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Worcester S.L.A.T.E. Pediatric Ambulance

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Worcester S.L.A.T.E. Pediatric Ambulance
A Major Qualifying Project

Submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the degree of

Bachelor of Science

in

Mechanical Engineering

by

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Abstract

Emergency Medical Service (EMS) are staffed with Basic, Intermediate, and Advanced life support (BLS, ILS, ALS) or Emergency Medical Technicians that provide pre-hospital care to the sick and injured, and transport patients to hospital clinics, or rehabilitation centers for extended evaluation. This project focuses on developing a new pre-hospital medical service for pediatric and obstetrics and gynecology (OB/GYN) care. This project creates and develops a S.L.A.T.E. (Safety, Lightweight, Affordability, Technology, and Efficiency) ambulance that can enhance the safety of pregnant women, newborns, and young children, and yet still function as a standard ambulance. During the design process, background research is conducted to locate and validate performance specifications for an ambulance box and chassis that can be used to provide pediatric, OB/GYN and standard ambulance care. Special storage devices, improved and mobile captain's chairs, an incubation station and an improved workspace are incorporated into the new pediatric and OB/GYN ambulance. We use lightweight materials and reinforced columns and arches to strengthen the structure and stiffness of the ambulance box. Analysis of a number of current ambulance chassis is also conducted to select the most suited one for the new S.L.A.T.E. pediatric and OB/GYN ambulance. Using indicators such as miles per gallon, gross vehicle weight, engine type, safety, reliability, and stability, the chassis for the pediatric and OB/GYN ambulance is selected. The new pediatric and OB/GYN ambulance with a resilient and adaptable chassis and box present a greater opportunity to enrich the quality of pre-hospital care across the country.
# Table of Contents

Abstract ................................................................................................................................................. i

Table of Contents ................................................................................................................................. ii

List of Figures ....................................................................................................................................... Iv

List of Tables ......................................................................................................................................... vi

Acknowledgements ............................................................................................................................... vii

Chapter 1. EMS AND LIFE SAVING PRACTICES ................................................................................ 1
  1. Introduction ........................................................................................................................................ 1

Chapter 2. EMS AND PATIENT-CENTRIC QUALITY CARE ................................................................. 3
  2. Introduction ........................................................................................................................................ 3
    2.1 Ambulances ..................................................................................................................................... 3
      2.1.1 History of Civilian Ambulance Use ......................................................................................... 4
      2.1.2 Emergency Medical Technicians ......................................................................................... 6
      2.1.3 Standards ............................................................................................................................... 7
      2.1.4 Design and Manufacturing ................................................................................................. 8
      2.1.5 Crash Safety ......................................................................................................................... 11
      2.1.6 Maintenance ........................................................................................................................ 12
      2.1.7 Interior .................................................................................................................................... 13
      2.1.8 Case Studies ........................................................................................................................ 15
    2.2 Pediatrics and Obstetrics and Gynecology ...................................................................................... 15
      2.2.1 Obstetrics and Gynecology ................................................................................................. 16
      2.2.2 Pediatric Ambulances ......................................................................................................... 18
    2.3 Worcester, Massachusetts ............................................................................................................. 19
      2.3.1 Geography and Climate ...................................................................................................... 20
      2.3.2 Worcester Facilities ............................................................................................................ 22

Chapter 3. DESIGN AND ANALYSIS ................................................................................................. 24
  3. Introduction ........................................................................................................................................ 24
    3.1 Ambulance Box Design ............................................................................................................... 24
      3.1.1 Problem and Goal Statement ............................................................................................... 25
      3.1.2 Objectives, Constraints, and Functions ............................................................................. 25
      3.1.3 Design Process ..................................................................................................................... 30
      3.1.4 Final Design ........................................................................................................................ 33
      3.1.5 Results and Considerations ................................................................................................. 41
    3.2 Chassis Selection .......................................................................................................................... 44
      3.2.1 Problem Statement ............................................................................................................... 45
      3.2.2 Specifications ....................................................................................................................... 45
      3.2.3 Project Goals ....................................................................................................................... 49
      3.2.4 Ford ....................................................................................................................................... 51
      3.2.5 Mercedes ............................................................................................................................ 55
      3.2.6 Ford Vs. Mercedes [9] ........................................................................................................ 66
      3.2.7 Results and Considerations ................................................................................................. 66
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Horse Drawn Ambulance, Madison Fire Department [13]</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Type III Ambulance Professional Vehicle Corporation [22]</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Star of Life, General Service Administration [8]</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>Pediatric Patient [21]</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>OBGYN Patient [26]</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>Pediatric Ambulance Exterior [21]</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Pediatric Ambulance Interior [21]</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>City of Worcester, MA [28]</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>Worcester, MA Climate Data [17]</td>
<td>21</td>
</tr>
<tr>
<td>13</td>
<td>Worcester Polytechnic Institute</td>
<td>23</td>
</tr>
<tr>
<td>14</td>
<td>Standards/S.L.A.T.E. Flow Chart</td>
<td>27</td>
</tr>
<tr>
<td>15</td>
<td>S.L.A.T.E. Pie Chart</td>
<td>28</td>
</tr>
<tr>
<td>16</td>
<td>AutoCAD Ambulance Layout</td>
<td>31</td>
</tr>
<tr>
<td>17</td>
<td>Initial SolidWorks Layout</td>
<td>32</td>
</tr>
<tr>
<td>18</td>
<td>Street-Side Interior View SolidWorks</td>
<td>33</td>
</tr>
<tr>
<td>19</td>
<td>Captain and CPR Chair</td>
<td>34</td>
</tr>
<tr>
<td>20</td>
<td>Chairs and Track</td>
<td>35</td>
</tr>
<tr>
<td>21</td>
<td>Exterior View of Ambulance Box</td>
<td>37</td>
</tr>
<tr>
<td>22</td>
<td>Data Display Screens</td>
<td>38</td>
</tr>
<tr>
<td>23</td>
<td>Vending Machine Storage (Light Blue)</td>
<td>39</td>
</tr>
<tr>
<td>24</td>
<td>S.L.A.T.E. Ambulance Interior</td>
<td>40</td>
</tr>
<tr>
<td>25</td>
<td>Ambulance Exterior</td>
<td>42</td>
</tr>
<tr>
<td>26</td>
<td>Ambulance Interior</td>
<td>43</td>
</tr>
<tr>
<td>27</td>
<td>Type I ambulance [6]</td>
<td>47</td>
</tr>
<tr>
<td>28</td>
<td>Type II Ambulance [6]</td>
<td>48</td>
</tr>
<tr>
<td>29</td>
<td>Type III Ambulance [22]</td>
<td>49</td>
</tr>
<tr>
<td>30</td>
<td>TYPE 1 FORD F-350/F-450/F-550 [7]</td>
<td>50</td>
</tr>
<tr>
<td>31</td>
<td>TYPE 1 F-650 [7]</td>
<td>50</td>
</tr>
<tr>
<td>32</td>
<td>E-350 SUPER DUTY EXTENDED VAN [7]</td>
<td>50</td>
</tr>
<tr>
<td>34</td>
<td>F-350 [7]</td>
<td>52</td>
</tr>
<tr>
<td>35</td>
<td>F-650 Pro Loader [7]</td>
<td>53</td>
</tr>
<tr>
<td>38</td>
<td>Mercedes Sprinter Layout [23]</td>
<td>55</td>
</tr>
<tr>
<td>39</td>
<td>Mercedes Sprinter Ambulance [23]</td>
<td>56</td>
</tr>
<tr>
<td>40</td>
<td>Typical Interior of Mercedes Sprinter [23]</td>
<td>57</td>
</tr>
<tr>
<td>41</td>
<td>Mercedes Sprinter Cargo Van [23]</td>
<td>59</td>
</tr>
</tbody>
</table>
Figure 35. Mercedes Sprinter Crew Van [23]................................................................. 61
Figure 36. Mercedes Sprinter Passenger Van [23]......................................................... 63
Figure 37. Mercedes Sprinter Cab Chassis [23].............................................................. 65
List of Tables

Table 1. Ambulance Manufacturers by State, Leasing 2 Fire Departments [12]........... 8
Table 2. S.L.A.T.E. Constraint Table................................................................. 30
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Chapter 1. EMS AND LIFE SAVING PRACTICES

1. Introduction

Emergency Medical Service (EMS) Ambulances are vehicles used for the transportation of patients that need immediate medical attention. What if the patient is an infant who needs to be transferred to a hospital, or a mother in the process of giving birth? There needs to be an option for scenarios where normal EMS ambulances cannot provide the tailored care for an infant who needs to be safely transferred to a hospital, or for a woman who is too far along and needs to give birth in a safe environment. Currently there are few ambulances that take into account these scenarios, and no ambulances that can provide the equipment and care to handle both. This project seeks to create a S.L.A.T.E. (Safety, Lightweight, Affordability, Technology, and Efficiency) ambulance that can support laboring women, newborns, and young children. This vehicle must be cost effective and be able to be implemented in healthcare systems throughout the nation. The requirements of the ambulance will be approached with a focus on S.L.A.T.E. with a concentration on: the vehicle, the medical facilities and the interior design. The vehicle includes the power source and transportation needs. The design of medical facilities will include every aspect needed to perform medical procedures. The interior design of the ambulance will include passenger safety, EMT safety, and aesthetic aspects. Every piece of the design will be assessed to maximize safety, function, and reliability.
The project team plans to conduct background research on current EMS ambulances and the services they provide; Obstetrics and Gynecology and the environment and equipment needed for the delivery of infants; and Pediatrics and the optimum equipment and environment for the transportation of newborns. The team will meet with health care professionals to discuss the specific needs of the patients that the ambulance will be servicing. The team will go through the design process for creating an ambulance specifically tailored for pediatric care, which will result in a complete and total re-design of the inner operations area of the rear of the ambulance. This project will also include the analysis and selection of an optimal chassis for the ambulance box to rest on. We will include both models of the interior of the ambulance as well as drawings for possible manufacture. Including this information included in the report will allow further projects to continue on this topic more easily.

The results of the project will be available in essay format, as well as in an oral and visual poster presentation given by the project group in D-term. This project may result in patents or journal articles depending on the success of the design. The remainder of this report contains research, our design process, and the results of the project. Chapter 2 describes the pertinent background research for the project that the group has conducted. Chapter 3 describes the team's design process, and chassis selection from initial specifications to the final designs of the pediatric ambulance, including detailed drawings, models, and analysis. Lastly, Chapter 4 encompasses our final remarks, overall results, and conclusions, as well as revisiting the goals and objectives and comparing them to our final design.
Chapter 2. EMS AND PATIENT-CENTRIC QUALITY CARE

2. Introduction

This project focuses on creating a pediatric and obstetrics and gynecology specific ambulance. This chapter will cover the relevant background material for the project, specifically focusing on major points that will be needed to effectively design and manufacture the ambulance. Major topics include: Ambulances, Pediatrics, Obstetrics and Gynecology, and the Worcester Area. Under these major topics are subtopics that will contain concentrated research into each area. This literature review reflects the relevant information that the group will use to complete the project effectively.

2.1 Ambulances

Ambulances are vehicles used in emergency situations to transport sick or injured patients that require medical attention. In this section we will cover: a short history of civilian ambulance use; emergency medical technicians; ambulance standards; the design and manufacturing of ambulances; crash safety; maintenance; the interior; equipment, and pharmaceuticals used in ambulances; communication systems; some specific case studies; and information on how a hospital purchases a new ambulance. This information will help the group identify the task specifications needed for general ambulance design, as well as gain a better understanding of the current ambulances used by hospitals across the country.
2.1.1 History of Civilian Ambulance Use

In America, ambulances were not first adapted for civilian use until the late 1860s, when horse drawn carriages were used to transport patients to hospitals, Madison Fire Department [13]. Around 1867, England began using horse-drawn carriages to transport smallpox victims to local hospitals. A dedicated service did not begin in London until 1887 according to EMT Resources [5].

![Figure 1. Horse Drawn Ambulance, Madison Fire Department [13]](image)

Starting in 1899, Haller [10], the first electric-powered ambulance was used in Chicago by Michael Reese Hospital; this soon spread to New-York City. With the motor age, and gasoline-powered vehicles a permanent niche for ambulances was created, and they became a permanent fixture in America. Following gasoline powered ambulances there were a number of innovations, such as ambulances that combined rescue with first aid. There were also ambulances that utilized specific technology, such as water ambulances, disaster units, and full surgical equipment.
for use in ambulances. All of these innovations led to the current day ambulances that are utilized now in 2013.

Currently there are a number of different ambulances models and types, which range from smaller van ambulances, to larger trucks according to the Professional Vehicle Corporation [22]. The size, and chassis used in each ambulance depend on the specifications of the manufacturer and the needs of the hospital that will be using the ambulance.

![Figure 2. Type III Ambulance Professional Vehicle Corporation [22]](image)

The National EMS Museum [15] lists the most common types of ambulances as type I, II, and III; however, with innovations and technology, many different types of ambulances have been developed to fulfill certain needs. From vans and trucks, to boats, helicopters, and fixed wing aircraft, ambulances have been adapted to respond to emergencies wherever they occur.
2.1.2 Emergency Medical Technicians

According to the Bureau of Labor Statistics [2], Emergency Medical Technicians (EMTs) respond to emergency medical situations. In the United States there are different levels of EMTs, which depends on the individual’s level of training. EMT-Basic, EMT-Intermediate, and Paramedics each have their own certifications and qualifications. When ambulances respond to emergency situations, it is the EMTs that use their training to assess and provide care to the patients.

Figure 3. An EMT back boarding a patient Bureau of Labor Statistics [2]

EMTs have a number of duties that they are responsible for. These include, but are not limited to: responding to 911 calls, assessing a patient’s condition and determining a course of treatment, using backboards and restraints to keep patients still during transport, transferring patients, and replacing used supplies and equipment after use. EMTs use their extensive training to keep patients safe when
attending to them in an emergency situation, when transporting patients in an ambulance, and when delivering them to a hospital or care center.

2.1.3 Standards

Standards are documents that specify requirements that must be followed within a certain professional field. There are many different standards that pertain to ambulances, and those standards also depend on the country and state where the ambulance will be used. In the United States there are two major ambulance standards. The first is the Federal Specifications for the Star-of-Life Ambulance: KKK-A-1822. These standards were created by the General Services Administration of the U.S. Federal Government, Sysign Engineering, LLC [24]. In the last few years the National Fire Protection Agency [16], (NFPA) created their own ambulance standards: NFPA 1917: Standard for Automotive Ambulances. There are also standards from the Ambulance Manufacturers Division, a part of the National Truck Equipment Association.

![Figure 4. Star of Life, General Service Administration](image)
Depending on the state, either or both of these standards could apply. The NFPA Standards are more recent, and therefore are more up to date. The NFPA standards can also be considered stricter than the KKK-A-1822 standards. Both standards cover the same type of information; the requirements that apply to ambulance such as: lighting, payload, signage, electrical systems, portable equipment, etc. All of these systems are important to understand when it comes to ambulances, and designing them because all ambulances must follow one of these standards (if being used in the United States). Almost all countries that have ambulances have a similar set of standards they use to make sure all ambulances will be safe, efficient, and effective, General Service Administration [8].

2.1.4 Design and Manufacturing

There are a large number of ambulance manufacturers in the United States. These manufacturers are responsible for complying with the standards for ambulance manufacturing and design, while also customizing the ambulance to the needs of their clients. The following table introduces some of the ambulance manufacturers according to the state they reside in.

Table 1. Ambulance Manufacturers by State, Leasing 2 Fire Departments [12]

<table>
<thead>
<tr>
<th>State</th>
<th>Manufacturer</th>
<th>Manufacturer</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>NC</td>
<td>American Emergency Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>American Fire &amp; Rescue</td>
<td>Marque Inc.</td>
<td>Medtec Ambulance Corporation</td>
</tr>
<tr>
<td>IA</td>
<td>Amtech Emergency Products Co.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OH</td>
<td>Braun Industries, Inc.</td>
<td>Horton Emergency Vehicles</td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>Company</td>
<td>Models</td>
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<td>---------------------------------</td>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td>LA</td>
<td>Life Line Emergency Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA</td>
<td>McCoy Miller Corporation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MO</td>
<td>Miller Coach Company</td>
<td>Ossage Ambulances</td>
<td></td>
</tr>
<tr>
<td>FL</td>
<td>National Ambulance Builders</td>
<td>Wheeled Coach Industries</td>
<td></td>
</tr>
<tr>
<td>NJ</td>
<td>Odyssey Emergency Vehicles</td>
<td>PL Custom Emergency Vehicles</td>
<td></td>
</tr>
<tr>
<td>MN</td>
<td>Road Rescue, Inc.</td>
<td></td>
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</table>

According to How Products Are Made [11], ambulance manufacturers purchase raw materials from outside suppliers, and make use of systems that are previously assembled. This includes: the chassis; lights; sirens; and radios. Most of the electrical, heating, air conditioning, and oxygen systems are purchased by the manufacturer, and not manufactured by them. Materials are selected by the manufacturer using a number of criteria such as: ease of cleaning, safety, and strength. Inside the box, the manufacturer selects materials, and builds the cabinets and containments for the equipment, the seats for the EMTs and passengers, and counters along the walls.

When it comes to specific ambulance design, the manufacturer will first select the type of ambulance specified by their customers. Following that they will add any customizations to the designs that the customers specify. The type of ambulance depends on the needs to the hospital: Type I is modular body built on a truck chassis, Type II ambulances are a van with a raised roof, and Type III are modular bodes on a van chassis. When conforming to the customer’s specifications the manufacturer must comply with the federal and state standards.
When it comes to the actual manufacturing process of ambulances, the process changes depending on the company. Figure 5 is an example overview of the ambulance manufacturing process.

**Building the body shell**
- Structural components welded together.
- Exterior pieces fabricated and welded into place.
- Outside of body: cleaned, sanded, primed, sealed, and painted.

**Preparing the cab and chassis**
- Additional wiring added to cab chassis and engine electrical system. Controls added to dashboard.
- Holes drilled in vehicle frame rails and mounting brackets installed.

**Mounting the body**
- The body shell is lowered onto the chassis and bolted in place
- Tape is placed and stripes are painted onto the body shell, cab, and mirrors.
- The front and rear bumpers are installed as well as the mirrors.

**Finishing the body**
- The electrical wiring in the body and ceiling is installed and foam insulation panels are installed.
- The oxygen piping and outlets are installed in the body walls, as well as the vacuum, and air-conditioning systems.
- The interior cabinets are installed and the walls, floors, and ceilings are covered. The electrical power distribution board is installed.
- The seats are assembled and fastened in place. The grab handles and containers are installed last.
Following manufacturing, the ambulances are tested to make sure each system, as well as the materials, complies with the standards and customer specifications. Once the manufacturer has certified everything, the ambulance can be delivered to the customer.

2.1.5 Crash Safety

Ambulances frequently travel at high speeds and often go through traffic lights or other dangerous intersections without stopping. While there are sirens and flashing lights to warn other vehicles of their approach, ambulances are involved in many crashes every year. According to Occupational Safety and Health Surveillance [19], from 2003 to 2007 there were 205 Ambulance crashes in the state of Maine alone.

It appears that while the ambulances might survive most crashes intact, the passengers, and EMTs are the ones suffering. It is found in most cases that in collisions where EMTs are injured, they were not using restraint systems. In many states, including Maine, there are no laws requiring safety belts for an EMT in the back of an ambulance.

The National Institute for Occupational Safety and Health conducted investigations and concluded that employers of EMTs should take the following steps:

• Ensure that EMTs use patient compartment vehicle restraints whenever possible
• Ensure patient cots have upper body restraints for emergency and non-emergency transport
• Ensure drivers and front-seat passengers of ambulances use vehicle restraints
• Ambulance Manufacturers and EMS should evaluate and develop protection systems to increase crash survivability of EMTs

Ambulance crashes should be avoided at all costs, however, it is something that we cannot completely prepare for and avoid, and the safety of the occupants of the ambulance should be the number one priority for all ambulance manufacturers.

2.1.6 Maintenance

One of the largest challenges that modern hospitals face today is the maintenance of their ambulance fleets. An interview with a hospital official showed that while many modern automobiles reach 150-200,000 miles without major suspension rebuilds, the ambulances in their fleet required them at least every 100,000 miles. Furthermore ambulances use suspension systems rated much higher than their payloads, according to Stephen Haynes.

The second system that tends to fail often in ambulances is the brakes. With such high Gross Vehicle Weight Rating (GVWR), modern ambulances wear through their brake pads rapidly. In order to decrease the cost of brake maintenance, the overall weight of the ambulance must be reduced. This may occur in the payload, the box, or the chassis. The main cause of this problem is the large size of American ambulances. While some fire departments use vans [6], many use large trucks such
as the Ford F-350. These trucks allow access to both sides of the patient. This increases the ability of EMT's to provide patient care, but increases the maintenance budget of the fleet.

2.1.7 Interior

The interior of the ambulance is governed by several different sets of standards in the United States. Depending on the state manufacturers may be able to pick and choose which standards to comply with, though most comply with all of them. The most prevalent standards are those of the National Fire Protection Association (NFPA), edition 1917. These standards are assembled by industry experts and include regulations on the chassis, patient compartment, electrical devices, and testing. The standards as they relate to S.L.A.T.E. are summarized in Appendix 1.

The second set of standards pertinent to modern ambulance design is the Star of Life, also known as KKK standards, specifically KKK-A-1822F. The federal government creates them, and govern the usage of the symbol known as the Star of Life, which was shown earlier in Figure 4. In order to use the symbol, the ambulance must abide by these standards. Almost all modern US ambulances follow these standards.

The KKK standards contain rules for Emergency Lighting, Certification & Payload Signage, Payload Calculation, the DC and AC electrical systems, and the portable battery charging circuit. These standards are the bare minimum that an ambulance must reach in order to use the decal. Most ambulances far exceed them.
The 1822F standards also reference other federal documents, including Federal Specification RR-C-901C on the use of compressed gas cylinders, Federal Standard No. 297 on Rust proofing, and various laws and regulations.

Standard 1822F provides for a classification of types of ambulances. Type I have a GVWR of 10,001 to 14,000 lb and are cab chassis with a modern ambulance body. Type I-AD (Additional Duty) is 14,001 lb or more and has the same definition as Type I. Type II is 9201 – 10,000 lb and is a long wheelbase van, with an integral cab-body. A Type III ambulance is a cutaway van with an integrated modular ambulance body, and weighs 10,001 to 14,000 lb. Type III-AD is the same as Type III, but may weigh greater than 14,000 lb. These classifications allow the standards to set different criteria and requirements for different weight rating of ambulances [8].

The next part of the standards is the Vehicle Operation, Performance, and Physical Characteristics section. Here factors such as the temperature, noise level and vehicle performance are defined. Notably, the ambulance must be able to maintain a speed of 65 MPH in normal conditions, and also be able to accelerate to 55 MPH within 25 seconds. Both of these specifications are well exceeded by modern chassis. The rest of the standard provides more minimum criteria for the chassis performance and the electrical systems of the ambulance, which are not the main focus of this project.

In an interview with a hospital official, the project team learned that they use two-way radios for communication in much the same way as fire departments across the country. It is notable that while every ambulance is equipped with a radio
unit, the manufacturer does not install it. The hospital installed all of their own communication equipment, including a digital modem to allow Internet access to the occupants of the ambulance.

2.1.8 Case Studies

The easiest way to create a great product is to integrate designs and ideas from pre-existing ones into a newer and better version. As such, it is always prudent to look at similar pediatric ambulances around the country. There are few ambulances created specifically for children, due to the limited scope and utility that this increased specialization brings. However, at the Florida Children's Hospital there is currently a pediatric ambulance in service. The improvements over a normal ambulance are mainly visual, with a few electronic components.

The Floridian ambulance has a welcoming and cartoonish color scheme to make the ambulance seem more inviting and personal. It also has a small TV screen set above the rear door so that children can watch TV or a movie, taking their minds off of the often-intimidating medical proceedings.

2.2 Pediatrics and Obstetrics and Gynecology

Pediatrics is a branch of medicine that specializes in medical care for infants, children and adolescents. This ranges from children from birth up to the age of 18. Like its adult counterpart, the aim of pediatrics is to reduce infant and child rate of deaths, control the spread of infectious disease and promote healthy lifestyles for children. The big difference between adult and pediatric medicine is the body size
differences, where a body of an infant is substantially different physiologically from that of an adult. Another difference between pediatrics and adult medicine is that most of the patients that pediatricians deal with are minors and therefore the issues of privacy, legal responsibility, informed consent and guardianship most always be considered, pediatrics [21].

Figure 6. Pediatric Patient [21]

2.2.1 Obstetrics and Gynecology

OB/GYN, which stands for Obstetrician/Gynecologist, are the specialists who are responsible for helping women have healthy pregnancies and healthy newborns. Obstetrician is a physician who delivers babies and a gynecologist is a physician who specializes in treating diseases of the female reproductive organs. The majority of their work includes monitoring pregnant women and the delivery of their newborns. Occasionally, OB/GYN practitioners also perform surgical procedures that include C-sections and hysterectomies, What is Ob-Gyn? [26].
In the United States alone, over four million babies are born each year and that’s after a recent US birth rate drop of about 3%. Even with the recent drop in births, United States is still the third most populous country in the world after China and India. The real trouble with baby births is while science has been able to estimate the due date to be more accurate; the due date is still more of a due month. This is where the problem lies. At any moment, a mother might go into labor and will need a medical transport and treatment. This is where developing a medical ambulance specifically for the OB/GYN and pediatric care will be beneficial, Women’s Heath [27].
2.2.2 Pediatric Ambulances

An ambulance that specializes in Pediatrics and OB/GYN care will be of great benefits not only to the patients but also to the hospital and medical care team. Ambulances focus on providing comforting surroundings as well as highly equipped medical treatment tools. Current ambulances cater to the younger demographic being transported within the ambulance with a paint job within including blue sky, balloons and birds to provide for a more calming atmosphere. Typically there are entertainment systems such as a TV or radio that provide an appropriate distraction for during a traumatic experience. The idea of these ambulances is to mobilize children’s hospitals and pediatric care units, so that patients can be treated at the scene or en-route to the hospital [21].
Worcester has an OB/GYN program at the University of Massachusetts Medical School. The division of General Obstetrics and Gynecology is the largest division of the UMASS faculty group, which includes 10 providers, 8 medical doctors, and 2 nurse practitioners. Their mission is to provide comprehensive care to women across the reproductive age span within the discipline of Obstetrics and gynecology. They are able to see patients through two ambulatory settings; one located within the UMASS memorial campus as well a community practice setting located in West Borough [18].

### 2.3 Worcester, Massachusetts

According to Worcester, MA [28], Worcester, the city founded as a town in 1722 and incorporated as a city in 1848, is the second largest city in Massachusetts, after a more known city, Boston. Worcester’s location in the central Massachusetts places it in a location near other main cities in the area. Driving to Boston, which is
on the Eastern Coast, it is about an hour drive East from Worcester. Worcester is also located about an hour North-East of Hartford, Connecticut, and about an hour North-West of Providence, Rhode Island. Worcester’s location in the center of Massachusetts has let it come to be known as the “Heart of the Commonwealth”, which is symbolized in Worcester’s seal shown below in Figure 10.

![Worcester seal](image)

**Figure 10 City of Worcester, MA [28]**

### 2.3.1 Geography and Climate

Worcester’s total area covers 38.6 sq mi, which is about 100 km². This leads to having various and diverse landscapes and roads, with a peak elevation of 480 feet, about 146 meters, but anyone who has visited Worcester knows that the area is not completely level and there are many peaks and valleys in the area. The population is said to be above 185,000 people, which leads to a density of about 4,678 people per square mile. In comparison, Boston is about 12,752 people per square mile, so Worcester is about a third as dense.

What both Boston and Worcester have in common is the continental climate typically to the New England region, National Weather Service Forecast Office [17]. There is a rapid change of weather that has lead to the saying, “if you don’t like the weather, wait five minutes and it will change”. This rapid change of weather is due
to the climate influences surrounding the area. There is dry air coming from the north, warm humid air coming from the south, and then the effect of the Atlantic Ocean from the East. This leads to a diverse four seasons, with temperatures hitting as high as 90 °F (32 °C) and as low as 10 °F (−12 °C). The typically 24-hour averages in the hottest month is 70.1 °F (21.2 °C) in July and the lowest month is January at about 23.6 °F (−4.7 °C). The Figure below depicts the Climate data for the past 19 years.

<table>
<thead>
<tr>
<th>Climate data for Worcester, Massachusetts (1981-2010 normals)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Month</strong></td>
<td>Jan</td>
</tr>
<tr>
<td><strong>Record high °F (°C)</strong></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td><strong>Average high °F (°C)</strong></td>
<td>31.5</td>
</tr>
<tr>
<td>(−0.3)</td>
<td>(1.6)</td>
</tr>
<tr>
<td><strong>Average low °F (°C)</strong></td>
<td>16.8</td>
</tr>
<tr>
<td>(−8.4)</td>
<td>(−7.1)</td>
</tr>
<tr>
<td><strong>Record low °F (°C)</strong></td>
<td>−19</td>
</tr>
<tr>
<td>(−28)</td>
<td>(−31)</td>
</tr>
<tr>
<td>(88.6)</td>
<td>(81.5)</td>
</tr>
<tr>
<td><strong>Snowfall inches (cm)</strong></td>
<td>18.6</td>
</tr>
<tr>
<td>(47.2)</td>
<td>(40.6)</td>
</tr>
<tr>
<td><strong>Avg. precipitation days (≥0.01 in)</strong></td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Avg. snowy days (≥0.1 in)</strong></td>
<td>8.4</td>
</tr>
</tbody>
</table>

*Source #1: NOAA*[^21]  
*Source #2: ThreadEx (extremes 1872-2009)*[^22]*

**Figure 11. Worcester, MA Climate Data [17]**

The region also has rain and snow, averaging almost 50 inches of precipitation a year and almost 70 inches of snowfall a year. Worcester is also in the direct path of the “Nor’easter weather”, which in one snowfall, can leave more then 50 inches of snow behind. All of this weather leads to everyone in the city including city officials to include the need to be prepared for whatever weather at whatever time.
2.3.2 Worcester Facilities

While Worcester is not a main level city, it is home to many different arts and cultural facilities and also sport teams, Central MA [4]. The arts and cultural offerings include The American Antiquarian Society, Ecotarium, The Higgins Armory Museum which is home to the largest collection of arms and armor in the western hemisphere and is shown below in the Figure. Worcester also is home to both Music and Opera groups, as well as an art and history museum.

![Figure 12. Higgins Armory [4]](image)

Worcester is also home to the following sport teams, the Worcester Tornadoes, a professional baseball team that play in the Canadian-American Association of Professional Baseball as well as the Worcester Sharks, who play in the American Hockey League.

Due to a large city with a dense population, there is a large education system in Worcester, as well as several different emergency departments due to the diverse base of incidents. Worcester public schools educate more then 23,000 students in
from kindergarten to the 12th grade. There are many colleges and institutes also located in Worcester, some of the most notable being Worcester Polytechnic Institute, Holy Cross, University of Massachusetts Medical School and Clark University, most of which operate within the Colleges of Worcester Consortium.

In emergency situations, Worcester is well prepared for any situation, US News [25]. The Worcester Fire Department employs over 400 firefighters that operate out of ten different fire stations located throughout the city. They have thirteen fire engines’ that can be used in a variety of situations including rescue and special operations units. Worcester is also home to 12 hospitals, many of which are nationally ranked and recognized. Most notable are UMass Memorial Medical Center and Milford Regional Medical Center. These hospitals in Worcester make up about 10% of the Hospitals in Massachusetts, which has 113 hospitals total.
Chapter 3. DESIGN AND ANALYSIS

3. Introduction

This chapter will cover the design and analysis of the major components of this project. The chapter is split into the two different components, the first part focuses on the design of the ambulance box, and the second will focus on the selection of the chassis for the box. The two sections are broken into subsections that will follow a similar progression. Topics to be covered are: problem statement, objectives, constraints, and functions, the methodology, or design process utilized, the final design or selection and results and considerations.

3.1 Ambulance Box Design

This section covers the interior and exterior design of the pediatric and OBGYN S.L.A.T.E. ambulance. The ambulance design has to take into account a number of different factors covered in the background section. While we want this ambulance to have a specific focus, we also want the ambulance to function as a stand-alone ambulance. It must be able to function as a normal ambulance at any time, and when need be it will be able to fulfill specific tasks that normal ambulances may be less suited for. In the next few sections we will cover: a detailed description of the problem, and the project, the objectives, constrains, and functions of the project, the full design process used in creating the ambulance, and the final, detailed, designs that could be used for manufacturing. Lastly we will cover the
results of the designs, as well as any flaws, or further items that need to be taken into consideration.

### 3.1.1 Problem and Goal Statement

This project seeks to assist current EMS, and further bolster their capabilities. EMS Services have the ability to transport pediatric patients safely to hospitals as well as deliver infants in the field, with both mother and child being stable after the procedure. However, we want to streamline these processes, and create a better environment for these activities. By creating a S.L.A.T.E. Pediatric and OB/GYN ambulance we can support and improve current EMS.

With this project we want to make clear that currently these problems are being dealt with, we simply wish to support these efforts, and make a safer ambulance for the patients and the EMS professionals.

This project seeks to design a S.L.A.T.E. ambulance specifically for obstetrics and gynecology as well as pediatric care. This project will seek to develop this ambulance to assist and synergize with current emergency medical services, as well as be able to act as a standard ambulance for every-day care.

### 3.1.2 Objectives, Constraints, and Functions

There are a number of specifications and constraints associated with this project; most of these have to do with creating a safe, lightweight, affordable, technologically advanced, and efficient ambulance. Because this ambulance must still be able to act as a standard medical ambulance, all of the functions, equipment,
and standards of a normal ambulance must be adhered to, in this section we will focus on the project group’s specifications for a S.L.A.T.E. pediatric and OB\GYN ambulance.

In the state of Massachusetts the Federal Specification for the Star-of-Life Ambulance KKK-A-1822F are the specifications that must be followed in regards to ambulances. The project group, however, wanted to get a further view of what other specifications there were for ambulances in the United States, as well as other countries. When looking at these standards, the project group decided the following aspects were the most important to look at as they correspond with S.L.A.T.E. values.

• Design
• Vehicle, Ambulance Components, Equipment, and Accessories
• Vehicle Operation, Performance, and Physical Characteristics
• Vehicle Weight Ratings and Payload
• Lighting, Exterior and Interior
• Cab-Body Driver Compartment and Equipment
• Ambulance Body and Patient Area
• Storage Compartments
• Environmental: Climatic and Noise Parameters
• Communications
• Additional Systems, Equipment, Accessories, and Supplies

These topics are very important for the development of ambulances, and must be taken into consideration when designing a SLATE ambulance as well.
The project group wanted to take into account as many standards as possible when creating the specifications for the S.L.A.T.E. ambulance. To keep track of the different standards, the project group classified the standards based on the S.L.A.T.E. principals, which can be seen in Figure 14.

![Figure 14. Standards/S.L.A.T.E. Flow Chart](image)

Using Figure 14, the project group would take the standards from the National Fire Protection Agency (NFPA), the Star-of-Life (KKK), and the British Ambulance Standards (BAS) to produce the specifications for the S.L.A.T.E. ambulance. The standards the project group felt were most important can be found in Appendix 1.

When approaching the design problem, the project team wanted to constrain the specifications and designs using the S.L.A.T.E. values. The ambulance must be designed in a way to make it safe, lightweight, affordable, technologically advanced,
and efficient. While some of this may seem obvious, as ambulances are already safe, the project team wishes to improve upon the existing systems to create a safer ambulance. Other constrains that have to do with S.L.A.T.E. are to use new and better materials to reduce the vehicle weight costs, and maintenance costs. The project group also wants to integrate new technologies and find ways to improve the power systems.

All of the S.L.A.T.E. constraints are important, however, the project team wanted to prioritize the inclusion of into the overall design to make sure that the design we developed was one that was most feasible.

![S.L.A.T.E. Importance Breakdown](image)

Figure 15. S.L.A.T.E. Pie Chart
As you can see from the pie chart in Figure 15, the project team wants to concentrate primarily on safety, followed by new technologies. Safety is the main concern of the project group because we feel that is where we can make the largest impact. While we would like to cover all of these topics equally, safety is our main priority, followed by technology. When it comes to efficiency, affordability, and lightweight they are all even because the project group feels that they will be covered, but the main design considerations will not always take them into consideration.

To go along with the constraints of S.L.A.T.E. the project team has a few functions, and concepts to be implemented in the ambulance, these critical elements of design will assist in fulfilling the constraints. The functions and concepts to be included in the S.L.A.T.E. ambulance are as follows:

- Vending Machine Storage
  - Pharmaceuticals and Medical Consumables
- Forward Facing Seats
- Access to All Sides of Patient
- Lightweight Reinforcement
- Less Maintenance
- Collect, Transmit, and Store Data
- Power Considerations
- Communications
  - Electronic Monitors
- Stow and Go Seats
• Reduce Costs

• Composite Materials

• Interior Compartment Layout

Each of these concepts or functions also fall under the S.L.A.T.E. constraint; an example of this is given in Table 2 below.

Table 2. S.L.A.T.E. Constraint Table

<table>
<thead>
<tr>
<th>Safety</th>
<th>Lightweight</th>
<th>Affordable</th>
<th>Technology</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Facing Seats</td>
<td>Composite Materials</td>
<td>Less Maintenance</td>
<td>Collect Transmit and Store Data</td>
<td>Power Considerations</td>
</tr>
<tr>
<td>Access to All Sides of Patient</td>
<td>Lightweight Reinforcement</td>
<td>Reduce Costs</td>
<td>Communications</td>
<td>Stow and Go Seats</td>
</tr>
</tbody>
</table>

As you can see from the table, the concepts and functions the team will include in the final design each correspond to parts of the constraints. While we would love to include all of these concepts and functions, the project team must be realistic, and when creating the final design not all of these may end up becoming a reality. If that is the case, they will become part of the recommendations section of this paper to be completed in the future.

3.1.3 Design Process

To correctly design something, a number of variables must be taken into account. With this project the design team had to take into account the problem statement and goals for the project after which the specifications, constraints, and functions must be developed and then applied to the design. As we developed those specifications, constraints and functions we conducted research to create the most
effective solution. These variables define the design that the group creates, as we develop the design itself. After the specifications, constraints, and functions that need to be part of the designs are fully defined, and then the physical designing can begin.

The project team decided to utilize ambulance drawings provided as references, and as a starting point for our designs. Using these we were able to develop sketches of the interior to be used as references for the final design to complete in SolidWorks. Based on feedback from the drawings, the project team was able to take the drawings and create a final interior layout for the ambulance in AutoCAD, as seen in Figure 16.

![AutoCAD Ambulance Layout](image)
With the final layout approved, the project team began creating initial parts in SolidWorks. After creating the walls and floor, we began to insert select features and components into the ambulance. The initial SolidWorks assembly was designed to look very similar to the layout created in AutoCAD to prove that our design was feasible, and would match with what the specifications, constraints, and functions outlined previously.

![Initial SolidWorks Layout](image)

Figure 17. Initial SolidWorks Layout

This layout actually had some differences to the AutoCAD version, such as an increased additional storage on the street-side wall, with the back co-captain’s chair being stored on the curbside wall instead of the street-side. The changes, and
differences between the two designs will be fully covered in the following chapter along with the rest of the designing that the project group did.

![Figure 18. Street-Side Interior View SolidWorks](image)

Overall these changes would be moved into the final design, with the layout not changing from the initial SolidWorks layout. The project group went on to complete the final SolidWorks ambulance design, which will be covered in detail in the following section.

### 3.1.4 Final Design

The project group’s final design is one that has included many of the features that were listed above. We attempted to comply with the Start-of-Life standards, as well as the NFPA standards. We have tried to apply the S.L.A.T.E. values whenever possible, and have tried to employ as many of the concepts and features that we
listed. This chapter will address the different aspects of the final design, using each part of S.L.A.T.E. as the main focus.

The final box design was developed by the team to increase functionality within the ambulance. The main concern, as expressed before, was safety. To address this issue, one must realize what it means to be safe in the back of an ambulance. After conducting background research, the design team realized this meant designing a box where the EMS team in the back of the ambulance was never out of their chairs, and while the ambulance was in transit, the EMS team could face forward to protect them in the case of a collision. To remedy these situations the design team developed a layout that would allow the personnel in the back of the ambulance to have access to the equipment they needed in transit, and allow them to face forward while the ambulance was in transit.

![Figure 19. Captain and CPR Chair](image-url)
From Figure 19 it can be seen that the CPR Chair was designed to have a rotating base, and there is room under the Isolette station for the legs of the user. The captain chair pictured is designed to be able to move along a track, shared with the co-captain chair. This allows the EMS personnel to access any equipment they may need, and for the chairs to be able to turn and face front.

Figure 20. Chairs and Track

Figure 20 displays the track that the chairs can move across. This would allow for a minimum of two EMS professionals to reach every item in the ambulance without having them to exit their seats. The track also gives EMS professionals access to all sides of the patient, which is very important because to be able to full treat patients, one must have full access to them. This is hard to accomplish in some ambulances, however, the design team wanted to specifically address this issue. The track also allows the captain and co-captain chairs to be stored out of the way when the ambulance is not in use. The captain chair can move up against the front wall, and the co-captain chair against the curb-side wall.

Other safety systems that have been implemented in the S.L.A.T.E. ambulance are the lights on the outside, which are similar to most other ambulances. The team
also implemented an isolette station. This station is a special area for an isolette that would house a child while in transit. This way both mother and child can be safety transported, or if the mother gives birth during transit, the baby can be safely kept in the isolette.

Ambulances are quite heavy, and adding more equipment from OBGYN and pediatrics does not help. When conducting research we found lists of equipment needed for medical first responders, which can be found in appendix 4. Because this ambulance is specialized in turn more equipment is needed, and therefore more weight is added. The added weight is dealt with by the chassis, which will be covered later in the chapter. To help cut down on weight the design group wanted to utilize composite materials within the structure of the box to increase the strength of the box, and also cut down on the weight. While the reinforcement was not implemented in the final design, it is covered fully in the following section.

When designing a specialized ambulance it is difficult to cut down on costs. To make the S.L.A.T.E. ambulance more affordable the design team wanted to try and cut down on maintenance costs for ambulances, which is done by choosing the correct chassis for the box, discussed further in chapter 3. The design team looked into implementing a system, as mentioned above, that would utilize composite materials to reinforce the box. With these lighter materials, the box would weigh less, and therefore less strain would be on the chassis and suspension. With less strain, the systems would need less upkeep, and therefore costs would go down in the long run. While was not something that was put into practice in the design
team’s final design, the team still considered how the system would be implemented.

To implement the composite materials into the structure of the ambulance box, the design team would need to design a truss-like system that would reinforce the inside of the walls. Much like a lattice on the side of a building, a frame would be formed inside the walls of the ambulance that would increase the stiffness of the walls, while making the vehicle lighter in the long run. This would mean reduced maintenance costs in the future, cutting down on high maintenance bills.

Utilizing these composite materials would be new technology for ambulances, another part of S.L.A.T.E. Besides the new materials being introduced in this design, the team also wanted to utilize new ways to communicate, as well as display data. Currently most ambulances communicate by radio, and some have
modems as well do send data ahead to the ambulance when in transit. This design utilizes three displays for computers that would be able to display data, for all three EMTs in the back of the ambulance when working on a patient. The computers would also allow them to store and transmit the data for the patient to the hospital they are traveling to.

![Image](image.png)

*Figure 22. Data Display Screens*

These data display screens would be invaluable for the EMTs, not only would they display data, but they would also control many of the functions in the back of the ambulance, such as the interior conditions, or lighting.

Efficiency is a top priority for ambulances. To improve the efficiency of the S.L.A.T.E. ambulance, the design group wanted to improve the power consumption. Unfortunately when it comes to power consumption ambulances use much more than other vehicles on the road. In a specialized ambulance such as this it would be hard to improve the power considerations, but the design team would have liked to work on the efficiency of these systems, to improve overall power consumption, not necessarily reducing them.

When it comes to having a more efficient ambulance something else the design team looked into was the storage of the medical consumables and
pharmaceuticals. To alleviate these problems in the S.L.A.T.E. ambulance, the design team wanted to implement a new type of storage system. This storage system, dubbed “Vending Machine Storage” would store the items inside, and deposit only the specific item that the EMT was trying to access, through the use of a keypad of some sort. By using the vending machine storage, the hospital would be able to keep track of who accessed what consumables or pharmaceuticals, and when. This storage would also keep the items inside from spilling everywhere if a crash occurred, as well as protecting the pharmaceuticals from being stolen or abused. While the design team did not design how the vending machine storage would work, they have been included in the final designs in four different places throughout the ambulance, as can be seen as the light blue objects in Figure 23.

Figure 23. Vending Machine Storage (Light Blue)
Only items of a certain size can be included in vending machine storage so there is still some traditional ambulance storage for the items and equipment that cannot fit inside the vending machines. These new storage methods allow most of the important and most used pieces of equipment to be accessed easily, and more conveniently as they are all in four different spots throughout the ambulance. Having most of the equipment in easy to access spots speeds up the EMTs when they are accessing equipment, and therefore makes the back of the ambulance a more efficient place.

After covering all the critical elements of design categorized by S.L.A.T.E. the design team presents the final S.L.A.T.E. ambulance design in Figure 24.

Figure 24. S.L.A.T.E. Ambulance Interior
The design team generated a full CAD model and drawings for the interior and exterior of the ambulance. The results of this design process, and full design will be covered in the following section.

3.1.5 Results and Considerations

With the final design presented, there are some results and considerations that need to be taken into account. This part of the project resulted in detailed SolidWorks drawings that can be viewed in Appendix 3. The ambulance designs were made as detailed as possible, and created with the S.L.A.T.E. considerations in mind. The project team wanted to keep all of these considerations, concepts, and functions in the forefront of the designs as well. When it comes to the chassis of the ambulance, the results can be seen in SolidWorks as a standard truck cab. The project team did not want to speculate on what chassis would end up being used in the final design, and thus decided to keep the chassis shown in the designs very basic.

The ambulance is a full SolidWorks model as seen below. On the outside all of the lights have been added as well as the doors for the doorways and equipment compartments.
Figure 25. Ambulance Exterior

More detail could be added such as the handles for the doors, and more detail could be added when it comes to the front of the ambulance, however, as mentioned before, we did not want to speculate on the type of chassis that would be selected so the front truck-part of the ambulance only has the bare minimum is shown.

On the interior of the ambulance the design team included the positions for the vending machine storage, the chairs and track, isolette station as well as monitors to store and transmit and store data.
The layout, in Figure 26, of the ambulance has been optimized to provide the EMTs with better efficiency to give them more access to the patient and the equipment while keeping them safer. Overall the ambulance design has some modifications that will help assist and improve pre-hospital services.

There are a number of flaws with our design, including design drawings for the vending machine storage, the chair track, and the reinforcement in the walls. The design team still wanted to cover these advancements in ambulance technology, and have them in the ambulance, however, there were a number of reasons the team did not design these. When it comes to the vending machine storage, the design team does not currently have the electrical engineering knowledge or expertise to design a vending machine-like setup. For the chair track and wall reinforcement the
group had solid ideas for both designs, however, the team ran out of time, and were not able to get these designs into SolidWorks. It would be easy for another MQP group to add and improve to these designs, and make them a reality. All in all the ambulance needs some work to become a fully functioning design, as the group is not a fully experienced ambulance engineering design team.

Overall this section has resulted in detailed drawings of the ambulance box that could potentially be used to manufacture the S.L.A.T.E. Pediatric and OBGYN ambulance. However, there were limitations to our design, and we want to be upfront and clear about these as they could result in the continuation of this project, where our designs could be expanded and improved upon.

3.2 Chassis Selection

One of the most important parts of a functioning ambulance is the chassis. It is what keeps the vehicle moving and functional. In order to create a SLATE ambulance, the project group looked at the various chassis on the market, as well as their specifications, and picked the one that fit the project goals and the needs of the customer.

Picking a chassis for an ambulance is not a trivial task. There are many factors that must be accounted for, including but not limited to: horsepower, torque, width, length, and gross vehicle weight rating (GVWR). Furthermore, there are multiple brands that must be compared against each other. In the interest of decreasing new training for hospital maintenance departments, only brands that are currently used as ambulances were considered.
From the pool of currently in-use ambulance chassis, only those that were able to support Advanced Life Support (ALS) ambulances were considered. From there, the chassis' were compared based on the available statistics. Later in the chapter, tables of specifications are available for every chassis - numbers such as wheelbase, engine type and horsepower were all considered.

3.2.1 Problem Statement

Throughout the world, there are many different types of ambulance vehicles in circulation today. Most are based on three different general types of ambulances known as Type I, Type II, and Type III ambulances that are all built under the specifications explained through documents such as the KKK-A-1822 or GCC. When an ambulance matches or exceeds the specifications in the KKK-A-1822, it is branded as a Star-of-Life ambulance. Some of the main Star-of-Life specifications can be founding the following section.

3.2.2 Specifications

[8] Temperature

• The ambulance needs to be able to operate if the exterior temperature is between 0 to 95 F

• The interior minimum temperature needs to be maintained at least at 50 F

Speed
• The ambulance must be able to maintain a sustained speed of 65 mph

• The ambulance must be able to pass at 70 mph

• Acceleration from 0 to 55 in 25 seconds

Hills

• The ambulance must be able to travel up a 3 % grade at 55 mph

• In additional the ambulance must be able to travel up a 35% hill (steep) at 5 mph

Fuel

• Range of 250 miles w/o refueling

Water Crossing (fording)

• The ambulance must be able to make 3 passes through 8 inches of standing water without flooding at 5 mph for a distance of 100 feet

• Width less than 96 inches excluding mirrors

• Loading height no more than 34 inches [8]

Most of these specifications are met by all chassis, so in the next sections we will be looking at the different types of ambulances. During this stage of the project, the group had not made the decision on which type of ambulance would be used. So, all types were examined to make sure that conclusions were not drawn too early.

**TYPE I**
The structure of a Type I is a Cab Chassis with integrated body, where the Gross Vehicle weight is over 10,001 pounds but less than 14,000 pounds. An example of a Type I ambulance is shown below in Figure 27.

![Figure 27. Type I ambulance [6]](image)

The telling feature of a Type I ambulance is that it is based on a truck style body with a separate driver compartment. A Type I AD ambulance is a subclass of the Type I configurations where AD stands for Additional Duty and it has a gross vehicle weight of 14,001 pounds or more with extra cargo capacity.

**TYPE II**

Type II ambulances are a long wheelbase van type with a cab design interior outfitted for medical use, as shown below in Figure 28. The gross vehicle weight is
between 9,201 pounds to 10,000 pounds. These are very useful in long-distance transport services where fuel efficiency and distance are important factors. However, due to their minimized interior, they generally do not make for practical emergency services and it only used when patients that only require Basic Life Support features need transporting patients.

Figure 28. Type II Ambulance [6]

**TYPE III**

Type I and III are very similar in that they both have a square patient compartment that is mounted onto the chassis. The chassis is the only difference between the two types. As mentioned earlier, Type I compartment is mounted on a truck chassis while Type III is mounted on a cut-a-way van chassis. This allows for the cab to be part of the ambulance. The gross vehicle weight is the same as for type I ambulances: 10,001 pounds to 14,000 pounds but there are Advanced Duty
ambulance types that are able to support a gross vehicle weight of over 14,001 pounds. Both Type I and III are used when patients need Advance Life Support [6].

![Type III Ambulance](image)

**Figure 29. Type III Ambulance [22]**

### 3.2.3 Project Goals

This project will focus on the Type I, II & III ambulances to be able to construct a S.L.A.T.E Ambulance for Worcester EMS. While the S.L.A.T.E design focuses on the interior design of the medical compartment, it is important to look at the chassis on which we will be placing the compartment on top of. There are a variety of different chassis, built by a large variety of companies including Dodge, Ford, Mercedes, GMC, and Chevrolet. Below are some of the types of ambulances chassis you can get from Ford, including dimensions of a Type I F-350/F-450/F-550, Type I F-650, and a Type II E-350 Super Duty Extended Van.
For comparison between companies, we will be looking into two major ambulance companies, Ford a renowned ambulance manufacture in the United States, and Mercedes, who business is mostly in Europe.
3.2.4 Ford

Ford builds 4 types of ambulances, two type I, one type II, and one type III.

![Figure 26. Ford Ambulance Line Up [7]](image)

For Type I ambulances, Ford uses their F-350/450/550 Super Duty truck as a chassis for demanding jobs and also an F-650 Pro Loader for even bigger jobs. The 350 and 450 have a 6 speed, Torqshift Automatic gearbox. The 350 is a 4 wheel model, while the 450 and 550 6 wheel models. All of the Ford trucks are rear wheel drive. The Super duty line up can be ordered with either a regular cab, Super Cab or Crew Cab, allowing for the medical unit to increase space up jumping up a class. This allows for a more spacious front seating and interior, translating to seating for six adults or a foldable rear bench for more storage area in a Crew Cab, Ford [7].
The ambulance is powered by a 6.7L Power Stroke V8 diesel engine that delivers up to 300 horsepower and 660 lb-ft of torque. The Super Duty Chassis cabs have a wide range of GVWRs, from 10,000 lbs. to 19,500 lbs., wheelbases, cab to axle length and payloads to choose from allowing more customization by the consumer. The 350 has a GVWR of 9,800 - 14,000 lb, the 450 is 16,500 lb, and the 550 is 19,500 lb.

![Figure 27. F-350 [7]](image)

The F-650 Pro Loader has a GVWR rating of up to 26,000 lbs. This line has a wide variety of set-ups as well, being able to choose from 12 wheelbase lengths, three cab configurations, engine/transmission combinations, choice of hydraulic or air brakes, height lowering kick up frame as well as rear air suspension package.
Ford’s type II ambulances are built on an E-350 Super Duty Extended Van Chassis, which have a maximum GVWR of 9,500. You have the choice of two gasoline engine power train, a 5.4L Triton V8 that delivers 255 Horsepower and 350 lb.-ft. or a 6.8L Triton V10 engine that delivers 305 Horsepower and 420 lb.-ft. torque. This ambulance was built with a body-on-frame mindset as well as a double wall cargo area construction. It has a 5,000 lb. capacity Twin I-Beam front axle and a rear axle with a capacity of over 6,000 lb. The electrical system also features a smart power distribution junction box.
Ford’s final ambulance, which is a Type III ambulance, is built on either an E-350 or an E-450 Super Duty cutaway. The E-350 Super Duty SRW has a maximum GVWR of over 10,000 with a 138” wheel base. The E-350 Super Duty DRW cutaway has GVWRs values of 11,500 and 12,500 lbs. with respective wheelbases of 158” and 176”. You have a choice of engine of 5.4L Triton V8 which delivers 255 Horsepower and 350 lb.-ft. or a 6.8L Triton V10 engine that delivers 305 Horsepower and 420 lb.-ft. torque, Ford [7].

![Figure 30. E-350 Super Duty Cutaway](image)

**TYPE I F-350**

**STYLE F-350 Truck**

**WHEELBASE (in.) 141/60-176/6182-296138138, 158, 176**

**GVWR (lbs.) 9,800-19,500**

**ENGINE 300 HP**

660 lb.-ft. Torque
660 lb.-ft. 255/305 HP

350/420 lb.-ft. 255/305 HP

350/420 lb.-ft.

**BRAKES** Four Wheel Disc with Anti-lock, Power Assist Hydraulic Brake system w/ traction control Four wheel disc with four wheel anti-lock Dual Piston Caliper, Anti-lock with Hydro-Boost

**FUEL TANK (gal)** 40 453340/55

### 3.2.5 Mercedes

While in America, Ford might be the king of the ambulance; the rest of the world turns to different manufacturer, Mercedes. Mercedes manufactures one of the more popular ambulance chassis models, known as the sprinter ambulance, which resembles what the United States of America would know as a Type II ambulance, which is an extended van.

![Figure 31. Mercedes Sprinter Layout](image-url)
Europe has been using this Sprinter model for years and other countries such as Australia have been starting to use the model due to increasing exchange rate prices for Ford and GMC chassis and spare parts, rising fuel costs, and Health and Safety regulations.

![Figure 32. Mercedes Sprinter Ambulance [23]](image)

The Mercedes model is popular due to the ability to incorporate cutting edge technology and safety systems, as well as the already existing sophisticated technology within the Mercedes. One reason that the model might not be as popular here is due to emphasis “Made in USA”, which has really derailed the Sprinters production and use here in the United States. Also European work and patient treatment methods differ then those in the United States, including that Europeans prefer high roof vans allowing staff to stand up while the United States tries to have everyone sit as much as possible. European safety standards also prohibit the use of side facing seats or squad benches in ambulances. It is important to note where the
Ford vehicles differ in vehicle wheelbase length, the Mercedes Vehicle differ in roof height, Sprinter [23].

Figure 33. Typical Interior of Mercedes Sprinter [23]

In the next sections we'll be looking at the different type of Sprinter Chassis.
## Cargo van

- **Measurements**
  - 2500 Standard Roof
  - 2500 High Roof
  - 2500 High Roof
  - 3500 High Roof
  - 3500 High Roof

- **144’WB**
  - 144’WB 170’WB 170’WB 170’WB
  - EXT

- **Turning Diameter**
  - 47.6
  - 654.5
  - 554.5
  - 547.5
  - 554.5

- **Ground to Sliding Door**
  - 20.2
  - 20.2
  - 19.9
  - 19.9
  - 22.0
  - 21.2
  - 21.2

- **Load Height – Rear**
  - 27.6
  - 27.6
  - 27.4
  - 27.2
  - 31.1
  - 30.9
  - 30.9

- **Cargo Bed Length**
  - 128.5
  - 128.5
  - 169.3
  - 185.0
  - 128.5
  - 169.3
  - 185.0

- **Cargo Width at Wheelhouse**
  - 53.1
  - 53.1
  - 53.1
  - 38.5
  - 38.5
  - 38.5
  - 38.5

- **Maximum width at Floor**
  - 70.1
  - 70.1
  - 70.1
  - 70.1
  - 70.1
  - 70.1

- **Interior height**
  - 65.0
  - 78.2
  - 78.2
  - 78.2
  - 78.2
  - 78.2
  - 78.2

- **Cargo Volume (cu ft.)**
  - 318.0
  - 371.0
  - 494.0
  - 547.0
  - 371.0
  - 494.0
  - 547.0

- **Maximum GVWR (lb.)**
  - 8,550
  - 8,500
  - 8,500
  - 11,030
  - 11,030
  - 11,030

- **Base Curb Weight (lb.)**
  - 5,124
  - 5,188
  - 5,545
  - 6,266
  - 6,266
  - 6,021

- **Maximum Payload (lb.)**
  - 3,426
  - 3,362
  - 3,005
  - 2,873
  - 4,155
  - 4,155

- **Maximum Towing (lb.)**
  - 5,000
  - 5,000
  - 5,000
  - 5,000
  - 5,000
  - 5,000

- **Fuel Tank Capacity (gal)**
  - 26.4
  - 26.4
  - 26.4
  - 26.4
  - 26.4
  - 26.4
<table>
<thead>
<tr>
<th>Measurements</th>
<th>2500 Standard Roof</th>
<th>2500 High Roof</th>
<th>3500 High Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning Diameter (ft) Wall to Wall</td>
<td>47.8</td>
<td>47.8</td>
<td>54.6</td>
</tr>
<tr>
<td>Ground To Slight Door Step - Side</td>
<td>20.2</td>
<td>20.2</td>
<td>19.9</td>
</tr>
<tr>
<td>Load Height - Rear</td>
<td>72.8</td>
<td>72.8</td>
<td>72.4</td>
</tr>
<tr>
<td>Door Opening - Side (height)</td>
<td>71.7</td>
<td>71.7</td>
<td>71.7</td>
</tr>
<tr>
<td>Door Opening - Rear (height)</td>
<td>72.4</td>
<td>72.4</td>
<td>72.4</td>
</tr>
<tr>
<td>Door Width - Side</td>
<td>81.6</td>
<td>81.6</td>
<td>81.6</td>
</tr>
<tr>
<td>Door Width - Rear</td>
<td>93.1</td>
<td>93.1</td>
<td>93.1</td>
</tr>
<tr>
<td>Cargo Bed Length</td>
<td>120.5</td>
<td>120.5</td>
<td>180.0</td>
</tr>
<tr>
<td>Cargo Width At Wheelbase</td>
<td>53.1</td>
<td>53.1</td>
<td>53.1</td>
</tr>
<tr>
<td>Maximum Width At Plan</td>
<td>95.1</td>
<td>95.1</td>
<td>95.1</td>
</tr>
<tr>
<td>Interior Height</td>
<td>95.0</td>
<td>95.0</td>
<td>95.0</td>
</tr>
<tr>
<td>Cargo Volume (cu ft)</td>
<td>110.0</td>
<td>110.0</td>
<td>148.0</td>
</tr>
</tbody>
</table>

**IT Capacity**

| Maximum Available GVM (lb)        | 18,050             | 18,050         | 22,050         |
| Base Curb Weight (lb)             | 5,124              | 5,100          | 5,045          |
| Maximum Payload (lb)              | 1,402              | 3,082          | 3,009          |
| Maximum GVWR (lb)                 | 13,050             | 13,050         | 13,050         |
| Maximum Towing (lb)               | 5,000              | 5,000          | 5,000          |
| Fuel Tank Capacity (gal)          | 28.4               | 28.4           | 28.4           |
| Max. Seating Capacity             | 2                  | 2              | 2              |

Figure 34. Mercedes Sprinter Cargo Van [23]
Crew Van

- **Measurements** 2500 Standard Roof 2500 High Roof 2500 High Roof
- 144'WB144'WB170'WB
- Turning Diameter 47.647.654.6
- Ground to Sliding Door Step-Side 20.220.219.9
- Load Height – Rear 27.627.627.4
- Cargo Bed Length 91.591.5131.5
- Cargo Width at Wheelhouse 53.153.153.1
- Maximum width at Floor 70.170.170.1
- Interior height 65.078.278.2
- Cargo Volume (cu ft.) 217.0255.0380.0
- Maximum GVWR (lb.) 8,5508,508,5008,500Base
- Curb Weight (lb.) 5,3905,456,865
- Maximum Payload (lb.) 3,1606,094,685
- Maximum Towing (lb.) 5,0005,0005,000
- Fuel Tank Capacity (gal) 26.426.426.4
**Figure 35. Mercedes Sprinter Crew Van [23]**

<table>
<thead>
<tr>
<th>Measurements</th>
<th>2500 Standard Roof</th>
<th>2500 High Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning Diameter (ft) Wall to Wall</td>
<td>47.6</td>
<td>47.6</td>
</tr>
<tr>
<td>Ground To Sliding Door Step - Side</td>
<td>20.2</td>
<td>20.2</td>
</tr>
<tr>
<td>Load Height - Rear</td>
<td>27.6</td>
<td>27.6</td>
</tr>
<tr>
<td>Door Opening - Side (Height)</td>
<td>50.0</td>
<td>71.7</td>
</tr>
<tr>
<td>Door Opening - Rear (Height)</td>
<td>50.0</td>
<td>72.4</td>
</tr>
<tr>
<td>Door Width - Side</td>
<td>51.2</td>
<td>51.2</td>
</tr>
<tr>
<td>Door Width - Rear</td>
<td>81.8</td>
<td>81.8</td>
</tr>
<tr>
<td>Cargo Bed Length</td>
<td>91.5</td>
<td>91.5</td>
</tr>
<tr>
<td>Cargo Width At Wholetop</td>
<td>83.1</td>
<td>83.1</td>
</tr>
<tr>
<td>Maximum Width At Floor</td>
<td>70.1</td>
<td>70.1</td>
</tr>
<tr>
<td>Interior Height</td>
<td>85.0</td>
<td>76.2</td>
</tr>
<tr>
<td>Cargo Volume (cu ft)</td>
<td>217.0</td>
<td>255.0</td>
</tr>
</tbody>
</table>

**Capacity**

| Maximum Available GVWR (lb)                 | 8,500              | 8,500          | 8,500          |
| Base Curb Weight (lb)                       | 5,900              | 5,450          | 5,900          |
| Maximum Payload (lb)                        | 3,160              | 5,044          | 2,865          |
| Maximum Available GCWR (lb)                | 13,550             | 13,550         | 13,550         |
| Maximum Towing (lb)                         | 5,000              | 5,000          | 5,300          |
| Fuel Tank Capacity (gal)                    | 28.4               | 28.4           | 28.4           |
| Max. Seating Capacity                      | 5                  | 5               | 5              |
Passenger Van

- **Measurements** 2500 Standard Roof 2500 High Roof 2500 High Roof
- **144’ WB** 144’ WB 170 ’WB
- **Turning Diameter** 47.6 47.6 54.6
- **Ground to Sliding Door Step-Side** 20.2 20.2 19.9
- **Load Height – Rear** 27.6 27.6 27.4
- **Cargo Bed Length** 32.5 32.5 73.2
- **Cargo Width at Wheelhouse** 53.1 53.1 53.1
- **Maximum width at Floor** 70.1 70.1 70.1
- **Interior height** 65.0 76.4 76.4
- **Cargo Volume (cu ft.)** 141.3 158.9 187.2
- **Maximum GVWR (lb.)** 8,550 8,500 8,500
- **Base Curb Weight (lb.)** 5,739 5,800 6,182
- **Maximum Payload (lb.)** 2,811 2,750 2,368
- **Maximum Towing (lb.)** 5,000 5,000 5,000
- **Fuel Tank Capacity (gal)** 26.4 26.4 26.4
<table>
<thead>
<tr>
<th>Measurements</th>
<th>2500 Standard Roof</th>
<th>2500 High Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning Diameter (ft) Well to Wall</td>
<td>47.8</td>
<td>47.8</td>
</tr>
<tr>
<td>Ground To Sliding Door Step - Side</td>
<td>20.2</td>
<td>20.2</td>
</tr>
<tr>
<td>Load Height - Rear</td>
<td>27.5</td>
<td>27.5</td>
</tr>
<tr>
<td>Door Opening - Side (Height)</td>
<td>70.1</td>
<td>70.1</td>
</tr>
<tr>
<td>Door Opening - Rear (Height)</td>
<td>72.4</td>
<td>72.4</td>
</tr>
<tr>
<td>Door Width - Side</td>
<td>51.2</td>
<td>51.2</td>
</tr>
<tr>
<td>Door Width - Rear</td>
<td>51.2</td>
<td>51.2</td>
</tr>
<tr>
<td>Cargo Bed Length</td>
<td>32.5</td>
<td>32.5</td>
</tr>
<tr>
<td>Cargo Width At Wheelhouse</td>
<td>13.1</td>
<td>13.1</td>
</tr>
<tr>
<td>Maximum Width At Floor</td>
<td>73.1</td>
<td>73.1</td>
</tr>
<tr>
<td>Interior Height</td>
<td>70.1</td>
<td>70.1</td>
</tr>
<tr>
<td>Cargo Volume (cu ft)</td>
<td>141.3</td>
<td>158.9</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Available GVWR (lb)</td>
<td>8,550</td>
<td>8,550</td>
</tr>
<tr>
<td>Base Curb Weight (lb)</td>
<td>5,730</td>
<td>5,800</td>
</tr>
<tr>
<td>Maximum Payload (lb)</td>
<td>2,811</td>
<td>2,750</td>
</tr>
<tr>
<td>Maximum Available GCWR (lb)</td>
<td>12,550</td>
<td>12,550</td>
</tr>
<tr>
<td>Maximum Towing (lb)</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Fuel Tank Capacity (gal)</td>
<td>28.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Max. Seating Capacity</td>
<td>Up to 12</td>
<td>Up to 12</td>
</tr>
</tbody>
</table>

**Figure 36. Mercedes Sprinter Passenger Van [23]**
Cab Chassis

- **Measurements** 3500 Standard Roof 3500 Standard Roof
- 144’ WB 170’ WB
- Turning Diameter 47.654.6
- Ground to Sliding Door Step-Side 0.00.0
- Load Height – Rear 0.00.0
- Cargo Bed Length 0.00.0
- Cargo Width at Wheelhouse 0.00.0
- Maximum width at Floor 0.00.0
- Interior height 0.00.0
- Cargo Volume (cu ft.) 0.00.0
- Maximum GVWR (lb.) 11,03011,030
- Base Curb Weight (lb.) 4,7124,804
- Maximum Payload (lb.) 6,3186,226
- Maximum Towing (lb.) 7,5007,500
- Fuel Tank Capacity (gal) 26.426.4
Figure 37. Mercedes Sprinter Cab Chassis [23]
3.2.6 Ford Vs. Mercedes [9]

<table>
<thead>
<tr>
<th>Make</th>
<th>MERCEDES-BENZ</th>
<th>FORD</th>
<th>CHEVROLET</th>
<th>GMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change Model</td>
<td>Sprinter Chassis Cab 35C</td>
<td>E-Series Cutaway Van</td>
<td>Express Cutaway Van</td>
<td>Savana Cutaway Van</td>
</tr>
<tr>
<td>Change Trim</td>
<td>Standard Roof 170-in. WB</td>
<td>E-350 SD 176-in. WB DR</td>
<td>3500 177-in. WB</td>
<td>3500 177-in. WB Diesel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Passengers (Std)</th>
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<th>2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Type</td>
<td>3.0L V6</td>
<td>5.4L V8</td>
<td>6.0L V8</td>
</tr>
<tr>
<td>Horsepower @ RPM</td>
<td>188@3400</td>
<td>255@4500</td>
<td>324@4700</td>
</tr>
<tr>
<td>Torque @ RPM</td>
<td>325@1400</td>
<td>370@2500</td>
<td>377@4400</td>
</tr>
<tr>
<td>Transmission Type</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
</tr>
<tr>
<td>Interior Standing Height (inches)</td>
<td>Not Listed</td>
<td>Not Listed</td>
<td>Not Listed</td>
</tr>
<tr>
<td>Cargo Volume (cubic feet)</td>
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<td>Not Listed</td>
<td>Not Listed</td>
</tr>
<tr>
<td>Maximum Payload (lbs.)</td>
<td>6179</td>
<td>7365</td>
<td>7248</td>
</tr>
<tr>
<td>Gross Vehicle Weight Rating (lbs.) Maximum</td>
<td>11030</td>
<td>12500</td>
<td>12380</td>
</tr>
</tbody>
</table>

3.2.7 Results and Considerations

After an in-depth look at the different chassis available on the market for ambulance purposes, the decision was really between America’s choice of chassis in Ford F-350 line and Europe’s choice of chassis in the Mercedes Sprinter line. Both chassis are top of the line products and either could be chosen to perform in a given situation. Both the Ford F-Series as well as the Mercedes Sprinter’s come standard with anti-lock brakes, stability control system, and disc rear brakes. Where the two differ is the engine power of the machines as well as the gross weight vehicle rating. While the horsepower of the Ford F-Series can top 400 HP at almost 6,000 RPM, the Mercedes Sprinter series carries on average only about 200 HP at 4,000 RPM. But due to the high weight of the F-Series, this leaves Sprinter with a higher power-to-
weight ratio at about 17 lb./hp for the F-Series and almost 30 lb./hp for the Sprinter. The Sprinter also comes with a Turbocharger air compressor that lets it maximize power output, while Ford does not feature an air compressor. All this allows the Sprinter to travel faster and more efficient, which would be an ideal for an ambulance.

Where the Ford F-Series outperforms that the Sprinter line is that gross weight vehicle rating, which is an essential focus for an ambulance machine. The Sprinter lines GWVR are typically around 7,000 to 8,000 lbs., but that the Ford F-series have GWVR ratings that can reach 15,000 lb., almost double the amount the sprinter line features. This is obviously a huge concern for ambulances, which typically carry equipment that outweighs a GWVR of at least 10,000 lb. This is the main reason we’re not able to pick the Mercedes Sprinter chassis, which Dodge has recently picked up and used in their own lines, is the fact that the GWVR is not high enough to accommodate for the equipment and passengers that ambulances in the United States are used to. Modifications need to be made in order for Mercedes or Dodge Sprinter chassis to be used in the United States as medical ambulances, but the Ford F-Series is a great choice to use as an ambulance chassis.
Chapter 4. CONCLUDING REMARKS

As shown by the previous chapters, there is great room for improvement in ambulance design. The S.L.A.T.E. ambulance addresses these issues with one possible design - but there are always multiple ways to look at a problem. In this chapter, other possibilities for design and future work are examined from the framework of the SLATE ambulance.

Ambulance design is a complex topic. Small changes to the design can lead to large differences in function and perception by the user. It is to this effect that the group hopes continuing research and development can use the ideas and layouts presented in this paper to continue the improvement of ambulance designs.

This chapter contains a summary of the entire project, some considerations and difficulties, and recommendations for future research based upon the results and challenges conquered during this project. Whether or not the entire SLATE ambulance is brought into development, it is important to note that many of its features can be used on their own in subsequent designs. While not all hospitals may require a specialized ambulance specifically created for pediatric and OB/GYN use, it is the group's belief that all ambulances can benefit from the safety innovations found in the SLATE ambulance.
4. Project Summary

These days, most technological innovations happen not when come up with a novel invention, but instead when you’re able to take a product and make it safer, lighter, more affordable, or more efficient. This is exactly the type of innovation the project team had in mind when we undertook the opportunity to build an S.L.A.T.E. ambulance alongside MIRAD Laboratories and Worcester E.M.S. The project team sought to advance ambulance technology for primary use as a mobile medical station and focus on its use as an OB/GYN medical site. It was important to incorporate all of S.L.A.T.E; safety, lightweight, affordable, technology, and efficient.

After studying current ambulances and talking with not only patients and patrons of the ambulance but E.M.S and emergency personal, we were able to determine areas in which the ambulance could be improved. One of the most important factors in any ambulance is safety and the project team made this our top priority. Focusing on the interior of the ambulance and the emergency personnel riding within the ambulance, it was clear from the interviews and studies that emergency personnel weren’t staying seated and buckled in throughout a ride. It was clear, in order for them to do their job properly and efficiently, they need to be able to move around the cab to be able to access different comportments and different areas of the patient. One of our main designs included a mobile captain’s chair that would allow 360-degree rotation as well as movement along a track implanted in the floor to allow for movement around the cabin, while keeping the personnel securely strapped and safe.
Creating a more efficient ambulance was also a major focus, which incorporated making the cabin more lightweight and involving a bit of technology. The project team designed a vending machine specifically for the ambulance, which allowed the timely and accurate delivery of medical gear when requested, such as band-aids or gauze pads. This system will allow lead to a more accurate and precise use of the medical gear, but also create an easy method for restocking as well as cleaning.

With vast improvements, both major and minor, in the cabin portion of the ambulance it was important to analyze the chassis on which the cab sits. It was intriguing to find that most ambulances throughout the United States use a Ford, Dodge, or Chevy chassis which themselves range in sizes, while most of the European countries for example, use a Mercedes chassis. Shown in the paper, both have their pros and cons with the biggest difference being the gross vehicle weight ratings that the chassis are able to support. It is because of this that the Ford chassis was picked, but we believe in the future when we're able to continue to cut down on weight, the emergency medical vehicles will slowly transition to more mobile, lightweight, and efficient chassis, such as the one Mercedes supplies.

We understand and it is very evident that people do not want a drastic change to norm, but the project team along with MIRAD Laboratories believes that these improvements are the right steps forward to furthering health care.
4.1 Considerations and Difficulties

There are a number of factors that need to be taken into consideration when approaching this project. First and foremost when it comes to the ambulance industry, it is hard to implement innovation. Not that the innovation is not there, as ambulance manufactures would love to improve existing systems, as well as add to them. The problem is that to implement new systems, they must be tested and made to comply with the ambulance standards. So, when it comes to new innovations to ambulances, such as the ones we have proposed in the project, it may be hard to make them a reality. The project team is quite hopeful when it comes to our innovations because of the research and design theories behind them. These innovations, hand-in-hand with S.L.A.T.E. may make it possible to implement them in ambulances across the country, or in specific pediatric and OBGYN ambulances.

Another consideration when looking at this project is that it was tough to get all of our critical elements of design into our final design. The project group has already made it clear that our main focus was safety for everyone traveling in the back of the ambulance, and the group decided to pursue those avenues that we felt we could have the biggest impact. That is why the design group chose to focus mostly on safety, as a portion of S.L.A.T.E. In the future more of our critical elements of design could be further explored, designed, and implemented in the S.L.A.T.E. ambulance.

One of the major difficulties of this project was what made this project unique. S.L.A.T.E. Safety, Lightweight, Affordable, Technology, and Efficiency, when this group was working on the ambulance had some conflicts with S.L.A.T.E. and
the critical elements of design. For example, when trying to implement more technology, and safety elements, it is hard to then turn around and keep the weight or the price of the ambulance from growing, rather than shrinking. Also the use of composite materials would be very expensive, and could make the S.L.A.T.E. ambulance initial costs rise, while the overall costs down the line (maintenance) could be reduced. The project team had some difficulty determining what elements could be focused on, while still keeping every part of S.L.A.T.E. a priority. Thus, this issue needs to be taken into consideration, especially when it comes to later projects.

As with any project, the team knew difficulties would arise, however, we felt we rose to the challenge, and throughout the whole project the team had no internal conflicts, and every issue was resolved in a timely manor. Overall the team feels they designed a strong ambulance that with some more work can be implemented into the United States health care system.

4.2 Future Work

The project team feels this project would be a good candidate for future MQP continuation. This project could be an ongoing project at WPI until the ambulance becomes a reality. There are still some of the critical elements of design that need to be designed fully, and added into our current final design. With all of the critical elements of design added in, the ambulance would be fully functioning, with new technology, some of which has never been used or seen in ambulances.
An ambulance manufacturer could also continue this project. The project team stands behind its full design, however, the team recognizes that some of the innovations that have been introduced from this project could be utilized in current ambulances. Therefore, the project could continue on by having an ambulance manufacturer apply certain parts of this S.L.A.T.E. ambulance to other ambulances. That way the project group's innovations could be utilized and still assist pre-hospital care across the nation.
REFERENCES


APPENDICES

1. Ambulance Standards

1.1 Star of Life KKK-A-1822F Standards S.L.A.T.E. Classified

3.1.1 Design

3.2 VEHICLE, AMBULANCE COMPONENTS, EQUIPMENT, AND ACCESSORIES.

3.4 VEHICLE OPERATION, PERFORMANCE, AND PHYSICAL CHARACTERISTICS.

3.5 VEHICLE WEIGHT RATINGS AND PAYLOAD.

3.8 LIGHTING, EXTERIOR AND INTERIOR.

3.9 CAB-BODY DRIVER COMPARTMENT AND EQUIPMENT.

3.10 AMBULANCE BODY AND PATIENT AREA.

3.11 STORAGE COMPARTMENTS.

3.13 ENVIRONMENTAL: CLIMATIC AND NOISE PARAMETERS.

3.14 COMMUNICATIONS.

3.15 ADDITIONAL SYSTEMS, EQUIPMENT, ACCESSORIES, AND SUPPLIES.

1.1.1 Definition of Ambulance

The ambulance is defined as a vehicle used for emergency medical care that provides:

- A driver’s compartment.
• A patient compartment to accommodate an emergency medical services provider (EMSP) and one patient located on the primary cot so positioned that the primary patient can be given intensive life-support during transit.
• Equipment and supplies for emergency care at the scene as well as during transport.
• Safety, comfort, and avoidance of aggravation of the patient’s injury or illness.
• Two-way radio communication.
• Audible and Visual Traffic warning devices.

3.4.10 VEHICLE PHYSICAL DIMENSIONAL REQUIREMENTS

3.4.10.1 LENGTH
Overall length of the ambulance (OAL) shall be specified by the purchaser, including bumpers, rear step and bumper guards.

3.4.10.2 WIDTH
The overall width of ambulance bodies having dual rear wheels shall be a maximum of 96", excluding mirrors, lights, and other safety appurtenances. The ambulance body sides, on a chassis with dual rear wheels, shall be symmetrical and within +/- 2.5" of the overall width of the tires (outside sidewalls). The 2.5" allowance is not cumulative; it applies individually to each side. Tires shall not extend beyond the fenders.

3.4.10.3 HEIGHT
The purchaser shall specify the overall height of the ambulance when loaded to curb weight. This includes roof-mounted equipment, but excludes two-way radio antenna(s).

3.5.4 WEIGHT DISTRIBUTION

Purchasers and FSAMs shall locate vehicle-mounted components, equipment, and supplies to provide a vehicle that is laterally balanced and within the GVWR and each gross axle weight rating (GAWR).

The right and left wheel(s) of each axle of a completed ambulance shall be weighed to determine horizontal and lateral weight distribution. The weight distribution of a properly loaded ambulance on a level surface shall permit conformance to the FMVSS braking requirements in accordance with the statements provided by the OEM. All specifications and requirements for weight distribution and center of gravity of the OEM shall take precedence over the requirements contained in this section where the OEM’s requirements are more restrictive or comprehensive.

- The weight between the right and left side of a given axle, when on a level surface, shall be within 5%.

- When loaded to the GVWR and within the GAWR for each axle, the front to rear weight distribution shall have not less than 20% of the total weight on the front axle, and not less than 50% nor more than 80% on the rear axle.

- The FSAM shall locate the center of gravity (CG) of the vehicle according to the requirements set by the OEM to determine and assure that the CG of the completed ambulance does not exceed any maximum horizontal and/or vertical limits.
To meet the above weight distribution requirements, consideration shall be given by the purchaser and FSAM to locate equipment and components to permit inherently proper lateral balance, front/rear axle loading, and center of gravity position.

3.8 LIGHTING, EXTERIOR AND INTERIOR

3.8.1 AMBULANCE EXTERIOR LIGHTING

The basic exterior ambulance lighting shall include daytime running lights when available from the OEM. The lower front and rear side marker lights shall flash in conjunction with the directional signals. The FSAM shall furnish light assemblies that are manufactured with weather resistant materials that are installed in a manner that will not cause electrolysis of light housings or vehicle body.

3.8.2 AMBULANCE EMERGENCY LIGHTING

An emergency lighting system shall provide the ambulance with 360°of conspicuity for safety during its missions. The system shall display highly perceptible and attention getting signals that function in a modal system, and convey the message in the “PRIMARY MODE” — “Clear the Right-of-Way” and in the “SECONDARY MODE” — “Hazard, Vehicle Stopped on Right-of-Way.” The ambulance standard warning light system shall not impose a continuous average electrical load exceeding 40 amperes at 14.2 volts. Warning light systems shall not impair the effectiveness of the ambulance’s exterior lighting with conformity to the requirements of FMVSS No. 108.

3.8.2.1 EMERGENCY LIGHTING SYSTEM CONFIGURATION

The ambulance standard emergency warning light system shall contain twelve fixed red lights, one fixed clear light and one fixed amber light. These lights shall function
in a dual mode system as shown in Table 1 and meet the physical and photometric requirements. The upper body warning lights shall be mounted at the extreme upper corner areas of the ambulance body, below the horizontal roofline. The single clear light shall be centered between the two front facing, red, upper corner lights or in a dedicated housing mounted forward of the body on the cab roof. If due to limited body dimensions and physical size of the outboard forward facing lights, the lights may also be mounted in dedicated housings on the cab roof. Doors or other ancillary equipment shall not obstruct the standard warning lights. The amber light shall be symmetrically located between the two rear facing red lights. The red “grille” lights shall be located at least 30” above the ground and below the bottom edge of the windshield and be laterally separated by at least 18”, measured from centerline to centerline of each lamp. The lateral facing intersection lights shall be mounted as close as possible to the front upper edge of each front fender and may be angled forward a maximum of 30°. All warning lights furnished shall be mounted to project their highest intensity beams on the horizontal plane.

3.10 AMBULANCE BODY AND PATIENT AREA

3.10.1 BODY ACCOMMODATIONS

The ambulance body and patient compartment shall be sufficient in size to transport occupants and all specified stretchers, cots, and litters. There shall be space around the patient(s) to permit an EMSP to administer life support treatment to the primary patient during transit.

3.10.2 CAB/PATIENT COMPARTMENT ACCESS WINDOW
The ambulance and body bulkheads shall have an aligned window opening of at least 150 sq. in., for visual checking and voice communications between the cab and the patient’s compartment for non-walkthrough vehicles. The window in the cab or body shall be of the sliding type, shall be aligned, and connect with the modular body window opening and shall conform to requirements of the partition. The window shall be latchable from the cab side and shall be an adjustable, transparent, shatterproof panel.

**3.10.3 EMERGENCY MEDICAL SERVICES PROVIDER (EMSP) SEATING**

The EMSP shall be provided with a seat conforming to all applicable FMVSS Standards, and be equipped with a safety belt and a padded back and a padded headrest. The seat shall be not less than 15" deep by 18" wide and a minimum distance of 43" from the top of the padded seat to any overhead obstruction. The EMSP seat shall be located to allow for the care of the primary patient.

**3.11 STORAGE COMPARTMENTS**

Storage compartments shall be furnished for all items required by this specification and/or specified by the purchaser and include storage for, but not be limited to; backboards, portable cots/litters, stair chairs, and any other specified patient handling devices. Any absorbent material such as carpeting, fabric, or inside/outside plastic type carpeting, etc. that resists cleaning and decontamination shall not be used in any storage or patient compartment.
1.2 British Ambulance Standards S.L.A.T.E. Classified

Safety

Exposed edges that could come into contact with the occupant's hands, legs, head etc., during normal use shall have a radius of curvature of not less than 2.5 mm except in the case of projections of less than 3.2 mm, measured from the panel. In this case, the minimum radius of curvature shall not apply provided the height of the projection is not more than half its width and its edges are blunted.

All persons and items e.g. medical devices, equipment and objects normally carried on the road ambulance shall be restrained, installed or stowed to prevent them becoming a projectile when subjected to accelerations/decelerations of 10 g in the forward, rearward, left, right and vertical directions.

Lightweight

Net vehicle mass; unloaded mass net vehicle mass according to 92/21/EEC modified of the road ambulance including the driver taken as 75 kg and all fixed installations

Affordability

The road ambulance shall be designed and constructed to accommodate the items listed in the Tables 9 to 19 and provide the following levels of care:

• the patient transport ambulance (types A1 and A2) shall have basic professional equipment for first aid and nursing care;
• the emergency ambulance (type B) shall have equipment for basic treatment and monitoring of patients with the current methods of pre hospital care;
• the mobile intensive care unit (type C) shall have equipment for advanced treatment and monitoring of patients with the current methods of pre hospital intensive care.

The source of supply shall consist of one or more of the following (see also 5.1.3 of EN 737-3:1998):

a) gas in cylinders, e.g. oxygen, air;
b) non-cryogenic liquid in cylinders, e.g. N2O, CO2;
c) cryogenic liquid in cylinders, e.g. oxygen;
d) cryogenic liquid in stationary vessels, e.g. oxygen;
e) non-cryogenic liquid in stationary vessels, e.g. N2O, CO2;
f) an air compressor system;
g) a proportioning system, e.g. oxygen and nitrogen;
h) a vacuum system.

**Technology**

The ceiling, the interior side-walls and the doors of the patient’s compartment shall be lined with a material that is non-permeable and resistant to disinfectant.

The edges of surfaces shall be designed and/or sealed in such a way that no fluid can infiltrate. If the floor arrangement does not allow fluids to flow away, one or more drain with plugs shall be provided.
Drawers should be secured against self-opening and where lockers are fitted with doors that open upwards they should be fitted with a positive hold open mechanism. Type B and C road ambulances shall be equipped with a lockable drugs compartment with security lock.

The device shall be designed for use in mobile situations and in field applications7).

If a medical device is designated as "portable" (except patient handling equipment according to Table 9) it shall be in accordance with EN 60601-1 and shall be possible to be carried by one person8) have its own built in power supply (where relevant); be capable of use outside the vehicle.

**Efficiency**

In addition to the heating of the driver’s compartment there shall be an independent adjustable system as follows:

- heating for type A and B road ambulance;
- fresh air heating for type C road ambulances.

This system shall be such that given an outside and inside temperature of −10 °C, or in extremely cold zones a temperature of −20 °C, the heating up to at least 5 °C shall not take longer than 15 min. After 30 min a temperature of at least 22 °C shall be reached in the patient’s compartment. The inside temperature shall be measured in the centre of the stretcher(s) and at the mid point from the heater outlets (if several outlets are available).

The heating shall be controlled by an adjustable thermostat or by an electronic
climate control system. The actual temperature shall not vary from the set temperature by more than 5 °C.

The heating system shall be capable of meeting the performance criteria with the ventilation system switched off and the heating system set to re-circulate the air in the patient’s compartment.

The installation of the system shall not encourage exhaust gases entering the patient’s compartment.

A cooling system is optional. Where a cooling system is fitted the following requirement are recommended.

The cooling system should be such that, given an outside and inside temperature of 32 °C, the cooling down to at most 27 °C in the patient's compartment should not take longer than 15 min. After 30 min a temperature of at most 25 °C should be reached. The inside temperature should be measured in the centre of the stretcher(s) and at the mid point from the cooling outlets (if several outlets are available).

The installation of the system shall not encourage exhaust gases entering the patient’s compartment.

All equipment required for a set procedure shall be stowed in a specified location. Essential equipment required for use outside the vehicle shall be easily accessible via normally used doors. All equipment shall be securely and safely stowed to prevent damage or injury whilst the vehicle is in motion (see 6.3.5).
1.3 Alberta Ambulance Standards S.L.A.T.E. Classified

SAFETY

To the greatest extent possible, the interior walls and ceiling of the ambulance shall present a simple plane surface.

The interior of the patient and driver compartments shall be free of all sharp projections.

All hangers or supports for equipment, lighting, controls and other devices shall be mounted as flush as possible with the surrounding surface.

All exposed edges and corners without padding shall be rounded with the largest possible radius or chamfer. At minimum, there shall be a 15 mm radius or a 3 mm chamfer.

Bolsters (padded cushions) shall be provided at all locations which may prove dangerous to persons moving about or seated within the ambulance, or entering and leaving the ambulance.

The patient compartment of an ambulance must have the following:

(a) at least 1600 mm between the finished floor and the ceiling;

(b) not less than 3000 mm between the bulkhead partition immediately behind the driver’s seat and the inside of the rear doors;
(c) not less than 680 mm between the backrest of the rear-facing attendant’s seat and the forward edge of the main cot;

(d) not less than 250 mm between the rear edge of the main cot mattress and the inside of the rear doors; and

(e) a clear aisle of not less than 250 mm in width between the main cot and the face of the squad bench or the second cot. The aisle shall not be reduced by more than 40 mm by any cantilever of a squad bench seat.

A rear-facing bucket seat with a minimum 3-point restraint system and an integral child safety seat shall be installed immediately in front of the forward edge of the main cot;

In a single cot configuration, at least one additional seating position shall be located on the curbside.

In a dual cot configuration, a flip-down squad seat shall be installed over the curbside cot. The height of the squad seat above the floor shall be the minimum required to accommodate the cot, complete with mattress and linen, below the lowered seat.

An ambulance shall be equipped with a piped medical oxygen system installed in the patient compartment. The system shall include the following minimum components:

(a) a medical oxygen cylinder having at least a 2000-litre capacity that is fitted with
a pressure-reducing regulator complete with a contents gauge and preset to 344.5 kilopascals;

(b) non-ferrous piping or low pressure, electrically-conductive, medical grade hose;

(c) not fewer than 2 self-sealing wall outlets that have gas-specific threaded connectors; and

(d) a pressure-compensated flow meter for each wall outlet that is being used to administer oxygen to a patient.

The oxygen system must meet the requirements in Testing Standard 17.20.

All seating positions in an ambulance shall have a seat belt that complies with CMVSS.

**LIGHTWEIGHT**

An ambulance shall be weighed in accordance with the requirements in Testing Standards 17.18 and 17.19 and be certified as meeting the weight distribution, payload allowance and centre of gravity standards.

**AFFORDIBLE**

**TECHNOLOGY**

Windows in medical supply cabinet doors and the bulkhead door (see 5.5.5) or communication window (see 5.5.6) shall be made of transparent polycarbonate and
bear a permanent identifying mark that certifies compliance with Transport Canada Regulations for motor vehicle glazing.

All interior cabinets shall be constructed of metal or lightweight materials with a metal framework, and be attached to the body of the ambulance in compliance with 3.5.2.

The finish of all interior surfaces, other than those installed by the OEM, shall be impervious to soap and water, disinfectants and mildew.

Modular bodies shall be constructed of aluminum and shall be of all-welded construction.

Construction methods shall prevent electrolytic action between dissimilar metals and materials.

Despite 6.1.1, the Registrar may approve other construction materials and methods.

The body shall be mounted to the chassis with high-strength fasteners and vibration-isolating rubber body mounts designed and installed in accordance with the chassis manufacturer's guidelines.

Modular bodies shall not be welded to the frame at any point.
Switches to control the patient compartment lights, heating, air conditioning, suction and other patient compartment functions shall be mounted on a switch panel located on the action wall.

In addition to the requirement in 7.9.1, these functions may also be controlled from secondary locations in the ambulance.

Patient compartment lighting shall have variable intensity capabilities.

A climate control system that consists of heating, ventilation and air conditioning components shall be installed in the patient compartment.

This climate control system shall be independent of the cab’s climate control system and have controls that are easily accessible to the attendant.

A thermostat system shall automatically control the heating and cooling functions so that the temperature in the patient compartment is maintained within +/- 2°C of the set temperature.

The motors used to exhaust or intake air for air exchange shall comply with C-UL requirements for spark protection (marine).
If an auxiliary interior heater is used in an ambulance to maintain the interior temperature above 10°C, the interior heater must be permanently installed in a protective metal box mounted within a cabinet in the patient compartment and be equipped with a thermostat.

If the auxiliary heater is powered by 120 volt AC, it must be permanently and directly wired through a ground-fault interrupt breaker to a shoreline connection located on the exterior of the ambulance and have an automatically resetting high-temperature cutout switch.

An ambulance shall have a communication system that allows for all required communication between the ambulance attendants, dispatch and medical direction.

**EFFICIENCY**

The interior of an ambulance shall have readily accessible space for the storing and securing of all equipment and supplies.

Medical supply cabinets that are equipped with hinged door frames, and all other spaces where equipment and supplies may be stored, must be fitted with restraint devices that meet the requirements in Testing Standard 17.12.
If a side-facing CPR seat is installed in the street side cabinetry, there must be a clear aisle of not less than 200 mm from the face of the cabinet wall to the main cot, and it shall not reduce the distance required in 7.1.1(e).
2. Preliminary Ambulance Designs
Street side interior view

Chair

Extra

Standing

Bab"
3. Final Ambulance Designs
4. Equipment for Ambulances

**Equipment for Ambulances [20]**

American College of Surgeons Committee on Trauma,
American College of Emergency Physicians,
National Association of EMS Physicians,
Pediatric Equipment Guidelines Committee—Emergency Medical Services for Children (EMSC) Partnership for Children Stakeholder Group,
American Academy of Pediatrics

Almost 4 decades ago, the Committee on Trauma of the American College of Surgeons (ACS) developed a list of standardized equipment for ambulances. Beginning in 1988, the American College of Emergency Physicians (ACEP) published a similar list. The 2 organizations collaborated on a joint document published in 2000, and the National Association of EMS Physicians (NAEMSP) participated in the 2005 revision. The 2005 revision included resources needed on ambulances for appropriate homeland security. All 3 organizations adhere to the principle that emergency medical services (EMS) providers at all levels must have the appropriate equipment and supplies to optimize prehospital delivery of care. The document was written to serve as a standard for the equipment needs of emergency ambulance services in both the United States and Canada.

EMS providers care for patients of all ages, who have a wide variety of medical and traumatic conditions. With permission from the ACS Committee on Trauma, ACEP, and NAEMSP, the current revision includes updated pediatric recommendations developed by members of the federal Emergency Medical Services for Children...
(EMSC) Stakeholder Group. The EMSC Program has developed several performance measures for the program's state partnership grantees. One of the performance measures evaluates the availability of essential pediatric equipment and supplies for basic life support (BLS) and advanced life support (ALS) patient care units. This document will be used as the standard for this performance measure. The American Academy of Pediatrics (AAP) has also officially endorsed this list.

For purposes of this document, the following definitions have been used: a neonate is 0 to 28 days old, an infant is 29 days to 1 year old, and a child is >1 through 11 years old with delineation into the following developmental stages:

- Toddlers (1–3 years old)
- Preschoolers (3–5 years old)
- Middle childhood (6–11 years old)
- Adolescents (12–18 years old)

These standard definitions are age based. Length-based systems have been developed to more accurately estimate the weight of children and predict appropriate equipment sizes, medication doses, and guidelines for fluid volume administration.

**PRINCIPLES OF PREHOSPITAL CARE**

The goal of prehospital care is to minimize further systemic insult or injury and manage life-threatening conditions through a series of well-defined and appropriate interventions, and to embrace principles that ensure patient safety. High-quality, consistent emergency care demands continuous quality improvement and is directly
dependent on the effective monitoring, integration, and evaluation of all components of the patient's care.

Integral to this process is medical oversight of prehospital care by using preexisting protocols (indirect medical oversight), which are evidence based when possible, or by medical control via voice and/or video communication (direct medical oversight). The protocols that guide patient care should be established collaboratively by medical directors for ambulance services, adult and pediatric emergency medicine physicians, adult and pediatric trauma surgeons, and appropriately trained basic and advanced emergency medical personnel. Current Institute of Medicine (IOM) recommendations encourage each EMS agency to have a pediatric coordinator to specifically coordinate the capability of the service to care for no adult patients.

**EQUIPMENT AND SUPPLIES**

The guidelines list the supplies and equipment that should be stocked on ambulances to provide the accepted standards of patient care. Previous documents regarding ambulance equipment referred to essential or minimal equipment necessary to adequately equip an ambulance. Equipment requirements will vary, depending on the certification levels of the providers, population densities, geographic and economic conditions of the region, and other factors.

The following list is divided into equipment for BLS and ALS ambulances. ALS ambulances must have all of the equipment on the required BLS list as well as equipment on the required ALS list. This list represents a consensus of
recommendations for equipment and supplies that will facilitate patient care in the out-of-hospital setting.

**REQUIRED EQUIPMENT: BLS AMBULANCES**

**A. Ventilation and Airway Equipment**

1. Portable and fixed suction apparatus with a regulator (per federal specifications; see Federal Specification KKK-A-1822F reference)
   - Wide-bore tubing, rigid pharyngeal curved suction tip; tonsillar and flexible suction catheters, 6F–16F, are commercially available (have 1 between 6F and 10F and 1 between 12F and 16F)

2. Portable oxygen apparatus capable of metered flow with adequate tubing

3. Portable and fixed oxygen-supply equipment
   - Variable flow regulator

4. Oxygen-administration equipment
   - Adequate-length tubing; transparent mask (adult and child sizes), both nonrebreathing and valueless; nasal cannulas (adult, child)

5. Bag-valve mask (manual resuscitator)
   - Hand-operated, self-expanding bag; adult (>1000 mL) and child (450–750 mL) sizes, with oxygen reservoir/accumulator; valve
(clear, disposable, operable in cold weather); and mask (adult, child, infant, and neonate sizes)

6. Airways
   
   o Nasopharyngeal (16F–34F; adult and child sizes)
   
   o Oropharyngeal (sizes 0–5; adult, child, and infant sizes)

7. Pulse dosimeter with pediatric and adult probes

8. Saline drops and bulb suction for infants

**B. Monitoring and Defibrillation**

All ambulances should be equipped with an automated external defibrillator (AED) unless staffed by ALS personnel who are carrying a monitor/defibrillator. The AED should have pediatric capabilities, including child-sized pads and cables.

**C. Immobilization Devices**

1. Cervical collars
   
   o Rigid for children aged 2 years or older; child and adult sizes

   (small, medium, large, and other available sizes)

2. Head immobilization device (not sandbags)
   
   o Firm padding or commercial device

3. Lower extremity (femur) traction devices
   
   o Lower extremity limb-support slings, padded ankle hitch, padded pelvic support, traction strap (adult and child sizes)

4. Upper and lower extremity immobilization devices
   
   o Joint-above and joint-below fracture (sizes appropriate for adults and children), rigid support constructed with appropriate
material (cardboard, metal, pneumatic, vacuum, wood, or plastic)

5. Impervious backboards (long, short; radiolucent preferred) and extrication device

Short (extrication, head-to-pelvis length) and long (transport, head-to-feet length) with at least 3 appropriate restraint straps (chin strap alone should not be used for head immobilization) and with padding for children and handholds for moving patients

D. Bandages

1. Commercially packaged or sterile burn sheets

2. Triangular bandages
   - Minimum of 2 safety pins each

3. Dressings
   - Sterile multitrauma dressings (various large and small sizes)
   - ABDs, 10 × 12 in or larger
   - 4 × 4-in gauze sponges or suitable size

4. Gauze rolls
   - Various sizes

5. Occlusive dressing or equivalent
   - Sterile, 3 × 8 in or larger

6. Adhesive tape
   - Various sizes (including 1 and 2 in), hypoallergenic
   - Various sizes (including 1 and 2 in), adhesive
7. Arterial tourniquet (commercial preferred)

**E. Communication**

Two-way communication device between EMS provider, dispatcher, and medical control

**F. Obstetrical Kit (Commercial Package Is Available)**

1. Kit (separate sterile kit)
   - Towels, 4 × 4-in dressing, umbilical tape, sterile scissors or other cutting utensil, bulb suction, clamps for cord, sterile gloves, blanket
2. Thermal absorbent blanket and head cover, aluminum-foil roll, or appropriate heat-reflective material (enough to cover newborn)

**G. Miscellaneous**

1. Sphygmomanometer (pediatric and adult regular- and large-sized cuffs)
2. Adult stethoscope
3. Length/weight-based tape or appropriate reference material for pediatric equipment sizing and drug dosing based on estimated or known weight
4. Thermometer with low temperature capability
5. Heavy bandage or paramedic scissors for cutting clothing, belts, and boots
6. Cold packs
7. Sterile saline solution for irrigation (1-L bottles or bags)
8. Flashlights (2) with extra batteries and bulbs
9. Blankets

10. Sheets (minimum of 4), linen or paper, and pillows

11. Towels

12. Triage tags

13. Disposable emesis bags or basins

14. Disposable bedpan

15. Disposable urinal

16. Wheeled cot (conforming to national standard at the time of manufacture)

17. Folding stretcher

18. Stair chair or carry chair

19. Patient care charts/forms

20. Lubricating jelly (water soluble)

H. Infection Control*

1. Eye protection (full peripheral glasses or goggles, face shield)

2. Face protection (for example, surgical masks per applicable local or state guidance)

3. Gloves, no sterile (must meet 1999 National Fire Protection Association requirements, which can be found at www.nfpa.org)

4. Coveralls or gowns

5. Shoe covers

6. Waterless hand cleanser, commercial antimicrobial (towelette, spray, liquid)
7. Disinfectant solution for cleaning equipment
8. Standard sharps containers, fixed and portable
9. Disposable trash bags for disposing of biohazardous waste
10. Respiratory protection (for example, N95 or N100 mask—per applicable local or state guidance)

I. Injury-Prevention Equipment

1. All individuals in an ambulance need to be restrained (there is currently no national standard for transport of uninjured children)
2. Protective helmet
3. Fire extinguisher
4. Hazardous material reference guide
5. Traffic-signaling devices (reflective material triangles or other reflective, nonigniting devices)
6. Reflective safety wear for each crew member (must meet or exceed American National Standards Institute/International Safety Equipment Association performance class II or III if working within the right of way of any federal-aid highway; visit www.reflectivevest.com/federalhighwayruling.html for more

REQUIRED EQUIPMENT: ALS AMBULANCES

For emergency medical technician-paramedic services, include all of the required equipment listed for the basic-level provider, plus the following additional equipment and supplies. For emergency medical technician–intermediate services
(and other nonparamedic advanced levels), include all of the equipment for the
basic-level provider and selected equipment and supplies from the following list, on
the basis of local need and consideration of prehospital characteristics and budget.

A. Airway and Ventilation Equipment

1. Laryngoscope handle with extra batteries and bulbs
2. Laryngoscope blades, sizes 0–4, straight (Miller); sizes 2–4, curved, (MacIntosh)
3. Endotracheal tubes, sizes 2.5–5.5 mm uncuffed and 6–8 mm cuffed (2
each), other sizes optional
4. Meconium aspirator adaptor
5. 10-mL non-Luerlock syringes
6. Stylettes for endotracheal tubes, adult and pediatric
7. Magill (Rovenstein) forceps, adult and pediatric
8. Lubricating jelly (water soluble)
9. End-tidal CO₂-detection capability
   o Colorimetric (adult and pediatric) or quantitative capnometry

B. Vascular Access

1. Crystalloid solutions, such as Ringer’s lactate or normal saline solution
   (1000-mL bags x 4); fluid must be in bags, not bottles; type of fluid may
   vary depending on state and local requirements
2. Antiseptic solution (alcohol wipes and povidone-iodine wipes preferred)
3. Intravenous-fluid pole or roof hook
4. Intravenous catheters, 14–24 gauge
5. Intraosseous needles or devices appropriate for children and adults

6. Venous tourniquet, rubber bands

7. Syringes of various sizes, including tuberculin

8. Needles, various sizes (1 at least 1½ in for intramuscular injections)

9. Intravenous administration sets (microdrip and macrodrip)

10. Intravenous arm boards, adult and pediatric

C. Cardiac

1. Portable, battery-operated monitor/defibrillator
   - With tape write-out/recorder, defibrillator pads, quick-look paddles or electrode, or hands-free patches, ECG leads, adult and pediatric chest attachment electrodes, adult and pediatric paddles

2. Transcutaneous cardiac pacemaker, including pediatric pads and cables
   - Either stand-alone unit or integrated into monitor/defibrillator

D. Other Advanced Equipment

1. Nebulizer

2. Glucometer or blood glucose measuring device
   - With reagent strips

3. Large-bore needle (should be at least 3.25 in long for needle chest decompression in large adults)

E. Medications (Preloaded Syringes When Available)

Medications used on advanced-level ambulances should be compatible with current guidelines as published by the American Heart Association's Committee on
Emergency Cardiovascular Care, as reflected in the Advanced Cardiac Life Support and Pediatric Advanced Life Support courses, or other such organizations and publications (ACEP, ACS, NAEMSP, and so on). Medications may vary depending on state requirements. Drug dosing in children should use processes that minimize the need for calculations, preferably a length-based system. In general, medications may include:

- Cardiovascular medication such as 1:10000 epinephrine, atropine, antidysrhythmic agents (eg, adenosine and amiodarone), calcium-channel blockers, β blockers, nitroglycerin tablets, aspirin, vasopressor for infusion
- Cardiopulmonary/respiratory medications such as albuterol (or other inhaled β agonist) and ipratropium bromide, 1:1000 epinephrine, furosemide
- 50% dextrose solution (and sterile diluent or 25% dextrose solution for pediatrics)
- Analgesics, narcotic and nonnarcotic
- Antiepileptic medications such as diazepam or midazolam
- Sodium bicarbonate, magnesium sulfate, glucagon, naloxone hydrochloride, calcium chloride
- Bacteriostatic water and sodium chloride for injection
- Additional medications as per local medical director

**OPTIONAL BASIC EQUIPMENT**
This section is intended to assist EMS providers in choosing equipment that can be used to ensure delivery of quality prehospital care. Use should be based on local resources. The equipment in this section is not mandated or required.

**A. Optional Equipment**

1. Glucometer (per state protocol)
2. Elastic bandages
   - Nonsterile (various sizes)
3. Cellular phone
4. Infant oxygen mask
5. Infant self-inflating resuscitation bag
6. Airways
   - Nasopharyngeal (12F, 14F)
   - Oropharyngeal (size 00)
7. Alternative airway devices (e.g., a rescue airway device such as the esophageal-tracheal double-lumen airway [ETDLA], laryngeal tube, or laryngeal mask airway [LMA]) as approved by local medical direction
8. Alternative airway devices for children (few alternative airway devices that have been approved by the Food and Drug Administration have been studied in children; those that have been studied, such as the LMA, have not been adequately evaluated in the prehospital setting)
9. Neonatal blood pressure cuff
10. Infant blood pressure cuff
11. Pediatric stethoscope
12. Infant cervical immobilization device

13. Pediatric backboard and extremity splints

14. Topical hemostatic agent

15. Appropriate chemical, biological, radiologic, nuclear, explosive personal protective equipment (CBRNE PPE), including respiratory and body protection

16. Applicable chemical antidote autoinjectors (at a minimum for crew members’ protection; additional for victim treatment based on local or regional protocol; appropriate for adults and children)

B. Optional Advanced Equipment

1. Respirator
   - Volume-cycled, on/off operation, 100% oxygen, 40–50 psi pressure (child/infant capabilities)

2. Blood-sample tubes, adult and pediatric

3. Automatic blood pressure device

4. Nasogastric tubes, pediatric feeding tube sizes 5F and 8F, sump tube sizes 8F–16F

5. Pediatric laryngoscope handle

6. Size 1 curved (MacIntosh) laryngoscope blade

7. 3.5- to 5.5-mm cuffed endotracheal tubes

8. Needle cricothyrotomy capability and/or cricothyrotomy capability
   (surgical cricothyrotomy can be performed in older children in whom
the cricothyroid membrane is easily palpable, usually by the age of 12 years)

**OPTIONAL MEDICATIONS**

**A. Optional BLS Medications**

1. Albuterol
2. EpiPens
3. Oral glucose
4. Nitroglycerin (sublingual tablet or paste)

**B. Optional ALS Medications**

1. Anxiolytic agents
2. Intubation adjuncts including neuromuscular blockers

**INTERFACILITY TRANSPORT**

Additional equipment may be needed by ALS and BLS prehospital care providers who transport patients between facilities. Transfers may be done to a lower or higher level of care, depending on the specific need. Specialty transport teams, including pediatric and neonatal teams, may include other personnel such as respiratory therapists, nurses, and physicians. Training and equipment needs may be different depending on the skills needed during transport of these patients. There are excellent resources available that provide detailed lists of equipment needed for interfacility transfer such as the American Academy of Pediatrics Guidelines for Air and Ground Transport of Neonatal and Pediatric Patients.

**APPENDIX: EXTRICATION EQUIPMENT**
Adequate extrication equipment must be readily available to the EMS responders but is more often found on heavy rescue vehicles than on the primary responding ambulance. In general, the devices or tools used for extrication fall into several broad categories: disassembly, spreading, cutting, pulling, protective, and patient related. The following is necessary equipment that should be available either on the primary response vehicle or on a heavy rescue vehicle:

- **Disassembly tools**
  - Wrenches (adjustable)
  - Screwdrivers (flat and Phillips head)
  - Pliers
  - Bolt cutter
  - Tin snips
  - Hammer
  - Spring-loaded center punch
  - Axes (pry, fire)
  - Bars (wrecking, crow)
  - Ram (4 ton)

- **Spreading tools**
  - Hydraulic jack/spreader/cutter combination

- **Cutting tools**
  - Saws (hacksaw, fire, windshield, pruning, reciprocating)
  - Air-cutting gun kit

- **Pulling tools/devices**


o Ropes/chains
o Come-along
o Hydraulic truck jack
o Air bags

• Protective devices
  o Reflectors/flares
  o Hard hats
  o Safety goggles
  o Fireproof blanket
  o Leather gloves
  o Jackets/coats/boots

• Patient-related devices
  o Stokes basket

• Miscellaneous
  o Shovel
  o Lubricating oil
  o Wood/wedges
  o Generator
  o Floodlights

Local extrication needs may necessitate additional equipment for water, aerial, or mountain rescue.