approaches together with general design principles and considerations.

2.1 Product Development Process

The general product development process is a structured sequence of activities that help transform an initial idea into a marketable product. The process begins with a planning phase, where the mission statement is formed based on available technology and identified market segments. The planning phase is followed by concept development, where competitors are analyzed, customer needs are identified, ideas are generated and concepts are evaluated. An important aspect of the process is its iterative nature. Rather than progressing linearly, product development involves cycles of refinement, evaluation, and feedback. Concepts are developed, assessed, and improved repeatedly to reduce uncertainty and risk. This iterative approach allows to better satisfy technical requirements and customer expectations (Ulrich et al., 2020).

Although the product development process extends beyond these stages into system-level design, detail design, testing and refinement, and production ramp-up, this project focuses on the early development (Ulrich et al., 2020), such as the concept development phase, and some prior planning was needed to ensure understanding of the context and the product. The key parts of phase one and phase two that was implemented are illustrated in Figure 1.

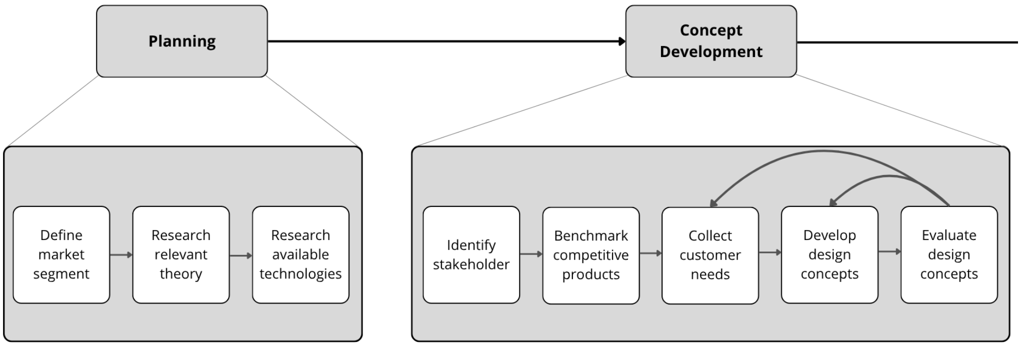

Figure 1: *Overview of early Product Development Process*

2.2 Systems Engineering

Systems Engineering (SE) is a broad and integrated approach used to support the successful creation, use, and retirement of engineered systems. It is based on system thinking, which means understanding the whole system and how its different parts work together to achieve a common goal. The main purpose of SE is to manage risks, such as delays, cost overruns, and unexpected problems, and to make sure the final system works as intended. By carefully thinking about both the problem and possible solutions early in the process, SE helps reduce technical debt and supports a smooth development process from early conceptual design to final product (International Council on Systems Engineering, 2023).

At the beginning of the development process, SE focuses on understanding and balancing the needs of stakeholders, defining real needs and requirements, and identifying the necessary system functions. During this phase, engineers explore and compare different solution ideas and system designs (International Council on Systems Engineering, 2023).

Building on the general principles of SE, an important concept used early in the development process is the Concept of Operations (ConOps) document. While SE provides the overall framework for understanding systems, managing complexity, and aligning stakeholder needs, ConOps focuses more specifically on how the system is intended to be used in its real-world context (International Council on Systems Engineering, 2023).

The ConOps document describes how an organization plans to operate and use the system to achieve its goals. It outlines the system's role within a broader operational environment, including assumptions about existing and future systems, and how different stakeholders interact with it. In this way, it helps translate high-level stakeholder needs into a clearer picture of system use (International Council on Systems Engineering, 2023).

At the same time, ConOps captures a user-oriented perspective by describing how the system will function in practice: its purpose, environment, expected capabilities, and key qualities such as performance, safety, and security. It also considers how to ensure correct use of the system and reduce risks related to misuse or unintended interactions (International Council on Systems Engineering, 2023).

Traditional text-based ConOps documents present several challenges, particularly when multiple stakeholders must collaborate. To overcome these limitations, integrating graphical visualization enables interactive communication among users, developers, and stakeholders. This support efficient discussion of the desirable system design (Mostashari et al., 2011).

2.3 Why Efficient Evacuation Is Important

The previous expectation of evacuating wounded soldiers to surgery within sixty minutes in the so-called Golden Hour will likely not be realistic in future large-scale combat operations. In future conflicts, airspace will be contested, transportation routes will be disrupted, and units will be spread out. Units will have to operate with the assumption that evacuation timelines are uncertain and potentially long. From a medical standpoint, immediate care at the point of injury remains critical. Tactical Combat Casualty Care (TCCC), especially rapid bleeding control, continues to be the first priority. In addition, medical personnel must be trained not only to stabilize patients briefly, but to manage them over extended periods (Gurney et al., 2025).

2.4 Tactical Methods During Operations

Modern battlefield operations increasingly rely on autonomous and semi-autonomous systems, enabling adaptable, resilient tactics that reduce risk to personnel. This section explores some key tactical methods discussed during interviews or found during background research that utilize unmanned systems to enhance operational effectiveness. Together, these methods reflect a shift toward more data-driven and resilient battlefield tactics, where collaboration between systems plays a central role in completing missions under challenging conditions.

2.4.1 Swarming

Swarming is a battlefield tactic based on the collective behavior of multiple unmanned vehicles. Rather than relying on a single platform, swarming distributes the task across many expendable vehicles. Swarming is particularly useful when supplies must be delivered to areas closer to the frontline where the risk to soldiers conducting resupply by foot would be too high. The benefits of swarming are substantial on the battlefield. If a single platform is destroyed or fails, only a small fraction of the supplies are lost, and the remainder of the vehicles can still complete the task. This reduces the vulnerability compared to if you only sent one larger vehicle with all the supplies.

Swarming can be applied to both ground and air domains. Ground vehicles do face more challenges due to difficult terrain and their vulnerability to ground threats. In contrast, aerial swarms offer greater flexibility as they are not constrained by road infrastructure and difficult terrain, and although aerial platforms carry smaller payloads than the ground vehicles, distributing loads across both types of platforms enables meaningful overall delivery capacity (Thornton & Gallasch, 2018).

2.4.2 UAV & UGV Collaboration

UAV-UGV collaboration in the battlefield refers to the coordinated operation of Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) to perform military missions more effectively together than either system alone. UAVs provide rapid aerial surveillance, wide-area monitoring, and real-time target detection, while UGVs carry out ground-level tasks such as inspection, transport, and operations in hazardous areas (Munasinghe et al., 2024).

The purpose of this collaboration is to combine aerial mobility with ground-based endurance and interaction. UAVs supply critical situational data from above, guiding UGVs on the ground through communication and coordination mechanisms, including formation control in dynamic combat scenarios. The main benefits include enhanced situational awareness, faster decision-making, improved mission efficiency, and reduced risk to human personnel (Munasinghe et al., 2024).

2.5 Identified Key Design Principles of an UGV

Using evacuation UGVs close to the frontline puts them at significant risk. Because evacuation UGVs operating at the frontline are likely to face a high chance of being lost, they should be designed to be affordable, reusable, and equipped only with the essential features needed to complete their mission. Keeping the cost per vehicle low would allow more units to be purchased, helping to make up for those that may be lost (Halme et al., 2026). Also, the vehicle should have compact dimensions so it can move easily through thick vegetation and rough terrain to ensure good accessibility (Ćosić et al., 2025).

For smaller UGVs, the significant vibrations transmitted through a mounted stretcher may pose a potential health risk to the patient, depending on the nature and severity of the injury. Excessive vibration and mechanical shock can aggravate existing trauma, particularly in cases involving spinal injuries, fractures, internal bleeding, or head trauma. This highlights the need for increased knowledge and further research regarding vibration levels and patient safety thresholds to ensure safe medical transport using UGVs. One example of a solution is shock-absorbing stretcher systems that can be integrated onto or mounted within an UGV, with the aim of reducing vibration exposure and improving patient safety during transport (Robinson et al., 2020).

Route planning that accounts for vibration levels can further improve casualty transport by selecting paths that minimize shocks and strain during travel. This is achieved by analyzing terrain characteristics and estimating how different route choices affect vibration levels, which can contribute to a safer and more comfortable transport for the patient (Tolt et al., 2026).

2.5.1 Insights from NATO Safe Ride Standards

NATO has developed formal safe-ride standards and capability recommendations for the use of UAVs in casualty evacuation roles, recognizing the potential for unmanned systems to support CasEvac and MedEvac missions. The report outlines both operational requirements and medical equipment recommendations for future

UAV-based evacuation platforms that would be needed to safely transport and care for wounded personnel. These standards and recommendations provides a valuable foundation that can be adapted and translated to UGVs in this project (NATO, 2012).

Accordingly, the suggested medical equipment that would be advantageous to include on a CasEvac platform consist of standard medical supplies such as stretchers, securing straps, intravenous fluids, and blankets (NATO, 2012).

MedEvac transports involve advanced medical equipment and trained healthcare personnel, and can last up to multiple hours. The patients are typically critically injured or seriously ill and requires intensive care. In addition to the equipment described above, a large amount of equipment is recommended in the NATO standard. Different health monitoring and treatment capabilities such as blood pressure monitors, infusion pumps, and oxygen therapy (NATO, 2012).

For both CasEvac and MedEvac missions, a padded flooring could be beneficial, as it improves patient comfort during transport. The use of padded floors or mattresses can help reduce discomfort and provide a more stable and supportive surface for patients during movement (NATO, 2012).

3

Methodology

This chapter presents the methodology that guided the execution and evaluation of the project. Using the general product development process as a foundation, and implementing principles from Systems Engineering into the concept development phase, the project was structured into four main parts: *Background Research, Functions & Scenarios, Systems Engineering & Documentation* and *Modeling & Evaluation.*

3.1 Background Research

The first part consisted of literature-based research aimed at providing an overview of the technical landscape of UGVs in both military and civilian contexts. The research began with a background study to establish a foundational understanding, including the current state of UGV innovation and applications. Particular attention was given to recent real-world contexts, such as the use of UGVs in Ukraine, to ground the study in current operational realities.

The research further explored key factors influencing the design and use of UGVs. This included the importance of efficient evacuation and rapid response, as delays can have significant consequences for patient outcomes. It also examined general design considerations and relevant standards to understand how performance, safety, and reliability are addressed in existing solutions. Operational aspects were investigated to understand how systems are used in critical and high-risk situations. This was important to identify common strategies, coordination between different platforms, and the practical challenges faced in real scenarios.

To ensure reliability, all information gathered from online sources was cross-checked against academic research, official reports, and other peer-reviewed publications. This approach helped filter out unverified claims and ensured that the findings were based on credible and relevant data.

A study of the current market was conducted to further deepen the understanding of today's UGVs. The analysis was structured across several key segments, including unmanned ground vehicles, CasEvac and MedEvac solutions, civil medical vehicles, and military vehicles. The methodology was designed to support a structured analysis of ground vehicles with basis in the technical reports and other articles with relevant images. The analysis focused on identifying technical characteristics, operational capabilities, and limitations, with the aim of understanding maturity and feasibility, as well as providing reference points and potential inspiration for the project.

For UGVs, the analysis focused on technological maturity, levels of autonomy, and how the vehicles are used in practice. In the evacuation-focused segments, attention was given to how evacuation is carried out in high-risk environments and what this means for interior design. These vehicles served as practical examples of what functions are needed and how limited space can be organized and used efficiently. This provided concrete examples of space utilization and modularization, supporting the development of adaptable design solutions for the project.

The findings from each segment were then synthesized to identify overarching trends, existing gaps, and potential areas for innovation. These insights formed the basis for the concluding section, where key takeaways and opportunities for future development were outlined.

To be sure that the project is grounded in real user and customer expectations, the next research contained a customer and user needs analysis which will be based on an interview study of potential users, customers, stakeholders, and experts. Here, semi-structured interviews were used to gather detailed insights regarding experiences and viewpoints. Semi-structured interviews were selected because of their balance between structure and flexibility, enabling more spontaneous discussions while ensuring that the responses remain relevant to the research topic.

The interview sessions were conducted individually and each session was scheduled to last approximately 60 minutes. Before a planned interview, an interview guide with questions was sent out to all interviewees. This supports more thoughtful and concrete responses, improving the quality of the collected input. The interview guide primarily consisting of open-ended questions. This approach ensured that essential areas were addressed while allowing room for discussion and additional questions.

3.2 Functions & Scenarios

After the interviews were conducted, the answers were translated into needs and functional statements as well as divided into categories with the help of a KJ analysis methods. Together with potential findings from the market research, a complete functions list was developed, with the intent to help prevent scope drift and enable objective evaluation of alternative concept solutions.

Based on insights from literature findings, market analysis, and conducted interviews, a set of use scenarios and corresponding missions was defined to support a more structured and targeted concept development process. Since operational needs and priorities vary between missions, the development process was approached scenario-by-scenario to develop concepts tailored to specific missions, rather than aiming for one universal solution.

Throughout this project, various visualization tools were used to enhance understanding and communication. Initially, the scenarios were illustrated to provide a clear picture of the context in which the system or solution will be applied. These visual representations help stakeholders grasp the environment, key interactions, and overall purpose of the use cases before moving into more detailed analysis and design.

3.3 Systems Engineering & Documentation

The project adopts a Concept of Operations (ConOps) approach as a central framework. Rather than treating ConOps as a static document, the process has been used as an iterative and collaborative tool to capture stakeholder perspectives, define operational contexts, and explore use scenarios and the corresponding missions. The NASA Systems Engineering Handbook has been used as a foundational reference. The handbook provided a structured approach to understanding complex systems, with a strong emphasis on aligning stakeholder needs, operational context, and technical design (NASA, 2007).

The structure of the ConOps was adapted from Appendix S of the handbook, which offered an annotated outline of recommended content. This has been used as a guiding framework, while being adapted to suit the specific context on an UGV. Rather than treating ConOps as a standalone document, it was therefore considered part of a broader, continuous engineering process throughout the development project.

To get a better understanding of the finalized concept and its usability, the concept needed to be documented in a way that clearly explains how it is intended to be used in practice, what the user interacts with, and how the system behaves across different missions. Model-Based Systems Engineering (MBSE) was employed in this project as an effective approach for visualizing and structuring complex systems. By representing system components, functions, and interactions through formalized models rather than solely textual descriptions, MBSE enables a clearer and more consistent understanding of the system architecture (International Council on Systems Engineering, 2023).

The first system models were created in the operational analysis level, to get an overview of the operational needs of the system. The next models were created in the system analysis level, these models were built with the help of the operational analysis to further develop the system and its functions. The modeling process was concluded at the system analysis level, as the projects scope focuses on defining and validating system-level functionality. The system model was instead used as a foundation for the 3D modeling phase.

3.4 Modeling & Evaluation

The selected missions were modeled in a 3D CAD environment, enabling detailed exploration of functional requirements as well as a to-scale representation of the UGV and its interior. The first step of the modeling was a brainstorming session of equipment and interior layouts of the vehicle. This session was based on the initial knowledge, including initial requirements, the identified user needs, and potential solutions that was found throughout the background research. To see these brainstormed ideas in-scale, a first iteration was made in a CAD software. With the internal dimensions of a 20 ft. container as constraints, predetermined size of wheels and thereby the wheel house, a primary vehicle could be modeled. The purpose of the first iteration of the concept development was to see the different parts that were known early in the project in relation to each other as early as possible, allowing these aspects to be integrated and assessed within a realistic context.

A second and final iteration was conducted after the system models were finalized. Building on insights from the first iteration, this phase refined the overall design approach. The system model diagrams played a key role in guiding the 3D modeling process, enabling the development of more detailed and efficient UGV concepts for each scenario.

3.5 Declaration of Artificial Intelligence Usage

In this thesis, artificial intelligence, ChatGPT, has been used as a supportive tool for content generation, such as image generation, assistance with LaTeX coding for tables and figures, and support in structuring parts of the document.

4

Market & Competitor Analysis

The purpose of this chapter is to analyze the current market of ground vehicles used for logistics and evacuation in both military and civil contexts. The analysis is structured to identify existing technical solutions, understand the capability gaps, find recurring design patterns and constraints, and to try to position the projects future concept within the current market landscape. To achieve this, the chapter explores vehicles ranging from remote-controlled platforms to armored ambulances and military vehicles.

Based on these observations, the market analysis provides a grounded base for requirement formation and concept development. It clarifies where current vehicles and UGV solutions clusters, highlights trade-offs between size, weight, and functionality, and identifies a concrete layout that can form a feasible and usable interior concept.

4.1 Unmanned Ground Vehicles

The UGVs were explored to establish a clear overview of where unmanned ground vehicle development stands today, with a particular focus on platforms relevant to logistics and evacuations. The intention is to review a small set of platforms to understand maturity and feasibility to provide reference points and potential inspiration for the project.

Arion-SMET

The Arion-SMET is a 6x6, fully electric unmanned ground vehicle aimed at infantry support in rough terrain, developed by Hanwha Defense. In a military setting its main value is as a risk-reduction platform, moving supplies and other loads, supporting casualty evacuation, and doing remote scouting and surveillance so soldiers can keep their distance from threats. It is also has off-road autonomy features such as follow-me behaviors and safe fallback behaviors when communications are lost.

It is a 2-tonne platform with a 550 kg payload, meaning it can carry a useful amount of supplies or mission equipment rather than just small loads. Its 34–43 km/h top speed supports quick repositioning on roads and trails. With its battery, it has a range of 100 km om one charge. Being battery operated can reduce noise and thermal signature during combat (Automated Decision Research, n.d.).

PROTECTOR

The PROTECTOR is a remote operated ground drone intended to take on high-risk tasks close to the frontline, primarily logistical tasks like ammunition and equipment transportation and has the space for three soldiers in case of a casualty evacuation. It is diesel-operated and is reported to carry a payload of up to 700 kg, with a top speed of around 45 km/h, making it suited for moving significant loads while keeping personnel out of exposed routes (Galadei, 2025).

Misson Master

Rheinmetall's Mission Master family, include three variants of UGVs that mainly differ by size, terrain and load class. Mission Master SP2 is the quiet, battery-powered option meant for stealthy dismounted support, with autonomy features aimed at silent watch, last-mile resupply deliveries, and transporting lighter payloads close to the squad.

Mission Master CXT moves up to heavier work, it uses a combination of a diesel engine with a silent electric motor, and keeps the same autonomous navigation focus as the first one. The CXT is intended for heavier payloads of up to 1000 kg with a stated 450 km range without refueling.

Mission Master XT is the biggest heavy hauler of the family, it keeps the autonomous navigation, supports payloads up to 1000 kg, and emphasizes maximum endurance with a stated 750 km range without refueling (Rheinmetall, n.d.).

Squad Mission Support System (SMSS)

The Squad Mission Support System is a six-wheeled UGV developed by Lockheed Martin for U.S. Army, built to reduce the load burden of soldiers. It can conduct autonomous navigation along a pre-programmed route using GPS waypoints. Its purpose is transporting equipment, supplies, arms, and ammunition so soldiers can move faster and arrive less fatigued. It is turbo-diesel powered, and its weight is 1,724 kg, with a 544 kg payload, making it heavy enough to carry meaningful squad loads while remaining a tactical support vehicle rather than a full-size combat platform (Army Technology, 2012).

HAVOC

The HAVOC 8x8 Robotic Combat Vehicle (RCV) by Milrem Robotics, Figure 2, is a combat-focused vehicle that increases firepower and situational awareness while reducing risk to the crew by keeping humans at standoff distance. It uses advanced AI-driven navigation to operate across varied terrains and climates, and it carries mission modules such as weapon stations and other payloads.

HAVOC's has a weight of 15 tonnes and has a maximum payload up to 5 tonnes, with an all-wheel hybrid electric drive, and it is rated for 110 km/h on-road and 50 km/h off-road (Milrem Robotics, n.d.).

Figure 2: *The HAVOC 8x8 Robotic Combat Vehicle (RCV) by Milrem Robotics (Milrem Robotics, n.d.). Reprinted with permission.*

4.2 CasEvac & MedEvac Vehicles

This section reviews CasEvac and MedEvac solutions for a military contexts, to deeper look at how evacuation is handled in high-risk environments and what it implies in the interior design. These vehicles provide practical reference points for what an evacuation-vehicle needs to include, and how the limited space is optimized.

MAUL

MAUL is a remote controlled UGV intended primarily for casualty evacuation and logistics. It is a dedicated evacuation capsule with shock absorption and secure fixation to move wounded personnel under fire, while also delivering ammunition, equipment, and supplies into areas that are too dangerous for soldiers to enter directly.

MAUL is a wheeled 4x4 platform with overall dimensions of about 2300 x 1450 x 620 mm, a total weight of 620 kg, and a payload capacity of 200 kg. It is listed with a maximum speed of 50 km/h on paved roads and 40 km/h on unpaved roads (AIDronesUA, n.d.). This vehicle is relevant to the project because it helps illustrate the current direction of development for remote controlled, unmanned CasEvac vehicles.

Gurkha

The Gurkha armored vehicles by Terradyne are built on a Ford F-550 Super Duty chassis and are part of the Light Armored Patrol Vehicle family designed for combat medical evacuation. This vehicle has a high cross-country mobility and are adapted for medical roles, moving wounded personnel from frontline positions to medical facilities (Militarnyi, 2023a).

Inside, these vehicles are configured to support medical evacuation, both seated and on stretchers, indicating internal accommodations for multiple patients in different postures. From the provided pictures, the interior consists of two padded benches along each outer side with the possibility to put stretchers on top (Militarnyi, 2023a).

Kozak-7

Kozak-7 is designed specifically for frontline medical evacuation with a rear medical compartment, large enough to carry up to four wounded lying down plus a medic. The design includes one large door in the back and two escape doors on the sides. It is built on a modified Ford F-550 4×4 truck chassis and is developed for the Ukrainian Military (Militarnyi, 2023b), see Figure 3.

Figure 3: *Kozak-7 (Army inform, 2022). CC BY 4.0.*

Military Utility Vehicle (MUV)

The Military Utility Vehicle (MUV) by Iveco Defence Vehicles (IDV) is a 4x4 light multirole military vehicle designed as a highly mobile, modular platform for various roles including medical evacuation, troop transport, logistics, and communications (IDV, n.d.-c). One example of an ambulance is described by Valpolini (2026). This model has two stretchers and two seats is mounted on each side.

Light Multirole Vehicle (LMV) Field Ambulance

An additional vehicle by IDV is Light Multirole Vehicle 4x4 (LMV). It is a modern, modular tactical vehicle designed for a wide range of military roles. It has a wheelbase of 3230 mm, width: 2275 mm, overall length of 4850 mm, height (cabin) of 2200 mm, and a ground clearance of 350 mm (IDV, n.d.-a), see Figure 4

The company NODIN (Nodin Aviation AS, n.d.) has supplied 92 LMV field ambulances with shock- and vibration-damped patient transport systems (Nodin Aviation AS, 2022). The solution contains of a padded bench and headrest on the left side, a stretcher on the right side, and storage in the front.

Figure 4: *IDV Light Multirole Vehicle Ambulance (Reise, 2019). CC BY-SA 4.0.*

INKAS Sentry AMEV

The INKAS Sentry AMEV is a fully armored medical evacuation vehicle engineered to rapidly and safely transport wounded personnel and medical staff through high-risk environments (Inkas, n.d.).

The interior consists of two stretchers along each outer side and a seat in the front. It is equipped with storage compartments for medical supplies, and practical features such as a wash basin with water tank and a hydraulic rear ramp to facilitate easier loading and unloading of patients on stretchers (Inkas, n.d.).

Converted MedEvac Vehicle

The company Ferno Norden has developed cost-effective, durable, and highly functional medical evacuation vehicles based on civilian vans (Ferno Norden, n.d.-b). Volkswagen Transporters with the long-wheelbase were converted into MedEvac platforms, optimized for operation in demanding environments (Ferno Norden, n.d.-a). This initiative highlights the value of dual-use solutions, where civilian vehicle platforms are adapted to support both military and civilian rescue operations.

Each vehicle is equipped with essential systems to ensure safe and efficient casualty evacuation, including a transfer mattress, backboard, and the ambulance stretcher with mattress and restraint belts that enable safe loading, transport, and transfer of casualties during operational conditions, see Figure 5. Besides the stretcher, a dedicated medic seat with ceiling-mounted grab handles is installed (Ferno Norden, n.d.-a), see Figure 6.

Figure 5: *Strecther in Ferno Norden MedEvac Vehicle (Ferno Norden, n.d.-a). Reprinted with permission.*

Figure 6: *Overview of Ferno Norden MedEvac Vehicle (Ferno Norden, n.d.-a). Reprinted with permission.*

The medical compartment is further fitted with wall-mounted brackets for critical medical equipment, a rear heat exchanger to maintain operability in cold climates, and core emergency medical devices such as a defibrillator. Lastly, red and white rear lighting for night and low-visibility operations is mounted in the ceiling (Ferno Norden, n.d.-a).

Dzhura-EVAC

The Dzhura-EVAC is a Ukrainian-built armored evacuation vehicle for casualty evacuation duties. It features a powerful diesel engine, a 4×4 drivetrain and is built on the Toyota Land Cruiser 70 chassis. It has an armored hull that provides protection against small arms fire and shrapnel (Militarnyi, 2025).

It can carry up to six people in total, and three passenger seats is located besides the stretcher that is located on the left side and is equipped with an automated loading system (Militarnyi, 2025).

4.3 Civil MedEvac Vehicles

Civil vehicles were researched to discover how medical evacuations can look in a non-military context. For this section, smaller light commercial vehicles have been the priority to get a better look at how compact medical vehicles should look.

WAS 4x4 All Terrain Ambulance

The WAS 4×4 All-Terrain Ambulance, see Figure 7 and Figure 8, is a compact off-road ambulance conversion intended for patient transport and emergency medical response in difficult terrains. It is built on a Volkswagen VW Amarok DoubleCab base with a dedicated box-body compartment for the patients, and has a total maximum weight of 3040 kg.

Figure 7: *WAS 4x4 All Terrain Ambulance Exterior (WAS, n.d.). Reprinted with permission.*

Figure 8: *WAS 4x4 All Terrain Ambulance Interior (WAS, n.d.). Reprinted with permission.*

This vehicle is particularity interesting to look at due to the use of a light commercial vehicle and its compact size compared to a traditional ambulance. The box-body compartment includes a removable stretcher, storage, and a seat for medical personnel (WAS, n.d.).

Toyota Land Cruiser 78 Ambulance

The Toyota Land Cruiser 78 Armored Ambulance by International Armored Group (IAG) is intended for medical response and casualty evacuation in high-risk environments, where crews need ballistic protection while still retaining strong off-road mobility. It is built on the Toyota Land Cruiser 78 platform and is converted specifically for ambulance use and is shown in Figure 9 and Figure 10 below. This Toyota LC is presented due to the appropriate interior layout of the vehicle. It has two stretchers for patients, a full wall for storage, and a bench with additional storage and seating for multiple crew members (International Armored Group, n.d.).

Figure 9: *Toyota Land Cruiser 79 Ambulance Exterior (International Armored Group, n.d.). Reprinted with permission.*

Figure 10: *Toyota Land Cruiser 79 Ambulance Interior (International Armored Group, n.d.). Reprinted with permission.*

4.4 Military Vehicles

Military vehicles are relevant to explore since they often use modular concepts between different use-cases, to show how the base can be configured into logistics and medical variants. This provides concrete examples of space utilization and modularization for the project.

SISU GTP

The SISU GTP 4x4 is a modular tactical all-terrain vehicle designed for demanding operational environments and is shown in Figure 11. It provides high mobility, customizable protection, and multi-role capability, serving as a troop carrier and adaptable platform for various mission sets including command, reconnaissance, and specialized roles (Sisu Auto, n.d.).

Figure 11: *The SISU GTP 4x4 by SISU Auto Oy (Armins, 2018). CC BY-SA 2.0*

The vehicle has a height of 2559mm, width 2500mm, lenght 6000mm, and a wheelbase of 3800mm with a ground clearance of 400 mm. The gross weight is 16500kg with a payload up to 5000kg. Lastly, the wheel dimensions are 365/85 R20 or 395/85 R20 (Sisu Auto, n.d.).

The vehicle is built on a modular platform that allows the same base vehicle to be configured for multiple roles. The mission module (rear body) can be exchanged to support different functions such as troop transport, command and control, logistics, or medical variants (Sisu Auto, n.d.).

Kamrat

The Kamrat Armoured Vehicle is a Soviet-era influenced 4x4 armoured personnel carrier (APC) developed by Ukrainian Armor, and is built on the KrAZ-5233 off-road chassis, see Figure 12. It is designed for general troop transport with tactical mobility and survivability suited for rough terrain and combat support operations. The vehicle has an overall length of 7190 mm, width of 2550 mm, and height of 2600 mm, with a gross weight of 16,400 kg and seating for a crew of two plus eight passengers (Army Technology, 2022).

Figure 12: *Kamrat by Ukrainian Armor (*Kamrat-M, Kyiv 2021*, 2021). CC BY-SA 4.0*

Novator

Novator is a light armoured 4x4 personnel carrier developed by Ukrainian Armor, intended for patrol, reconnaissance, troop transport and related missions in varied operational environments and is shown in Figure 13. It combines tactical mobility with protection against small arms and explosive threats, and is built on a reinforced Ford F-550 chassis adapted for military use (Ukrainian Armor, n.d.) (Militarnyi, 2024).

Novator measures 6400 mm in length, 2350 mm in width and 2385 mm in height, with a wheelbase of 3605 mm and ground clearance of 300 mm. The gross vehicle weight is 8845 kg with a payload capacity of 1845 kg. Seating configurations support a capacity between 5 and 10. Lastly, the wheel dimension is 335/80R20.

The vehicle platform is flexible, enabling variants including command, reconnaissance, and personnel transport, and can be adapted with mission-specific equipment or weapon systems.

Figure 13: *Novator by Ukrainian Armor (National Guard of Ukraine, 2020). CC BY-SA 2.0*

Medium Tactical Vehicle (MTV)

The Medium Tactical Vehicle (MTV) by IDV is a modular 4x4 tactical vehicle, see Figure 14. It is designed for demanding operational environments with high mobility, modular configuration options and protection, serving roles such as personnel transport, logistics support, command post, and medical variants (IDV, n.d.-b).

Figure 14: *Medium Tactical Vehicle (MTV) by Iveco Defence Vehicles (IDV) (Netherlands Ministry of Defence, n.d.). CC BY-SA 4.0*

The vehicle has an length of 5,760 mm, width of 2,430 mm, and height of 2,760 mm, with a wheelbase of 3,460 mm and ground clearance of 350 mm. Gross vehicle weight is 12,000 kg and it can carry a payload of 2,000 kg (IDV, n.d.-b).

The platform supports multiple configurations, including hard-top, soft-top, pick-up, medical transport, personnel carrier and command post models, which can be adapted to specific missions including evacuation operations (IDV, n.d.-b).

Combat Boat 90 H

Combat Boat 90 H is a high-speed military boat designed to quickly move troops and cargo in costal environments and is shown in Figure 15. The 90 H version has the ability to transport and deploy half a platoon of fully armed infantry (Naval Technology, 2021), but seating for up to 20 troops. The boat has a length of 14.90 m, 18 ton displacement and 45 knots as its top speed (Dockstavarvet, n.d.-b).

Figure 15: *Combat Boat 90 H (Zhuravlev, 2016). CC BY-SA 2.0.*

The boat can be reconfigured for ambulance operations, enabling MedEvac in both civilian and military contexts (Dockstavarvet, n.d.-a). Although this vehicle is far larger than an UGV, it remains a valuable reference for the project. Its operational purpose is comparable, and several of its design principles, particularly those related to interior layout, can be adapted and applied to a smaller transport vehicle.

4.5 Key Takeaways from Market Analysis

The following summarizes trends, gaps and key findings from the conducted market analysis. It highlights the main trends among existing UGVs, evacuation vehicles and military vehicles, identifies the current gaps in the landscape, and underlines the most relevant insights to the future development of the project.

4.5.1 Identified Findings

CasEvac is frequently presented as an add-on capability rather than a primary design driver. In many vehicle programs, casualty evacuation is accommodated by adapting existing troop transport or utility vehicles with modular systems. As a result, compromises are often made in areas such as interior layout, patient access, and medical workflow.

For evacuation and other tactical missions, using truck tires is suitable. Their compatibility with run-flat inserts and central tire inflation systems further enhances mobility and survivability, ensuring that rescue vehicles can continue operating even after damage and reach casualties in environments where standard tires would fail.

Flexible stretcher positioning and robust fastening solutions are critical enablers for effective medical evacuation. The ability to install and fasten stretchers in different positions and heights allows vehicles to support varied casualty situations, medical workflows, and space constraints, while well-adapted attachment systems ensure patient safety, rapid loading and unloading, and stability during transport. Together, these features enhance adaptability across missions and improve both caregiver access and overall operational efficiency.

The study shows clear variation in door configurations, ranging from vehicles equipped with several smaller access doors to those featuring one larger rear opening or ramp system. This design difference has a direct impact on evacuation efficiency, workflow, and safety during loading and unloading. Vehicles with multiple doors can offer improved access flexibility, allowing medical personnel to reach patients from different angles and enabling simultaneous entry and exit. This can be particularly advantageous in confined environments or when space behind the vehicle is limited.

Conversely, vehicles with one larger rear door or ramp often provide superior ergonomics for stretcher loading, especially for heavier patients or when mechanical loading systems are used. A wide opening reduces handling complexity and supports faster, more controlled patient transfer, which is critical in high-stress or hostile environments. However, reliance on a single access point may reduce flexibility if that area becomes obstructed or inaccessible.

The research indicated that UGVs are not widely developed or used specifically for dedicated MedEvac roles. Instead, the few unmanned solutions identified are primarily designed for CasEvac, typically involving smaller platforms capable of transporting one casualty over short distances without onboard care. The existing UGV market is dominated by platforms intended for logistical support and combat functions. As a result, the application of UGVs in the medical domain remains limited and largely focused on fast evacuation tasks rather than medical transport capabilities.

4.5.2 Identified Gaps

Throughout the market analysis, a gap was identified in the current market between unprotected or lightly protected platform UGVs, and armored, combat-derived vehicles, which typically exceed 3,500 kg. The research found different variants of vehicles aimed at or adapted for rescue and evacuation within these two areas, but there was significantly fewer vehicles under 3500kg adapted for a maximum of two people in the rear space. The current UGVs used for CasEvac were adapted for one casualty, clearly showing a gap for a vehicle with a higher capacity.

This gap highlights the need for a medium-weight, protected UGV that balances mobility, protection, payload capacity, and adaptability. A vehicle capable of operating closer to the frontline than unprotected systems, while being more flexible than traditional armored combat vehicles.

Few systems optimized for mixed seated or lying layout in terms of total re-furnishing. The presented vehicles show several solutions for different layouts of the rear space, as an example with foldable passenger chairs to enable full usage of the space when not in use. To enable full re-furnishing due to, for example, change of mission into a logistics unit, the possibility to move or remove all furniture is needed. Ideally, allowing rapid reconfiguration without specialized tools or without causing damage to the furniture.

There is currently insufficient consideration of dual civil–military use, particularly in the context of natural disasters and large-scale emergencies. The analyzed UGVs are designed with a narrow operational focus, either strictly military or purely civilian.

5

Customer & User Needs Analysis

This chapter examines and analyzes the needs and demands that potential customers and the market have for an UGV in a dual-use context. The needs analysis was structured into a brief summary of the interviews, extracted quotes, functional statements, and a concluding section.

5.1 Interviews

The interviews were of a qualitative and semi-structured nature, allowing for discussions exploring user needs, previous experiences, and perspectives while maintaining a clear focus. Together, the interviews provided insights across operational and strategic levels of evacuation and logistics in the military and civilian contexts. The structure of the interviews helped identify recurring themes and context-specific considerations, forming a foundation for customer and user needs. Appendix A presents the general interview guide used across all interviews. However, the specific questions were adapted to suit each interviewee and their background.

5.1.1 Interviewee 1

Interviewee 1 is educational nurse within the Swedish Armed Forces *(Försvarsmakten)*, working with training personnel in military healthcare. Interviewee 1 has a professional background as a registered nurse in the civilian sector, as well as an ambulance nurse, providing clinical competence in acute and pre-hospital care. Participating in military medical training contributed in practical insights into the specific challenges and conditions associated military healthcare.

The first interview provided several valuable insights for the project. Particularly, the chain of evacuation from the point of injury. A big emphasis throughout the interview was the challenges of transporting wounded on stretchers across different types of terrain, the importance of accessibility, and the need for new solutions that are simple and quick to use. Furthermore, more related to UGV, the need for modular interior configurations depending on the proximity to the frontline during evacuations, highlighting the importance of adapting evacuation and medical transports to its context.

5.1.2 Interviewee 2

The second interviewee has a background as an education officer within the Swedish Armed Forces *(Försvarsmakten)* and as a project manager in medical projects, as well as experience in materiel development. The second interview provided several insights regarding the entire sequence of events of an evacuation, but also important specific insights that are useful for concept development.

An important insight from the interview concerned material selection. From a hygiene perspective, the interior of the vehicle must be easy to clean, particularly when used for transporting casualties where contamination and infection risks are high. Hygiene requirements are not a secondary detail but a core functional aspect of a medical transport system. Interviewee 2 further described the importance of being able to transport casualties back, possibly with minimal or even no accompanying personnel, would free up resources and allow the unit to continue operating forward.

The interviewee also highlighted the logistical dimension and the need to safely deliver supplies and spare parts to units engaged in combat. Logistics are critical to maintaining operational capability and that transport missions often involve risk and tie up personnel. Finally, the interviewee emphasized the importance of ease of use. The UGV and its interior should be intuitive and not require extensive training or specialized technical expertise to operate effectively in the field.

5.1.3 Interviewee 3

Interviewee 3 serves as a chief physician at Home Guard *(Hemvärnet)*, and has previous career as a civilian physician. The professional background within military medical services, including deployments in Africa, provided firsthand insights into operations in demanding and resource-constrained environments.

Interview 3 generated various important insights related to the overall chain of events in different types of mass casualty situations. The discussion also addressed the medical interventions in limited hygiene and with scarce resources results in acceptable outcomes, emphasizing that sanitation and medical equipment does not need be the biggest priority in this context. Particular attention was also placed on the challenges caused by the Nordic climate, especially the significant risk of hypothermia in wounded soldiers, even in climate that is not perceived as extreme.

5.1.4 Interviewee 4

The fourth interviewee works within Swedish Civil Defence and Resilience Agency *(Myndigheten för civilt försvar)* that functions as a reinforcement resource for medical evacuation and operates at the highest level of the national and international resource chain. The mission includes, as an example, transporting soldiers from Ukraine onward to Europe for advanced medical care and, on average, conducting one planned transport per month, with approximately 5–8 patients per flight. The operations include trauma injuries, cancer, and other serious medical conditions.

A key lesson from the interview is that patient evacuation at a higher strategic level requires a comprehensive decision-making and coordination system. This can be contrasted with patient evacuation at the group or tactical level, where decision-making must be significantly more direct and action-oriented. Each individual decision should not require extensive formal anchoring but instead rely on predefined procedures and delegated authority to enable rapid and effective action in a demanding operational environment.

5.2 Statements From Interviews

The qualitative data collected through interviews were transcribed and analyzed using a systematic approach. Central insights, statements, and representative quotations from the interviewees were identified and extracted. A few examples of interview statements is presented in Table 1 below:

Table 1: *Examples of interview statements*

No.	Interviewee	Type	Statements
1	Educational nurse	User	*"Get assistance from the unit that has taken casualties. With something that can transport the injured as close as possible, to avoid having to carry them. Carrying injured personnel is very physically demanding and requires a lot of manpower. Carrying a stretcher requires almost four people, who also need replacement personnel."*
2	Educational nurse	User	*"The further forward you are, the more you can accept a spartan environment."*
3	Project manager for medical projects	Expert/customer	*"The logistical advantages of being able to deliver supplies to places where you don't want to risk injuries."*
4	Project manager for medical projects	Expert/customer	*"Being able to move casualties without having to allocate personnel to transport them back, and without needing a lot of manned vehicles. Instead, having a transport that can run in a shuttle service, for example between medical units or between the frontline and a medical unit."*
5	Chief physician	Expert/user	*"Simple, inexpensive vehicles, since they are constantly being expended."*

5.3 Concluded Functional Statements

The extracted interview quotations were interpreted and translated into functional statements. During this process, both explicit needs that were directly expressed by participants and latent needs that were implied from underlying statements, were identified and included. Using the KJ analysis method, the functional statements were systematically grouped into categories based on similarities and patterns. The analysis resulted in four functional categories, which are presented below together with brief explanations. The complete list of functions is provided in Table 2.

- **Goal:** Defines what the concept is intended to achieve.
- **Usability:** Emphasizes intuitive design and clear usage indicators.
- **Interior:** Covers the internal functions and required equipment.
- **Performance:** Ensures the ability to operate under challenging conditions.

Table 2: *Concluded functional statements from customer and user needs analysis*

Category	Functional Statement
Goal	reduces manpower need during evacuation
	enables transport of casualties between evacuation points
	enables low-cost and high-utility transport
Usability	interior provides indicators of correct usage
	interior is intuitive
	enables operation during dark hours
	interior prevents improper usage
	enables operation and cargo handling by personnel with minimal training
Interior	MedEvac enables higher-level of care
	CasEvac enables simple care
	allows for high-capacity transportation
	interior ensures easy access during patient care
	interior ensures efficient use of space
	allows for adaptable interior
	allows for flexible cargo configurations
	allows tool-less reconfiguration of cargo area
	allows compatibility with standardized stretcher systems
	ensures total light discipline
	enables transport of supplies between evacuation points
	interior enables medical guidance
	ensures safe transport of medications
	should ensure robust interior
	enables internal and external communication
	interior is moisture resistant
	ensures safe internal temperature
	allows for sanitation of interior
	enables drainage of liquids
	ensures safe transport of liquids
	enables protection of personnel and cargo
	enables safe transport of personnel and cargo
	enables temperature-controlled transport
Performance	enables safe transport under G-forces
	enables operation on low ground bearing terrain
	is adapted to all ground terrain

5.4 Key Takeaways from Customer & User Needs Analysis

After the customer and user needs analysis, several key insights were identified regarding the UGV system and the operational environment. These include the challenging and dynamic conditions such systems must function in, the need for reliability and adaptability in uncertain terrain, and the importance of minimizing risk to personnel while maintaining effective logistical and evacuation capabilities. This together with the initial requirements, listed in Table 3, adds to a number of different scenarios, which are presented in the following chapter.

Table 3: *Initial requirements*

Initial requirements
The UGV allows for both manual and remote operation
The UGV must fit inside a 20 ft. container
The UGV interior allows for wheel model 14.00 R20
The UGV enables operation within LCV classification
The UGV must fit standard NATO stretchers

In addition, preliminary considerations regarding the UGV system design such as modularity, robustness, and scalability, were recognized as important factors influencing its effectiveness in these contexts. These aspects will be explored in greater detail in later chapters.

6

Scenarios & Missions From Research Findings

Based on literature findings, the market analysis, and the interview study, several use scenarios and specific missions were defined. Because the needs and priorities vary a lot between missions, concept development is approached scenario-by-scenario rather than attempting to create a single, universal solution. This framing makes it possible to define clearer requirements, evaluate trade-offs more consistently, and generate targeted concepts that are well-adapted to specific missions.

For each scenario, two missions were defined to narrow the scope and make the following concept development more focused and manageable. This approach enabled a more structured process, ensuring that each direction remained clear and actionable rather than overly broad or abstract. By organizing the work in this way, the concepts developed were grounded in well-defined insights, increasing their relevance and supporting the translation of ideas into meaningful solutions.

6.1 Scenario 1: CasEvac

Scenario 1 focuses on casualty evacuation (CasEvac), which in this scenario is defined as the evacuation from the point of injury (POI) to a designated casualty collection point (CCP). In this scenario, the UGV would operate closer to the frontline, in a high-risk environment, where the priority is to extract the wounded as quickly as possible to reduce the time exposed to threats.

The main purpose of the CasEvac scenario is immediate evacuation, enabling a rapid handover to a higher level of care, and bridging the gap between initial field care and a more formal medical evacuation. This UGV CasEvac would take place so close to the frontline that it could potentially replace soldiers who would otherwise carry the wounded on a stretcher in these areas. CasEvac is typically carried out using any vehicle or platform that is available, rather than a dedicated medical vehicle, and the medical capability during transport is therefore limited. The supposed route is usually short and focused on speed and direct extraction rather than medical treatment on the move. For involved entities, actors, and main functions for scenario 1, see Figure 16. Regarding the missions within scenario 1, the primary focus was placed on injury severity levels.

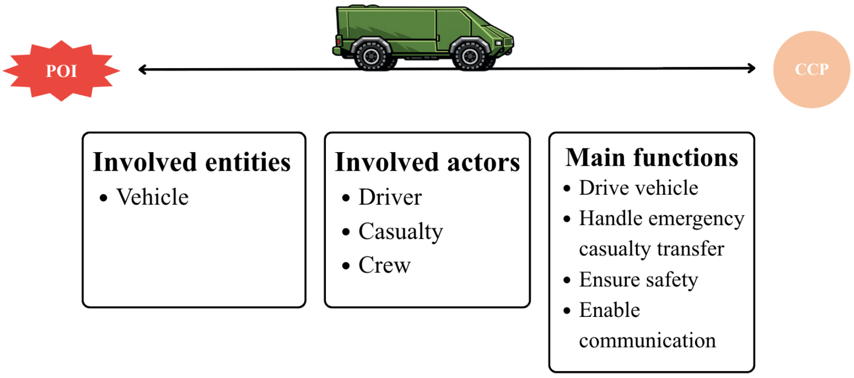

Figure 16: *Scenario 1: CasEvac*

6.1.1 Mission 1A - Moderate Injuries

Casualties in Mission 1A have sustained moderate injuries but remain conscious and capable of limited movement and they are possibly still able to load themselves onto the UGV with minimal or no direct physical assistance. The casualty can approach the vehicle and board it independently, allowing for a faster extraction from the dangerous area.

6.1.2 Mission 1B - Life-threatening Injuries

In this mission, casualties have sustained life-threatening injuries and may be unconscious or immobilized. Due to their condition, they are unable to evacuate on their own and require external assistance to be carefully positioned and secured onto the UGV for evacuation to a safer location for further medical treatment.

6.2 Scenario 2: MedEvac

Scenario 2 focuses on medical evacuation (MedEvac), which is defined in this scenario as the planned transport between the previously mentioned casualty collection point (CCP) to an ambulance exchange point (AXP) or another medical facility. Compared to the previous scenario, scenario 2 occurs farther from the frontline in a less high-risk area of the battlefield, where routes and points are coordinated in advance.

The purpose of the MedEvac is to ensure that the wounded soldiers can receive appropriate care during transport while being transferred to an ambulance or medical facility with even higher treatment capability. Throughout the MedEvac route, trained medical personnel maintain continuous supervision, using medical equipment for monitoring and for providing early-stage treatment during transport. See Figure 17 for involved actors, entities and main functions for scenario 2. The missions in scenario 2 emphasize the UGVs capacity and internal configuration, as they occur further back in the logistical chain where operational risk is reduced.

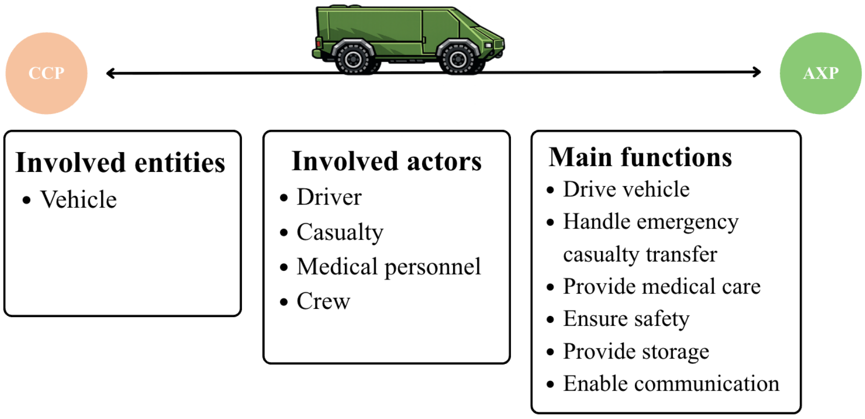

Figure 17: *Scenario 2: MedEvac*

6.2.1 Mission 2A - Moderate Injuries

In Mission 2A, casualties have moderate injuries and are generally stable and able to be transported without immediate assistance. The UGV should handle a larger number of casualties at once, highlighting the need for efficient use of space and to facilitate both seated and supine capacity within the UGV.

6.2.2 Mission 2B - Life-threatening Injuries

The casualties in Mission 2B have sustained severe injuries and are generally unstable, requiring medical attention during transport. The UGV will need to handle fewer casualties at a time due to the urgency and complexity of care, emphasizing the need for specialized medical equipment and continuous observation.

6.3 Scenario 3: Logistics

Lastly, scenario 3 centers around the use of UGVs to support frontline logistics in high-risk zones by providing necessary supplies and equipment. Normally, delivering these materials would require sending personnel into areas, exposing them to unnecessary danger. In this scenario, the UGV is sent instead. Because no crew is needed inside, the loss of the vehicle does not result in casualties or serious socio-political consequences (Michalski & Nowakowski, 2020).

The UGV transports supplies from a safer area to frontline positions, unloads the cargo, and can return with damaged goods or new requests. By taking over these dangerous logistical tasks, it reduces the need for manpower, helps protect lives, and ensures that essential supplies reach troops even under the most hazardous battlefield conditions. For more details regarding involved actors, entities and main functions for scenario 3, see Figure 18. The following missions of scenario 3 is focused on the specific supplies to be distributed, which requires different needs and functions.

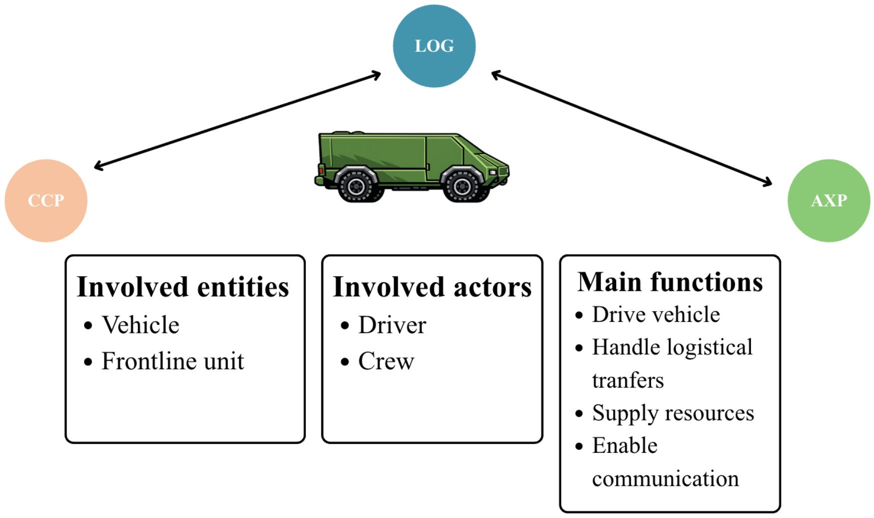

Figure 18: *Scenario 3: Logistics*

6.3.1 Mission 3A - Supply of Medical Necessities

For mission 3A, an UGV is tasked with delivering critical medical supplies to frontline units operating in high-risk areas. The vehicle transports essential items such as first aid kits, medical equipment, and medications that require controlled or specialized storage conditions. The mission focuses on maintaining a steady flow of vital resources to the frontline so that troops can continue without interruption.

6.3.2 Mission 3B - Electrical Power Supply

Mission 3B is conducted to ensure that frontline troops maintain access to reliable electrical power during operations. For this mission, the UGV is tasked with transporting energy resources to forward positions where soldiers depend on powered equipment, without endangering other personnel for transportation.

6.4 Key Takeaways from Scenario & Mission Identification

From this set of missions, one mission per scenario was selected for further considerations and development. The selection was based on the availability and depth of insights gathered during earlier research phases. By prioritizing areas with the strongest informational foundation, the continued tasks remained both informed and strategically grounded. The chosen missions are presented below:

- Scenario 1 - Mission 1B - Life-threatening Injuries
- Scenario 2 - Mission 2A - Moderate Injuries
- Scenario 3 - Mission 3B - Electrical Power Supply

7

Implementing Systems Engineering for Early Product Development

In frontline environments during crisis situations, the operations are increasingly shaped by uncertainty, rapid change, and high-risk exposure for human personnel. UGVs offer significant potential to enhance operational effectiveness by taking on tasks related to movement and support activities in such environments. However, to be truly valuable, these systems must not only be technically capable but also operationally resilient. It must be able to function under dynamic conditions while aligning with the needs, constraints, and practices of the users.

This chapter establishes the Systems Engineering foundation for the continued development of the UGV concept. Building on the insights gathered from the earlier stages in this report, and the previously defined operational scenarios and missions, the work transitions from exploratory analysis to structured system overview.

To formalize the operational context, a ConOps is developed, capturing how the proposed system is intended to be used. Then, a Model-Based Systems Engineering (MBSE) approach is applied using Capella, following the Arcadia methodology.

By grounding the systems engineering process in validated inputs and realistic scenarios, this chapter ensures that the resulting system design is both traceable and aligned with the intended operational use.

7.1 ConOps as an Evolving Working Document

The ConOps has been used as a living document throughout the project to structure collected information and to stimulate new ways of thinking where knowledge gaps were identified. Predefined context and scope within the thesis, and knowledge from the overall research conducted in the project, were continuously sorted into the corresponding sections of the established ConOps structure. Particular attention is given to chapter 3 and onward in the appendix of NASA Systems Engineering Handbook, where the core SE processes are described. These sections focus on how systems are iteratively defined, analyzed, and refined, which aligns well with the approach taken in this project.

This approach provided a clear overview of existing knowledge and facilitated a structured understanding of the system. It also helped bring together technical viewpoints and operational experiences, creating a more unified picture of how the system of an UGV should function. In particular, the ConOps enabled a concise description of key elements such as actors and interactions, system boundaries and constraints, and stakeholder needs related to safety, reliability, autonomy, and usability.

In chapter *6.0 Operational Scenarios, Use Cases and/or Design Reference Missions*, a merged image of all three scenarios is included along with each image of the different missions as presented in the previous chapter. The merged image is shown in Figure 19 below and worked as the common ground throughout the project.

Figure 19: *Merged image of all three scenarios (OpenAI, 2026)*

Examples of how information was incorporated into the ConOps document are in section *7.3 Scientific/Technical Impacts*, which outlines anticipated operational impacts. For instance, efficiency improvements were identified through automation of repetitive tasks, reduced manpower requirements, and enhanced logistical flows supported by insights from interviewee two and interview statement 4 in Table 1.

Another example is the risk of transmitted vibrations that may cause health risks to casualties by aggravating injuries such as spinal trauma, fractures, or head injuries. The solution to decrease vibrations with route planning, as previously presented by Tolt et al. (2026), was incorporated in chapter *8.0 Risks and Potential Issues*, where different concerns are listed. This demonstrates how a shared document, used to organize and structure diverse knowledge and inputs, can provide significant support to the project.

The structured knowledge captured in the ConOps was further utilized in system modeling and design activities. As the project progressed, new insights and considerations continuously emerged and were iteratively incorporated into the document. In this way, the ConOps served as a space for knowledge, but also as a foundation for ongoing validation and refinement as the system concept evolved.

7.2 Model-Based Systems Engineering

This chapter presents the use of the Capella software as a MBSE tool for structured modeling and development of UGV concepts. In this chapter, Scenario 1 - CasEvac and mission 1B is used as the main example to illustrate the modeling process, while the MedEvac and logistic missions are provided in Appendix B and Appendix C. The chapter describes how the model was developed from Operational Analysis, where mission needs and actors were identified, to System Analysis, where these were refined into functions, interactions, and constraints. Through this process, Capella served as a systematic support for translating operational needs into a more concrete system representation.

7.2.1 Operational Analysis

The purpose of the Operational Analysis stage is to capture what the users of the future system need to accomplish within the operational context. This is done by identifying the relevant actors and entities, together with their relationships, in order to establish a structured understanding of the operational needs the system must fulfill.

7.2.1.1 Operational Capabilities Diagram (OCB)

The initial step in developing system models for the UGVs in Capella started with an Operational Capabilities diagram (OCB), which was created to describe the system from an operational perspective. The purpose of this was to identify the main actors involved in the mission and the key capabilities, as the system's main functional requirements.

The modeling began by defining the operational context and identifying the relevant actors, such as the driver, the casualty, the crew, and the vehicle itself, for the CasEvac scenario. After this, the main capabilities of the system were established based on the second scenario description, as previously shown in Figure 16. These included driving the vehicle, handling emergency casualty transfer, ensuring safety, and communication, see Figure 20.

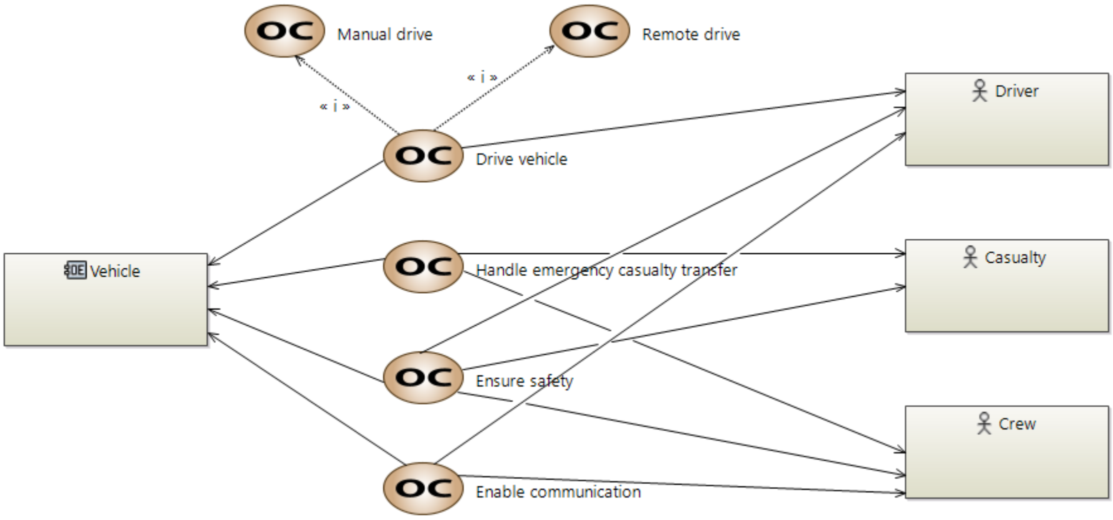

Figure 20: *OCB diagram for CasEvac mission 1B*

7.2.1.2 Operational Activity Diagram (OAB)

After establishing the operational capabilities in the OCB, the next step in Capella was to develop an Operational Activity diagram (OAB) for the CasEvac UGV. The purpose of this model was to move from what the system must achieve to how the work is carried out through activities and exchanges between actors and entities.

The modeling process began by transferring the main actors identified in the OCB into the OAB and clarifying whether they are presented as a human actor or a non-human entity. Based on the capabilities defined earlier, new operational activities were then also introduced. During this stage, additional entities that were necessary to describe the operations in more detail were also introduced, such as the control center. This made it possible to represent information exchanges not only within the vehicle and its crew, but also between the vehicle and external operational support.

Interactions between activities were then added to show how operational activities flow through the system during a CasEvac mission. The capability names from the OCB were used as names of the operational processes that defined the flow of activities and interactions, see Figure 21 for the detailed diagram.

By introducing new entities and further developed activities, this diagram served as an important step between the OCB and the next step of system analysis.

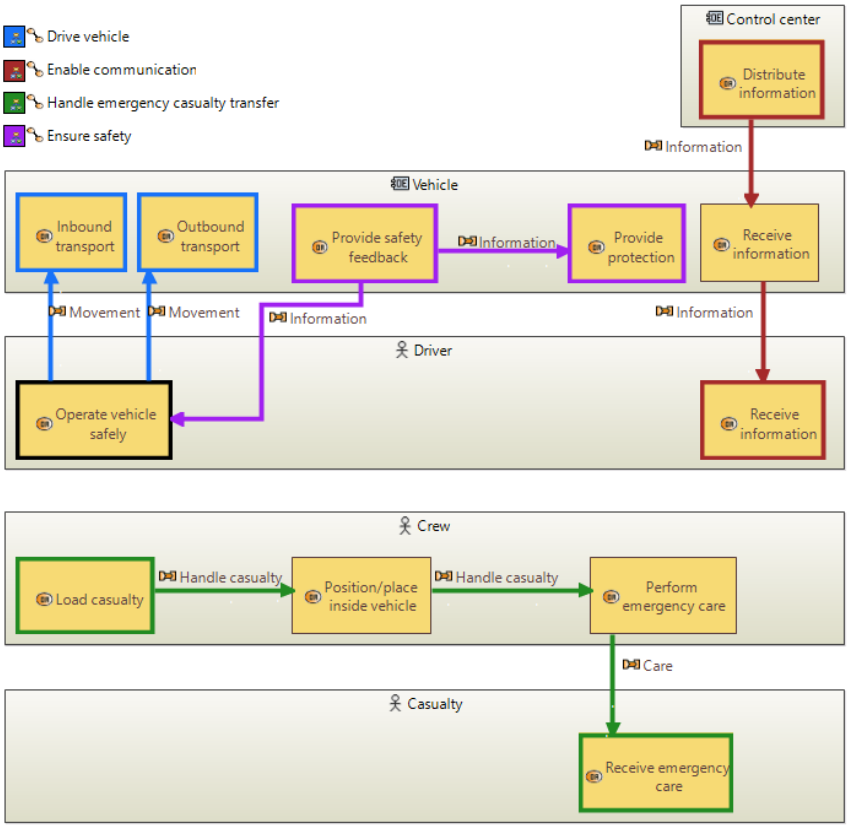

Figure 21: *OAB diagram for CasEvac mission 1B*

7.2.2 System Analysis

The System Analysis level builds on the operational analysis by translating the identified operational behavior into a more concrete system description. The focus shifts from activities to the system itself, its surrounding actors, and the functions it must perform. The purpose of this stage is therefore to identify the relevant system actors, define the system functions, and describe how these functions interact.

7.2.2.1 System Architecture Diagram (SAB)

The next step in Capella was to refine the CasEvac UGV model in a System Architecture diagram (SAB). The modeling process began by bringing the previously identified actors and entities into the diagram and representing them as system actors. This created a clearer boundary between the UGV system itself and the external actors interacting with it. After this, the functional transition in Capella was used to transfer the operational activities from the OAB into corresponding system functions. In this way, the activities identified at the operational level were linked between the levels and reinterpreted as functions that the system must perform.

Once these initial system functions had been introduced, they were further refined into more detailed system functions in order to describe the behavior of the system and system actors more precisely. This allowed the model to move from a general operational description to a more structured representation of what the system must do to support casualty evacuation.

As a final step, constraints were added to the model. These constraints represented measurable system requirements and helped connect the functional model to concrete physical expectations, see Figure 22 for the final diagram. This made the system analysis more precise by ensuring that the CasEvac UGV model was not only behaviorally structured, but also linked to requirements that can be verified later in the concept development process.

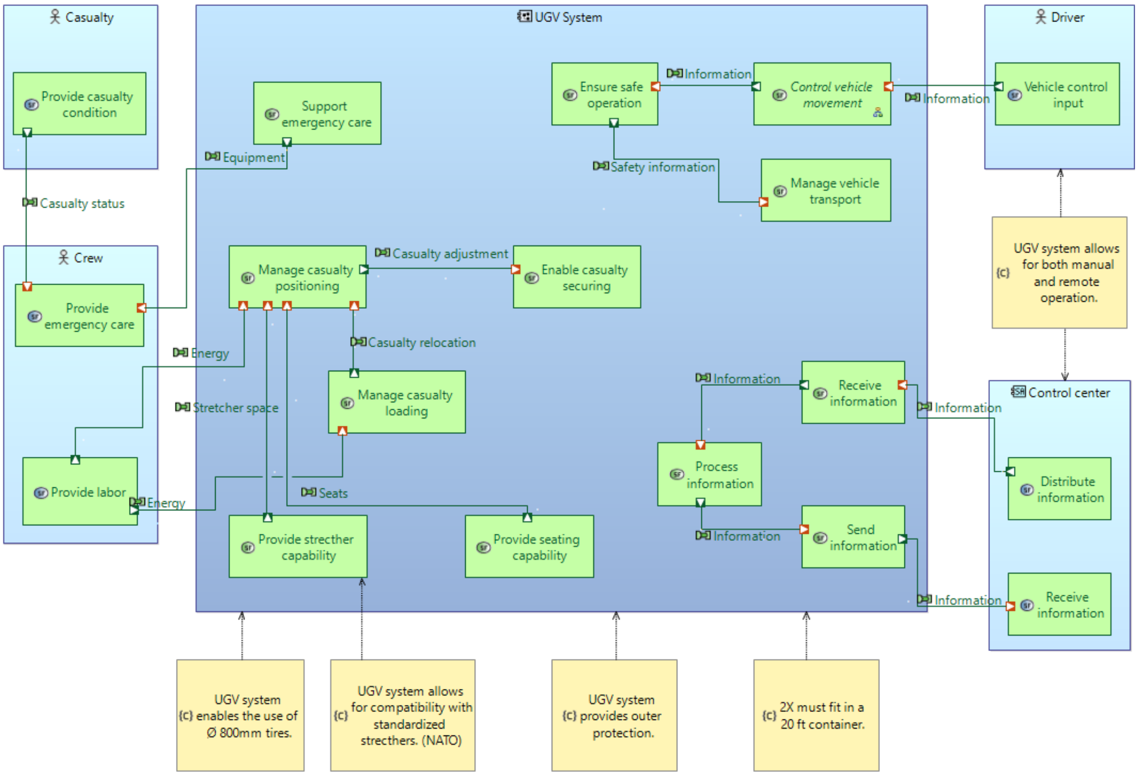

Figure 22: *SAB diagram for CasEvac mission 1B*

7.2.2.2 Example of Functional Breakdown Diagram (SFBD)

As a last part of the system analysis, a Functional Breakdown Diagram was created for the common system function *Control vehicle movement*, which appears across all three of the chosen missions. The purpose of this was to explore the internal complexity and depth that can exist behind a single function defined in the System Architecture diagram (SAB) . At system level, it is beneficial to keep the model relatively simple and readable, focusing on key system functions and their interactions rather than detailed internal behavior. Overly detailed models at this stage risk reducing clarity and making the architecture harder to communicate and analyze in the initial stages of the concept development process. However, the Functional Breakdown Diagram (SFBD) provides a useful complement by enabling a deeper exploration of specific functions when needed. It allows for a more detailed understanding of how system responsibilities can be decomposed and supports further development in the design phases.

While the SAB presents system functions at a relatively high level of abstraction, the breakdown demonstrated that a function such as controlling vehicle movement involves multiple underlying sub-functions, including receiving control inputs, interpreting commands, generating motion commands, and monitoring vehicle behavior. This highlights how each main function in the SAB can contain a significant amount of internal logic and coordination. Creating additional Functional Breakdown diagrams was rather simple and appears in the main breakdown diagram. As an example, *Interpret control input* was further detailed with its own sub-functions of some inputs that is needed for the system. See Figure 23 for the final SFBD model.

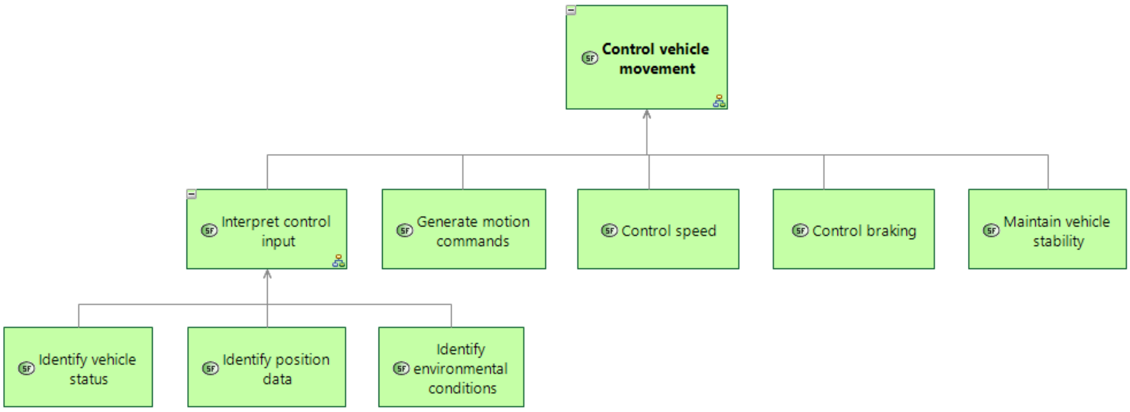

Figure 23: *SFBD diagram for CasEvac mission 1B*

At the same time, some limitations were observed when using this approach in Capella. In particular, it is not possible to include external actors within the breakdown diagrams, which makes it harder to map all interactions in a clear way.

Overall, the use of Functional Breakdown Diagrams proved valuable for illustrating the hidden complexity behind each system function, while also reinforcing the importance of keeping the system architecture at a manageable and communicative level of abstraction.

7.3 Key Takeaways from Systems Engineering

The Systems Engineering work in this chapter has translated operational needs into a structured system architecture, defining key functions, actors, and constraints. This provides a clear and traceable foundation for further development of the UGV concepts.

The following 3D modeling phase builds on these results by giving physical form to the system, using the defined functions, requirements, and operational constraints to guide layout, component integration, and overall vehicle design.

8

Modeling of Concept Proposals

The scope of this project remains on a conceptual system level, focusing on the most critical needs and core functions rather than detailed solutions. The resulting CAD models serves as a complement in the SE framework, and by visualizing and bringing early models, the sense of the concept can be communicated among stakeholders. The following chapter presents the second iteration of CAD models for each scenario, that were based on brainstorming sketches such as Figure 24.

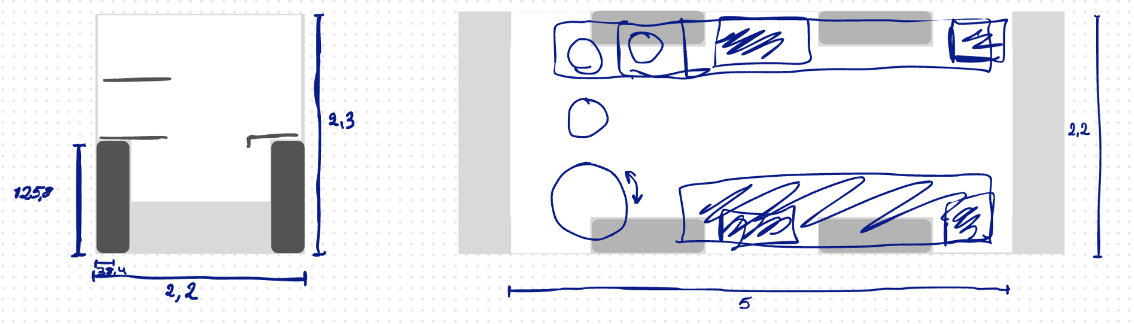

Figure 24: *Example of initial sketches from brainstorming sessions*

8.1 Modeling of Mission 1B

Based on prior insights of swarming strategies and for instance interview statement 5 in Table 1, an additional requirement was established here: the CasEvac vehicle needs to be smaller and two vehicles must fit within a standard 20 ft. container. This constraint answers the need for a more compact UGV, improving transport efficiency, possibilities, and thereby enabling evacuation closer to the frontline. The primary goal was to maximize CasEvac capability within a limited space, ensuring that all design choices consider major physical limitations such as the wheel housing. The layout must also include a driver's seat to support operation in case of manual drive.

The CasEvac vehicle has a total length of 2800 mm, a width of 2100 mm (2136 mm including wheels) and an inner height of 1600 mm. On the right side, two stacked stretchers was placed, one on the bench and one with the help of a wall mount. On the left, a padded bench accommodates either one stretcher or up to three seated passengers. The bench is also used for extra storage during operations, see Figure 25.

Figure 25: *Vehicle layout with open bench for CasEvac mission 1B*

The driver's seat is positioned to allow for rotation towards the back, facing the stretchers to maximize its use for driving or attending to causalities during transportation, see Figure 26.

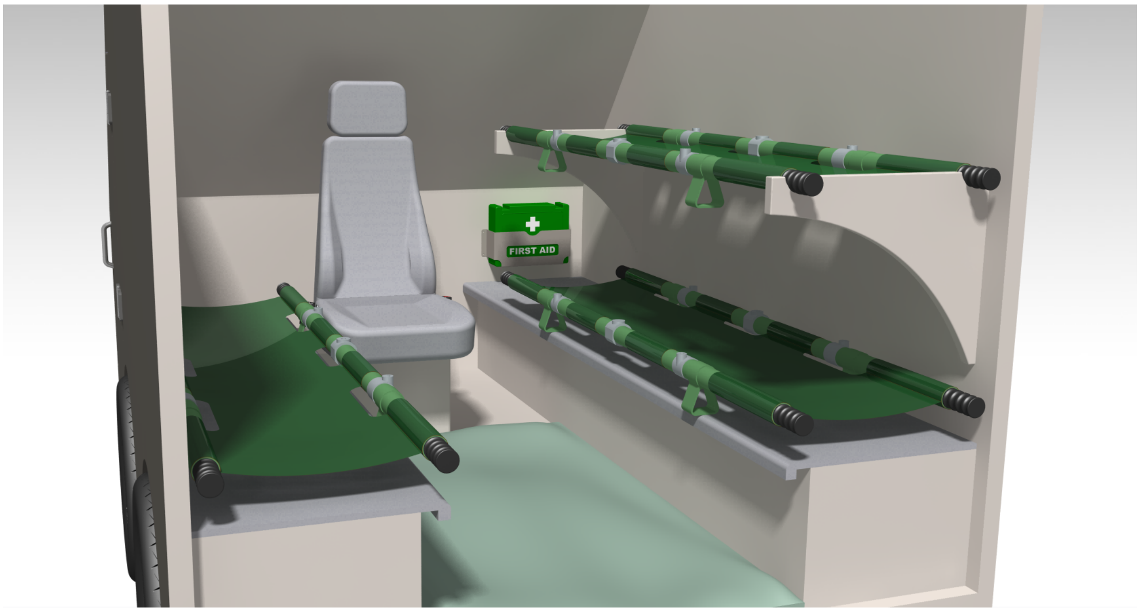

Figure 26: *Vehicle layout with rotated chair for CasEvac mission 1B*

As described in the section regarding Nato Safe Ride Standards, the suggested use of padded floor, was included in the middle aisle of the model, see Figure 27. The padded floor, with dimensions 1000 mm x 1700 mm, can provide comfort when the evacuation is severely insecure and requires a rapid loading of the casualty without securing onto the stretchers. Now the casualty can rest on the padded floor until a safer location or until arrival at CCP.

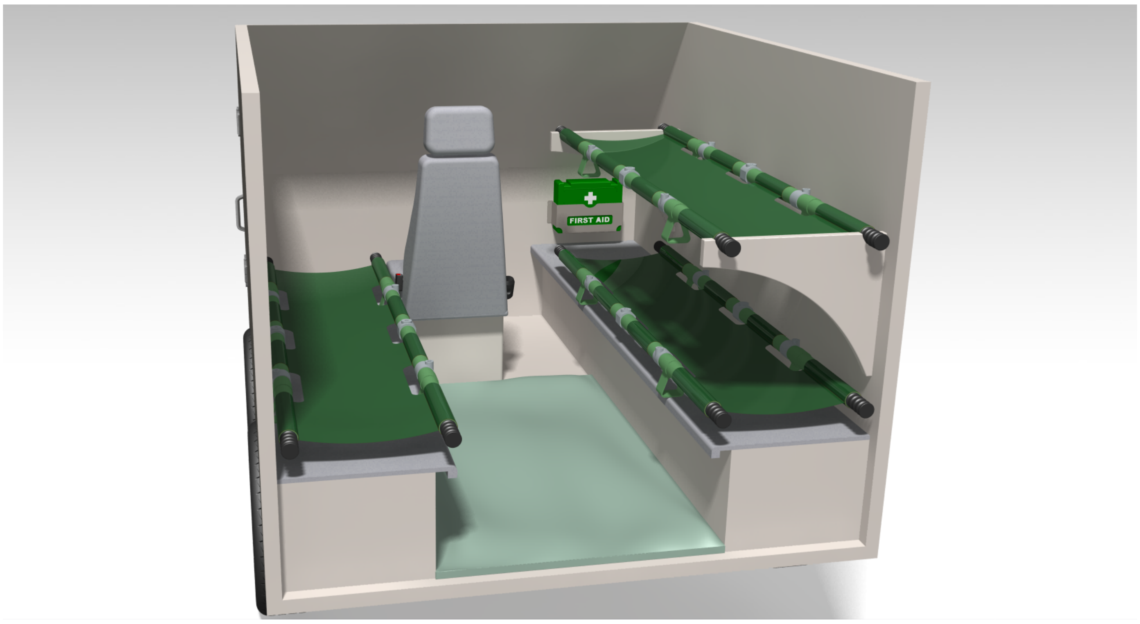

Figure 27: *Overview of interior for CasEvac mission 1B*

8.2 Modeling of Mission 2A

A primary focus was to ensure that essential medical needs are met as effectively as possible within the given dimensional constraints. The design must account for structural limitations such as the wheel housing, and optimizing layout and accessibility. Additionally, the configuration should incorporate both a dedicated driver's seat and at least one medic's seat, ensuring functionality and operational efficiency.

Because of medical necessities, the MedEvac needed to be bigger than the CasEvac and has a total length of 4900 mm, width of 2100 mm (2156 mm including wheels) and inner height of 1600 mm. The UGV does not utilize the entire length of the container, partly because it would be a disproportionately long and narrow vehicle and thereby unstable. Another reasoning is to make room for storage and maintenance in front of or behind the UGV when loaded into the container. This idea was a result from considering section *3.3 Interfaces* and *3.4 Modes of Operations* in the ConOps outline. The need for service and refueling facilities in maintenance mode was identified, which led to the idea of utilizing the container's interior for this purpose.

On the right side of the vehicle, two stretchers were positioned along the wall, see Figure 28. Above them, enclosed storage compartments were included to provide space for medical equipment and supplies. Due to the limited internal height of the UGV, a two-level stretcher layout was not feasible. There would not be enough space between the stretchers to allow medical personnel proper access to the patient or to provide high-quality medical care during transport.

Figure 28: *Internal layout with stretchers and enclosed storage compartments for MedEvac mission 2B*

On the left side, the area covering the wheel house was designed to carry three seated casualties and two dedicated seats for the medics and is shown in Figure 29.

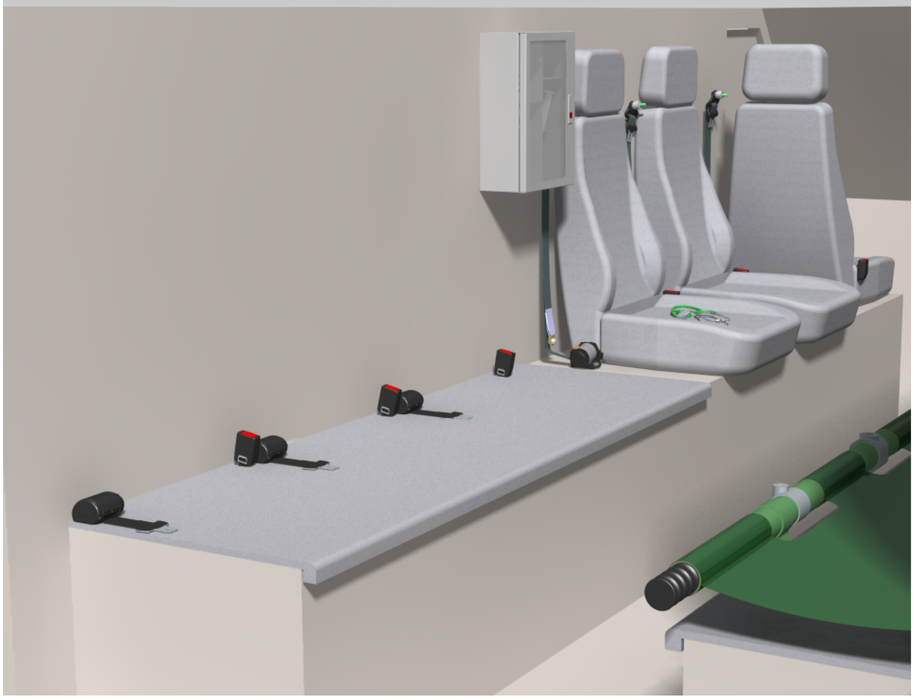

Figure 29: *Seating capabilities for MedEvac mission 2B*

The large tire size results in a high entry point at both driver's door and rear door, requiring the use of a ramp or steps. This necessitates further investigation to assess feasibility and determine additional solutions needed to ensure safe and convenient entry and exit from the UGV. This was noted in the ConOps document as a future consideration to be addressed.

8.3 Modeling of Mission 3B

The main objective of mission 3B is to optimize cargo transport, more specifically battery and energy transport. Bcause logistics vehicle will also travel closer to the frontline, the same arguments was used here as in Scenario 1 - Mission 1B: two vehicles must fit within a standard 20 ft. container to enable more efficient transport and reduce the barrier to deploying multiple units closer to the frontline.

The vehicle has a total length of 2800 mm, width of 2100 mm (2136 mm including wheels) and an inner height of 1600 mm. The middle aisle is 1010 mm wide and 2750 mm long, and can thereby carry an EUR pallet (800mm x 1200mm) and is modeled in Figure 30. This is a big advantage since the standardization ensures compatibility with existing logistical systems and other transport vehicles. In the CAD model, a portable electrical generator is placed on the EUR pallet to demonstrate the usability with large and heavy equipment. This configuration sets the requirements for the rear door to meet the needs of loading and unloading large objects. This is a further consideration, outside the scope of the thesis, but is noted in the ConOps document as an example of a sub-system that requires further investigation.

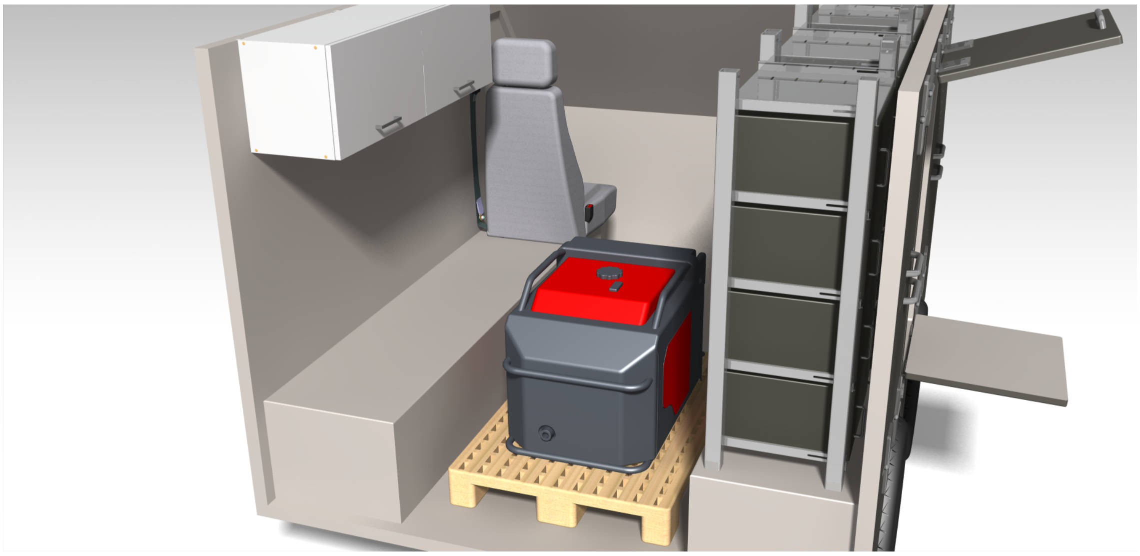

Figure 30: *Overview of the interior for Logistics mission 3B*

On the left side, the flat surface over the wheel house is left empty to allow for either seating or as a workbench. With cabinets above, there is a possibility to work at the workbench and to have close access to equipment in the storage.

In Figure 31, a battery charging and storage station is placed on the right side, with smaller doors that open towards the outside. This solution facilitates rapid battery replacement in the field or during operations, with access provided from the exterior. The split-door design illustrates a possible solution in which the upper door functions as a roof and weather protection, while the lower door can be folded down to serve as a workbench. This improves usability, as the batteries may be heavy to handle.

However, this places requirements based on, for example, user experience (UX) design related to the functions presented earlier. For example, *The UGV ensures total light discipline* means that no lights may be visible to the outside to indicate the charge level of the batteries. Here, other solutions are required to communicate the information to the user. This also applies to other UGVs regarding external indications. As an example, the vehicle should provide clear instructions on how personnel can open it, how to secure the patient, and signals indicating availability.

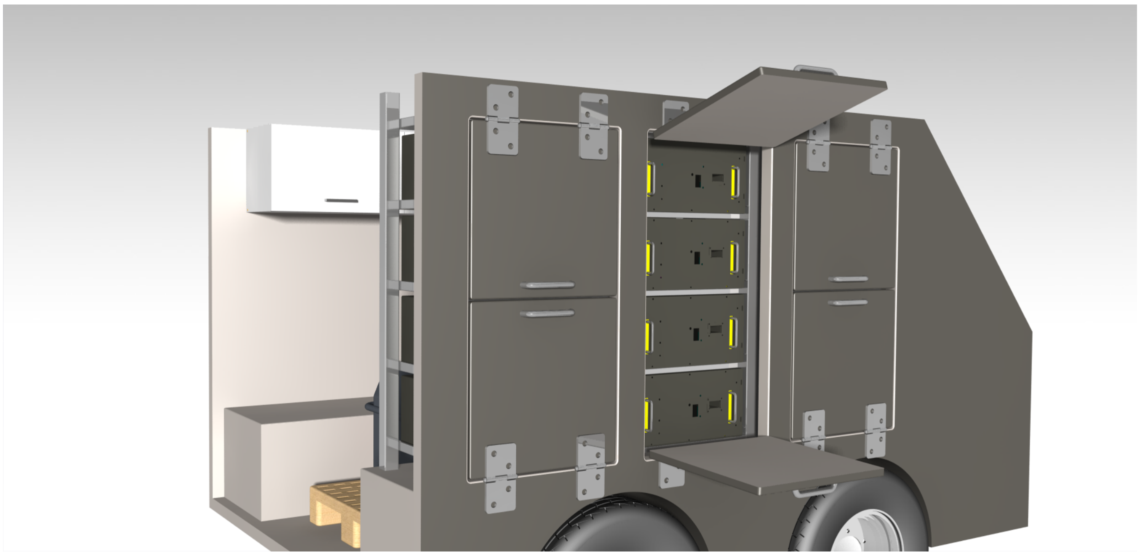

Figure 31: *Battery storage layout for Logistics mission 3B*

8.4 Key Takeaways from Modeling of Concept Proposals

The initial requirement regarding the 20 ft. container, impacted the primary design constraints on all three vehicles. By integrating the wheels and wheel housings within the UGV, the interior cargo volume could be maximized. However, this configuration reduced the flexibility for integrating components along the outer sides of the vehicle.

The additional considerations identified for inclusion in the ConOps document during the concept development phase illustrate the iterative and non-linear nature of the early development process. In this context, having an established method for documenting newly acquired insights throughout the design process proved valuable in ensuring that important details were not overlooked.

As an example, traveling with the stretchers or heavy equipment requires rigid fastening possibilities to ensure safety and this were documented in the ConOps document as a consideration for future implementation.

9

Discussion

In this chapter, the research questions for the thesis are discussed and evaluated. Attention is given to the overall topic, the theoretical framework, the research methods and process, as well as the results. The chapter also addresses ethical, societal, and ecological aspects relevant to the project.

9.1 Discussion of Research Questions

RQ1: *What are the needs among the user, customer, and stakeholder segments for the UGVs?*

The background research, market analysis, and interviews indicate that the need for UGVs is driven by several overlapping user, customer, and stakeholder needs. For the direct users, such as military personnel, medical teams, and operators in near-front environments, the main needs concern reducing human exposure to danger, improving evacuation efficiency, and enabling casualty transport under difficult operational conditions. These users require a vehicle concept that can operate in complex terrain, support rapid evacuation, and provide sufficient space and functionality for basic casualty handling without being too large, heavy, or difficult to deploy.

From the customer perspective, the need is not only for a technically capable vehicle, but for a flexible and adaptable system that can be used across different missions and operational contexts. The customer therefore requires a concept that supports modularity, scalability, transportability, and survivability while remaining feasible to develop and integrate into existing military structures. This creates a need for a balanced solution rather than a vehicle optimized for only one function or scenario.

Other stakeholder segments, such as logistics personnel, maintenance teams, and manufacturers, also introduce important needs. These include ease of transport, maintainability, operational reliability, compatibility with existing infrastructure, and the ability to adapt the vehicle to changing mission requirements. The interviews showed that these needs are strongly connected to practical implementation, where a resilient UGV must be useful not only in theory, but also under real operational limitations such as terrain, time pressure, limited resources, and security risks.

The study also shows that these needs exist within a rapidly developing and partly restricted field. Technological development in unmanned systems appears to be moving faster than formal doctrine, standards, and publicly available research, which made it difficult to identify many directly comparable vehicle concepts during the market analysis. This suggests that autonomous evacuation platforms are still an emerging application area, especially compared to more established unmanned logistics or combat-support systems. At the same time, the classified nature of defense-related development limits access to detailed operational requirements, performance data, and ongoing programs.

Because of these limitations, interviews with key persons became important. They provided specialized operational knowledge that would have been difficult to obtain through public sources alone. The consistency between theory, market observations, and interview findings strengthens the credibility of the identified needs, especially regarding modularity, evacuation efficiency, operational flexibility, risk reduction, survivability, and mobility.

Overall, the needs among the different segments point toward a resilient UGV concept that must balance several conflicting requirements. The main challenge is not identifying individual functions, but understanding how these functions compete within strict operational and physical constraints. For example, improved casualty care requires interior space and medical equipment, while mobility, transportability, and terrain accessibility require compact dimensions and low weight. Therefore, the needs identified in this study should be interpreted as indicative rather than definitive, but they provide a clear direction for early-stage product development and show that future resilient UGVs must be adaptable, mission-oriented, and designed around the practical needs of multiple stakeholder groups.

RQ2: *In which scenarios does the UGV concept offer the highest operational value?*

The analysis indicates that the UGV concept offers the highest operational value in scenarios where it can reduce risk to personnel, increase operational reach, and support tasks that are physically demanding or time-critical. Based on the scenarios developed in this study, the strongest areas of operational value were identified as CasEvac, MedEvac, and logistics. In these contexts, the UGV can contribute by transporting casualties, medical equipment, supplies, or other critical resources while limiting the exposure of human personnel to dangerous or inaccessible environments.

These scenarios also showed that a single optimized UGV configuration cannot fully satisfy all operational needs simultaneously. Each UGV place different demands on the system, such as capacity and accessibility. As a result, the value of the UGV depends strongly on how well its functions are prioritized for the specific mission context. For example, a CasEvac or MedEvac scenario requires strong focus on casualty handling, medical accessibility, and safe transport, while a logistics scenario places greater emphasis on payload capacity, robustness, and efficient movement of supplies.

This means that the objective is not simply to maximize the number of functions included in the vehicle concept. Instead, the highest operational value is achieved when the concept balances capability, simplicity, adaptability, and feasibility in relation to the mission it is intended to support. Attempting to satisfy all possible functions at once would likely increase system complexity, cost, and operational inefficiency. Therefore, identifying the most relevant functions for each scenario became an important part of the development process.

At this early stage of UGV concept development, each of the identified scenarios could be developed into a separate and more detailed project. This study therefore provides an initial structured understanding of where the UGV concept appears most valuable, rather than a complete evaluation of all possible operational applications. To maintain focus, only one mission per scenario was selected for further development and analysis. This made it possible to examine the most relevant operational needs in greater depth instead of producing a broad but superficial overview.

However, the findings remain strongly connected to the selected missions and the assumptions made during the study. Changes in terrain, threat level, available technology, medical requirements, logistical demands, or stakeholder priorities could affect which scenario provides the highest operational value. Therefore, while CasEvac, MedEvac, and logistics were identified as the most valuable scenarios in this study, the applicability of these findings should always be considered in relation to the specific operational context.

RQ3: *To what extent do the final UGV concept proposals address stakeholder and operational needs?*

The final UGV concept proposals address stakeholder and operational needs to a considerable extent at a conceptual level, by translating identified requirements into concrete vehicle configurations. By maintaining a system-level perspective throughout the project, the concepts were not developed as isolated technical solutions, but as responses to the broader operational problem of evacuation, transportation, accessibility, and mission adaptability. This made it possible to assess how well the proposed designs could support the needs of different stakeholders.

One important way in which the concepts address operational needs is through their focus on transportability and spatial feasibility. The requirement regarding the 20 ft. container, was explored through CAD modeling using realistic dimensions. This showed that compact vehicle concepts are possible, but also highlighted trade-offs between transportability, internal accessibility, and casualty capacity. While smaller dimensions improve logistical deployment, they may limit the available space for medical personnel to access and handle casualties safely.

The concepts also address operational needs by exploring different casualty configurations, including lying patients, seated patients, and mixed layouts. The 3D models made it possible to compare how many stretchers could be accommodated and how different internal arrangements affected accessibility. For example, stacking stretchers can increase capacity and improve space efficiency, but it may also reduce ergonomic access and increase the workload during loading, unloading, and casualty handling. This indicates that the concepts respond to the operational need for casualty transport, but also reveal that maximizing capacity alone is not sufficient if it compromises personnel efficiency or patient handling.

Another important contribution of the final concepts is that they clarify the relationship between stakeholder needs and design trade-offs. The modeling process showed that no single UGV configuration can fully satisfy all operational demands at the same time. A concept optimized for high casualty capacity may be less suitable for rapid access and treatment, while a concept optimized for medical accessibility may carry fewer casualties. Similarly, a compact and easily transportable concept may have limitations in terms of internal movement and layout flexibility. In this sense, the concepts address stakeholder and operational needs not by providing one universally optimal solution, but by making the consequences of different design priorities visible.

However, the extent to which the concepts address stakeholder and operational needs remains limited by the absence of physical prototype testing and direct validation in field-like conditions. CAD modeling can support early-stage assessment of dimensions, layout, capacity, and spatial constraints, but it cannot fully validate factors such as stretcher handling, personnel movement, casualty transfer, ergonomics, or usability under operational stress. Therefore, the final concepts should be understood as conceptually promising proposals rather than fully verified solutions.

Overall, the final resilient UGV concept proposals address the identified stakeholder and operational needs to a meaningful extent by demonstrating feasible design directions, clarifying important trade-offs, and connecting technical layouts to each operational scenario. At the same time, the results suggest that future development should focus on modularity and mission-specific configurations rather than attempting to satisfy all requirements within one fixed platform. The iterative development of the CAD models also strengthened the connection between the concepts and the operational context. As the models developed, operational questions influenced design changes, while design limitations revealed new operational considerations.

RQ4: *To what extent has Systems Engineering contributed to the early product development phases?*

Systems Engineering (SE) contributed to the early product development phases to a significant extent by giving the project a structured way to move from an initially broad operational problem toward more concrete system concepts. A particularly important contribution was that Systems Engineering supported the iterative nature of early product development. During the work with scenarios, the ConOps document, Capella models, and CAD models, new needs and constraints continuously emerged. This showed that the early phases were not linear, but rather a process where requirements, functions, and design ideas developed together. In this sense, Systems Engineering did not only help document decisions, but also helped reveal what needed to be investigated further.

The approach also contributed by making the system easier to discuss at an abstract level before committing to detailed engineering solutions. By using operational scenarios and system models, it became possible to reason about what the UGV system should achieve, how different actors interact, and which functions are necessary to support the missions. This was valuable because the project concerned a complex system with several interacting parts, where early mistakes in problem framing could affect the later concept development.

However, the contribution of SE was not without limitations. The usefulness of the approach depended strongly on how clearly the ConOps document and Capella models were created and communicated. Since different people may model the same system in different ways, there is a risk that diagrams and documents are interpreted differently than intended. This is especially relevant when models are handed over between stakeholders or used as a basis for further development. Without a shared understanding, there is a risk that the models are interpreted differently than intended.

Therefore, SE contributed most clearly as a structuring, communication, and analysis support in the early phases, rather than as a method that automatically produces a final or complete design. Its value relied on continuous reflection, consistent modeling choices, and a shared understanding of the purpose of each model.

ConOps as a Documenting Tool

The ConOps document contributed to the early product development phases by providing a structured foundation for understanding the operational context of the proposed UGV system. It helped collect information about missions, users, needs, limitations, and assumptions in one place, which made the early development work more systematic. The structure, inspired by NASA's ConOps outline, was especially useful because it guided the project toward considering aspects that may otherwise have been overlooked in a more informal concept development process.

By initially using the document to capture known information and identify knowledge gaps, the project gained a clearer understanding of what was already defined and what still needed to be explored. This was important in the early phases, where the challenge was not only to design a vehicle concept, but also to understand the operational needs that the vehicle should respond to.

Another important contribution was that the ConOps document functioned as a living document. As the project developed through MBSE activities and CAD modeling, the document was revisited and updated with new insights. This made it possible to connect later design decisions back to earlier operational reasoning. This demonstrates how the document has not only functioned as a means of documentation, but also as a tool for supporting analysis and guiding the overall design process.

For this project, the ConOps approach was especially effective because the work was carried out by a small team. With only two active contributors, it was relatively easy to keep the document updated and maintain a shared understanding of its content. In a larger organization, however, the same approach would likely require more formal coordination, clearer ownership, and established routines for how the document should be edited, reviewed, and communicated. As discussed by Mostashari et al. (2011), collaborative use of ConOps documents can become more challenging when many stakeholders, distributed teams, and complex communication structures are involved.

Therefore, the ConOps document contributed to a high extent in the early product development phase by improving structure, traceability, and reflection. However, its effectiveness in a larger development context would depend on how well the organization manages collaboration, version control, and shared interpretation of the document.

Capella as a MBSE Tool

The Capella software contributed to the early product development phases by translating operational capabilities from the ConOps document into formal system models. This helped move the project from written descriptions to a clearer visual representation of actors, system boundaries, functions, and interactions. In this way, Capella supported the transition from understanding the operational problem to defining what the system needs to do.

Since the main actors and mission context were relatively clear from the beginning, Capella made it possible to structure the system around these actors and their interactions. This was valuable in the early development phase because it helped clarify what belongs inside the system, what belongs outside the system, and how the system interacts with its environment. Establishing these boundaries early supported more focused concept development and reduced the risk of treating the UGV as an isolated vehicle rather than part of a broader operational system.

One of the strongest contributions of Capella was that it made dependencies and interactions more visible. Instead of only listing functions, the modeling process required the project to consider how information, commands, resources, and control flows between different parts of the system. This helped reveal missing exchanges, overlapping responsibilities, and common functions across missions.

A key challenge was distinguishing between functional flows and broader system-level qualities. For example, *provide safety* was difficult to model as a single exchange because safety does not come from one isolated function. Instead, it emerges from several functions working together, such as vehicle control, communication, environmental awareness, and operator decisions. This highlighted that some aspects are better understood as overall system properties rather than as direct flows between functions. This insight was important for the early product development phase because it showed that not everything relevant to the concept can be represented as a simple sequence of interactions. Some system qualities need to be considered across multiple functions and design decisions. Therefore, Capella contributed not only by producing diagrams, but also by forcing reflection on what the system must achieve and how this should be represented.

Another limitation was that real operational behavior was difficult to represent as a single linear scenario. Many interactions, such as communication between the Control Center and the UGV, occur continuously and in parallel throughout an operation. This made it difficult to capture all system behavior in step-by-step diagrams. However, this limitation also contributed to the project by revealing the complexity of the operational environment and showing that some interactions must be understood as ongoing system behavior rather than isolated steps.

Furthermore, the work proved to be iterative rather than linear. As more missions were modeled, previous diagrams had to be revised. Missing exchanges, repeated functions, and inconsistencies between missions became visible only when the models were compared to each other. This shows that Capella contributed to the early development process by supporting iterative refinement and cross-checking between different operational scenarios. The models improved over time as the understanding of the system improved.

Overall, Capella contributed by supporting actor identification, functional decomposition, system boundary definition, interaction analysis, and architectural reasoning. Its main value in the early product development phase was not that it delivered a final system architecture, but that it helped reveal how the system should be understood, structured, and further developed.

9.2 Ethical, Societal, & Ecological Aspects

To maintain a credible methodology, a variety of peer-reviewed articles, books from reputable publishers, and established frameworks in the field were used. Before usage, each source is critically evaluated for reliability. To achieve this, several databases for peer-reviewed research and literature were used, for example Scopus. Also, to reduce bias and ensure balanced interpretation, the data was triangulated from multiple perspectives.

Regarding the customer, user, and stakeholder analysis, all interviews and results were anonymized by removing personally identifiable information. In addition, informed consent will be obtained from all participants before data collection, ensuring that participation is voluntary and that participants are fully informed about the purpose of the study, and how the data was used.

The interviewees provided personal information such as gender and profession. Ethical issues to consider was therefore to protect their privacy, ensuring confidentiality, and preventing any potential identification or misuse of their personal data.

From a societal perspective, the proposed concept can contribute to improved safety and survival outcomes by reducing the need for for human presence in high-risk situations. If injured soldiers can be reached, assessed, and evacuated with less exposure to rescue teams, there is a higher chance of a succeeded rescue mission. This can lower casualty rates, shorten response times, and support more effective decision-making under pressure. Additionally, the project may lead to more effective and efficient operations, for example, by improving logistical abilities. Improved efficiency can result in faster response times, better allocation of resources, and improved decision-making. This may increase the success rate of missions and humanitarian efforts since mainly material damage is at risk when using an UGV.

At the same time, there are important ethical issues that must be considered. One concern is the potential misuse of the concepts in warfare. Although the UGVs is intended for rescue operations and logistical support, the same technology could be adapted for more aggressive purposes. There is also a risk that increased reliance on unmanned systems could lower the threshold for engaging in military or terror operations, potentially leading to an increase of conflicts and threats.

In military applications, environmental considerations are rarely the primary focus. Even so, there is value in integrating measures that limit unnecessary environmental impact. This can include improving energy efficiency, reducing excess material use, and adopting design strategies that support maintenance, repair, and reuse over time.

Considerations such as personnel and patient safety have not been examined in detail within the scope of this project. This was a deliberate decision to maintain focus and manage the project scope. These aspects are, however, recognized as important and should be addressed in future work. This includes alignment with relevant safety standards and ergonomic guidelines, such as human body measurements, to ensure suitability, compliance, and overall effectiveness in practical use.

10

Conclusion

This chapter concludes the thesis by revisiting the original aim and reflecting on the findings in relation to the research questions. The purpose of this master's thesis was to investigate how Systems Engineering methods can support early product development, applied to the conceptual system-level design of unmanned ground vehicles in dual-use and near-front operations. The following sections answer the four research questions and summarize the key findings and contributions of the thesis.

RQ1: *What are the needs among the user, customer, and stakeholder segments for the UGVs?*

The main identified needs are to reduce personnel exposure in high-risk areas, reduce manpower during evacuation and logistics, and thereby enable safe transport of casualties, supplies, and equipment.

The UGV must furthermore satisfy a set of operational and design-oriented needs identified across the user, customer, and stakeholder segments. The platform should be robust, cost-efficient, and adaptable to varying mission profiles while remaining intuitive to operate for personnel. Emphasis is placed on modularity and flexibility, enabling rapid reconfiguration of the vehicle interior for mission-specific equipment. The design must ensure compatibility with standardized cargo dimensions, while maintaining reliable operation in challenging terrain and demanding environmental conditions.

RQ2: *In which scenarios does the UGV concept offer the highest operational value?*

The UGV concept best supports three operational scenarios: CasEvac, MedEvac, and logistics. These scenarios represent different operational priorities: rapid casualty extraction, planned medical transport further back in the evacuation chain, and supply or energy transport to high-risk areas.

RQ3: *To what extent do the final UGV concept proposals address stakeholder and operational needs?*

The concept proposals address the most central customer needs at a conceptual system level by demonstrating how mission-specific layouts can support evacuation, patient transport, and logistics within the defined dimensional and operational constraints. The CAD models provided a valuable way to evaluate spatial feasibility, compare layout alternatives, and show how the UGV could be adapted for different missions. While physical testing was outside the scope of the thesis, the concepts create a strong foundation for future validation, where aspects such as stretcher handling, personnel movement, ergonomics, casualty transfer, and field usability can be tested and refined further.

RQ4: *To what extent has Systems Engineering contributed to the early product development phases?*

Systems Engineering contributed significantly by structuring the early product development process and creating traceability between user needs, operational scenarios, system functions, and concept proposals. The ConOps document worked as a living document for collecting assumptions, insights, and knowledge gaps, while MBSE helped visualize actors, functions, interactions, and system boundaries. This made the design process more systematic and supported the later CAD modeling phase by reducing the risk of overlooking important functions and constraints.

11

Recommendations for Future Work

Another important aspect for companies to consider is the management of version history throughout the product development process. During the early phases of a new development project, a large number of decisions are continuously made in order to progress the work. A key challenge is therefore how previous information, assumptions, and decisions can be documented and preserved within the Systems Engineering framework to ensure traceability over time.

As the project evolves, new information may emerge that invalidates or alters earlier decisions. Such changes can subsequently affect a range of downstream design choices and system elements. In this context, a MBSE approach provides significant advantages. By using system models and diagrams, for example in Capella, dependencies between functions, components, and requirements can be visualized more clearly. This enables engineers and stakeholders to identify which parts of the system are affected by a design change, thereby improving change management, traceability, and decision support throughout the development process.

For completely new and previously unexplored systems within a company or project group, a Systems Engineering approach can be highly beneficial. By utilizing simple and freely available models and software tools, as demonstrated in this project, a structured foundation and systems-oriented mindset can be established already from the early development stages without requiring major investments. For new systems and concepts such as the one addressed in this project, early knowledge, requirements, and assumptions can be collected and organized systematically. Structuring and visualizing information from the beginning enables more concrete and efficient discussions among stakeholders, potentially improving requirement alignment, supporting decision-making, and reducing misunderstandings during early concept development.

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A

Appendix A

A.1 Interview Questions

Background & Context

Can you briefly describe your role and experience as a [job title], both in civilian and military settings?

In what types of environments or situations have you worked with injured patients *(e.g., urban, rural/terrain, combat-adjacent, training exercises)?*

Based on your experience, how does casualty evacuation differ between civilian and military contexts?

Current Practices in Casualty Transport / Evacuation

Can you describe how a typical casualty evacuation is carried out in your work today?

Which stages or tasks do you consider most critical during casualty transport?

What types of vehicles or equipment are currently used for transport?

Are there situations where current solutions do not work optimally? If so, why?

Needs & Challenges in Frontline / High-Risk Environments

What are the biggest challenges when evacuating casualties in frontline or high-threat environments?

How do threat level, terrain, and time pressure affect how evacuations are carried out?

Are there situations where personnel safety conflicts with patient needs? How is that managed today?

Autonomous / Unmanned Vehicles

What is your immediate reaction to the idea of an autonomous vehicle for casualty evacuation?

In what situations do you think such a vehicle would be most useful?

Are there situations where you believe an autonomous vehicle would not work at all?

Requirements from a Medical & User Perspective

What functions or capabilities would be absolutely necessary for you to use such a vehicle?

What is most important for you as medical personnel during casualty transport?
(e.g., patient access, vehicle stability, ability to monitor the patient, loading/unloading)

How important is the ability to influence or override the vehicle's control or maneuvering?

Are there any clear "deal breakers" - characteristics that would make you unwilling to use the system?

What is the most common reason why transports fail or become dangerous today?

What medical equipment is essential for "last mile" patient transport?

Is there anything important about casualty transport that you feel is often overlooked?

What are your thoughts on seated versus lying-down patient transport?

Any additional ideas regarding what would be needed in such a vehicle?

If you could dream freely, what would the "ideal" solution for evacuation?

Differences Between Civilian & Military Needs

Which requirements differ the most between civilian ambulance solutions and military CasEvac solutions?

Are there civilian work methods or technical solutions that should be transferred into the military context - or vice versa?

What are your thoughts on interoperability between civilian and military systems?

Implementation & Acceptance

What would be required for medical personnel to trust an autonomous casualty evacuation vehicle?

How important is education and training for such a system to become accepted?

Do you see any organizational or cultural barriers to implementation?

Transport of Supplies

What types of supplies are most critical to transport?

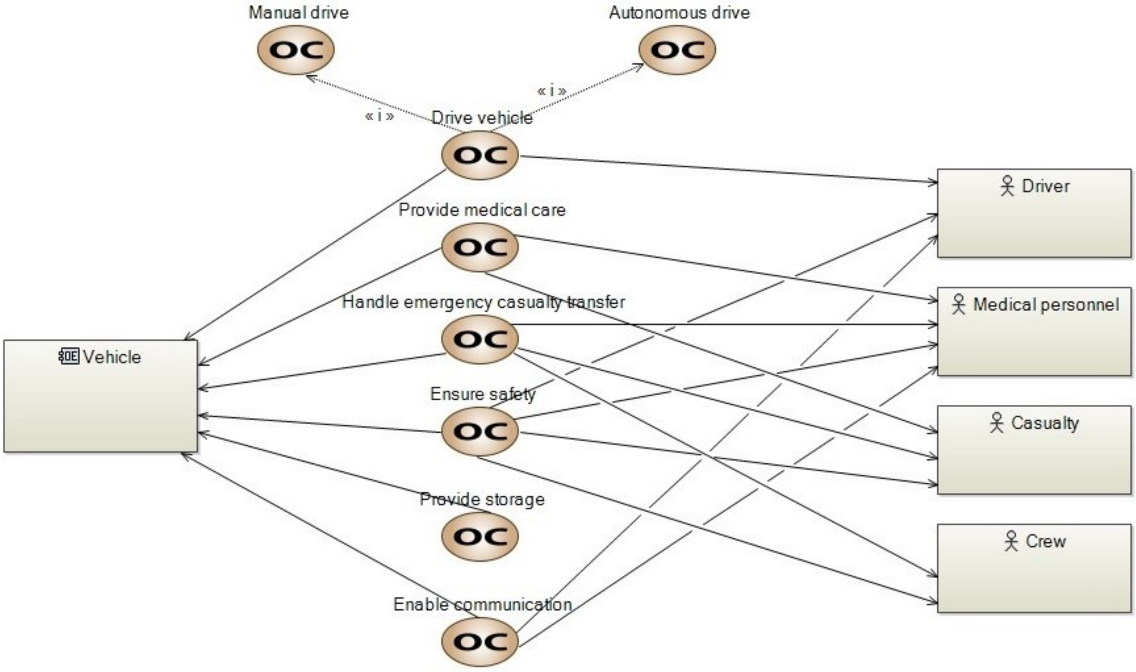
How important is rapid unloading versus ensuring that cargo is extremely secure?

Are there any systems or vehicles you have used that offer good solutions we should take inspiration from?

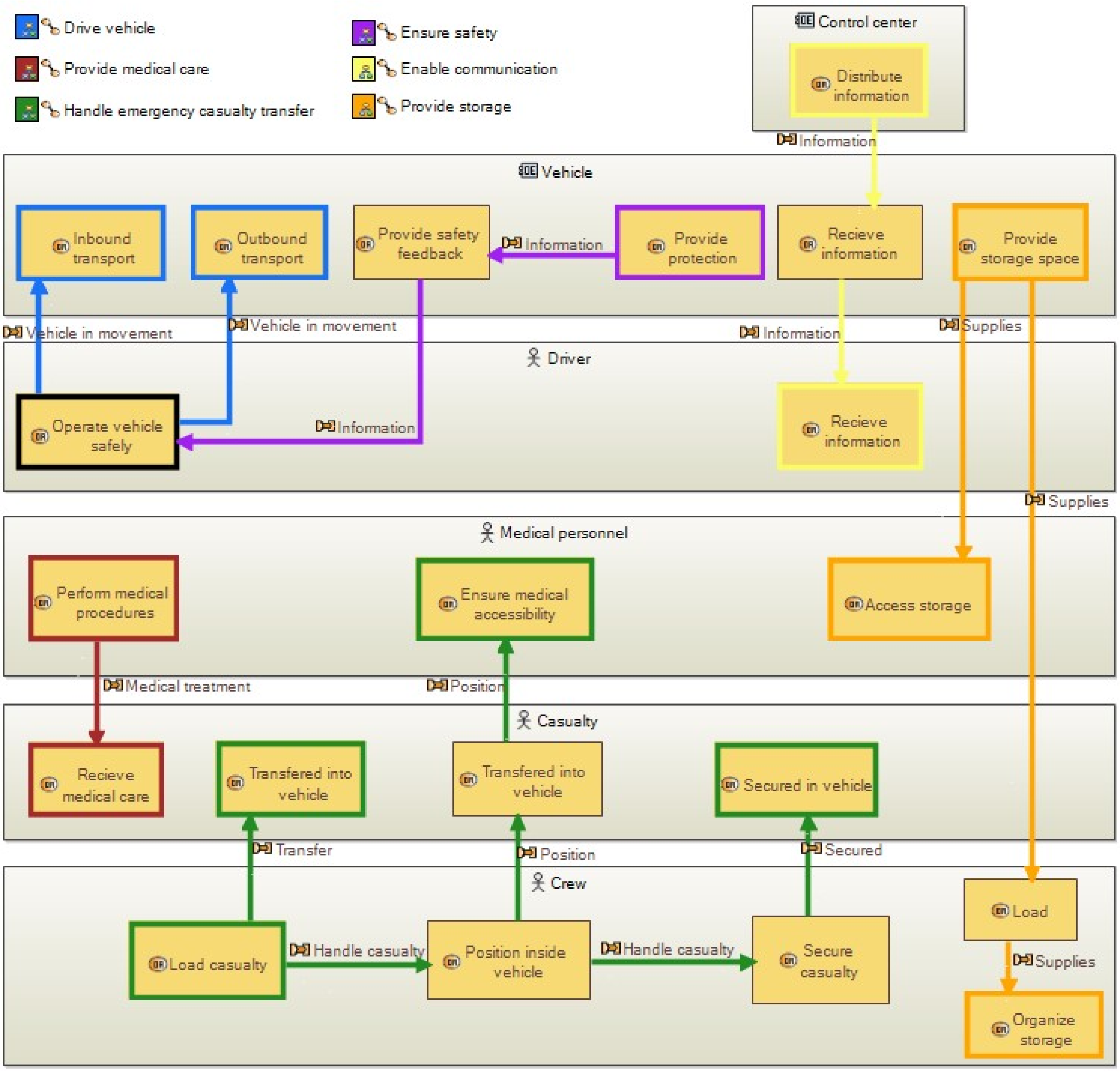
B

Appendix B

B.1 OCB diagram for MedEvac mission 2A



B.2 OAB diagram for MedEvac mission 2A



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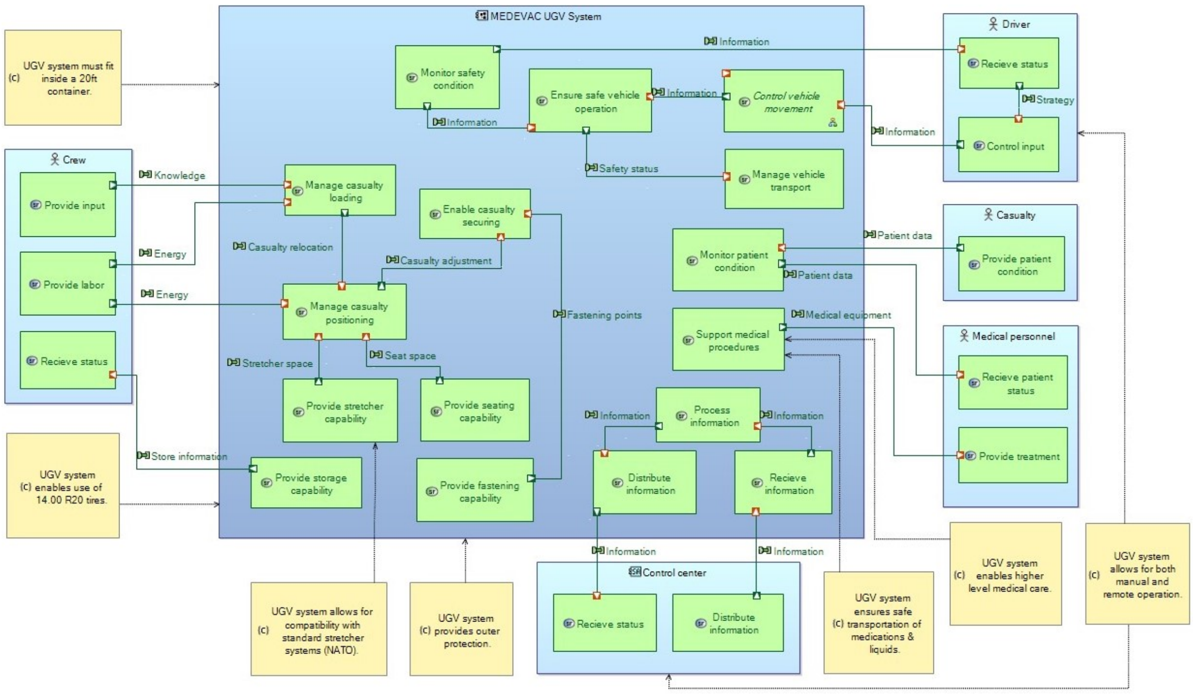
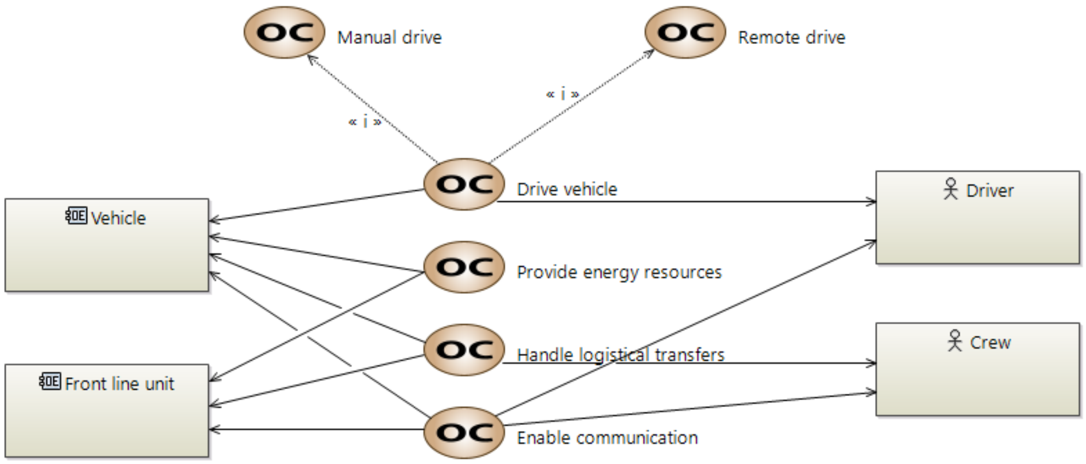
B.3 SAB diagram for MedEvac mission 2A



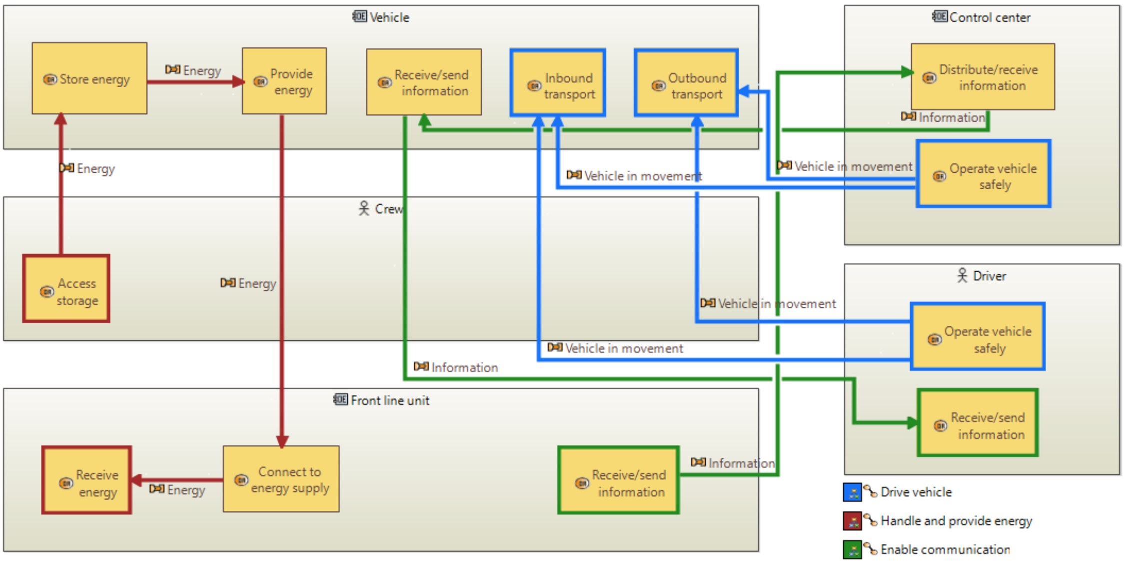
C

Appendix C

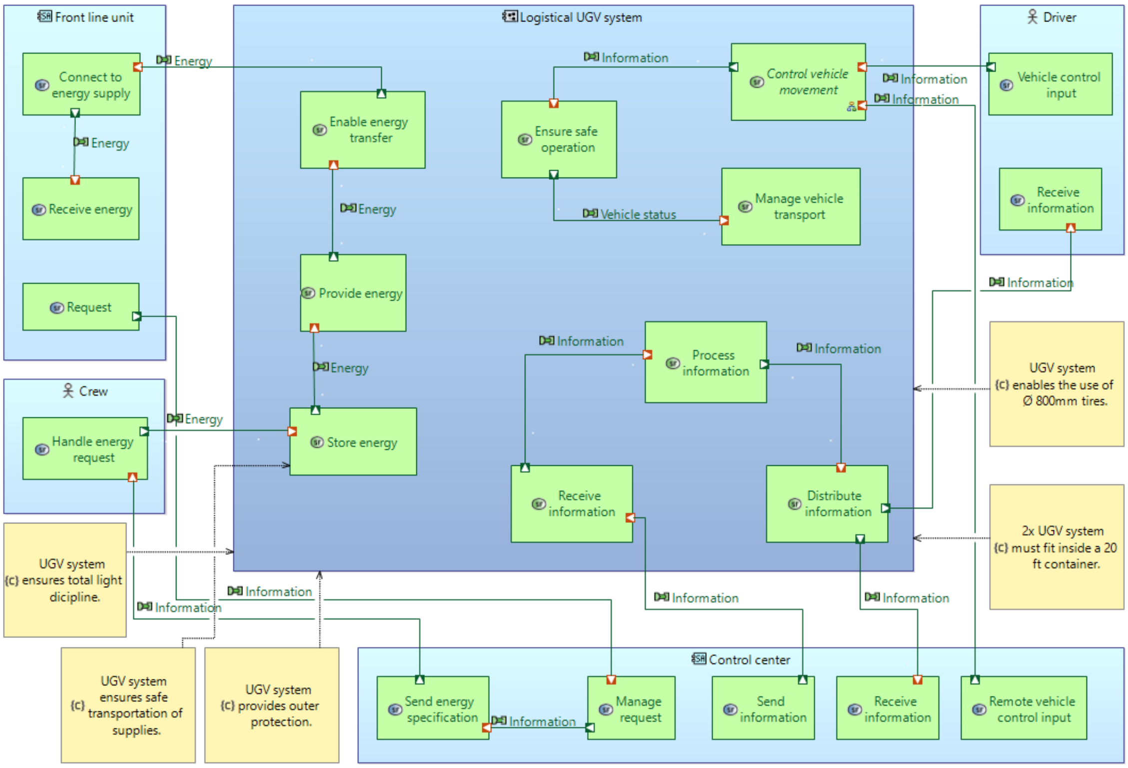
C.1 OCB diagram for Logistics mission 3B



C.2 OAB diagram for Logistics mission 3B



C.3 SAB diagram for Logistics mission 3B



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