Ambulance Patient Compartment Human Factors Design Guidebook

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Foreword

Ambulance crashes are one of many hazards faced by emergency medical services providers (EMSP). Data from the National Highway and Traffic Safety Administration indicates EMSP experience a fatality rate three times the average national occupational injury rate and cite ambulance crashes and related vehicle accidents as one of the threats facing EMSP. Studies also found EMSP and patient deaths or serious injuries occurred at a high rate within the patient compartment of the ambulance during transport. These incidents were often related to EMSP not using restraint systems, such as seatbelts, improperly restrained patients and equipment, unpadded or intrusive equipment that could cause serious head-impact injuries, and structural design deficiencies in the vehicle itself.

EMSP, the Federal Interagency Board and national emergency medical services (EMS) associations expressed the need for safer ambulance design standards to the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) First Responders Group (FRG). The FRG has brought together members of the private sector, EMS leaders and research and development partners. This group aims to design and develop safety standards, produce crash standards and design recommendations that will lead to the next generation ambulance compartment and ultimately a safer work and patient care environment.

This Ambulance Patient Compartment Human Factors Design Guidebook (the Guidebook) has been developed as a best practices guide to help augment that safer work and patient care environment. It is a result of more than four years of research and development, testing, modeling and simulation, human performance measurements, assessment and interaction with the EMS community, ambulance manufacturers and component providers. This Guidebook provides examples and recommendations for the steps to take when designing an ambulance patient compartment and best practices that can help reduce EMSP and patient injuries. This document will also help streamline the compartment layout and make it more conducive to providing patient care. The Guidebook has been developed to be beneficial to EMS leaders, EMSP, ambulance specification committees and manufacturers. The Guidebook is not intended to provide solutions or a standard design, but to establish a framework for the EMS community to implement a higher level of safety and patient care quality. The Guidebook is built upon an analysis of current standards and recommendations and will help EMSP through a needs-centered process that leads to a next-generation ambulance interior focused on safety, effectiveness and efficiency.

The Guidebook is part of a larger program funded and developed by the FRG that is concentrated on reducing risks associated with ambulance crashes and the safety assessment of ambulance components, to include all aspects of the patient compartment including seats, personnel and equipment restraints, storage cabinets, patient cots, and fastening mechanisms. Recommendations from this program will also be found in the 2016 Edition of the National Fire Protection Association (NFPA) 1917 Standard for Automotive

Ambulances (expected for release in early 2016) and in seven international standards adopted by the Society of Automotive Engineers (SAE).

Some of the recommendations contained in the Guidebook represent possibilities for future design and may present challenges for near term implementation. The Guidebook serves to stimulate discussion regarding what equipment and practices are necessary in the patient compartment and may spur changes in all forms of EMSP and patient safety for the EMS community. While this body of research has helped to develop recommendations and safer components for the ambulance patient compartment, it is not meant to be considered a solution to eliminating injuries and death for patients and EMSP.

Executive Summary

The Ambulance Patient Compartment Human Factors Design Guidebook, hereafter referred to as the Guidebook, is the result of a multiyear effort on the part of the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) First Responders Group (FRG). It is intended to provide tools and guidance to the Emergency Medical Services (EMS) community that will enable the design and manufacture of ambulance patient compartments that are safer and more efficient. The FRG received support in the development of the Guidebook through collaboration between the National Institute of Standards and Technology (NIST), the National Institute for Occupational Safety and Health (NIOSH), BMT Designers and Planners (D&P), and Carlow International as well as input from members of the EMS community representing both EMS providers (EMSP) and manufacturers.

EMSP routinely perform essential medical care as they stabilize patients at emergency scenes and provide treatment en route to medical facilities. High injury and fatality rates among EMSP (Maguire, 2002; Green et al., 2008; Reichard et al., 2011; Maguire, 2013) underscore the need for safer and more resilient ambulance design and construction, more efficient patient compartment layouts that allow EMSP to be seated and restrained while tending to patients, and ergonomically designed work spaces that keep EMSP and their patients safe and comfortable and EMSP productive while performing their tasks.

Consistent analytics regarding ambulance standards will ensure EMSP and patient safety while enhancing EMSP patient care. Although standards such as the National Fire Protection Association (NFPA) 1917 Standard for Automotive Ambulances, 2013 Edition and the General Services Administration (GSA) KKK-A-1822F Federal Specification for the Star of Life Ambulance outline the requirements for mobile emergency medical service vehicles, they do not provide in-depth design criteria and best practices that address EMSP safety, health and performance. To augment these requirements, FRG in partnership with NIST, NIOSH, D&P and Carlow International launched a study to develop standards, guidelines and best practices for ambulance patient compartments. This research focuses on addressing resiliency in a vehicle accident, patient safety and comfort, and EMSP safety, health and performance.

NIOSH is currently characterizing injury risks associated with ambulances crashes. They are also assessing the durability of components in patient compartments, including seats, restraints, cabinets and fastening mechanisms, and drafting specifications that will guide the design and selection of safer patient compartment components. These specifications have been proposed for inclusion in the 2016 Edition of NFPA 1917 Standard for Automotive Ambulances and published as Society of Automotive Engineers (SAE) International standards.

Under the guidance of the FRG and NIST, D&P and Carlow International conducted a multiyear user-centered design (UCD) process that developed and refined ambulance

patient compartment design requirements and guidelines by actively engaging EMSP and manufacturers (Avery et al., 2013; Feeney et al., 2012; Moore et al., 2011; Moore et al., 2012; Dadfarina et al., 2012; Lee et al., 2013; Kibira et al., 2012). This effort began with EMSP soliciting the help of the FRG with the objective of centralizing and eventually standardizing a best practices approach to ambulance safety. By sharing user research, the FRG was provided a more detailed understanding of the nature of EMS work and an awareness of EMSP needs gathered through observations and discussions with users, focus groups and surveys. From this list of needs, design requirements and guidelines were developed and iteratively refined and confirmed through EMSP reviews. The requirements and guidelines were further validated through the development of designs as a proof-of-concept of the application of the design guidelines. Based on reviews by EMSP, manufacturers, and other EMS community representatives, the design concepts, requirements and guidelines were updated and finalized.

This process has resulted in a comprehensive list of design guidelines and best practices for ambulance patient compartments that fulfill the needs and requirements of a wide range of EMS provider organizations (EMSPO). Of these requirements and guidelines, those that were suitable for standardization were proposed for inclusion in the upcoming version of NFPA 1917.

The Guidebook documents a UCD and evaluation process tailored for ambulance patient compartment design and a full list of requirements and guidelines. This Guidebook is intended to serve as a tool to enable EMSPO and manufacturers to design and specify future ambulance patient compartments based on its unique user needs that maximize EMSP performance and ensures the safety and health of the EMSP and patients.

The Guidebook addresses the following topics associated with patient compartment design:

- Human factors engineering;
- User-centered design;
- Seating and restraints;
- Equipment and supplies;
- Storage;
- Workspace;
- Ingress and egress;
- Communication; and
- Type II ambulances (A Type II ambulance is based on a standard van chassis and typically has a much smaller integral patient compartment).

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1.0 Introduction

The Ambulance Patient Compartment Human Factors Design Guidebook, hereafter referred to as the Guidebook, is the result of a multiyear effort on the part of the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) First Responders Group (FRG). It is intended to provide tools and guidance to the Emergency Medical Services (EMS) community that will enable the design and manufacture of ambulance patient compartments that are safer and more efficient.

EMS providers (EMSP) face high injury and fatality rates due to the nature of their work, providing critical patient care in rapidly moving ambulances, as has been cited in numerous publications (Maguire, 2002; Green et al., 2008; Reichard et al., 2011). They also experience high levels of musculoskeletal injuries due to lifting of patients or other equipment (Maguire, 2013). Much of this risk can be attributed to the design and layout of patient compartments, which are typically not designed to allow EMSP to perform their patient care tasks while remaining seated and restrained.

These vehicle accidents involving ambulances have a significant financial impact on the EMS community. Costs associated with an accident may include medical expenses, lost work time, disability expenses, legal fees, equipment repair and replacement expenses, workman's compensation, recruitment and training costs for employee replacement and increased insurance costs. Motor vehicle crashes cost employers $60 billion annually in medical care, legal expenses, property damage and lost productivity (McGowan 2012). The average crash costs an employer $17,500. When a worker has an on-the-job crash that results in an injury, the cost to their employer is $74,000. Costs can exceed $500,000 when a fatality is involved.

Designing and manufacturing safer and more efficient patient compartments can be facilitated through the implementation of a user-centered design (UCD) process. The UCD process integrates safety, ergonomics and human factors principles and best practices, as well as an understanding of how EMSP perform their job, into the design and manufacturing of an ambulance. The goals of applying this design process are to:

a. Ensure EMSP needs (e.g., provide safe and effective patient care) and all practical and functional requirements (e.g., ability to reach a patient's body from head to knee from a seated and restrained position) are identified early in the process.

b. Engage EMSP and other subject matter experts throughout the ambulance patient compartment design and build a process to provide feedback on whether the design is functional, usable, safe and meets the needs and requirements that were identified.

c. Provide a final design that will optimize not only EMSP performance and safety, but also overall ambulance design effectiveness.

1.1 Purpose and Scope

This Guidebook includes design guidelines and best practices based on safety, comfort, functionality and usability. All of these design guidelines and best practices resulted from needs expressed by the EMS community. They are not meant to be definitive, but are intended to provide assistance for industry to develop ways to achieve a new standard of safety in future design. The design guidelines and best practices included in the Guidebook are focused on advanced life support (ALS) and basic life support (BLS) patient care typically performed in Type I and III ambulances. Type I ambulances are based on a conventional truck chassis and typically have a large, box-shaped patient compartment. Type III ambulances, conversely, are based on a cutaway van cab-chassis, but have been modified to carry a larger, box-type patient compartment. For the most part, the contents of the Guidebook are also applicable to Type II ambulances (see Chapter 10.0 for more information).

This Guidebook complements existing and emerging standards for the design of ambulances, such as National Fire Protection (NFPA) 1917 Standard for Automotive Ambulances (NFPA, 2013). The Guidebook is more effective when used in conjunction with the most current edition of the standards that have been adopted by state jurisdictions.

One of the goals set forth by the Guidebook is for EMSP organizations (EMSPO) and manufacturers to apply the contents of the Guidebook to develop patient compartment designs. Doing so will enable EMSP to perform primary patient care tasks and optimize patient outcomes while remaining seated and safely restrained whenever the ambulance is in motion, thus reducing EMSP and patient injury risk as well as improve patient care.

1.2 Intended Audience

The intended audience for this Guidebook includes the following:

a. EMSPO that develop specifications for the procurement of ambulances.

b. EMSPO that planto evaluate existing or proposed patient compartment designs in terms of efficiency and safety.

c. Manufacturers and vendors that want to incorporate additional design practices and guidelines into their ambulance design and construction processes that address safety, comfort, functionality and user-friendliness.

1.3 How to Use the Guidebook

The information contained in the Guidebook provides tailored, but not necessarily exhaustive, design guidelines and best practices for ambulance patient compartments. There are two distinct types of information provided in the Guidebook; one assists with implementation of the best practices set forth by this

Guidebook, while the other presents pertinent information to help optimize the patient compartment of an ambulance.

Chapters 2.0 and 3.0 provide guidance on how to implement a UCD process and integrate the contents of Chapters 4.0 through 10.0 into the design of a safe and efficient ambulance patient compartment. They cover a sample process and best practices for identifying requirements and integrating them into the design process for a next generation ambulance patient compartment.

Chapters 4.0 through 10.0 present detailed design guidelines that are based on research and standards that help improve and optimize the layout of ambulance patient compartments. Applying these to the design of a patient compartment will increase the quality of patient care safely and successfully. Additional explanatory information is presented in a box following each guideline, where appropriate.

This Guidebook can be used when performing the following:

a. **Designing a new ambulance**. When designing a new ambulance patient compartment, Chapters 2.0 and 3.0 should be reviewed to determine the most appropriate methods and processes to develop the patient compartment design. Chapters 4.0 through 10.0 should be reviewed to identify relevant design guidelines.

b. **Retrofitting an existing ambulance**. When incorporating new technology into, or enhancing the design of, an existing patient compartment, the Guidebook can be used similarly to create a new ambulance design. The goal is to integrate new technologies into the patient compartment without having a negative impact on overall patient care and EMSP safety. A process can be developed from Chapter 3.0 and more detailed specifications can be developed using Chapters 4.0 through 10.0 for input, which documents the retrofit. Retrofit changes may impact the following key areas for EMSP:

    - Workflow;
    - Ability to reach the patient and common, critical equipment and supplies while in the ambulance compartment; and
    - Ability to perform patient care safely.

c. **Evaluating a patient compartment design**. When evaluating how well an existing patient compartment design supports EMSP ability to provide patient care while remaining safe, refer to the guidelines contained in Chapters 4.0 through 10.0 to identify strengths and weaknesses of the design. An evaluation process is outlined in Section 3.3.

2.0 Human Factors Engineering in Patient Compartment Design

Human factors engineering (HFE), which should be considered when designing an ambulance patient compartment, is a systems engineering discipline focused on incorporating human performance and safety considerations into the design of systems like ambulances. It seeks to ensure that humans, such as EMSP, are capable of performing their tasks safely and effectively in a comfortable environment. The objective of HFE is to optimize overall system performance by ensuring human performance and safety requirements are balanced with engineering requirements. This includes fitting the task to the human rather than making the human have to fit the task.

2.1 General HFE Principles Applied to Ambulance Design

While a wide range of principles is associated with the application of HFE to ambulance patient compartment design, some key design principles include the following:

a. Understand the entire system by asking the following questions:

- Who are the users, including their physical capabilities, aptitudes, training and motivation?
- What tasks will the users be performing?
- What are the task performance requirements, such as accuracy, frequency, duration, workload and decision making?
- What is the context (e.g., environment) within which the users will perform their tasks, including noise, vibration, lighting, physical and emotional stress, comfort and fatigue?

b. Design for the most frequent and critical patient care scenarios.

c. Design for the worst-case scenario in terms of the environment the ambulance will experience.

d. Design for the total system and not just a part of the system. For example, design for the total patient compartment, not just for seating and design for the patient compartment within the context of the complete vehicle.

e. Keep the design simple, use only the capabilities and features required for performing the required tasks successfully.

f. Optimize the design by employing a tradeoff process between human performance, technology, engineering and costs.

g. Design to minimize training requirements.

h. Design to reduce the incidence and impact of EMSP errors and to promote human error tolerance, i.e., human errors are detectable and correctable before their consequences are realized.

i. Standardize the design as much as possible.

j. Design to accommodate the full range of physical dimensions, also called anthropometrics, of the expected EMSP user population. This includes, but is not limited to, standing stature, sitting height, and reach from a 5th percentile female to a 95th percentile male. See Appendix A for more information.

2.2 Human Factors Engineering in Patient Compartment Design

HFE ensures the system design does not require the EMSP to make significant adjustments mentally or physically to be able to provide safe, effective patient care. HFE is concerned with the design of user interfaces, which include controls, displays, alarms, workspace, work environments, communications and procedures. HFE includes ergonomics, which focuses on the physical design of equipment and workplaces and reducing injury risk including musculoskeletal, cumulative trauma or repetitive strain injuries (RSI).

2.2.1 Objectives of HFE for Patient Compartment Design

High-level objectives for HFE as applied to the design of patient compartments include:

a. Ensuring, enhancing and sustaining EMSP performance and patient outcomes under all expected operating conditions.

b. Reducing the incidence and impact of EMSP error through design of user interfaces and workspace to enhance usability.

c. Implementing a standardized and formalized design process that emphasizes integrating EMSP early in the design process and keeps them involved throughout.

d. Eliminating or controlling hazards to the health and safety of EMSP and patients.

2.2.2 HFE Design Goals in Patient Compartment Design

Consider the following HFE design goals where the patient compartment should:

a. Ensure that EMSP can effectively and safely perform all required activities while seated and restrained whenever the ambulance is in motion with no risk to the patient's safety.

b. Minimize the risk of death or serious injury to EMSP, patients and other passengers of the compartment in the event of an accident or evasive maneuver of the ambulance.

c. Facilitate the safe and effective ingress and egress of EMSP and patients.

d. Accommodate a range of EMSP body sizes ranging from a 5th percentile female to a 95th percentage male through workspace and equipment arrangements.

e. Maintain the patient compartment environment at a level that is comfortable (i.e., temperature, lighting, ventilation) for the patient and facilitates EMSP performance.

f. Enhance patient care by EMSP through layout and equipment arrangements.

g. Reduce the incidence of ergonomic injury (e.g., musculoskeletal disorders including lower back strain, repetitive strain injuries and cumulative trauma) to EMSP.

h. Facilitate patient compartment cleaning and decontamination after each response.

i. Facilitate communication among the EMSP in the patient compartment, the driver of the ambulance, the patient, and involved third parties such as the medical facility, attending physicians, or other health care personnel.

3.0 User-Centered Design and Evaluation

HFE can be used to design an ambulance through the application of a UCD and evaluation process. The UCD process is discussed in the following sections.

3.1 User-Centered Design Process

The UCD process focuses on early and continuous involvement of the user, in this case EMSP, and develops requirements and designs iteratively over the design cycle of an ambulance. The goals of applying UCD are to:

a. Ensure that a systematic process is used to identify and integrate needs and requirements in the design process.

b. Engage EMSP throughout the design and build processes to provide feedback on the usability of the design and ensure that the design meets their needs and requirements. One way to do this is to establish a “core user group” who provide end-user input throughout the entire design process.

c. Provide a final design that will optimize not only human performance and safety, but also overall ambulance effectiveness.

There are five basic phases of a UCD process, as illustrated in Figure 1. The UCD process should be preceded by a planning step.

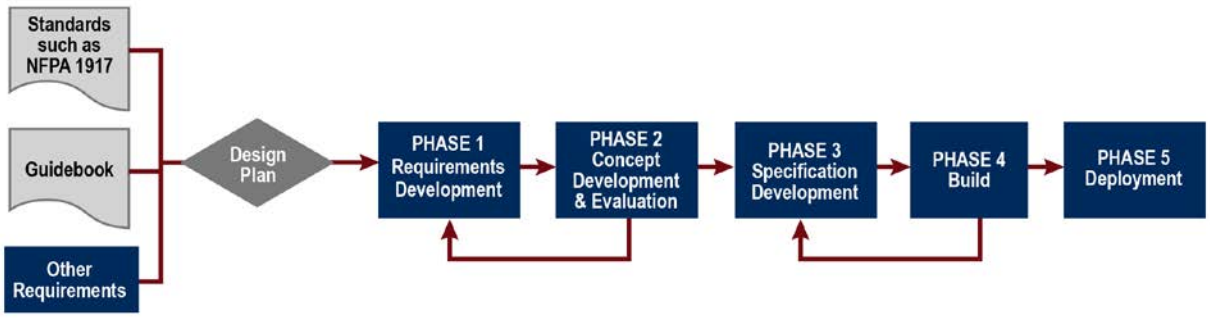


Figure 1. Basic User-Centered Design Process

As Figure 1 illustrates, the UCD process is based on on-going feedback loops to continually refine and enhance requirements, designs and specifications.

Ideally, UCD is performed by a multidisciplinary team comprised of representatives of the end user and other relevant stakeholders. The mix of team members may vary, depending on the needs and resources of the EMSPO, but should always include EMSP. The main takeaway is that a team of different types of experts will

provide more expansive input to the design. Table 1 presents a list of potential members of an ambulance UCD design team and their roles. The team should include an individual who can independently facilitate meetings.

Table 1. Potential UCD Team Members

Member	Role	UCD Phase
EMS Providers (EMSP)	Provide: • User needs and requirements • Operational scenarios, • Design feedback. Should be composed of EMSP from all levels (BLS and ALS) who will use the ambulance.	Phases 1-5
EMSPO Management	Provide: • Management and budget oversight. • Insights on safety and health considerations for the design, training requirements, specialized equipment, and emergency room and bay design.	Phases 1-5
Engineering Specialists	Provide specialized engineering input to the design.	Phases 1-3
Manufacturer	Provide feedback on the design, including the purchase specification; provide detailed design drawings; build the ambulance.	Potentially all phases, depending on the EMSPO procurement strategy, but at a minimum, phases 4 and 5

3.1.1 Design Plan

To apply a UCD process to patient compartment design, a patient compartment design plan should be developed first. Inputs to this plan will include, but not be limited to, existing ambulance design standards such as NFPA 1917, the Guidebook, and other requirements such as local and state rules and regulations. This plan should describe:

a. The objectives of the design effort.

b. The core user group, the participants who will be involved in the design process from start to finish. This group will be instrumental in developing and evaluating the requirements and design concepts. This group of

users should include EMSP and other first responders who will use the ambulance. This core user group should be augmented by additional users as required to help validate requirements and concepts, as well as other stakeholders and professionals, such as human factors engineers who can provide specialized knowledge and skills.

c. The UCD methods to be used that are most appropriate to the time, funding and manpower available to the design effort, as well as expected complexity of the effort.

d. The schedule for applying the design process.

e. Any potential barriers or risks that will need to be managed, such as funding levels and schedules.

3.1.2 Phase 1-Requirements Development

The requirements development phase is focused on iteratively identifying and validating user design needs, requirements and design guidelines. This will allow the EMSPO to systematically think through how the patient compartment needs to support patient care and safety of the EMSP and patients. It will also provide a sound foundation for developing the actual patient compartment design. Table 2 presents typical definitions for design needs, requirements and guidelines.

Table 2. Definiton of User Design Need, Requirement and Guidelines

User Design	Definition
Needs	High-level user performance and safety goals identified by the user.
Requirements	Functions, capabilities or support that will satisfy or fulfill the need.
Guidelines	Specific elements of design that support the fulfillment of a design requirement.

An example of a patient compartment related user need, associated requirements and guidelines is presented in Table 3.

Table 3. Example of a Patient Compartment User Design Need, Requirements and Guidelines

User Design Need	Requirement	Guidelines
The EMSP are able to provide safe and effective patient care from a seated and restrained position in the ambulance patient compartment.	The EMSP are able to reach the patient's body from head to knee while in a seated and restrained position.	Seats and restraints should be designed to allow EMSP, from a 5th percentile female through a 95th percentile male, to reach a restrained patient's body from the crown of the head to the kneecap with both hands. This includes having a male patient who is 95th percentile in stature on the cot.
	The EMSP are able to reach common and critical equipment and supplies from a seated and restrained position.	Seats and restraints should be designed to allow EMSP from a 5th percentile female through a 95th percentile male to reach common and critical equipment and supplies with either hand at a maximum functional reach from a seated and restrained position.
	Seating incorporates best practices in ergonomic/anthropometric design to support safe and comfortable use by the diverse users in the EMSP population.	The seat height should be a maximum of 21 inches (533mm), measured from the floor surface where the EMSP will place his or her feet. Preferably, the seat height should be adjustable in one inch (25mm) increments from 15 inches-21 inches (381mm-533mm).
		The seat pan width should be a minimum of 18 inches (460mm).
		The seat pan depth should be a maximum of 15.9 inches (405mm).

User design needs, requirements and guidelines are determined through the application of a number of methods including, but not limited to, those presented in Table 4.

Table 4. UCD Methods

Method	Description
Task analysis	Tasks EMSP have to perform are identified and analyzed to understand what is required to perform them successfully. This includes, but is not limited to, information required, what supplies and equipment are used, decisions that must be made, actions that must be taken, skills and training required, performance and safety risks, and environmental factors.
Focus groups	EMSP are brought together in a facilitated group discussion to elicit their opinions and insights. Participants should perform research prior to meetings on what design elements they may like for patient compartments.
Feedback from users	Representative EMSP are interviewed individually or in small groups to elicit their opinions and insights, either formally with interview guides or informally.
Observations of EMSPs performing patient care	EMSP are observed performing patient care tasks and scenarios in their normal or simulated work environment.
Surveys	EMSP's opinions, insights and experiences are collected using questionnaires. These can be through paper forms or Internet-based forms.
Reviews of the open literature and other relevant documents	Documents such as research papers, magazine articles, conference proceedings, standards, regulations and laws, or other sources are identified and reviewed to find relevant information on EMSP needs and requirements.
Analysis of lessons learned	Lessons learned from previous ambulance designs are identified and analyzed to provide input to the new design. This may include contacting other EMSPO to understand successes and difficulties that they have had in the past.
Physical measurement of equipment and supplies	Existing equipment and supplies required to be carried on the ambulance are inventoried and measured to understand the size storage space needed.

Using all or a combination of these techniques will aid in the development of initial user design needs, requirements and guidelines. Typical steps in the requirements development process include the following:

a. **Gather background information**. This will include lessons learned from EMSPO experience with previous ambulance patient compartments, applicable standards, such as NFPA 1917, state regulations and rules, Guidebook chapters 4.0 through 10.0, information on types and frequency of patient transports or emergency responses, and EMSPO historical accident and injury data. Talking with and visiting other EMSPO to obtain their lessons learned about what worked and did not work in their ambulances is also very helpful.

b. **Define patient care scenarios**. Patient care scenarios describe the flow of steps the EMSP will perform in providing patient care for a particular medical issue (e.g., trauma or cardiac care). For each step, the equipment and supplies required and EMSP actions should be described. These are used to determine what is needed for patient care and where it needs to be located to treat a patient. Information on the types and frequency of patient transports and emergency responses can be used to identify the patient care scenarios that should be used in developing requirements. Some of the factors that should be considered in the scenario include:

   - Number of patients;
   - Ages of patients (e.g., children, elderly);
   - Patient medical problem(s);
   - Requirements for specific procedures;
   - Number of EMSP in the patient compartment;
   - Distance to the hospital; and
   - Requirements for special care that are time constrained.

c. **Perform requirements sessions**. The requirements sessions are meetings with the core user group that are used to develop the design requirements for the patient compartment. Other key stakeholders such as EMSPO management may also attend. These meetings should initially focus on defining what the patient compartment needs to do and then develop requirements that satisfy each need, as well as guidelines that lead to the realization of the requirement in the design. There should be a number of requirements sessions, with each session adding more details and validating previously defined requirements. The end-product would be a comprehensive list of needs, requirements and guidelines that will be used to guide the development of the patient compartment design concept. Chapters 4.0 through 10.0 of the Guidebook may provide

significant help in developing these requirements. Key elements to successful requirements sessions include:

- Each meeting should have a facilitator whose role is to guide the discussions.
- Visual aids such as white boards or flip chart easels should be used to help visualize and capture requirements.
- The size of existing and potential future equipment and supplies should be measured to help understand storage space requirements.
- State and local requirements should be understood as this will impact the requirements.
- Common and critical equipment and supplies should be identified. These are those equipment and supplies that are frequently used in, or critical to, patient care that should be within reach of the EMSP while seated and restrained.
- During the requirements sessions, some sort of database should be used to track and manage the requirements. This will also allow others who cannot attend the sessions to maintain awareness of the emerging requirements.

3.1.3 Phase 2-Concept Development and Evaluation

The purpose of this phase is to use the requirements and guidelines defined in Phase 1 to develop the design concept for the patient compartment. This will provide a visual representation of the design and form the basis for the design specification developed during Phase 3, as well as validate the requirements and guidelines. During this phase, tradeoffs are performed to determine the ideal implementation of the guidelines, and to narrow down design options into one design concept. Figure 2 illustrates the concept development process.

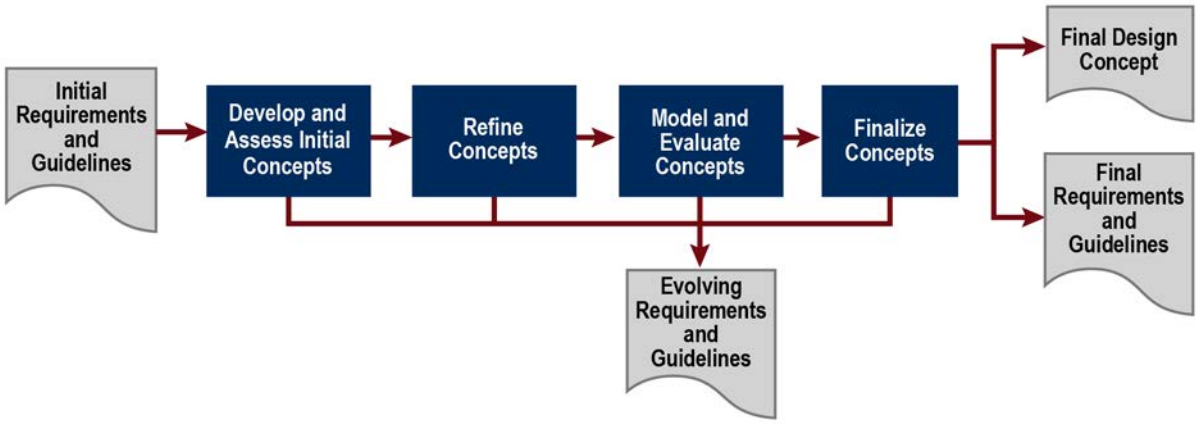


Figure 2. Process for Development and Evaluation of Concepts

Concept development is an iterative process accomplished over a series of design sessions. Each design session should result in a definition of, and details on, the patient compartment design. Design sessions, like requirements sessions, should be facilitated meetings with the core user group and other stakeholders. Each step is described below.

a. **Develop and assess initial concepts.** The first step is to develop a visualization of basic layout concepts for the patient compartment. This should be done during the first design session. The core user group should identify design alternatives, and then assess the alternatives to rule out ones that do not meet the requirements and guidelines or seem to be unworkable. Key elements for the development of design concepts during this step include:

- Each meeting should have a facilitator whose role is to guide the discussions.
- Visual aids such as white boards or flip chart easels help visualize and capture requirements. Hand drawn concepts also work well.
- As many design alternatives as possible should be explored to encourage thinking “out of the box.” Figure 3 illustrates some early design alternatives developed during the research for this Guidebook.
- Design should start at a high level with basic concepts. More detail should be developed in later design sessions.

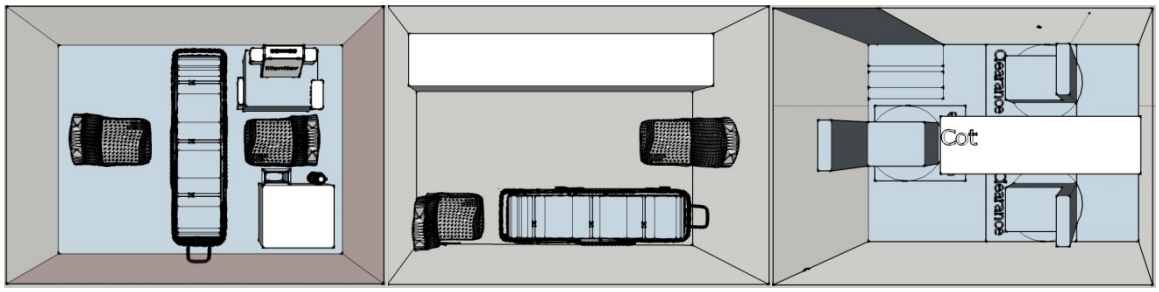


Figure 3. Illustration of Initial Design Concepts

b. **Refine concepts**. Based on the results of the initial concept assessment and tradeoffs against the requirements, the concept or concepts determined to be feasible should be expanded and detailed, such as determining storage locations for common and critical equipment and supplies. If appropriate, additional concepts are developed. Figure 4 presents an example of a more detailed design concept.

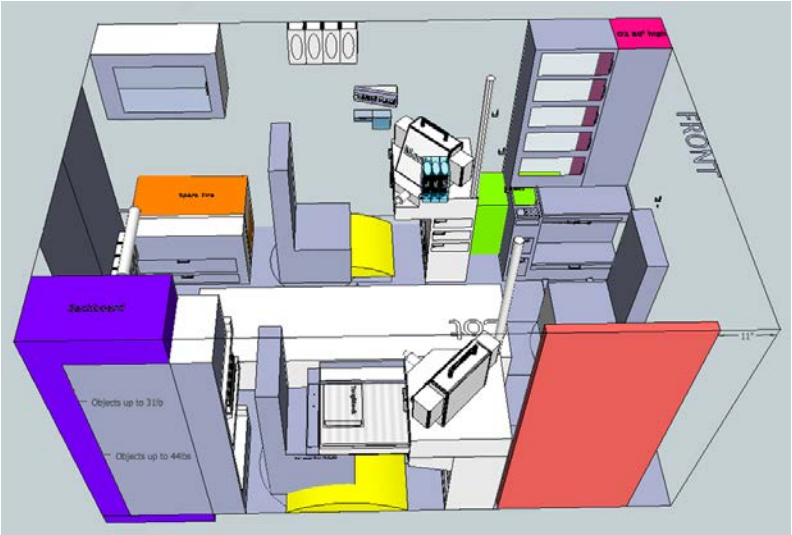


Figure 4. Illustration of a More Detailed Design Concept

These more detailed design concepts should be used to explore tradeoffs of one implementation versus another in order to determine which concepts best meet the requirements and what, if any, constraints exist with the concepts. These tradeoffs should compare types and brands of equipment and different patient compartment layouts. The tradeoff process should also ensure that the selected design concept complies

with not only the design requirements and guidelines, but also meets any other constraints such as financial limitations and technical incompatibilities. This tradeoff process tries to balance a number of factors including:

- Different design concepts or implementations.
- Competing technologies, such as one seat design versus another.
- EMSP performance considerations or improved functionality versus costs or engineering limitations, such as vehicle weight.
- Feasibility of the design concept based on costs, engineering or technology constraints.
- Impact of state and local requirements for equipment and supplies and storage space availability.
- Manufacturer's constraints if they are involved during this phase.
- Compliance with other standards, such as the applicable Federal Motor Vehicle Safety Standards.

An example of a key tradeoff might be designing the work area to ensure that common and critical equipment and supplies can be reached by a seated and restrained EMSP, while at the same time ensuring that the EMSP are protected during an accident. EMSPO may have to tradeoff EMSP head-strike safety risk against the ability to provide patient care while seated and restrained, as well as the costs associated with incorporating protective devices such as padding, stronger restraints, or helmets that reduce body and head movement during an accident.

c. **Model and evaluate concepts**. While patient compartment layout concepts will be evaluated throughout Phase 2, a more formal evaluation using some sort of 3-D modeling is extremely helpful in understanding the strengths and weaknesses of a patient compartment layout. This includes reach distances, storage, seating, workspace design and workflow. 3-D modeling can include:

- Creating a physical representation of the patient compartment using boxes, chairs or other objects. This allows EMSP to walk through patient care scenarios to assess reachability and location of equipment and supplies as well as how well the design supports overall patient care. Using something like foam core board can also help in building a full-scale mockup of the patient compartment.

- Using a computer aided design (CAD) tool to develop a 3-D model allows EMSP to assess the design on screen and make real-time changes to the design to address issues. Some tools allow the user to measure design elements like reach distances, whereas others allow the user to place a human mannequin in the 3-D model of the work environment to assess the patient compartment layout. Figure 5 shows an illustration of a 3-D model with a human mannequin. There are a number of tools that are available with varying capabilities. In developing the Guidebook, Google Sketchup© and Jack[1] were used, but there are others available.

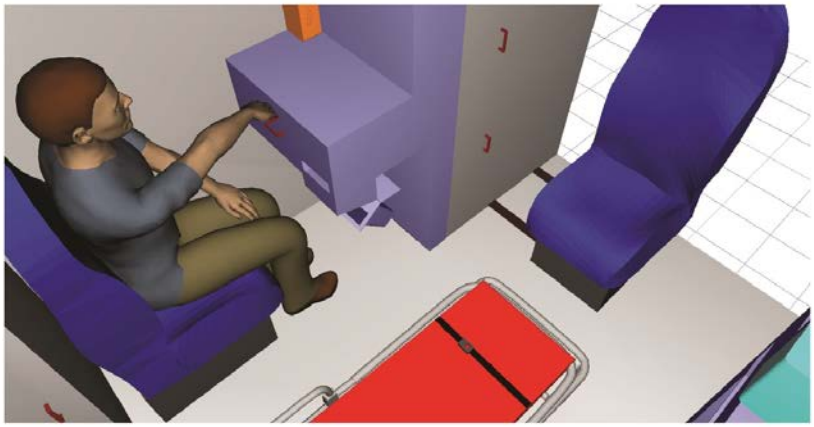


Figure 5. Illustration of a Jack Model for Assessing Reach in a Design Concept

d. **Finalize the design concept.** Based on the results of the modeling and evaluation, the concept for the ambulance patient compartment design along with the requirements and guidelines should be finalized. These will be used for the next phase. Figure 6 presents an example of a final design concept.

[1] http://www.plm.automation.siemens.com/en_us/products/tecnomatix/assembly_planning/jack/index.shtml

Figure 6. Illustration of a Final Design Concept

3.1.4 Phase 3-Design Specification Development

The next phase is to use the requirements, guidelines and concepts developed in the previous phases to develop an ambulance design specification. The design specification provides detailed and explicit design requirements and guidelines drawn from the results of Phases 1 and 2, appropriate standards, and Chapters 4.0 through 10.0 of the Guidebook. It will help guide the manufacturer in building the ambulance and likely give the manufacturer a better idea of what is expected. It should include detailed drawings, where appropriate and possible, to convey dimensions and layouts of equipment and supplies.

As the specification is developed, a subset of the entire core team should review to ensure that the resulting product will meet their needs, provides the right level of detail, and is as unambiguous as possible. In some cases, a manufacturer will have already been identified. If that is the case, they should be considered a stakeholder and involved in the specification development. In other cases, EMSPO may elect to complete the specification prior to sending it to manufacturers for bid.

3.1.5 Phase 4-Build

During this phase, the specification is used to guide the construction of the ambulance. Once the specification has been submitted to the manufacturer and construction initiated, design implementation issues may arise that need clarification or modification. The manufacturer may also offer different solutions that still achieve the same ends. Representatives of the EMSPO, particularly the EMSP, should work closely with the manufacturer, including reviewing proposed design changes, physical mockups and interim builds to ensure that human performance and safety requirements are being met and identify any issues with the design. These reviews should include patient care scenario walkthroughs to explore ergonomic and workflow considerations. The design specification is revised, as required, based on any design changes to ensure that there is a fully documented “as-built” design document.

3.1.6 Phase 4-Deployment

Once the ambulance is deployed or placed into service, the EMSPO will likely learn strengths and weaknesses of the design. They are captured in some sort of “lessons learned” database or document to be used for the next ambulance design.

3.2 Tailoring of the UCD Process

The UCD process discussed in the preceding paragraphs provides the ideal approach to implementing UCD. In many cases, EMSPO may not be able to, or need to, follow the full process due to constraints in personnel time, budget or calendar time. Therefore, EMSPO may need to tailor the process to meet their needs and constraints. Tailoring might include building off existing EMSP knowledge by applying just a few requirements development methods, doing fewer design concepts and evaluation iterations, starting from an existing specification, or starting from an existing patient compartment design.

The two key elements of UCD that should be incorporated into the ambulance design process, regardless of constraints, are:

a. **Continuous user involvement**. Selected end users drawn from EMSPO should become part of a “core user group” who work with other stakeholders to develop and evaluate the requirements, provide input to the specification, and review design concepts, drawings and mockups. Since experienced EMSP will already have an understanding of the work environment and issues with existing patient compartment design, many of the methods described in Table 4 may be unnecessary.

b. **Iterative design**. With iterative design, the design of the patient compartment is developed in steps with each step being evaluated by EMSP who identify strengths, weaknesses and recommendations for the design. They also may provide input into tradeoffs that need to be made between requirements. Typically, the design evolves from a very simple concept to a fully detailed version of the patient compartment.

3.3 User-Centered Evaluation of Existing Designs

The Guidebook can also be used to support the evaluation of existing ambulance patient compartment designs to determine how well they support patient care and safety of EMSP. This can be done by both EMSPO and manufacturers. Evaluations are performed on written specifications, drawings, 3-D models or full-scale mockups using the following methods.

3.3.1 Design Inspection

Design inspections are performed on written specifications, drawings, 3-D models or full-scale mockups. In a design inspection, experts representing EMSPO and other key stakeholders review the design and compare it to the appropriate design guidelines contained in the Guidebook and other requirements documents to determine if it is compliant or not. Where possible and appropriate, physical measures such as reach distance are noted. If appropriate, a design checklist, which is an abbreviated list of guidelines as illustrated in Figure 7, is used to facilitate this comparison. Elements of the design that are not compliant with the design guidelines are identified and assessed for their potential impact on EMSP performance and EMSP and patient safety.

Ambulance Patience Compartment Design Checklist					
Seating and Restraints		Yes	No	N/A	Comments
1	All EMSP, including 5th percentile females, can reach restrained patients body from head to kneecap with both hands (4.1.1).				
2	Seating and restraints allows EMSP to access either side of patient's body (4.2.b).				
3	EMSP can face and interact with patient while seated and restrained (4.2).				
4	All EMSP, including 5th percentile, can reach common and critical equipment while seated and restrained (4.4).				
5	Seat height is a maximum of 21 inches, measured from floor surface and adjustable in 1 inch increments				

Ambulance Patience Compartment Design Checklist					
Seating and Restraints		Yes	No	N/A	Comments
	from 15-21 inches (4.5.1a).				
6	Seat pan width is a minimum of 18 inches (4.5.1.b).				
7	Seat pan depth is a maximum of 15.9 inches (4.5.1.c).				
8	Supporting backrest with lumbar support with width of 18-20 inches is provided at each seat (4.5.1.d).				
9	Backrest and headrest accommodate 5th percentile female through 95th percentile male EMSP (4.5.1.e).				
10	Backrest is cushioned with at least 1 inch of compressible material (4.5.1.f).				

Figure 7. Illustration of a Design Checklist

3.3.2 Tabletop Walkthrough

EMSPO can use tabletop walkthroughs to evaluate drawings as well as 3-D models. Drawings can include the overall layout of the patient compartment workspace, workstations or equipment user interfaces. In this method, EMSP and other key stakeholders visualize how patient care and other scenarios will be performed while reviewing the drawings or 3-D model. Workflow, workspace design and other elements of the patient compartment design, including rudimentary measurements of reach distances and available space, are explored. Elements of design that are not consistent with design guidelines from the Guidebook and other sources are noted along with other issues. Each issue is assessed for its potential impact on the performance of EMSP and the safety of EMSP and patients.

3.3.3 Human Modeling and Simulation

EMSPO can also use human modeling and simulation (M&S) with 3-D models to evaluate workflow, reach distances, visual envelopes and other aspects of patient care performance. In this method, a human simulation tool puts human mannequins in a 3-D model where patient care scenarios are performed with mannequins representing EMSP with body dimensions ranging from a 5th percentile female to a 95th percentile male. As an example, during the development of the Guidebook, a virtual human simulation tool called Jack was used to evaluate design concepts. Potential issues with human performance and safety are identified and then assessed for their

potential impact on the performance of EMSP and the safety of EMSP and patients.

3.3.4 Real-time Task Walkthroughs

EMSPO can perform real-time walkthroughs where there is a full-scale mockup of the patient compartment design, or using existing manufacturer's ambulances. This might include ambulances built for other EMSPO by manufacturers. In this method, also called human-in-the-loop simulation, EMSP walk through patient care scenarios in the full-scale patient compartment and identify issues with both human performance and safety. In many cases, an observer watches the task walkthroughs and provides observations on issues associated with how the design supports patient care. This allows EMSP to examine issues related to workflow, equipment and supply accessibility and location, and comfort and safety of seating and restraints. A patient simulation mannequin is a powerful tool that can provide a more real-world experience for EMSP. Issues are assessed for their potential impact on the performance of EMSP and the safety of EMSP and patients.

3.4 System-Level Design

One of the keys to successful ambulance patient compartment design in terms of the performance of EMSP, patient care and safety of patients and EMSP, is ensuring the design is developed from a total system perspective. Total system perspective refers to an approach where the design of a subsystem is developed while concurrently considering the design and integration of all the other subsystems and their components that make up the total system.

For an ambulance, the system is the complete ambulance, including the subsystems of the chassis, driver compartment, patient compartment and the EMSP who will use the ambulance. The patient compartment subsystem is comprised of components that include seating and restraints, equipment, storage, overall workspace, entry and exit paths, and communications. Design each of these components while considering the implications on, and integration with, the other components in the subsystem. Design each subsystem while considering its integration with the other subsystems in the ambulance. Key factors for applying a system-level design approach include the following.

a. **Start with system-level functional requirements**. System-level design considers high-level functional requirements for the total ambulance system. Functional requirements define:

- Quantity (how many, such as how many patients need to be transported);
- Quality (how well, such as percentage of good patient outcomes);

- Coverage (how far, such as both rural and urban environments);
- Timelines (when and how long, such as distance to nearest hospital); and
- Availability (how often, such as number of typical calls during a shift).

These functional requirements define how the full system needs to perform in its intended environment. The functional requirements are used to guide the design of the ambulance subsystems, including the patient compartment. For example, functional requirements that specify that the ambulance will be used in rural environments, with long distances to the nearest hospital, may require that the patient compartment accommodate multiple patients and more supplies.

b. **Perform system-level design tradeoffs**. When determining system-level functional requirements that describe the high-level goals for the total ambulance system, explore the impact on any subsystems or other components through a tradeoff process. An example would be the system level requirement for the ambulance to be able to drive in areas of heavy snowfall. While this requirement primarily affects the chassis, the implementation of this requirement in terms of the wheel well size required to install snow tires or tire chains may impact space available inside of the patient compartment and may dictate the placement of seats or other components. This tradeoff process should include cost comparisons between different solutions and against the total budget.

c. **Incorporate systems integration processes**. Systems integration refers to the process of melding together components and subsystems into a fully functional system, where a key subsystem is the human user. For an ambulance, this would include integrating equipment with other equipment and humans in the patient compartment, the patient compartment with the chassis, and the ambulance with the infrastructure with which it needs to operate, such as hospital ambulance bays, maintenance facilities, and the environment (roads, weather, etc.).

4.0 Seating and Restraints

This chapter discusses the design of seating and restraint systems, a key element to achieving the goal of EMSP providing high quality patient care while remaining safe.

Considerations for the Seating and Restraints

The challenge in designing ambulance seating and restraints is how to ensure the seats and restraints provide the necessary protection, while at the same time allowing EMSP to reach the patient and equipment and supplies to provide patient care. Seats and restraints should also be designed to maximize the incorporation of ergonomic considerations and minimize injury. Where required, seating and restraints should also accommodate infant and children patients and the needs of any additional riders in the patient compartment.

There are a number of design considerations regarding seats and restraints. These include:

a. **Costs versus safety features**. The more injury protection provided and adjustability offered, the higher the potential cost of the seat and restraint system. Since safety of EMSP is the highest priority, EMSO or the manufacturer should understand the potential costs associated with EMSP injury and the tradeoff of the costs of the seats and restraints against other costs associated with the patient compartment and ambulance design.

b. **Frequency of seat use versus sophistication**. Seats that are not used as frequently, such as airway seats, may not need to be as large and complex as primary care seats, though the level of safety should not be compromised. However, if it is anticipated that the seats will be used for longer transports, they should provide equal ergonomic support.

The following paragraphs provide detailed design guidelines and best practices for ambulance patient compartment seats and restraint systems.

4.1 Reach to Patient

4.1.1 Minimum Patient Care Reach

Seats and restraints should be designed to allow EMSP, from a 5th percentile female through a 95th percentile male, to reach a restrained patient's body from the crown of the head to the kneecap with both hands, as illustrated in Figure 8. This includes a male patient on the cot who is 95th percentile in stature and waist circumference (girth).

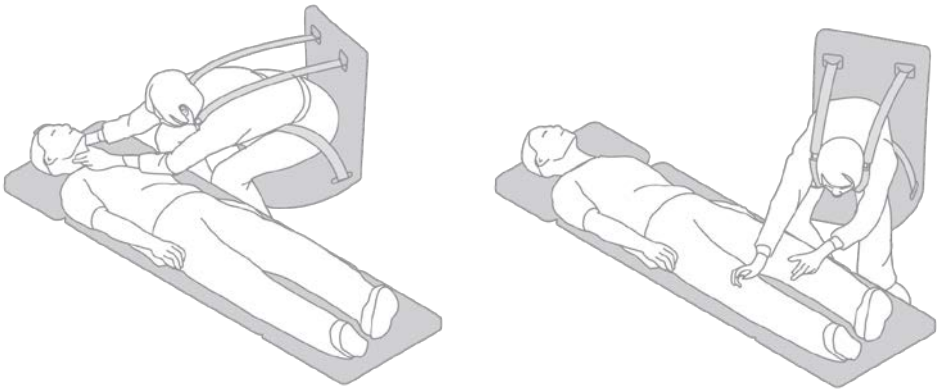


Figure 8. Illustration of Minimum Patient Reach

4.1.2 Optimum Patient Care Reach

To provide optimum patient care, EMSP need to reach the patient's full body length while seated and restrained.

a. Seats and restraints should be designed to allow EMSP, from a 5th percentile female through a 95th percentile male, to reach a restrained patient's full body length with both hands. This includes a male patient on the cot who is 95th percentile in stature and girth.

b. In addition to accessing the full length of the body, EMSP should be able to access either side of the patient's body from a seated and restrained position.

> These guidelines allow EMSP to remain safely seated and restrained while still able to treat the patient's injuries on any part of the body.

4.2 Facing the Patient

EMSP should be able to face and interact with the patient while seated and restrained.

> This guideline ensures that EMSP can see the patient and observe for any changes while also calming the patient. Rotating seats, if used, need to have a locking detent (the mechanism to catch or stop a rotating object) in an orientation that faces the patient.

4.3 Performing Cardiopulmonary Resuscitation While Restrained

EMSPO will need to determine how EMSP address cardiopulmonary resuscitation (CPR) when the ambulance is in motion. Consider the following if CPR will be performed when ambulance is in motion:

a. The restraint system has to allow EMSP to perform CPR while restrained. A restraint system that allows EMSP to perform CPR while restrained needs to be used only in conjunction with a seat that protects EMSP in the event of an accident or evasive maneuver.

> Manual CPR requires EMSP to stand over the patient's chest in order to perform compressions with adequate force, which places EMSP at risk when the ambulance is in motion if he or she is not properly restrained and protected. If CPR is required while the ambulance is in motion, restraints and seats need to be designed to both protect EMSP from potential injury and support proper CPR technique for the safety of the patient.

b. A CPR device, if used, should be put in place before the ambulance is in motion. If adjustments are to be made to the device, it should be reached from a seated and restrained position.

4.4 Accessing Equipment

Seats and restraints should allow EMSP from a 5th percentile female through a 95th percentile male to reach common and critical equipment and supplies, communications equipment,and storage with either hand at a maximum functional reach from a seated and restrained position. Maximum functional reach is defined in the Definitions section. Figure 9 illustrates maximum functional reach for a 5th percentile female.

> This guidance is most appropriate for discrete types of tasks such as reaching out to make an adjustment to the patient, grabbing supplies or equipment, or adjusting controls and then returning to a normal (back straight, 0° lean) sitting posture. When EMSP have to perform continuous tasks such as entering data in a laptop, it should be done in a normal sitting posture to reduce the risk of cumulative trauma types of injury.

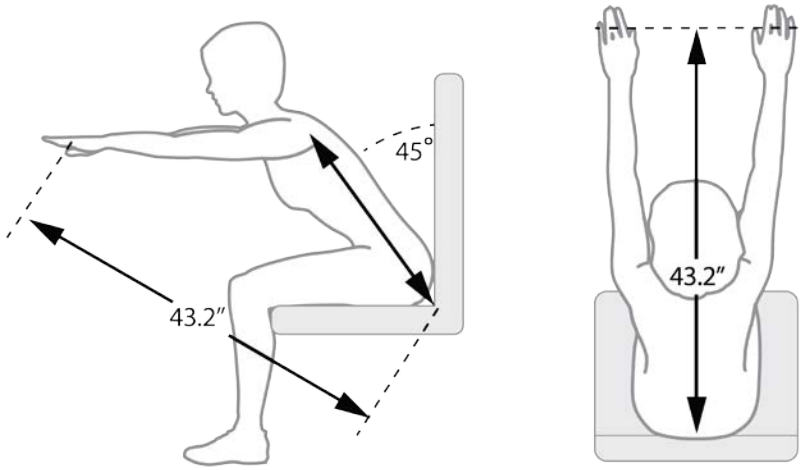


Figure 9. Illustration of Maximum Functional Reach for 5th Percentile Female

4.5 Ergonomic Design

4.5.1 Seating

Seating that incorporates best practices in ergonomic design supports safe and comfortable use by a diverse population of EMSP. These aspects of ergonomic seat design are illustrated in Figure 10.

a. The seat height should be a maximum of 21 inches (533 millimeters [mm]), measured from the floor or surface where EMSP will place their feet. The seat height should be adjustable in one inch (25 mm) increments from 15-21 inches (381-533 mm).

b. The seat pan width should be a minimum of 18 inches (460 mm).

c. The seat pan depth should be a maximum of 15.9 inches (405 mm).

d. A supporting backrest with lumbar support should be provided for each seat. The width of the lumbar support should be 18-20 inches (460-510 mm).

e. Both the backrest and headrest should accommodate the range of EMSP from a 5th percentile female through a 95th percentile male with seated heights (seat to top of head) between 32.9 inches (836 mm) and 38.8 inches (986 mm) respectively.

f. The backrest and seat should be cushioned with at least one inch (25 mm) of compressible material for comfort.

> A seat that properly supports the full range of EMSP, from a 5th percentile female through a 95th percentile male, not only increases comfort and satisfaction, but can also reduce repetitive motion and musculoskeletal injuries and protect EMSP in the event of an accident or evasive maneuver.

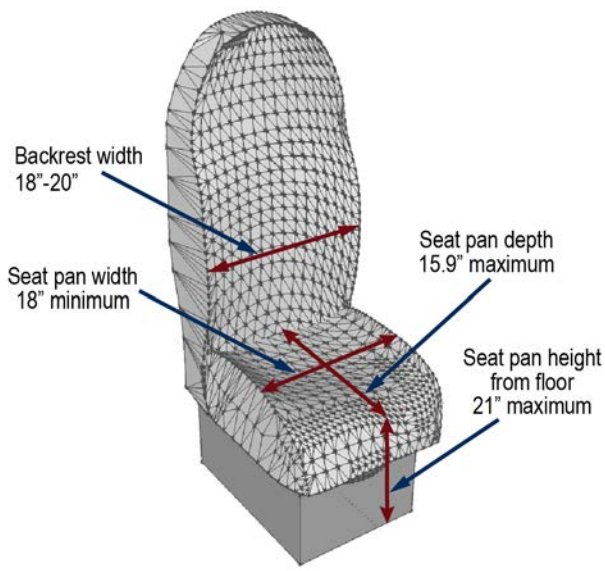


Figure 10. Diagram of Elements of an Ergonomic Seat

4.5.2 Restraint Systems

A restraint system (which includes all types of restraints, seat belts and their fasteners) that incorporates ergonomic design minimizes the risk of injury and supports safe and comfortable use by a diverse population of EMSP.

a. Restraints should fit all body types of a 5th percentile female to a 95th percentile male, including but not limited to the following representative body dimensions for the population of EMSP:

- Seated height range of 32.9-38.8 inches (836-986 mm).
- Weight range of 129-263 pounds (lbs.) (58.5–119.3 kilogram [kg]).
- Waist circumference range of 38-56 inches (965–1422 mm).

b. The restraint system should be adjustable to prevent pressure on the front of the neck or other sensitive areas, including large blood vessels, nerves, and areas lacking muscular or skeletal protection, for a 5th percentile female through a 95th percentile male.

> The restraints need to be comfortable to encourage continuous and consistent use; therefore, adjustability to a comfortable yet safe position is important.

c. Restraints should be designed such that it can be verified visually or by feel that restraints are in place and connected.

d. Restraints should be designed to ensure that once secured, the seat occupant will remain restrained.

4.6 Equip Each Work Position with Restraints

Each working position needs to be equipped with its own restraint system that meets all other restraint guidelines to ensure that all EMSP and other caretakers are restrained while the ambulance is in motion.

> It is imperative that all EMSP are able to safely use a properly fitting restraint system to ensure their safety in the event of an accident or evasive maneuver.

4.7 Ensure Quick Donning and Doffing of Restraints

EMSP needs to be able to quickly put on and take off a restraint system.

a. The restraint system's fastening mechanism should require minimal steps to operate.

b. The restraint system's unfastening mechanism should require only one motion or click to operate.

c. The restraint system's unfastening mechanism should be operable with only one hand.

> Restraints that are quick and easy to operate will encourage continuous and consistent use.

d. Restraint system fastening mechanisms should be highly visible against the background to make it easier for EMSP to identify.

4.8 Design Seating for Safety

Seating needs to minimize injury to EMSP, in all working positions, from the forces and energy imparted during an accident or evasive maneuver.

a. Seats should have resilient material or mechanisms under the cushion to absorb shocks.

b. Seats that are stationary should be fixed in a forward or rear facing position. Seats that can rotate should be lockable in a forward or rear facing position.

> Forward- or rear-facing seats better protect EMSP in the event of an accident or evasive maneuver than side-facing seats.

c. Seats that can rotate should have a locking detent at a minimum of every 45 degree throughout the range of the seat rotation to secure the seat when rotated in the event of an accident or evasive maneuver.

d. The headrest should be contoured to provide energy absorption qualities to minimize whiplash injuries. The headrest should fit the full range of EMSP from a 5th percentile female through a 95th percentile male with seated heights between 32.9-38.8 inches (836-986 mm).

e. Seats should be designed so that the seat pan is molded to reduce the likelihood of side slippage of the EMSP hips and buttocks.

f. Seat design should not hinder ingress and egress paths while loading or unloading a patient.

g. Seat adjustment handles should be made of highly visible materials to ensure that EMSP can find them quickly.

h. Seats and restraints should be cleanable in accordance with Occupational Safety and Health Administration (OSHA) blood borne pathogen standards (OSHA 2012).

4.9 Transport of Children

The ambulance needs to include seats capable of securing infants and children of any age for transport.

a. Child seat restraints, in order to properly restrain children that do not fit in the standard restraints, should fit all body types from a newborn to a 90th percentile 8 year old, including but not limited to the following representative body dimensions:

- Height of up to 54.8 inches (1392 mm);
- Weight of up to 92.8 lbs. (42.1 kg); and

- Waist circumference of up to 31.9 inches (810 mm).

b. The restraints for child seats should be adjustable to prevent pressure sensitive areas, including large blood vessels, nerves and areas lacking muscular or skeletal protection, for the comfort and safety of the child.

c. Child car seats, if used, should be compliant with state car seat laws.

4.10 Transport of Additional Passengers

The ambulance design should incorporate seats and restraints for all riders, including those other than the primary EMSP, which are based on an ergonomic and anthropometric design to minimize risk of injury and support safe and comfortable use by diverse rider populations.

5.0 Equipment and Supplies

This chapter discusses the equipment used by EMSP to safely and effectively provide patient care, including equipment for transporting patients into and out of the ambulance.

Considerations for Equipment and Supplies

The amount of space for storing and using equipment and supplies inside of the patient compartment is limited. It is critical to properly determine the amount, type and location of equipment and supplies carried on the ambulance to optimize the level of patient care that can be provided, while maintaining a safe environment for EMSP and patients. The patient compartment should be designed for easy access to and easy use of equipment and supplies. Items that are crucial for performing patient care, referred to throughout this Guidebook as common and critical equipment and supplies (see the definition in the Terms and Definitions section), need to be determined by EMSPO based on the type and frequency of calls that the organization performs, as well as state and local regulatory requirements.

Specific considerations regarding equipment and supplies include:

a. **ALS versus BLS service**. The higher or more complex the level of patient care offered by the ambulance, the more equipment and supplies that the ambulance will need to carry. In some cases (e.g., critical care units), the equipment and supplies will be larger and more specialized. EMSPO should determine its equipment needs for each type of ambulance in the fleet, while also keeping in mind that flexibility may be required for repurposed ambulances.

b. **Frequency and criticality of equipment and supplies**. The more often equipment and supplies are used or the more critical the items are for providing patient care, the easier it should be for EMSP to access that equipment or those supplies.

c. **Stabilizing patient at scene versus in the ambulance**. If the patient is stabilized at the scene prior to transport, more equipment and supplies will need to be carried in First-In Kits. First-In Kits (also sometimes called jump bags or house bags) include the equipment and supplies that are carried out of the ambulance to the patient. If First-In Kits are secured within immediate reach of the seated and restrained EMSP, then less equipment and supplies may need to be duplicated in storage at the patient compartment work areas.

The following paragraphs provide detailed design guidelines and best practices for ambulance patient compartment equipment and supplies.

5.1 Patient Transport and Loading

5.1.1 Cot Loading

The cot and the patient compartment loading area must support safe loading and unloading of a patient on a cot without undue musculoskeletal strain on or safety hazard to EMSP.

a. The center of gravity of the cot should be low to reduce the risk of a tipping hazard during loading and unloading.

b. The floor height and design of the patient compartment should allow for the cot to be inserted into the compartment by just one of the EMSP without having to bear the full weight of the cot.

> The patient compartment floor height must be low enough to allow EMSP to place the leading edge of the cot on the floor, preventing the need to lift the front end of the cot, therefore preventing potential injury.

c. Ingress and egress doors and steps should be designed for safe patient loading of a cot or other patient loading device. Cot loading mechanisms should be compatible with rear doors and steps.

5.1.2 Cot Loading Mechanisms

A cot loading mechanism, if part of the ambulance equipment, needs to support safe loading and unloading of a cot with a patient without undue musculoskeletal strain on or safety hazard to EMSP.

> A cot loading mechanism refers to a mechanical or hydraulic device that is used to load the cot into the patient compartment without requiring EMSP to lift the cot to the height of the rear door. This can include ramps, lift gates and the newer power loaders being offered.

a. A cot loading mechanism should allow use only if all of its parts are in the proper position. EMSP should be able to immediately verify that the cot loading mechanism is in the proper configuration for use.

> This prevents EMSP from operating the cot loading mechanism improperly and potentially harming themselves or the patient.

b. The cot loading mechanism should facilitate proper placement of the cot such that the cot can be guided into the patient compartment and locked in one motion.

> Lining up the cot loading mechanism with the cot securing mechanism allows EMSP to secure the cot with minimal physical effort.

c. A cot loading mechanism should require minimal number of steps to set up.

d. The cot loading mechanism should not sag or flex during cot loading or unloading.

e. The cot loading mechanism should be free of pinch points and sharp projections or edges.

> A cot loading mechanism that is stable and does not have pinch points or sharp projections protects the patient and EMSP from injury.

5.1.3 Cot Guidance and Securing

The mechanism for guiding the cot into the ambulance and securing it in the patient compartment needs to allow for quick and easy use without undue musculoskeletal strain on or safety hazard to EMSP.

a. The cot guidance and securing mechanisms should remain secured in the patient compartment during an accident per the requirements of SAE J3027, Ambulance Litter Integrity, Retention, and Patient Restraint (SAE, 2014).

b. The cot guidance and securing mechanism should be free of pinch points and sharp projections or edges.

c. The force required to secure and to release the cot from the cot securing mechanism should be no greater than 23 Newtons (N) (80 ounces [oz] of force).

> This allows all EMSP, regardless of stature or strength, to secure the cot without excessive effort.

d. EMSP should be able to engage the guidance and securing mechanism with minimal lateral (side-to-side) movement of the cot.

e. The cot guidance and securing mechanism should facilitate proper placement of the cot such that the cot can be guided into the patient compartment and locked in one motion.

> EMSP should be able to guide and secure the cot with minimal physical effort.

f. EMSP should be able to immediately verify, either visually or by touch, if the cot has been properly secured.

g. The cot guidance and securing mechanism should be able to accommodate specialty (e.g., bariatric) cots.

5.1.4 Cot Restraints

The cot restraints need to keep the patient safely and securely in place on the cot throughout normal vehicle movements and in the event of an accident or evasive maneuver.

a. The cot restraint system should minimize patient forward movement during an accident as specified in SAE J3037, Ambulance Litter Integrity, Retention, and Patient Restraint (SAE 2014).

b. The cot restraint system should avoid or minimize pressure on sensitive areas, including large blood vessels, nerves and areas lacking muscular or skeletal protection.

c. The length of the cot restraints should be adjustable to fit all patient body types from a 5th percentile female to a 95th percentile male, including, but not limited to the following representative body dimensions:

- Height range of 59.3-74.3 inches (1506-1887 mm);
- Weight range of 111.2-270 lbs. (50.4-122.6 kg); and
- Waist circumference range of 28.3-50.3 inches (719-1278 mm).

> It is imperative that the patients' restraints fit properly in order to ensure their safety in the event of an accident or evasive maneuver.

d. The cot design should allow for additional restraints to be installed.

> This allows patients that do not fit into standard cot restraints and those that require additional restraints to be safely and properly restrained.

e. Cot restraints should be designed such that it can be verified visually or by touch that restraints are in place and connected.

f. Cot restraints should be designed to ensure that once secured, the patient will remain restrained.

g. Cot restraints should be designed to ensure that they can be adjusted to expose parts of the patient's body that are critical to care, such as application sites for the defibrillator pads or electrocardiogram (EKG) sensors and still secure the patient to the cot.

> This allows EMSP to safely access areas of the patient's body necessary for performing patient care while the patient remains safely restrained.

h. Child cot restraints should fit all male and female child body types from a newborn to a 90th percentile eight-year-old, including, but not limited to the following representative child body dimensions:

- Height of 54.8 inches (1392 mm);
- Weight of 92.8 lbs. (42.1 kg); and
- Waist circumference of 31.9 inches (810 mm).

> It is imperative that child patients' restraints fit properly in order to ensure their safety in the event of an accident or evasive maneuver.

5.1.5 Cot Equipment Storage

EMSP need to ensure that equipment and supplies transported with the cot do not become potential projectiles during an accident or evasive maneuver, nor impede loading or unloading of the patient.

a. Secure storage should be available on the cot for equipment that may be carried on the cot, such as:

- Portable oxygen tank;
- Cardiac monitor; and
- Laptop (if used).

> A dedicated storage location on the cot for equipment keeps the patient safe from loose equipment and keeps the equipment secure and accessible.

b. All equipment mounted to a cot during patient transport in the ambulance should remain secure on the cot during an accident per the requirements of SAE standards J2917 Occupant Restraint and Equipment Mounting Integrity – Frontal Impact System-Level Ambulance Patient Compartment (SAE 2010) and J2956 Occupant Restraint and Equipment Mounting Integrity – Side Impact System-Level Ambulance Patient Compartment (SAE 2011).

c. Equipment stored on the cot should be quickly removable with release mechanisms being highly visible in the patient compartment environment.

d. An intravenous (IV) pole should be available on the cot to secure IV bags during transport from the scene to the ambulance. The IV pole should be located away from the center of the cot to ensure that it is out of the way of the EMSP, is highly visible and has a strap for the IV bag.

5.1.6 Powered Cot

A powered cot or its battery, if used, needs to be able to be charged in the patient compartment before, during and after a call.

a. A powered cot or battery should have a dedicated storage and charging system within the patient compartment.

b. A powered cot battery should be removable for charging or capable of being charged on the cot.

5.1.7 Cot Height

The height of the cot, while secured in the patient compartment, should be adjustable up to 29.9 inches (759 mm) above the floor.

> A higher cot reduces the distance EMSP must lean forward to access the patient, reducing strain on the lower back and making patient care easier.

5.1.8 Backboard

The backboard needs to allow EMSP to safely secure and transport the patient.

a. The backboard should have handholds located around its full perimeter for stability when transporting a patient.

> This allows for as many EMSP as necessary to grip the backboard from any position while safely transporting the patient.

b. Restraints used to secure the patient to the backboard should require no more than two EMSP to install.

c. The length of the backboard restraints should be adjustable to accommodate a 5th percentile female to a 95th percentile male patient, including but not limited to the following representative body dimensions:

- Height range of 59.3-74.3 inches (1506-1887 mm);
- Weight range of 111.2-270.3 lbs. (50.4-122.6 kg); and
- Waist circumference range of 28.3-50.3 inches (719-1278 mm).

> Patients' restraints need to be easily applied and fit properly in order to ensure their safety during transport.

5.2 Equipment Accessibility While Seated and Restrained

The EMSP needs to be able to access and use equipment while seated and restrained.

a. Frequently used display faces (e.g., cardiac monitor) should be perpendicular to the user's normal line of sight, not less than 45 degrees (0.79 radians) from the normal line of sight, and within a viewing distance of 28 inches (710 mm) (see Figure 11 below).

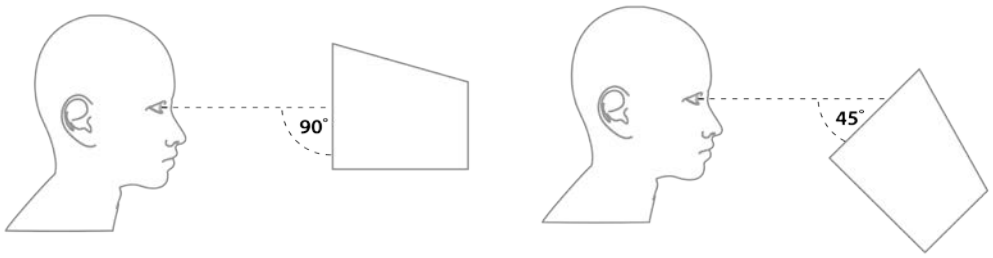


Figure 11. Orientation of Patient Compartment Displays

b. Equipment that requires EMSP use should be located to allow EMSP, from a 5th percentile female through a 95th percentile male, to reach it with either hand at a maximum functional reach from a seated and restrained position. See Figure 5 and the Definitions section for more information.

c. Equipment should not be secured so that it blocks physical or visual access to any other equipment and supplies or their storage locations.

d. Equipment that requires EMSP use should be secured or mounted with the equipment controls accessible to EMSP while in a normal restrained working position.

e. Equipment securing mechanisms should not impede use of that equipment by obscuring equipment controls, openings or other critical areas of the equipment.

5.3 Labeling and Text Displays

Visible and legible labels and text allow EMSP to quickly and easily locate labeled items and read messages and other text displays, thereby reducing the risk of error.

a. Labels should be oriented horizontally and read left to right.

b. Labels should not be located where EMSP normal hand or arm position or any other item will obscure the label or where the label obscures any other information.

c. Labels should be easy to read accurately from the operational reading distances and in the anticipated vibration, motion and illumination environments.

d. Text should be written with black characters on a light background.

e. The character height (CH) of text should be appropriate for the viewing distance. Table 5 presents character heights for a viewing distance of 28 inches (710 mm). For viewing distances that differ from 28 inches (710 mm), multiply the values in Table 5 by the actual distance (D) divided by 28 (710).

Table 5. Character Height of Labeling

Type of Label	Character Height *
Critical labels with variable positions (e.g., numerals on dials)	0.12 – 0.20 inches (3.0 mm – 5.0 mm)
All other labels	0.10 – 0.20 inches (2.5 mm – 5.0 mm)

* CH = Value from Table 5 x D/28

f. The character width of alphanumeric text should be 0.6 to 0.8 of the character height except for single stroke characters (e.g., I, 1), which should be between 0.1 and 0.2 of the height. The character width for “4” should be 0.8 of the height (see Figure 12).

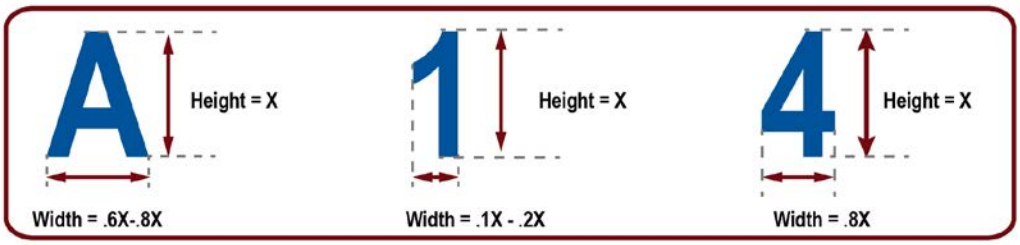


Figure 12. Character Width

g. The stroke width of text (see Figure 13) should meet the following:

- For black characters on a white (or light) background, the stroke width should be 0.1667 to 0.1429 of the height. The stroke width should be the same for all letters and numerals of equal height.
- For transilluminated characters (backlit), the stroke width should be 0.1 of the height.
- The stroke width ratios should apply regardless of how tall characters are made for distance viewing. However, for certain applications, characters with different stroke widths may be used on the same sign for emphasis. In this case, the thinnest character stroke should be no less than 0.125 nor the thickest character stroke no greater than 0.2 of the respective character heights.

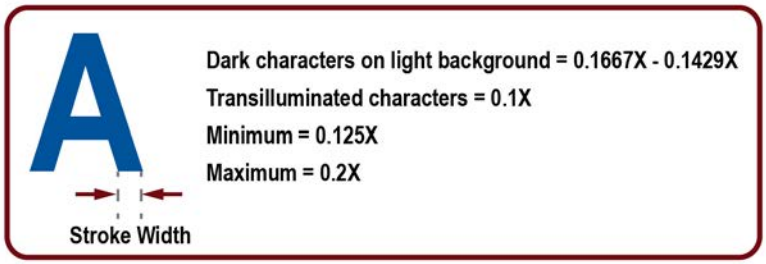


Figure 13. Character Stroke Width

h. Text letters and numerals should be of a plain style without serifs (i.e., sans serif fonts), except as may be necessary to distinguish between characters which would otherwise be confused (e.g., “L,” “I,” “1,” “0,” “O”).

i. For text on a digital display or cardiac monitor, variable length lines should be avoided by use of hyphenation of words at line breaks to improve readability on small screens.

j. For digitally displayed text, scrolling markers should be provided when content cannot be displayed in one screen to enable users to identify where they are on the page.

5.4 First-In Kits

First-In Kits include the equipment and supplies that are carried out of the ambulance to the patient. EMSP typically work directly out of these kits to initiate treatment of a patient at the scene and therefore need to be able to locate, access and use equipment stored within the kits quickly and easily.

a. First-In Kits, when stored in the patient compartment, should remain secured per the requirements of SAE J3043 Ambulance Equipment Mount Device or Systems (SAE 2014) and be stored in easily accessible locations.

b. Storage for First-In Kits should allow access from both inside and outside the patient compartment to reduce the injury risk associated with carrying it out of the patient compartment.

c. First-In Kits should be able to be opened and closed quickly.

d. First-In Kits should remain closed once closed.

e. First-In Kits, if used during transport, should be secured within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, from a seated and restrained position.

> First-In Kits may need to be accessed frequently, therefore it is ideal to locate them close to EMSP if possible.

f. The interior compartments of First-In Kits should allow EMSP to organize and identify the location of different supplies and equipment.

> Keeping First-In Kit within reach and organized allows EMSP to quickly and easily locate, access and retrieve items that are necessary for patient care.

g. First-In Kits should be lightweight and optimally no more than 25 lbs. (11.3 kg) when fully loaded.

h. First-In Kits should be packed with the weight of its contents evenly distributed throughout the kit.

i. The handles of First-In Kits should be located to evenly distribute the weight of the kit and its contents when being carried.

j. The handles of First-In Kits should be accessible while the bag is in use and in storage.

> These design attributes allow EMSP to easily lift and transport First-In Kits without putting undue physical strain on EMSP.

5.5 Reduced Injury Risk

Equipment and supplies must not pose an injury risk to EMSP when storing, using, securing or accessing items.

a. All equipment that is not stored in cabinets or drawers should be secured to a surface in the patient compartment per SAE J3043 Ambulance Equipment Mount Device or Systems (SAE 2014).

b. The design of the patient compartment should provide routing such that cords, leads and tubing, when in use, minimize crossing any walking paths, do not present entanglement hazards or protrude into aisles.

> This allows EMSP to safely move through the patient compartment safely when the ambulance is stationary.

c. Routing of cords, leads and tubing should not allow snagging of the cords on protruding areas in the patient compartment during loading or unloading of the patient and cot.

> This allows EMSP to safely load and unload the patient without risking disconnecting vital equipment or supplies from the patient.

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

> This protects EMSP from striking hazards when moving through the patient compartment when the ambulance is stationary.

e. Securing and unsecuring equipment should require minimal steps.

> Equipment securing mechanisms that are quick and easy to use will encourage continuous and consistent use, which is critical to preventing equipment from becoming a potential projectile in the event of an accident or evasive maneuver.

4.11 Automated CPR Devices

An automated CPR device, if available, should allow EMSP to remain seated and restrained after setting up the device.

a. Sufficient secure storage space should be provided for the automated CPR device, if the device is used.

b. If an automated CPR device is not available, the restraint system should allow for proper CPR technique.

> CPR is a critical task for patient care that also puts EMSP at risk for injury. It is imperative that EMSP is able to remain restrained while administering CPR when the ambulance is in motion, either through equipment or innovative restraint systems design. Another alternative is to only perform CPR when the ambulance is stationary.

6.0 Storage

This chapter discusses enabling EMSP to safely store all supplies and equipment required for patient care.

Considerations for Storage

The patient compartment must provide a storage location for all equipment and supplies that may be needed for patient care. Designated storage locations with consistent organization and labeling allow EMSP to locate and retrieve required items quickly and easily. Secure storage locations protect EMSP and patients from potential projectiles in the event of an accident or evasive maneuver. EMSP need safe access to common and critical equipment and supplies while seated and restrained. They also need safe access to all storage locations while standing in a stationary ambulance. These factors allow EMSP to quickly and easily locate, access and retrieve items necessary to perform patient care. Storage needs should be developed in conjunction with equipment and supply needs to ensure adequate storage space. The following should be considered:

- All items required by EMSP to provide effective patient care should be capable of being identified and accessed by EMSP while seated and restrained at their workstations.
- All items inside storage compartments must be within reach of the smallest female EMSP (5th percentile in stature and arm reach).
- EMSP reach to a storage location must also be unencumbered or not blocked by structures, equipment or elements of patient care equipment (e.g., wires, cables, tubing, IV bags, etc.).
- EMSP must have an unobstructed line of sight to the storage location to visually identify the correct storage compartment and the correct item in the compartment.
- EMSP should have an unobstructed view of readable identification labels for compartments and items in compartments.

Specific considerations regarding storage include:

a. **Working out of First-In Kits versus on-ambulance storage**. Where First-In Kits are used as the primary source for immediate patient care equipment and supplies during transport, First-In Kit storage needs to be designed to be secured within reach of the primary patient care seat(s). Where First-In Kits are used only to treat the patient outside of the patient compartment, they need to be secured in the compartment so that they do not become projectiles in the event of an accident or sudden evasive maneuver. Where First-In Kits are not used as the primary source of patient care equipment and supplies during transport, then other storage needs to be

designed within reach of the primary workstation(s) for immediate patient care items, especially common and critical equipment and supplies.

b. **Minimum versus maximum equipment and supplies**. The amount of supplies and equipment the ambulance carries will have a direct impact on the amount and configuration of storage. Carrying the minimal amount of supplies and equipment required for patient care allows for a potentially more efficient compartment layout and lighter vehicle. However, the vehicle may require more frequent resupply. Consideration must also be given to the items required to be carried on the ambulance by the state in which EMSPO are operating.

The following paragraphs provide detailed design guidelines and best practices for the design and arrangement of ambulance patient compartment storage areas.

6.1 Adequate Storage Space Available

Determine the size and location of interior storage areas based on the type of equipment and supplies that need to be carried on the ambulance and whether those items may need to be accessed while in transit.

a. Interior storage cabinets, shelves and drawers should have adequate space to store the equipment and supplies designated for that storage location.

b. Interior storage cabinets, shelves and drawers and exterior storage compartments should be designed to preclude movement of contents due to vehicle motion or vibration.

> This keeps the items from shifting thus making it easier to locate, access and retrieve items, and reduces the risk of those items becoming potential projectiles upon opening the storage area.

6.2 Accessibility While Standing

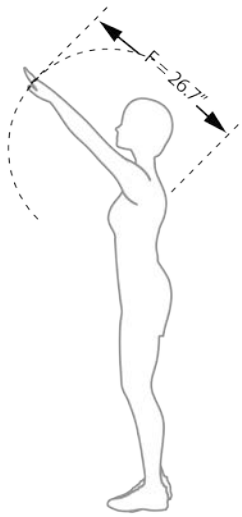
EMSP must be able to access the securing mechanism and contents of all storage areas while standing in a stationary ambulance.

a. Interior storage cabinets, shelves and drawers should be within reach of EMSP, from a 5th percentile female through a 95th percentile male, while standing on the patient compartment floor (see Figure 14 and Appendix A).

b. The securing mechanism of interior storage cabinets and drawers and exterior storage compartments should be within reach of EMSP, from a 5th percentile female through a 95th percentile male, while standing on the patient compartment floor.

c. Standing EMSP, from a 5th percentile female through a 95th percentile male, should be able to retrieve the contents of all interior storage cabinets, shelves and drawers.

d. The design of interior storage compartments should facilitate restocking of items to be stored.



Measured from the shoulder blade to the tip of the thumb

Figure 14. Illustration of 5th Percentile Female's Functional Reach while Standing

e. The lowest cabinets, shelves and drawers should be reachable by EMSP from a 5th percentile female through a 95th percentile male.

6.3 Accessibility While Seated and Restrained

Seated and restrained EMSP must be able to retrieve items that are common or critical to performing patient care.

a. Interior storage cabinets, shelves and drawers whose contents include common and critical equipment and supplies should be within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, while seated and restrained. See Figure 5 and the Definitions section for more information.

b. The securing mechanism of interior storage cabinets and drawers whose contents include common and critical equipment and supplies should be within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, while seated and restrained.

> Storage areas and their securing mechanisms need to be easily accessible by a 5th percentile female while still allowing easy and comfortable access by all EMSP up through a 95th percentile male.

6.4 Storage Cabinet Doors and Drawers

The design of storage cabinet doors and drawers must facilitate and not impede safe and effective patient care.

a. The securing mechanism of interior storage cabinets and drawers should be operable with one hand.

> One-handed operation allows EMSP to access storage areas easily and to do so while keeping one hand free for performing other patient care activities.

b. Interior storage cabinet doors should not intrude on working space.

> This allows a door to open in a way that does not present a striking hazard or hinder patient care activities.

c. Storage cabinet doors and drawers should automatically soft close (e.g., slow close).

d. Interior storage cabinet doors and drawers and exterior storage compartment doors should stay closed once closed and should not open due to vibration and vehicle motion.

e. All compartments and drawers should have rounded edges and corners and, where appropriate, padding.

f. If the storage area contains items required to be locked up (e.g., pharmaceuticals), the storage cabinet or drawer locking mechanism should be within maximum functional reach of all EMSP, from a 5th percentile female through a 95th percentile male and well lit.

g. If required, the locking mechanism should be operable with one hand.

> One-handed operation allows EMSP to quickly and easily unlock, access and retrieve sensitive items from a locked storage area.

6.5 Consistency and Organization

Consistency and organization of storage areas and their contents allows EMSP to quickly and easily locate equipment and supplies.

a. Interior storage cabinets, shelves and drawers should not be obscured by other equipment or structures.

> Designing storage areas for unimpeded access allows EMSP access to all storage areas.

b. The location and arrangement of storage cabinet, shelves and drawers should be as consistent as possible across same purpose ambulances within a given ambulance fleet.

c. The location and arrangement of items within storage cabinets, shelves and drawers should be consistent across same purpose ambulances within a given ambulance fleet.

> Consistency allows EMSP to rely on memory and easily locate items in storage areas on all same purpose ambulances.

6.6 Reduced Injury Risk

Storage areas must not pose an injury risk to EMSP when storing and retrieving items.

a. The design should allow for items greater than 31 lbs. (14 kg) to be stored no higher than 60 inches (1520 mm) from the floor and for items greater than 44 lbs. (20 kg) to be stored no higher than 36 inches (910 mm) from the floor, as illustrated in Figure 15.

> Limiting the height at which heavier items are stored protects EMSP from potential lifting injuries.

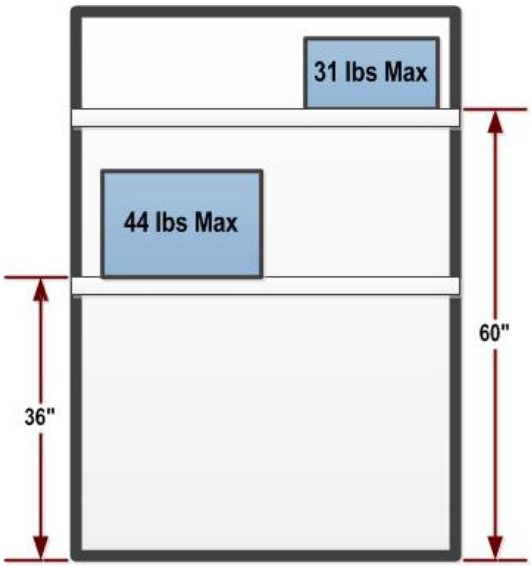


Figure 15. Maximum Lift Heights

b. If a twisting motion is required to store or remove an item, it should be limited to a maximum of 30degrees left or right of the body centerline.

c. If the body has to twist through more than 15 degrees while lifting an object, the recommended acceptable weight for that lift height (Refer to 6.6.a) should be reduced by 20percent (Figure 16). For example, items greater than 24.8 lbs. (11.2 kg) should not be stored higher than 60 inches (1520 mm) from the floor and items greater than 35.2 lbs. (16.0 kg) should not be stored higher than 36 inches (910mm) from the floor.

> Limiting the need to twist to access storage areas protects EMSP from potential musculoskeletal injuries.

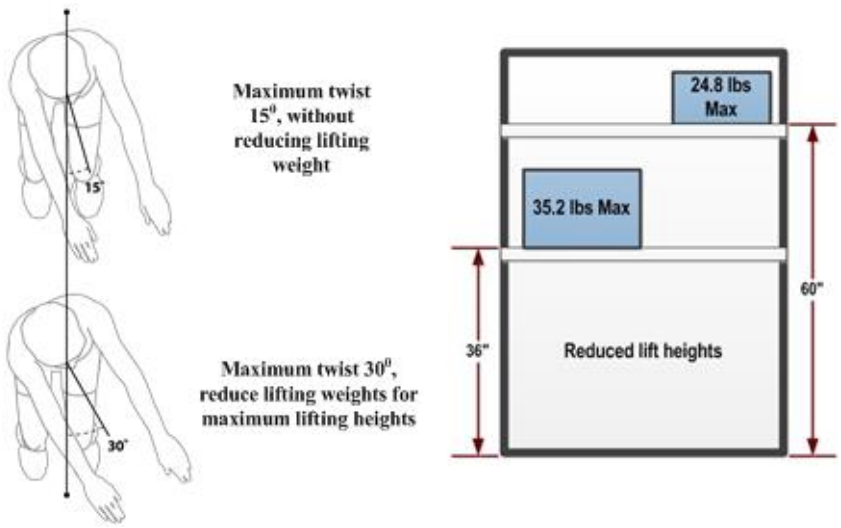


Figure 16. Maximum Twisting Motion

d. Storage should be designed with hand clearance in mind, with a recommended 5.9 inches (150 mm) clearance for items that require a two-handed grip, as illustrated in Figure 17.

> Adequate room for grasping objects in storage could reduce pinching and other injuries to hands or fingers.

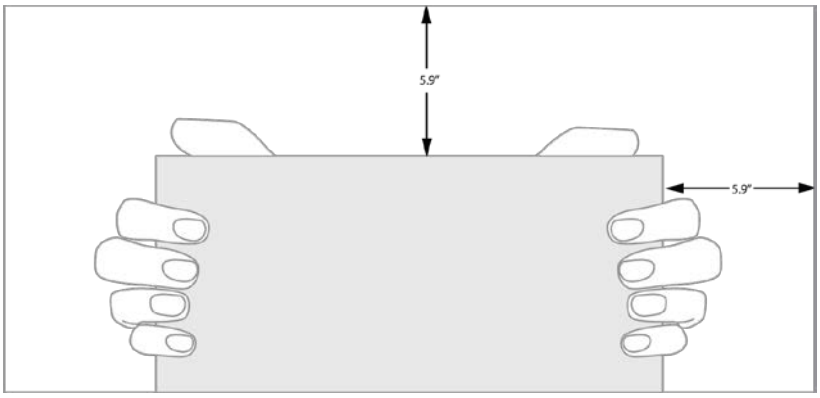


Figure 17. Hand Clearance

e. Interior storage cabinet, drawer or exterior storage compartment handles should not pose a risk of injury, especially for the finger.

> Design handles with room to prevent pinching, jamming, twisting or otherwise injuring hands or fingers while opening storage areas.

6.7 Labeling and Identification

Clear and concise labeling of storage areas and their contents allows EMSP to quickly and easily locate the correct equipment and supplies.

a. Interior storage cabinets, shelves and drawers should be labeled with the contents.

b. Labels should be visible when the storage compartment door is closed.

> Visible labels of the contents of storage areas allow EMSP, especially those unfamiliar with the ambulance, to quickly and easily locate items.

c. Storage compartment label size and contrast should be designed in accordance with the guidelines in paragraph 5.3.

> Properly sized text and contrasting text and label coloring allow EMSP to quickly and easily read labels.

6.8 Secure Personal Belonging Storage

Personal belongings for EMSP and patients need to have a secure storage area separate from patient care items.

a. Personal belongings should be secured in a location where the contents are not exposed to pathogens, or compromise performance or safety of the EMSP.

> Storage for personal belongings protects them from exposure to health risks and keeps the patient compartment clear of potential projectiles.

b. Personal storage space for EMSP should be lockable to protect belongings from theft.

7.0 Workspace

This chapter discusses the workspace environment and patient compartment layout that support EMSP in providing patient care.

Considerations for Patient Compartment Workspace

The ambulance patient compartment workspace needs to be able to support all patient care activities performed by EMSP in a timely, safe, effective and comfortable manner. EMSP need easy access to the patient, equipment and supplies, as well as adequate space to use equipment and prepare treatment options. If required, the patient compartment should be capable of transporting a second patient while still allowing EMSP to treat both patients. Transporting a second patient should not introduce injury risks to EMSP or patients.

Considerations for designing workspace include:

a. **Transport of single versus multiple patients**. The number of patients that the ambulance is expected to transport will have a significant impact on how the patient compartment is designed. Where only one patient is being transported, all patient care support in terms of supplies, storage, equipment and seating can be focused around a single cot. Transporting multiple patients will require that the design be flexible enough to allow EMSP to monitor both patients while remaining safe.

b. **Reach distances versus exclusion zones**. Ensuring that all EMSP can reach equipment and supplies, and the patient while seated and restrained will significantly improve both their safety and patient outcomes. This may also put equipment and supplies within the excursion zone—the area around a seat within which EMSP bodies will move during an accident. This introduces the risk of EMSP striking an object during an accident. Achieving the goal of performing patient care while seated and restrained may require that certain risks be accepted and mitigated through other means, such as padding.

c. **Single versus multiple workstations**. The higher the level of patient care provided such as for ALS missions, the greater the need for additional primary and secondary workstations in the patient compartment. While additional workstations allow EMSP to work from more than one location or for multiple EMSP to provide care to the patient, additional workstations will also increase the cost and the weight of the ambulance, while decreasing the space available for storage or other items.

The following paragraphs provide detailed design guidelines and best practices for the ambulance patient compartment workspace.

7.1 Comfortable and Appropriate Working Environment

Comfortable levels of heating, ventilation, air conditioning, lighting, noise and power help the EMSP provide more effective patient care.

7.1.1 Heating, Ventilation, and Air Conditioning (HVAC)

The HVAC system needs to be able to maintain a comfortable environment for both the patient and EMSP in all weather conditions and bring in adequate fresh air.

a. The heating and air conditioning systems should have the capacity to reestablish the set temperature in no more than 30 minutes of closing the patient compartment doors.

b. The heating and air conditioning systems should provide controls to maintain a temperature in the range of 68degrees Fahrenheit (F) to 78degreesF (20degrees Celsius [C] to 24degreesC) throughout the patient compartment.

> This will ensure that the patient compartment is maintained in a temperature zone to keep the patient comfortable and not interfere with patient care, while supporting EMSP in working comfortably and safely.

c. The temperature of the air at floor level and at head level at EMSP positions should not differ by more than 10degreesF (5.5degreesC). A temperature difference of less than 6degreesF (3.0degreesC) is preferred. Sidewalls of the compartment should be kept at equal temperatures insofar as possible; however, temperature differences of 20degreesF (11degreesC) or less do not significantly degrade comfort.

> Consistent temperatures throughout the patient compartment ensure that EMSP are comfortable in all possible working positions.

d. Cooling and heating air should be designed such that cool or hot air discharge is not directed on EMSP or patients, with the option to direct air discharge onto patients if deemed medically necessary.

> This ensures that air flow is not distracting or bothering EMSP or patients.

e. The HVAC system should be capable of providing and maintaining a relative humidity within a range from 30percent minimum to 70percent maximum, with 40percent to 45percent preferred.

f. Adequate ventilation should be assured by introducing outside air into the patient compartment.

g. Air vents should be located where they will not be obscured or blocked by interior storage cabinet doors, other equipment storage or EMSP.

h. If the enclosure volume is 150 cubic feet (ft^3) (4.25 cubic meters [m^3]) or less per person, a minimum of 30 ft^3 (0.85 m^3) of ventilation air per minute per person should be introduced into the enclosure.

> Adequate ventilation helps to keep the patient compartment free of unpleasant odors and contaminants, as well as maintains the comfort of patients and EMSP.

i. Air velocities should not exceed 100 feet (30 meters [m]) per minute at any measured position in the space. An exception would be locations where spot cooling of EMSP or patients is provided. In these cases, air should be moved past personnel at a velocity not more than 200 feet (60 m) per minute. Where manuals or loose papers are used, air velocity past these items should be not more than 65 feet (20 m) per minute to preclude pages in manuals from being turned by the air or papers from being blown off work surfaces.

> These air velocity limits prevent ventilation from interfering with patient care tasks.

7.1.2 Lighting

Sufficient lighting allows EMSP to easily see all areas of the patient compartment and to treat the patient during transport.

a. The lighting system should be able to fully illuminate all patient care areas at a minimum of 75 foot-candles (fc) (807 lux), 100 fc (1076 lux) preferred as measured at the work surface or 29.5 inches (750 mm) below the light.

b. Once set, the lighting system should maintain consistent lighting levels.

> Bright, consistent lighting allows EMSP to perform patient care tasks and reliably monitor the patient’s medical condition.

c. The lighting system should include the capability to dim the lights.

> During non-medically critical tasks such as patient transport, dimmed compartment lights improve the patient’s comfort, especially at night.

d. Lighting should not cause a change in the patient's perceived skin color, though a separate light source can be used to help identify blood.

e. Overhead lights should be recessed to eliminate a striking hazard.

f. Lighting controls should be available adjacent to each entry door and near EMSP workstations.

g. Lights should turn on automatically when the door is opened, though there should be a manual override and a time out mechanism.

> Easy to activate or automatic lights save time during patient loading.

7.1.3 Noise

Patient compartment noise levels in moving ambulances should not exceed 75 A-weighted decibels (dBA) to ensure successful communication between EMSP and the patient. If noise levels exceed 85 dBA, appropriate hearing protection should be provided.

> Limiting the noise level protects EMSP and patient hearing from unsafe noise levels, especially from the ambulance siren, and facilitates communication.

7.1.4 Power

Power receptacles should be located near open counter space or equipment that requires power (such as near a laptop dock or portable radio storage) and to meet patient care needs of EMSP.

> This allows powered or rechargeable equipment to be reliably powered and remain charged during a call.

7.2 Equipment Accessibility While Seated and Restrained

EMSP need to be able to access and use equipment while seated and restrained.

7.2.1 IV bag Accessibility

EMSP need to hang, administer and monitor an IV without risk of injury.

a. The IV bag hook should allow EMSP to hang an IV bag while seated and restrained.

> If an IV bag is not prepped and hung before a call or before departure, EMSP need to hang the IV bag while remaining seated and restrained, keeping the EMSP safe while the ambulance is in motion.

b. IV line location should not interfere with EMSP ability to perform patient care, and should not disturb the patient.

c. IV infusion pump controls, if used, should be within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile

male, while seated and restrained. See Figure 5 and the Definitions section for more information.

d. The bag and drip chamber should be visible from a seated and restrained position.

> Visibility of the bag and drip chamber allows EMSP to monitor the IV bag level and flow rate while remaining safely seated and restrained.

e. The flow control should be within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, while seated and restrained.

f. Metal IV hooks should not be used unless they are recessed. This will eliminate an injury risk.

7.2.2 Oxygen (O_2) and Suction Port Accessibility

EMSP need to administer and monitor oxygen (O_2) and suction without risk of injury.

a. O_2 and suction ports should be located within line of sight of EMSP such that they do not have to reach behind themselves, a structure or any equipment to access the ports.

b. O_2 and suction ports should be within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, while seated and restrained.

> This allows EMSP to safely access O_2 and suction ports while remaining safely seated and restrained.

7.2.3 Equipment, Supply and Control Operation and Access

The workspace needs to provide adequate space for accessing and using equipment, supplies and controls from a seated and restrained position.

a. Space should be provided within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, for placing equipment and supplies while in use. See Figure 5 and the Definitions section for more information.

> Each working position needs a surface for placing and using supplies and equipment that will keep the items in place during normal vehicle movement, such as a raised lip around the surface. Working surfaces will be accessed frequently and it is ideal to locate them close to EMSP, if possible.

b. Controls for HVAC, lighting, communications, etc., should be located within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, while seated and restrained or operable through a remote control stored within this reach envelope. See Figure 5 and the Definitions section for more information.

c. Equipment and controls should be operable by one hand.

> This allows EMSP to operate equipment and controls easily while keeping one hand free for performing patient care activities.

d. Controls should be distinguishable from each other visually or by feel (i.e., cannot confuse temperature controls with lights), and designed and arranged such that the chances of using the wrong control is minimized.

> Distinct controls allow EMSP to easily identify the appropriate control based on overt differences between controls, reducing the time needed to read labels on control panels, and the risk of operating an incorrect control.

e. Redundant controls for lighting, communications and HVAC should be provided at all primary (most frequently used) workstations.

> Redundant controls allow EMSP to access and use all controls while remaining safely seated and restrained from any primary workstation.

f. Patient compartment controls should remain operable when subjected to extreme temperatures, vibration, mechanical shock, dust and dirt contamination, electromagnetic and electrostatic interference and moisture.

7.3 Consistency and Organization

Consistent design and organization of controls, equipment and supplies enables EMSP to quickly and easily locate and operate these items.

a. The location of controls should be consistent across same purpose ambulances within a given fleet.

b. The size and shape of controls should be consistent across same purpose ambulances within a given fleet.

c. The location of equipment and supplies should be consistent across same purpose ambulances within a given fleet.

> Consistency allows EMSP to easily locate items in storage areas as well as identify and operate controls and displays on all same-purpose ambulances they may work on based on their memory and expectations, reducing the performance time and error risk. There are challenges to achieving this due to the introduction of new technology and enhanced designs.

7.4 Maintainability

Routine cleaning, sanitation and minor maintenance need to be easily performed in the workspace by EMSP.

a. The numbers, types and complexity of tools required for maintenance should be minimized.

b. All replaceable items, particularly items that are disposable or have high failure rates, should be replaceable: without removal or disassembly of other items or units; by opening a minimum number of covers, cases and panels; without hindrance from structural members or other parts; and along a straight or slightly curved line, rather than through an angle or more difficult pathway.

> This allows EMSP to replace common consumable materials such as light bulbs and air filters easily, without specialized tools, and without needing to take the ambulance out of service for maintenance.

c. All surfaces, edges, corners and joints that can be exposed to any fluid should be sealed by a liquid-proof bonding material.

d. Cabinet doors and drawers should seal against liquids in the event that the patient compartment needs to be hosed down for rapid cleaning or otherwise decontaminated.

> This allows EMSP to clean the patient compartment without the risk of liquid damaging the compartments or anything stored within.

e. Surface materials and their color should allow EMSP to distinguish clean from soiled surfaces.

> This allows EMSP to visually determine if an area is clean or requires cleaning.

f. Surfaces that can be potentially exposed to contamination should be reachable and accessible for sanitization and cleaning.

7.5 Interior Structure and Layout

The structure and layout of the ambulance patient compartment needs to support safe and easy movement through the compartment.

a. No objects should be stored or located within a minimum of 12 inches (305 mm) around a standard size cot and ingress/egress doors. The preferred distance is15 inches (381 mm).

b. There should be no head strike obstacles in movement pathways or around the cot.

> This allows EMSP to travel through the patient compartment, prior to and after transport, without the risk of striking injuries in their path.

c. Objects that pose a potential head strike risk to EMSP while seated should be designed to reduce injury risk through padding or other means.

> An area around seating that is clear of obstacles, or has padding around obstacles when they cannot be avoided, reduces EMSP risk of injury in the event of an accident or evasive maneuver.

d. Clearance under a workstation overhang, as illustrated in Figure 18, should be at least 25.5 inches (647.7 mm) to accommodate the thighs and knees of a seated 95th percentile male EMSP.

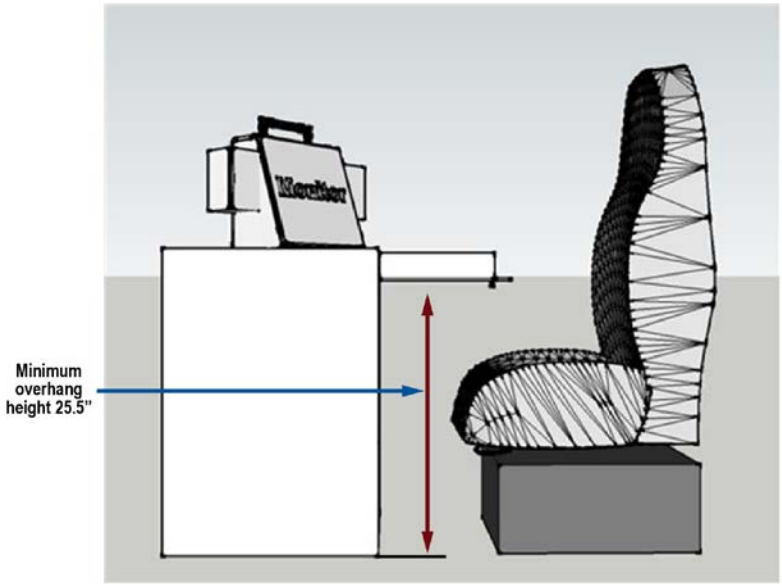


Figure 18. Workstation Overhang Clearance for EMSP Knees

e. Interior height of the patient compartment should be at least 76 inches (1930 mm) to accommodate a 95th percentile male standing in boots.

> This reduces strain on EMSP backs by allowing them to stand up straight inside of the patient compartment and reduces the risk of the head striking the ceiling.

f. Ceiling handholds should be recessed and installed overhead, and run the full length of, each walking path in the patient compartment. There should be sufficient hand clearance to grasp the handholds.

g. Handholds should have a high contrast with background surfaces.

h. Handholds should have a nonslip surface.

> Handholds help EMSP to safely move through the patient compartment of stationary ambulances and to help reduce the risk of injury from slips and falls.

i. Flooring material should be made of a multi-directional aggressive gripping surface with a static friction coefficient equal to or greater than 0.8 under dry conditions to minimize the risk of slipping.

> This protects EMSP from injury, especially if water, snow or ice is inadvertently tracked into the patient compartment.

j. Exposed edges that could come in contact with an occupant's body during normal use should be rounded.

k. The patient compartment should be designed without small crevices, cracks, protrusions or other structures that may trap or catch EMSP body remains, clothing or gloves.

> Curved, smooth and solid surfaces protect EMSP from striking, pinching or other injuries.

l. If seats can rotate or otherwise move, the workspace should allow EMSP to access equipment and supplies necessary for patient care from multiple orientations of the seat.

7.6 Trash and Sharps Disposal

EMSP need unobstructed access to trash and sharps disposal from all workstations.

a. Wall-mounted trash or sharps disposal containers should remain attached to the wall in the event of an accident or evasive maneuver.

b. Disposal of trash and sharps into disposal containers should require only one hand.

> One-handed disposal allows EMSP to dispose items easily and to do so while keeping one hand free for other patient care activities.

c. Securing mechanism for sharps and trash disposal containers should allow for containers to be removed and emptied without the use of tools.

d. Contaminated sharps should be discarded in containers that are closable, puncture resistant, leak-proof on sides and bottom, and maintained upright throughout use.

> These features protect EMSP from contamination.

e. Containers for contaminated sharps should be easily accessible by EMSP, from a 5th percentile female through a 95th percentile male, and located as close as is feasible to the immediate area where sharps are used or can be reasonably anticipated to be found.

> This allows EMSP to dispose of contaminated sharps while remaining safely seated and restrained while limiting the amount of time that EMSP and other riders are exposed to contaminants. EMSP should not have to reach over patients to dispose of sharps.

f. Sharps disposal containers should have warning labels affixed to the container that are compliant with OHSA bloodborne pathogens storage standards (OSHA 2012).

g. Sharps disposal container labels should include the biohazard legend.

h. Sharps disposal container labels should be fluorescent orange, orange-red or predominantly so, with lettering and symbols in a contrasting color.

i. Trash disposal containers should be labeled as “Not for Sharps.”

> Properly labeled and colored sharps containers protect EMSP from accidental contact with the contents of the container and allow EMSP to quickly and easily identify the proper disposal area for contaminated sharps.

7.7 Second Patient Transport

EMSPO should decide if the patient compartment needs to be configured to transport a second patient. If yes, the design should ensure that both patients and EMSP remain safe and patient care can be provided. The second patient should be stable and not require active patient care.

If a second patient is likely to be transported then:

a. Requirements in Chapters 4.0 through 10.0 that address patient access and patient care should be met for both patients.

b. Common and critical equipment and supplies should be accessible from the primary workstation when a second patient is being transported.

> This allows EMSP to access and use items that are critical to patient care, while remaining seated and restrained at a primary workstation in order to care for both patients during transport.

It should be noted that there are safety standards in place for cots and their restraint systems. At this time, there are no safety standards for securing backboards in the patient compartment. This should be considered when determining the need to carry an additional patient.

8.0 Ingress and Egress

This chapter discusses design considerations that will ensure safe and effective ingress and egress of EMSP and patients in all weather conditions and without undue strain on the EMSP. EMSP must be able to safely and effectively load and unload patients as well as enter and exit the ambulance.

Considerations for Ingress and Egress

EMSP must be able to efficiently enter and exit the ambulance, especially when transporting patients. Ambulance doors, handholds and steps must:

- Be durable to be effectively used over the life of the ambulance.
- Be usable in various weather conditions and while wearing gloves and boots so that they do not present a safety hazard resulting in injury to EMSP or further injury to their patient.
- Accommodate the anthropometric dimensions of EMSP.

In addition to the primary door, a secondary exit should be available for EMSP and their patients to safely and effectively exit the ambulance in a situation where the primary door is damaged or blocked, prohibiting normal egress. This secondary exit should not be blocked by equipment storage or obstructed by wires, tubing or equipment. It should be readily accessible in the event of the need for emergency egress.

One consideration regarding ingress and egress is:

a. **Step height versus vehicle clearance**. Lower steps are better for EMSP and reduce stress on the lower body yet reduce the clearance height of the vehicle. This

issue can be mitigated through installing steps that retract or rise while the vehicle starts in motion, including air and hydraulic ride systems.

The following paragraphs provide detailed design guideline and best practices for ambulance patient compartment ingress and egress pathways.

8.1 Ingress and Egress in Normal and Adverse Weather Conditions

EMSP need to safely enter and exit the ambulance patient compartment in dry, wet, wintry and reduced visibility weather conditions.

8.1.1 Doors

Doors need to allow quick and safe entry to and exit from the patient compartment.

a. All egress doors should have a failsafe method of opening the door and should not be lockable in a way that precludes egress from the patient compartment during an emergency.

b. Doors should require 44-133 N (10-30 lbs.) of operating force to open.

> This allows all EMSP, regardless of stature or strength, to enter or exit without delay and, at the same time, without inadvertently opening the door by casual contact with the handle.

c. Door handles should accommodate hand sizes ranging from 5th percentile female to 95th percentile male, including but not limited to the following representative EMSP body dimensions:

- Hand length (6.5-8.3 inches [165-211 mm]);
- Hand breadth (2.7-3.9 inches [69-98 mm]);
- Hand circumference (6.6-9.0 inches [168-229 mm]); and
- Palm length (3.5-4.6 inches [90-117 mm]).

d. Door handles should provide hand clearance between the mounting surface and the handle of at least 2.5 inches (63.5 mm) for a 95th percentile male-gloved hand.

e. Ingress/egress doors should provide positive feedback that the door is secured in the full open or closed position.

> This will prevent EMSP entering or exiting from inadvertently being struck by a moving door.

f. The full open position of patient compartment primary entry doors should be wide enough to allow for loading a patient on a cot or backboard.

g. Doors should be provided with a visual indication that they are open in reduced visibility conditions.

8.1.2 Steps

Steps need to accommodate safe movement of EMSP wearing boots from the patient compartment to the ground level.

a. Steps should be no greater than 7.8 inches (198 mm) in height with 6.5-7 inches (165-178 mm) preferred (see Figure 19).

b. Tread depth of all steps should be a minimum of 9.5 inches (240 mm) with 11-12 inches (280-305 mm) preferred (see Figure 19).

> Steps at a comfortable height with a depth large enough to support a 95th percentile male's boots reduce the strain on leg joints and the risk for slips and falls.

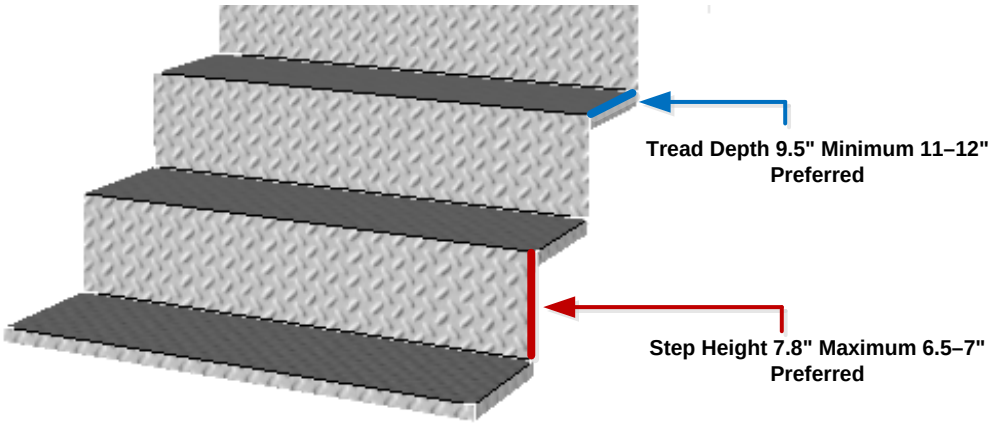


Figure 19. Step Height and Tread Depth

c. Steps should be the entire width of the doorway opening.

d. A safety grating step at the rear door opening should pivot to permit EMSP to move closer when loading and unloading a cot.

e. Pivoting steps should be designed to ensure that EMSP will not inadvertently exit the door when the step is pivoted up.

f. Steps should be treated with an anti-slip coating.

g. Where practical, exterior stair treads should be open.

> Open stair treads allow ice to melt and reduce the accumulation of mud and debris, thus reducing the risk of slips and falls.

h. Step surfaces should be lit by a minimum of 10 fc (107.6 lux) with 20 fc (215.3 lux) preferred.

> Step lights reduce the risk of falling.

8.1.3 Handholds and Handrails

Handholds and handrails assist EMSP when entering and exiting the patient compartment.

a. Handholds should be mounted on the inside of entrance doors and immediately inside each entrance to the patient compartment.

> Handholds assist a safer ingress and egress, and can provide aid for closing doors after entry.

b. Handholds should meet the requirements of 8.1.1.c and 8.1.1.d.

c. Handrails, if used in stairwells, should be placed 34-37 inches (864-940 mm), with 35 inches (889 mm) recommended, above the standing surface.

8.1.4 Windows

Windows provide visibility of the area past ingress and egress doors. They should allow for adequate viewing of the door opening or egress path.

> Windows allow EMSP to see potential obstructions or unsafe conditions before opening the door.

8.2 Emergency Egress

EMSP may need the ability to egress out of a secondary door (other than the main loading/unloading door) with a patient on a patient transport device. Egress out of that door should not require disassembly of any patient compartment structures or rotating the patient on the transport device away from a normal seated or supine position.

If there are issues that prevent egress through the main loading/unloading doors, secondary accessible doors allow for an emergency exit for EMSP and a patient loaded on a patient transport device.

9.0 Communication

This chapter discusses communication in the patient compartment, a vital part of the EMSP role in providing patient care. Communication systems utilize various methods and technologies to enable EMSP to receive information regarding the patient from dispatch prior to treatment, understand the patient's status and health concerns, communicate the patient's status to others, and to receive updates from the driver of the ambulance while en route.

Considerations for Communication

The ambulance can be a loud and chaotic environment. It is important that all lines of communication can be used effectively to ensure that the patient receives the best of care. EMSP in the back of the ambulance must be able to communicate with the ambulance driver. If a patient's condition worsens, EMSP may need to ask the ambulance driver to expedite the transport to the hospital or stop to allow the patient to be stabilized. If EMSP must temporarily remove their restraints to perform a task such as CPR, the driver needs to be aware of this situation so that he or she can pull over. The driver will also need to be able to inform the EMSP in the back if they intend to increase their speed or stop suddenly so that the EMSP can prepare themselves and their patient, minimizing the probability of injuring the EMSP or further injuring their patient.

Communication must also be effectively given to, and received from, dispatch and the medical facility or physician. EMSP need clear information on the patient's symptoms and their location so they know what medical condition to prepare for and what route will help them quickly locate their patient. They also need the capability to clearly inform the receiving medical facility of the patient's condition so that the medical team can accurately prepare the requisite medical equipment. The more awareness EMSP, dispatch and the medical facility have of the patient's needs, the better all parties can provide the patient with timely care. Therefore, it is important that communication is taken into consideration when designing the patient compartment. There also needs to be effective communication between EMSP and the patient.

Consider the following regarding communication in an ambulance patient compartment:

a. **Headsets versus portable communication systems**. Headsets allow for hands-free communications, yet may limit the ability to communicate verbally with the patient or other riders if using dual earpieces, limit freedom of movement if wired, and pose a sanitation concern. A headset with one earpiece may reduce some of these difficulties. Portable communications systems, such as hand radios or cell phones, when in use, limit EMSP to performing other actions with only one hand.

b. **Existing versus emerging technologies**. Advanced technologies, such as wireless radios or headsets, voice recognition or video conferencing, may improve the

effectiveness of communication by allowing easier or enhanced transmissions yet may also increase costs. Advanced systems may have not only a higher purchase and maintenance cost, but could also require additional training or time required to utilize the system and therefore reduce the amount of time EMSP are spending on patient care.

The following paragraphs provide detailed design guidelines and best practices for ambulance patient compartment communication systems.

9.1 Easily Understood Communication between EMSP, Driver and Third Parties

Communications between EMSP in the patient compartment, the driver, the patient, and third parties, such as the medical facility, need to be easily and quickly established, intelligible, and understandable within the operational environment of a patient compartment and driver's cab regardless of communication modality.

a. Speech should be understandable in accordance with Table 6 below.

Table 6. Intelligibility Guideline for Voice Communication Systems

Communication Requirement	Score	
	MRT	AI
Exceptionally high intelligibility	97percent	0.7
Normal acceptable intelligibility	91percent	0.5
Minimally acceptable intelligibility	75percent	0.3

> Speech intelligibility can be measured using the Modified Rhyme Test (MRT) or the Articulation Index (AI). MRT measures the percentage of correctly identified spoken words from a list of six rhyming words. AI measures the proportion of average speech that is correctly perceived. EMSPO should specify the need and the manufacturer should perform the measures to ensure speech intelligibility.

b. The communication system should be capable of power output of at least 15 decibels (dB) higher in sound intensity than the anticipated ambient noise. EMSP should have a volume control for adjusting the output level.

> EMSP need to be able to adjust the volume as appropriate to communicate over background noise.

c. Output sound pressure level should not exceed 115 dB peak voice levels at the ear.

> Setting a maximum sound level in communication equipment can reduce the risk of hearing loss due to exposure to high levels of both sustained and impulse noise.

d. The receiver and headset should have a frequency response of +3.0 dB between 250 and 6000 Hertz to maximize intelligibility.

e. The minimum setting of the volume control should be limited to an audible level.

> A volume minimum prevents EMSP from inadvertently disabling the communication system by turning the volume level off or otherwise below an audible level.

9.2 Accessibility to Communication Devices

Communication devices should be secured within maximum functional reach of EMSP, from a 5th percentile female through a 95th percentile male, from a restrained position. See Figure 5 and the Definitions section for more information.

9.3 Facilitation of Effective Patient Care by Communication Devices

Communication systems, when in use, need to allow EMSP to continue providing safe and effective patient care.

a. Built-in communication devices should allow one-handed or hands-free operation.

> One-handed or hands-free operation allows EMSP to operate equipment and controls easily and to do so while keeping one hand free for performing other patient care activities.

b. Where communications devices have hand controls, the controls should be a minimum of 0.4 inches (10 mm) in diameter and be highly visible.

c. Communication devices should not hinder unaided verbal communication within the patient compartment.

> EMSP need to be able to easily communicate verbally with the patient or other individuals in the patient compartment.

d. Headsets, if used, should pose no entanglement hazards.

e. EMSP in the patient compartment should have full control of the communications channels required for communication between the patient compartment and other individuals, such as the driver, medical facilities and dispatch.

This allows EMSP to adjust the communication channel without compromising attention to the patient.

9.4 Notifications from the Driver Compartment

Notifications from the driver of the ambulance can alert EMSP in the patient compartment to any driving hazards that could impact the safety of EMSP or patients, as well as provide any additional information received from dispatch or the receiving medical facility.

a. Notifications received from the driver should be obvious to EMSP in the patient compartment.

b. Notifications in the patient compartment should not be distracting to EMSP nor the driver of the ambulance.

c. Visual notifications, when used, should be visible from all primary workstations.

Visual notifications that are prominent but not distracting allow EMSP to notice the notification when they are not focused on another task without interrupting any tasks that require their immediate continued attention.

10.0 Type II Ambulance Patient Compartment Design Considerations

The contents of the Guidebook were originally developed within the context of the design considerations associated with Type I and III ambulance patient compartments, though most of the guidelines contained in the Guidebook are also relevant to Type II ambulances. While all ambulance types have challenges and issues associated with performing safe patient care, there are some unique challenges associated with Type II ambulances. These challenges are primarily due to the smaller size of Type II ambulances, which affects access to patients, equipment and supplies, and increases safety risks associated with ingress/egress and accidents. Specific challenges that Type II ambulance patient compartments present to EMSP include the following:

a. **Space limitations.** The interior of a Type II is considerably smaller than other ambulances, leading to:

- Increased risk of EMSP head injury due to the low ceilings and entry doors, as well as close proximity of the roadside storage when seated in the airway seat.
- Limited storage for equipment and supplies due to no outside compartments and limited cabinet space in the interior. This is particularly an issue if a Type II is used for ALS transport.
- Difficult access to equipment and supplies from both the airway seat and the curbside seat. For the airway seat, EMSP usually need to get out of the seat to reach equipment and supplies located anywhere away from the very limited storage adjacent to the seat. For the curbside seat, EMSP must reach over the patient to access the cabinets on the roadside. In addition, any roadside storage located lower than the cot height is completely inaccessible.
- Limited space for the safe placement of critical patient care equipment, such as cardiac monitors and infusion pumps that allow EMSP to monitor patient status and control the equipment.
- Difficult access to the patient's right side due to the proximity of the roadside storage wall. This makes it difficult to perform patient care activities that involve the right arm.
- Easy patient access to the roadside storage cabinets above the cot height.
- Limited comfort for EMSP due to cramped space between the cot and the airway and curbside seating, particularly for larger EMSP and during long transports.

b. **Stability.** Due to high centers of gravity and narrow wheelbases, Type II ambulances are more prone to the effects of high winds and air pressure from other large vehicles passing the ambulance.

Applicability of the Guidebook to Type II

Despite the size differences between Type II and Type I and III ambulances, most of the Guidebook is still applicable, though there will be challenges in designing future Type II patient compartments to meet the guidelines. Those Guidebook design guidelines that are exceptions include the following:

c. Chapter 4, Paragraph 4.1.2.b. It may be difficult to reach the right side of a patient in a Type II without unhooking the restraints and leaving the seat. Additionally, the patient tends to be up against the roadside wall which also makes it difficult to access the right side.

d. Chapter 7, Paragraph 7.5.b and 7.5.e. Given the size of the patient compartments of Type II ambulances, it will be impossible to have a ceiling height that will allow a 95th percentile male EMSP to stand erect and not have head strike obstacles since the whole ceiling becomes a head strike risk.

Definitions and Acronyms

Definitions

Anthropometrics. The measurement of human physical features and functions such as height, weight, reach distances. Anthropometric data is typically presented in terms of percentiles. See Appendix A for more information.

Common and Critical Equipment and Supplies. Frequently used or essential equipment and supplies which typically includes:

- Airway bag;
- Bag valve mask;
- Drug bag;
- First-in kit;
- Glucometer;
- IV kit;
- Cardiac monitor;
- Nasal cannula; and
- Trauma bag.

This list may differ between ambulance stations and ambulance missions.

Cot Guidance Mechanism. A mechanism that facilitates proper placement of the cot when stowing the cot within the patient compartment.

Cot Loading Mechanism. A mechanical or hydraulic device that is used to load the cot into the patient compartment without requiring EMSP to lift the cot to the height of the rear door. This can include ramps, lift gates and the newer power loaders being offered.

Cumulative Trauma. Injury caused by prolonged static postures and repeated dynamic body postures (repetitious movements) or the combination of both. These postures or combination of postures overload muscles beyond their inherent capacity for immediate recovery.

Design Guideline. Specific elements of design that support the fulfillment of a design requirement.

Design Needs. High-level user performance and safety goals identified by the user community.

Design Requirements. Functions, capabilities or support that will satisfy or fulfill the need.

First-In Kits. Also called jump bags or house bags, these are bags or boxes that include the primarily needed supplies that are carried to the patient when arriving on the scene.

Functional Reach. The maximal distance from the back of the shoulder (shoulder blade) and the fingertips with the arm and hand extended that one can reach forward, upward or to the side beyond arm's length, while maintaining a fixed base of support in a standing or seated position.

Human Factors Engineering. A systems engineering process that focuses on incorporating human performance and safety considerations into the design of systems.

Lateral. Directed towards the side(s).

Lockable/Locking Mechanism. A system that allows a cabinet or compartment to be locked by some method such as a key or code and prevents unauthorized access.

Locking Detent. The mechanism to catch or stop a rotating object.

Maximum Functional Reach. The measurement from the center point of the junction of the seat pan and seat back to the thumb tip, where the arm is fully extended parallel to the floor and the torso is leaning forward at a 45degrees angle. Maximum functional reach is calculated using the following formula, where F = functional reach and S = seat to shoulder sitting height.

$$Maximum\ functional\ reach\ (MFR) = \sqrt{F^2 + \frac{2FS}{\sqrt{2}} + S^2}$$

As an example using anthropometric data from MIL-STD-1472G, the maximum functional reach for a 5th percentile female, illustrated in Figure 20, is calculated using the seat (bottom of buttocks) to shoulder torso length (20.0 inches [508 mm]) leaned forward at a 45degrees degree angle and a functional reach as measured from the shoulder blade to thumb tip (26.7 inches [677 mm]) for a maximum functional reach of 43.2 inches (1097 mm).

$$MFR = \sqrt{26.7^2 + \frac{2(26.7)(20)}{1.41} + 20^2} = 43.2\ inches$$

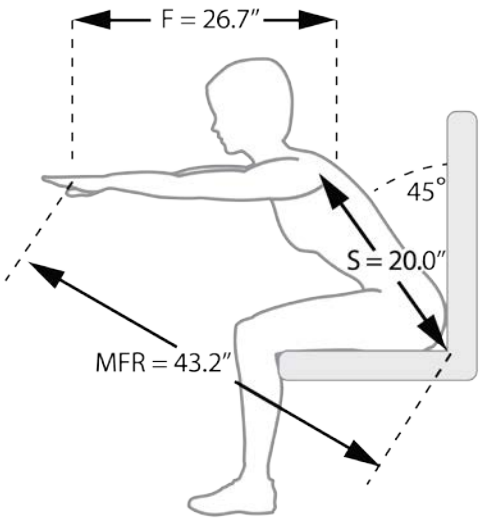


Figure 20. Maximum Functional Reach for a 5th Percentile Female

Neutral Seated Position. The seated position where EMSP are seated with the back and the spinal cord straight, weight evenly balanced, forearms and thighs parallel to the floor, and the hips are at a 90 degrees angle. An example of a non-neutral position would be an EMSP seated in a forward facing seat, but turned sideways to face the patient.

Pinch Points. Any area in the ambulance that could lead to fingers or any other body part being pinched or squeezed between equipment, supplies, ambulance structure or parts of those structures.

Primary Workstation. Most frequently used workstation with access to patient and common and critical equipment and supplies.

Raised Lip. A perimeter of elevated surface edge used to prevent objects from rolling off a flat surface.

Recessed. Sunken or set back into the wall or surface to which the object is fixed. Grab bars are commonly recessed to prevent striking hazards.

Restraint System. A system, which may include all types of restraints or seat belts, designed to secure all riders (EMSP and other passengers) against harmful movement that may result during an accident or evasive maneuver.

Rider. Persons transported in the emergency vehicle, including the patient, EMSP, companions of the patient, other first responders, students or other observers.

Repetitive Strain Injury. A condition in which the prolonged performance of repetitive actions, typically with the hands, causes pain or impairment of function in the tendons and muscles involved. Repetitive strain injuries are considered a subset of cumulative trauma injuries.

Seated Height. Height from the top of seat pan to the top of the head.

Seat Pan. The portion of the seat that supports the thighs and buttocks.

Secondary Door. A door other than the main loading/unloading door that provides access to the patient compartment.

Secure/Securing Mechanism. A system that fixes objects (such as the cot or equipment) to a surface or keeps a cabinet door or drawer closed such that items do not become a projectile or other injury risk in the event of an accident or evasive maneuver.

Serif. A slight projection finishing off a stroke of a letter.

Task Analysis. An analysis of the tasks a user has to perform in order to understand what is required to perform the tasks successfully. This includes, but is not limited to: information required, decisions that must made, actions that must be taken, skills and training required, performance and safety risks, and environmental factors.

Tipping Hazard. The hazard arising from the possibility of unsecured objects falling over on EMSP, patients or riders.

Type I. An ambulance that is based on a conventional truck chassis and typically has a large, box shaped patient compartment.

Type II. An ambulance that is based on a standard van chassis and typically has a much smaller integral patient compartment.

Type III. An ambulance that is based on a cutaway van cab-chassis, but has been modified to carry a larger, box type patient compartment.

Transilluminated. Light passed through an object from the opposite side; backlit.

Working Position. The position in which EMSP perform primary tasks.

Acronyms

AI	Articulation Index
ALS	Advanced Life Support
AMD	Ambulance Manufacturers Division
BLS	Basic Life Support
C	Celsius
CEN	European Committee for Standardization
CFR	Code of Federal Regulations
CH	Character Height
CPR	Cardiopulmonary Resuscitation
D&P	BMT Designers & Planners
dB	Decibel
dBA	A-weighted Decibel
DHS	Department of Homeland Security
DoD	Department of Defense
EMS	Emergency Medical Services
EMSP	Emergency Medical Services Providers
EMSPO	Emergency Medical Services Provider Organization
F	Fahrenheit
fc	Foot-candle
FMVSS	Federal Motor Vehicle Safety Standards
FRG	First Responders Group
ft^3	Cubic Foot
GSA	General Services Administration
HFE	Human Factors Engineering

HVAC	Heating, Ventilation, Air Conditioning
IV	Intravenous
kg	Kilograms
lbs.	Pound
m	Meters
mm	Millimeters
M&S	Modeling and Simulation
m^3	Cubic Meters
MRT	Modified Rhyme Test
N	Newtons
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
O_2	Oxygen
OSHA	Occupational Safety and Health Administration
oz	Ounces
SAE	Society of Automotive Engineers
S&T	Science & Technology
UCD	User-centered Design

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Appendix A-Ambulance Patient Compartment Anthropometric Data

Some of the guidelines included in the Guidebook incorporate anthropometric measurements representing the populations of EMSP and patients. These measurements have been drawn from a number of different sources due to the unavailability of a single relevant source of measurements. There is a research project currently being performed by NIOSH to develop an anthropometric database specific to EMSP, but it was not available at the time of publishing this Guidebook. Once this research has been published, the appropriate measurements from that database should replace the measures below. Figures 21 and 22 illustrate the anthropometric measures. Tables 7, 8 and 9 provide the actual measurements that were used in the Guidebook.

The following provides some definitions of terms in regard to EMSP measurements.

Anthropometrics The measurement of human physical features and functions, such as height, weight and reach distances. Anthropometric data is typically presented in terms of percentiles.

Percentiles Percentiles represent how large a person is for an anthropometric measurement compared to other people in that population. A population is assumed to range from 1 to 100, so if a person is 5th percentile, then they are 95percent smaller than others in the population whereas a person who is 95th percentile is 95percent larger than others in the population. An individual's body measurements may vary with someone being at the 50th percentile in height but have 40th percentile arm length. The design of an ambulance should consider a range in anthropometric data that represents the 5th percentile female through the 95th percentile male to ensure that all potential EMSPs can effectively perform patient care while remaining seated and restrained.

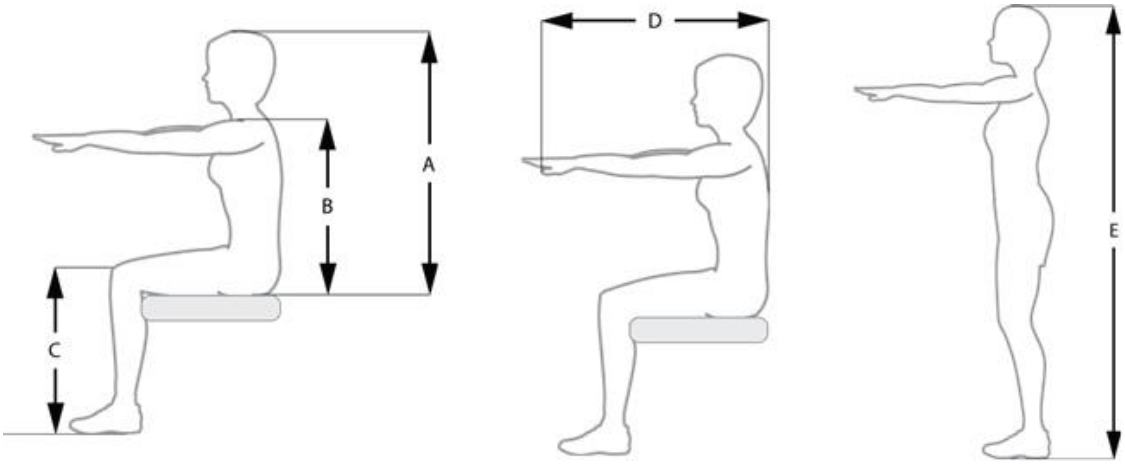

Figure 21. Adult Standing and Sitting Body Dimensions

Table 7. Adult Anthropometric Measurements Used in the Guidebook

Figure	Dimension	5th Percentile Female	95th Percentile Male	Source	Guidebook Paragraph
A	EMSP Seated Height	32.9 inches (836 mm)	38.8 inches (986 mm)	FAMA (2007)	4.5.1e, 4.8d
B	Shoulder Torso Length (Height Sitting)	20.0 inches (508 mm)	25.4 inches (64.6 mm)	DOD (2012)	4.4, Definition
C	EMSP Knee height	Not applicable	25.5 inches (647.7 mm)	FAMA (2007)	7.5d
D	Functional Reach	26.7 inches (677 mm)	34.9 inches (88.6 mm)	DOD (2012)	4.4, Definition
E	EMSP Standing Height Booted	63.9 inches (1623.06 mm)	76 inches (1930 mm)	FAMA (2007)	7.5e
E	Patient Stature	59.3 inches (1506 mm)	74.3 inches (1887 mm)	McDowell et al. (2008)	5.1.4b, 5.1.8c
NA	EMSP Weight	129 lbs. (58.5 kg)	263 lbs. (119.3 kg)	FAMA (2007)	4.5.2a
NA	EMSP Waist Circumference	38 inches (965 mm)	56 inches (1422 mm)	FAMA (2007)	4.5.2a
NA	Patient Weight	111.2 lbs. (50.4 kg)	270 lbs. (122.6 kg)	McDowell et al. (2008)	5.1.4b, 5.1.8c
NA	Patient Waist Circumference	28.3 inches (719 mm)	50.3 inches (1278 mm)	McDowell et al. (2008)	5.1.4b, 5.1.8c

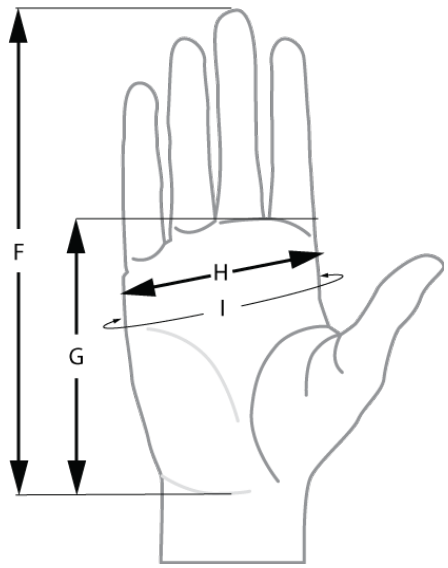

Figure 22. Adult Hand Measurements

Table 8. Adult Hand Anthropometric Measurements Used in the Guidebook

Figure	Dimension	5th Percentile Female	95th Percentile Male	Source	Guidebook Paragraph
F	Hand Length	6.5 inches (165 mm)	8.3 inches (211 mm)	DOD (2012)	8.1.1c
G	Palm Length	3.5 inches (90 mm)	4.6 inches (117 mm)	DOD (2012)	8.1.1c
H	Hand Breadth	2.7 inches (69 mm)	3.9 inches (98 mm)	DOD (2012)	8.1.1c
I	Hand Circumference	6.6 inches (168 mm)	9.0 inches (229 mm)	DOD (2012)	8.1.1c

Table 9. Child Anthropometric Data Used in the Guidebook

Figure	Dimension	90th Percentile Male	Source	Guidebook Paragraph
NA	Child Height 90th Percentile Male, 8 yrs old	54.8 inches (1392 mm)	McDowell et al. (2008)	4.9
NA	Child Weight 90th Percentile Male, 8 yrs old	92.8lbs (42.1 kg)	McDowell et al. (2008)	4.9
NA	Child Waist Circumference 90th Percentile Male, 8 yrs old	31.9 inches (810 mm)	McDowell et al. (2008)	4.9

Appendix B-Applicable Standards and Documents

There are numerous documents that have been used to develop the guidance provided within this Guidebook. In some cases, there is a defined standard (e.g., SAE standard) and in others there is a document in development that may become a standard (e.g., Ground Vehicle Standard (GVS-2015)). The documents or portions listed in this section contain provisions (e.g., standard) and reference data (e.g., anthropometric data) that constitute guidance of this Guidebook as cited in the text of Chapters 4.0 through 10.0. The latest versions of cited documents are recommended to be used. These documents as a whole can help assist in designing safer patient compartments. They may be obtained directly from the standards development organizations or other document distributors. In addition, each state regulates which standards it will adopt and therefore we strongly recommend that you become familiar with the standards that are adopted by your state and use the Guidebook in conjunction with the applicable standard(s). Table 10 provides a list of standards and documents relevant to the design of an ambulance patient compartment.

Table 10. Standards and Documents Relevant to the Design of an Ambulance Patient Compartment

Source	Document Number	Title
Ambulance Manufacturers Division (AMD)	AMD Standard 001	Static load test for ambulance body structure (July 1991)
	AMD Standard 002	Body door retention components test (October 1998)
	AMD Standard 003	Oxygen tank retention system (October 1998)
	AMD Standard 004	Litter retention system (October 1998)
	AMD Standard 005	Ambulance 12 Volt DC electrical system (October 1998)
	AMD Standard 006	Sound level test code for ambulance compartment interiors (October 1998)
	AMD Standard 007	Carbon monoxide levels for ambulance compartment interiors (July 1991)
	AMD Standard 008	Load test for ambulance patient compartment grab rail (October 1998)
	AMD Standard 009	120V AC electrical systems (October 1998)
	AMD Standard 010	Water spray test for ambulances (October

Source	Document Number	Title
		1998)
	AMD Standard 011	Ambulance equipment temperature test (October 1998)
	AMD Standard 012	Ambient temperature test (October 1998)
	AMD Standard 013	Weight distribution (October 1998)
	AMD Standard 014	Cooling system test (October 1998)
	AMD Standard 015	Ambulance main oxygen system test (October 1998)
Alberta Health and Wellness	NA	Ambulance Vehicle Standards Code (January 2010)
European Committee for Standardization (CEN)	CEN BS EN 1789:2007+A1:2010	European Committee for Standardization (CEN) Standard: Medical Vehicles and Their Equipment - Road Ambulances (Amendment, June 2010)
Fire Apparatus Manufacturers' Association	NA	Fire Fighter Anthropometric Data White Paper (October 20, 2007)
Federal Motor Vehicle Safety Standards (FMVSS)	Standard No. 207	Seating Systems: Passenger Cars (Effective 1-1-68), Multipurpose Passenger Vehicles, Trucks, and Buses (Effective 1-1-72)
	Standard No. 209	Seat Belt Assemblies: Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (Effective 3-1-67)
	Standard No. 210	Seat Belt Assembly Anchorages: Passenger Cars (Effective 1-1-68), Multipurpose Passenger Vehicles, Trucks, and Buses (Effective 7-1-71)
	Standard No. 213	Child Restraint Systems: Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses, and Child Restraint Systems for use in Motor Vehicles and Aircraft (Effective 4-1-71, amended 1-1-81)
	Part 572	Anthropomorphic Test Devices (Effective 8-1-75)
	(For the complete list of	

Source	Document Number	Title
	FMVSS standards and regulations, see http://www.nhtsa.gov/cars/rules/import/FMVSS/)	
General Services Administration (GSA)	KKK-A-1822 F (change notice 1-6)	Federal Specification for the Star-of-Life Ambulance (August 1, 2007)
Department of Defense (DoD)	MIL-STD-1472G MIL-STD-1474D	Military Standard: Design Criteria Standard – Human Engineering (January 11, 2012) Military Standard: Design Criteria Standard - Noise Limits (February 12, 1997)
National Fire Protection Association (NFPA)	NFPA 1901: 2009 Edition NFPA 1917: 2013 Edition	Standard for Automotive Fire Apparatus (2009) Standard for Automotive Ambulances (September 25, 2012)
Centers for Disease Control (CDC)	National Health Statistics Reports, Number 10	Anthropometric Reference Data for Children and Adults: United States, 2003–2006 (October 22, 2008)
SAE International	SAE J2917-2010 SAE J2956-2011 SAE J3027-2014	Occupant Restraint and Equipment Mounting Integrity – Frontal Impact System-Level Ambulance Patient Compartment (May 3, 2010) Occupant Restraint and Equipment Mounting Integrity – Side Impact System-Level Ambulance Patient Compartment (June 16, 2011) Ambulance Litter Integrity, Retention, and Patient Restraint (July 14, 2014)
Code of Federal Regulations (CFR)	29 CFR 1910.1030	Code of Federal Regulations: Bloodborne Pathogens Standard (the standard is under CFR's Part Number 1910 - Occupational Safety and Health Standards and Subpart Z - Toxic and Hazardous Substances) (CFR: July 1, 2012; e-CFR: July 10, 2014)
ASTM International	ASTM F2020 - 02a(2009)	Standard Practice for Design, Construction, and Procurement of Emergency Medical Services Systems Ambulances (adopted 2009)
Commission on Accreditation of Ambulance Services (CAAS)	GVS-2015	Ground Ambulance Vehicle Standard (estimated release January 2015)