Second Draft
Ambulance Patient Compartment Human Factors Design Guidebook

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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 Department of Homeland Security’s (DHS) First Responder Group (FRG) 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 has been supported 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), Carlow International, as well as input from members of the EMS community representing both EMS providers (EMSPs) and manufacturers.

EMSPs perform essential medical care as they stabilize patients at emergency sites and provide treatment en route to medical facilities. High injury and fatality rates among EMSPs\(^1\) underscore the need for crashworthy ambulance design and construction, better patient compartment layouts that allow EMSPs to be seated and restrained while tending to patients, and ergonomic well-designed work spaces that keep EMSPs safe, healthy, comfortable, and productive while they perform their tasks.

Consistent, science-based ambulance standards that will ensure EMSP and patient safety while enhancing EMSP patient care are needed. Standards such as National Fire Protection Association (NFPA) 1917 Standard for Automotive Ambulances, 2013 Edition\(^2\) and the General Services Administration (GSA) KKK-A-1822F Federal Specification for the Star of Life Ambulance\(^3\) as yet lack the desired level of science-based design criteria and best practices that address EMSP safety, health, and performance. To address this need, DHS S&T FRG’s partnership of NIST, NIOSH, D&P, and Carlow International has been performing research to develop standards, guidelines, and best practices for ambulance patient compartments that address crashworthiness, patient safety and comfort, and EMSP safety, health, and performance.

NIOSH is characterizing injury risks associated with ambulances crashes. They are also assessing the crashworthiness 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 will be proposed for inclusion in the 2016 Edition of the National Fire Protection Association (NFPA) 1917 Standard for Automotive Ambulances (NFPA, 2012), as well as published as Society of Automotive Engineers (SAE) International standards.

\(^1\) (Maguire, 2002), (Green et al., 2008), (Reichard et al., 2011), (Maguire, 2013)
\(^2\) (National Fire Protection Association, 2012)
\(^3\) (U.S. General Services Administration, 2007)
NIST, D&P and Carlow International have conducted a multi-year user-centered design process that iteratively developed and refined ambulance patient compartment design requirements and criteria by actively engaging EMSPs and manufacturers. This effort, which is further detailed in Chapter 3.0, User-Centered Design and Evaluation, of the Guidebook, began with user research, which provided an understanding of the nature of EMS work and a list of the needs of EMSPs and organizations as gathered through observations and discussions with users. From this list of needs, design requirements and design criteria were developed and iteratively refined and validated through EMSP reviews. The requirements and criteria were further validated through the development of designs as a proof-of-concept of the application of the design criteria. EMSPs, manufacturers, and other EMS community representatives reviewed the design concepts and the design requirements and criteria were subsequently updated based on their input, leading to a final version of design concepts and criteria.

This process resulted in a comprehensive list of design criteria, best practices, and conceptual design layouts of an ambulance patient compartment that fulfill the needs and requirements of a wide range of Emergency Medical Services Provider Organizations (EMSPOs). Of these requirements and criteria, those that were suitable for standardization were proposed for inclusion in the upcoming version of NFPA 1917.

The Guidebook documents a user-centered design (UCD) design and evaluation process tailored for ambulance patient compartment design and a full list of requirements and criteria. This Guidebook is intended to serve as a tool for the EMS community to enable EMSPOs to design and specify ambulance patient compartments based on its unique user needs that maximize EMSPs performance as well as their personal and patients’ safety and health.

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.

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4 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
# Table of Contents

Forward ......................................................................................................................... iii

Executive Summary ...................................................................................................... iv

1.0 Introduction ............................................................................................................. 1
   1.1 Guidebook Organization ....................................................................................... 1
   1.2 Scope ...................................................................................................................... 2
   1.3 Purpose .................................................................................................................. 2
   1.4 Intended Audience ............................................................................................... 3
   1.5 How to Use the Guidebook .................................................................................. 3

2.0 Human Factors Engineering in Patient Compartment Design ............................... 5
   2.1 General HFE Principles ....................................................................................... 5
   2.2 Human Factors Engineering in Patient Compartment Design .......................... 6
      2.2.1 Objectives of HFE for Patient Compartment Design .................................... 6
      2.2.2 HFE Design Goals in Patient Compartment Design ..................................... 6

3.0 User-Centered Design and Evaluation ................................................................... 8
   3.1 User-Centered Design Process .......................................................................... 8
      3.1.1 Phase 1-Requirements Development ................................................................. 9
      3.1.2 Phase 2-Concept Development and Evaluation ............................................... 12
      3.1.3 Phase 3-Specification Development .................................................................. 14
      3.1.4 Phase 4-Build .................................................................................................... 14
      3.1.5 Phase 4-Deployment ....................................................................................... 15
   3.2 Tailoring of the UCD Process ............................................................................. 15
   3.3 User-Centered Evaluation ................................................................................... 15
      3.3.1 Design Inspection ............................................................................................ 16
      3.3.2 Table Top Walkthrough .................................................................................. 17
      3.3.3 Link Analysis ................................................................................................... 17
      3.3.4 Human Modeling Simulation .......................................................................... 18
      3.3.5 Real Time Task Walkthroughs ....................................................................... 18
   3.4 System-Level Design .......................................................................................... 19

4.0 Seating and Restraints .......................................................................................... 21
   4.1 Reach to Patient ................................................................................................... 21
      4.1.1 Minimum Patient Care Reach ........................................................................ 21
      4.1.2 Optimum Patient Care Reach ....................................................................... 22
   4.2 Facing the Patient ............................................................................................... 22
   4.3 Performing Cardiopulmonary Resuscitation While Restrained .......................... 23
   4.4 Accessing Equipment ......................................................................................... 23
   4.5 Ergonomic Design ............................................................................................... 24
Figure 14. Illustration of Maximum Functional Reach for 5th Percentile Female........................................41
Figure 15. Maximum Lift Heights..................................................................................................................43
Figure 16. Maximum Twisting Motion.............................................................................................................44
Figure 17. Hand Clearance..............................................................................................................................45
Figure 18. Ventilation Requirements for Patient Compartments.................................................................50
Figure 19. Illustration of Maximum Functional Reach for a 5th Percentile Female..........................52
Figure 20. Workstation Overhang Clearance for EMSP Knees.................................................................56
Figure 21. Step Height and Tread Depth.......................................................................................................61
Figure 22. Illustration of Maximum Functional Reach for 5th Percentile Female................................65
Figure 23. Maximum Functional Reach for a 5th Percentile Female............................................................69

Tables

Table 1. Typical UCD Team Members ...........................................................................................................9
Table 2. Definition of User Design Need, Requirement, and Criteria......................................................10
Table 3. Example of a User Design Need, Requirements, and Criteria....................................................10
Table 4. Positive and Negative Pressure Levels Required for Safety......................................................49
Table 5. Intelligibility Criteria for Voice Communication Systems..........................................................64
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 Department of Homeland Security’s (DHS) First Responder Group (FRG) 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.

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

Designing and manufacturing safer, healthier, and more efficient patient compartments is accomplished through the implementation of a user-centered design (UCD) process and the application of human performance and safety based design criteria. The goals of applying a UCD process are to:

a. Ensure that EMSP needs and requirements are identified early in the process.

b. Engage EMSPs throughout the ambulance patient compartment design and build process to provide feedback on the usability and safety of the design and ensure that the design meets their needs and requirements.

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

1.1 Guidebook Organization

The Guidebook is organized into the following Chapters:

2.0 Human Factors Engineering in Patient Compartment Design

3.0 User-Centered Design and Evaluation

4.0 Seating and Restraints

5.0 Equipment and Supplies

6.0 Storage

7.0 Workspace

8.0 Ingress and Egress
1.0 Introduction

9.0 Communications
Definitions and Acronyms
References
Index

Appendix A–UCD Application to Patient Compartment Design
Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

1.2 Scope

The Guidebook includes design criteria and best practices based on human performance research, human factors engineering (HFE) processes and design standards, and EMS community requirements. These criteria and best practices are not meant to be proscriptive but to provide a target for industry to develop ways to achieve them in future design.

The design criteria and best practices included in the Guidebook are focused on advanced life support (ALS) and basic life support (BLS) patient care performed in Type I and III ambulances. While the design criteria and best practices contained in the Guidebook will have to be tailored for application to the design of Type II ambulance, the design processes are directly applicable.

1.3 Purpose

The purpose of the Guidebook is to help EMSPOs design and specify ambulance patient compartments. The application of the contents of the Guidebook will help enable EMSPs to perform their primary patient care tasks and optimize patient outcomes while remaining seated and restrained, thus reducing EMSP and patient injury risk.

The intent of the criteria and best practices contained in the Guidebook is to provide needs, requirements, and design goals that enable the EMS community to develop innovative solutions that meet their organization’s needs.

This Guidebook compliments existing and emerging standards for the design of ambulances, such as National Fire Protection (NFPA) 1917 Standard for Automotive Ambulances, and should be used in conjunction with the most current edition of the standards. In general, these ambulance related standards include some human performance and safety design criteria for patient compartments. The Guidebook provides additional design criteria and promotes best practices that will enable improved usability for, and safety of, the EMSP working in the patient compartment.
1.4 Intended Audience

The intended audience for this Guidebook includes the following:

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

b. EMSPOs that wish to evaluate existing or proposed patient compartment designs in terms of human performance and safety.

c. Manufacturers that want to incorporate human factors engineering design practices and criteria into their ambulance design and construction processes.

1.5 How to Use the Guidebook

The information contained in the Guidebook provides tailored, but not necessarily exhaustive, HFE and ergonomics design criteria and best practices. There are two distinct types of information provided in the Guidebook.

Chapters 2.0 and 3.0, as well as Appendix A, provide guidance on how to implement a HFE and UCD processes for designing an ambulance patient compartment. These are processes and best practices for identifying user requirements and integrating EMSPO input into the design process for ambulance patient compartments.

Chapters 4.0 through 9.0, as well as Appendix B, present detailed design criteria that are based on human performance and safety research and standards. Applying these to the design of a patient compartment will increase the likelihood that the EMSPO will be able to perform patient care safety and successfully. Where appropriate, additional explanatory information is presented in a box for each criterion. An example of a criterion and additional explanatory information is shown below.

7.1.3 Noise

Patient compartment noise levels in moving ambulances should not exceed 75 A-weighted decibels (dBA) and preferably not exceed 65 dBA to ensure successful communication between EMSPOs and the patient. If noise levels exceed 85 dBA, appropriate hearing protection should be provided.

Limiting the noise level protects EMSPOs’ and patients’ hearing from unsafe noise levels, especially from the ambulance siren, and facilitates communication between the patient, EMSPO, and driver.
1.0 Introduction

This Guidebook can be used to aid the EMSP in performing the following:

a. **Designing a new ambulance.** When designing a new ambulance patient compartment, the Guidebook user should review Chapters 2.0 and 3.0 to determine the most appropriate methods and processes to employ to develop the patient compartment design. Chapters 4.0 through 9.0 should be reviewed to identify relevant design criteria. The goal is to use appropriate design methods and criteria to optimize the ability of the EMSP to perform patient care safely while achieving positive patient care outcomes.

b. **Retrofitting an existing ambulance.** When incorporating new technology into, or enhancing the design of, an existing patient compartment, the EMSPO should use the Guidebook as one would in doing 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 EMS safety. A process similar to that in Chapter 3.0 should be employed where design requirements and criteria are identified, design concepts developed and evaluated, and a specification developed using Chapters 4.0 through 9.0 for input that documents the retrofit. Key issues that should be examined include impacts of the retrofit on workflow, EMSP reach to the patient and common and critical equipment and supplies, and the ability of the EMSP to perform patient care safely.

c. **Evaluating a patient compartment design.** When evaluating how well an existing patient compartment design supports the ability of the EMSP to perform their patient care while remaining safe, the Guidebook user should review the design using the criteria contained in Chapters 4.0 through 9.0 to identify strengths and weaknesses of the design. An evaluation process is outlined in Chapter 3.0 Section 3.3.
2.0 Human Factors Engineering in Patient Compartment Design

Human factors engineering (HFE) is a systems engineering discipline that focuses on incorporating human performance and safety considerations into the design of systems like ambulances. It seeks to ensure that humans, such as EMSPs, 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 that human performance 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

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

a. In designing a system, understand:
   - Who the user is, including their capabilities, physiology, training, and motivation;
   - What tasks the user will be performing;
   - What the task performance requirements are such as accuracy, frequency, duration, workload, and decision making;
   - What is the context (e.g., environment) within which they will perform their tasks, including performance shaping factors such as noise, vibration, lighting, physical and emotional stress, comfort, and fatigue.

b. Design for the worst case scenario as well as typical and frequent patient care scenarios.

c. 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. Design the patient compartment within the context of the complete vehicle.

d. Keep the design simple, using only the capabilities and features required for performing the required tasks successfully.

e. Optimize the design by employing a trade-off process between human performance, technology, engineering, and costs.

f. Design to minimize training requirements.

g. Design to reduce the incidence and impact of EMSP errors and to promote human error tolerance.
h. Standardize the design as much as possible.

i. Design to accommodate the full range of physical dimensions of the expected 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.

2.2 Human Factors Engineering in Patient Compartment Design

HFE ensures that the design of the system 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.

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 human 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, which emphasizes integrating EMSPs early in the design process and keeps them involved throughout.

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

2.2.2 HFE Design Goals in Patient Compartment Design

Some HFE design goals that guide the development of ambulance patient compartment from an HFE perspective are as follows:

a. The design of the patient compartment should ensure that EMSPs 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. The design of the patient compartment should minimize the risk of death or serious injury to EMSPs and patients and other passengers of the compartment in the event of an accident or evasive maneuver of the ambulance.
2.0 Human Factors Engineering

c. The patient compartment design should facilitate the safe and effective ingress and egress of EMSPs and patients.

d. The design of workspace and equipment arrangements in the patient compartment should safely and effectively accommodate a range of EMSP body sizes from a 5\textsuperscript{th} percentile female to a 95\textsuperscript{th} percentile male.

e. The interior environment of the patient compartment should be controllable so that it can be maintained at a level that is comfortable for the patient and EMSPs and which facilitates the performance of the EMSPs.

f. Patient compartment layout and equipment arrangements should be designed to enhance patient care by EMSPs.

g. Patient compartment layout and equipment arrangements should be designed to reduce the incidence of ergonomic injury (musculoskeletal disorders including lower back strain, repetitive strain injuries, and cumulative trauma) to EMSPs.

h. The design of the patient compartment should facilitate its cleaning and decontamination after each response.

i. The design of the patient compartment should facilitate communications between the EMSPs, the driver, the patient, and involved third parties, such as the hospital, attending physicians, or other health care personnel.
Human factors engineering (HFE) is integrated into the design of a system, such as an ambulance, through the application of a user-centered design (UCD) and evaluation process. The UCD process is discussed in the following sections.

### 3.1 User-Centered Design Process

The goals of applying UCD are to:

a. Ensure that emergency medical service providers (EMSPs) needs and requirements are identified early in the design process.

b. Engage EMSPs throughout the design and build process 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 design process.

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

The UCD process focuses on early and continuous involvement of the user, in this case EMSPs, and evolves requirements and designs iteratively over the development cycle of a system. There are five basic phases of a UCD process as illustrated in Figure 1.

As Figure 1 illustrates, the UCD process is based on on-going feedback loops to continually refine and enhance requirements, specifications, and designs. These phases are discussed in the following paragraphs. A more detailed discussion of the application of a UCD process to the design of the ambulance patient compartment is provided in Appendix A.

UCD is performed by a multidisciplinary team comprised of representatives of the end user and other relevant stakeholders. Table 1 presents a list of typical members of an ambulance UCD design team and their roles. The mix of team members may
vary, depending on the needs and resources of the Emergency Medical Services Provider Organization (EMSPO), but should always include EMSPs.

Table 1. Typical UCD Team Members

<table>
<thead>
<tr>
<th>Member</th>
<th>Role</th>
<th>UCD Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS Provider (EMSP)</td>
<td>As the core user group, provide user needs and requirements, operational scenarios, design feedback</td>
<td>Phases 1-5</td>
</tr>
<tr>
<td>EMSP Organization (EMSPO) Management</td>
<td>Provide:</td>
<td>Phases 1-5</td>
</tr>
<tr>
<td></td>
<td>• Management and budget oversight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Insights on safety and health considerations for the design, training requirements, specialized equipment, and emergency room and bay design</td>
<td></td>
</tr>
<tr>
<td>Human Factors Engineers</td>
<td>Facilitate requirements development, design and evaluation sessions; help interpret HFE design criteria; provide human performance expertise</td>
<td>Phases 1-4</td>
</tr>
<tr>
<td>Engineering Specialists</td>
<td>Provide specialized engineering input to the design</td>
<td>Phases 1-3</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Provide feedback on the design, including the purchase specification; provide detailed design drawings; build the ambulance</td>
<td>Potentially all phases, depending on the EMSPO procurement strategy. At a minimum, Phases 4 and 5</td>
</tr>
</tbody>
</table>

3.1.1 Phase 1 - Requirements Development

The requirements development phase, in a UCD process, is focused on iteratively identifying and validating user design needs, requirements, and design criteria. Table 2 presents typical definitions for design needs, requirements, and criteria.
3.0 UCD Process

Table 2. Definition of User Design Need, Requirement, and Criteria

<table>
<thead>
<tr>
<th>User Design</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs</td>
<td>High level user performance and safety goals identified by the user.</td>
</tr>
<tr>
<td>Requirements</td>
<td>Functions, capabilities, or support that will satisfy or fulfill the need.</td>
</tr>
<tr>
<td>Criteria</td>
<td>Specific elements of design that support the fulfillment of a design requirement.</td>
</tr>
</tbody>
</table>

An example of an EMSP user need and associated requirements and criteria is presented in Table 3.

Table 3. Example of a User Design Need, Requirements, and Criteria

<table>
<thead>
<tr>
<th>User Design Need</th>
<th>Requirement</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The EMSP is able to provide safe and effective patient care from a seated position in the ambulance patient compartment.</td>
<td>The EMSP is able to reach the patient’s body from head to knee while in a seated position.</td>
<td>Seats and restraints should be designed to allow EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, to reach a restrained patient’s body from the crown of the head to the kneecap with both hands. This includes a male patient who is 95\textsuperscript{th} percentile in stature.</td>
</tr>
<tr>
<td>The EMSP is able to reach the patient’s full body length while in a seated position.</td>
<td>Seats and restraints should preferably be designed to allow EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, to reach a restrained patient’s full body length with both hands. This includes a male patient who is 95\textsuperscript{th} percentile in stature.</td>
<td></td>
</tr>
<tr>
<td>In addition to accessing the full length of the body, the seating should allow the EMSP access to either side of the patient's body from a seated and restrained position.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

User design needs, requirements, and criteria can be determined through the application of a number of methods including, but not limited to:

a. **Task analysis**. Tasks an EMSP has to perform are identified and analyzed to understand what is required to perform them successfully.
3.0 UCD Process

This includes, but is not limited to, information required, decisions that must be made, actions that must be taken, skills and training required, performance and safety risks, and environmental factors.

b. **Focus groups.** EMSPs are brought together in a facilitated group discussion to elicit their opinions and insights.

c. **Feedback from users.** Representative users are interviewed singly or in small groups to elicit their opinions and insights, either formally with interview guides or informally.

d. **Observations of EMSPs performing patient care.** Users are observed performing patient care tasks and scenarios in their normal or simulated work environment.

e. **Surveys.** Users’ opinions, insights, and experiences are collected using questionnaires. These can be through paper forms and/or Internet based forms.

f. **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 user needs and requirements.

g. **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 EMSPOs to understand successes and difficulties that they have had in the past.

Using all or a combination of these techniques, initial user design needs, requirements, and criteria are identified. Chapters 4.0 through 9.0 should be used to help identify needs, requirements, and criteria.

These needs, requirements, and criteria will evolve through this phase as more is understood about the requirements through the application of the methods discussed above and other interactions with the EMS user community. Where a core user group has been established, the requirements development phase can be quicker and more efficient since the EMSPs on that group can easily provide much of the information typically derived from the methods.

A crucial requirement that needs to be identified during this phase is a list of common and critical equipment and supplies. This list includes items that are used frequently during the EMSPO’s typical responses as well as items that are otherwise essential to performing patient care during all types of
responses. Design concepts will be developed to place these items within easy reach of EMSPs.

### 3.1.2 Phase 2-Concept Development and Evaluation

The concept development and evaluation phase is used to explore design concepts that satisfy the requirements and criteria developed in the previous phase, identify and conduct design tradeoffs, and determine the optimum design for the ambulance that will be used for subsequent phases. A design concept is typically a visual representation of the layout of a workspace, workstation, or equipment user interface. It can include hand sketches, 2D computer-aided drawings, and 3D computer models. Figure 2 illustrates an early design concept while Figure 3 illustrates a more detailed design concept. The design concepts should represent the requirements and criteria identified in Phase 1 and incorporate appropriate detailed design criteria from Chapters 4.0 through 9.0 of the Guidebook.

![Figure 2. Illustration of an Early Design Concept](image.png)
Figure 3. Illustration of a More Detailed Design Concept

Initial concepts will be simplified representations of how the design should look and there may be multiple concepts at this early stage. In many cases, the EMSPO may use an existing design as the starting point for concept development.

Through an iterative process of evaluation, the concepts will be pared down to just one while more details are added and the design is refined. Alternative implementations for parts of the concepts can also be explored. These evaluations can take many forms including expert assessments of rudimentary concepts, reviews by groups of users, or computer modeling and simulation (M&S) where a human mannequin is placed in a model to assess ergonomics and work flow. As the concepts are evaluated, UCD team-defined requirements may also be validated, deleted, added, and refined where appropriate.

A key part of this phase is performing design tradeoffs. This tradeoff process tries to balance a number of factors such as:

a. Different design concepts or implementations.

b. Competing technologies, such as one seat design versus another.

c. Human performance considerations or improved functionality versus costs or engineering limitations such as vehicle weight.

d. Feasibility of the design concept based on costs, engineering, and/or technology constraints.
3.0 UCD Process

e. Impact of state regulation required equipment and supplies and storage space availability.

f. Manufacturer’s constraints if they are involved during this phase.

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 is protected during an accident. The 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 that reduce body and head movement during an accident or helmets.

Throughout this phase, representatives of the EMS user population should be involved. In addition, other stakeholders should also participate. These stakeholders might include engineers, trainers, operations staff, maintenance personnel, emergency room personnel, and even patients.

3.1.3 Phase 3-Specification Development

Using the requirements, criteria, and concepts developed in the previous phases, a design specification is developed. The design specification provides detailed and explicit design requirements and criteria drawn from the results of Phases 1 and 2, appropriate standards, and Chapters 4.0 through 9.0 of the Guidebook. It will guide the manufacturer in building the ambulance. It should include detailed drawings where appropriate to convey dimensions and layouts of equipment.

As the specification is developed, it should be reviewed by stakeholders, including EMSPs representing the end users, 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, the EMSPO may elect to complete the specification prior to sending it to manufacturers for bid.

3.1.4 Phase 4-Build

During the build 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 EMSPs, 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 task walkthroughs to explore ergonomic and workflow considerations. The specification should be modified, as required, based on any design changes to ensure that there is a fully documented “as-built” design.

3.1.5 Phase 4-Deployment

Once the ambulance is deployed or placed into service, the EMSPO will likely learn strengths and weaknesses of the design. These should be captured as “lessons learned” to be used for the next ambulance.

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, an EMSPO may not be able to, or need to, follow the full process due to constraints in personnel time, budget, or calendar time. Therefore, the EMSPO will need to tailor the process to meet their constraints. Tailoring might include building off existing EMSP knowledge by applying just a few requirements development methods, doing fewer design concept and evaluation iterations, starting from an existing specification, or starting from a standard manufacturer 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 the 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 EMSPs will already have an understanding of the work environment and issues with existing patient compartment design, many of the methods discussed in Paragraph 3.1.1 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 end users 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

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 EMSP safety. This can be done by both the EMSPO and the manufacturer.
Evaluations can be performed on written specifications, drawings, 3D models, or full scale mockups using the following methods.

### 3.3.1 Design Inspection

Design inspections can be applied to written specifications, drawings, 3D models, or full scale mockups. In a design inspection, experts representing the EMSPO and other key stakeholders review the design and compare it to the appropriate design criteria contained in the Guidebook and other requirements documents. Each element of the design is compared to the corresponding design criteria to determine if it is compliant or not. Where possible and appropriate, physical measures such as reach distance should be measured. A design checklist, which is an abbreviated list of criteria as illustrated in Figure 4, can be used to facilitate this comparison. Elements of the design that are not compliant with the design criteria should be identified and assessed for their potential impact on EMSP performance and EMSP and patient safety.

![Figure 4. Illustration of a Design Checklist](image)
3.3.2 Table Top Walkthrough

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

3.3.3 Link Analysis

A technique called link analysis can also be used to assess drawings or 3D models. A link analysis explores the relationships and connections between elements of the design of the patient compartment by mapping them out as illustrated in Figure 5. A link analysis is conducted by recording the frequency location of EMSPs’ interactions. These interactions include, but are not limited to, the following:

a. Communication between EMSPs in the ambulance and between the ambulance and others.

b. Reach from a seated and restrained position to common and critical equipment and supplies.

c. Movement around the patient compartment by EMSPs.

d. Sequence of patient care steps for each EMSP.

During the link analysis, issues with the design and layout should be identified. These may include issues such as the need to access certain equipment and supplies frequently when it is located too far to reach from a seated and restrained position, or having multiple EMSPs interfering with each other as they perform patient care. Any issues that are identified should be assessed for their potential impact on EMSP performance as well as EMSP and patient safety.
3.3.4 Human Modeling Simulation

Human modeling simulation can be used with 3D 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 3D model where patient care scenarios are performed with mannequins representing EMSPs with body dimensions representing 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\(^1\) was used to evaluate design concepts. Potential issues with human performance and safety should be identified and assessed for their potential impact on EMSP performance as well as EMSP and patient safety.

3.3.5 Real Time Task Walkthroughs

Where there is a full scale mockup of the patient compartment design, or where there are existing manufacturer’s ambulances, real time task walkthroughs can be performed. This might include ambulances built for other EMSPOs by manufacturers. In this method, also called human-in-the-loop simulation, EMSPs 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

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\(^1\) [http://www.plm.automation.siemens.com/en_us/products/tecnomatix/assembly_planning/jack/]
provides observations on issues associated with how the design supports patient care. Issues that can be examined include 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 the EMSP. Issues should be assessed for their potential impact on EMSP performance as well as EMSP and patient safety.

### 3.4 System-Level Design

One of the key tenets of HFE design, as well as the key to successful ambulance patient compartment design in terms of EMSP performance, patient care, and patient and EMSP safety, is ensuring that 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 EMSPs 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. Each of these components should be designed, or acquired, while considering the implications on, and integration with, the other components in the subsystem. Each subsystem should be designed 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 substantial distances to the nearest hospital, may require that the patient compartment accommodate multiple patients and a larger quantity of supply.

b. **Perform system-level design tradeoffs.** When determining system-level functional requirements that describe the high level goals for the total ambulance
system, the impact on any sub-systems or other components must be explored 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 will 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.). Systems integration processes include:

- **Requirements integration and tracking.** Requirements from all components and subsystems need to be cross-referenced, compared, and tracked relative to the other requirements as they change through the design process. Included in the requirements integration and tracking should be a prioritization of each requirement’s contribution to system-level functional requirements in order to facilitate tradeoffs when there are conflicts.

- **Systematic testing.** Typical systems integration testing follows a “bottom up” approach where testing starts with components, then the components are combined into subsystems to assess how they work together, and finally the full system is testing. Throughout all this testing, the human user should be fully involved and test scenarios should be designed to represent realistic conditions.
4.0 Seating and Restraints

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

Considerations for the Seating and Restraints

The challenge faced in designing ambulance seating and restraints is how to ensure that the seats and restraints provide the necessary protection while at the same time allow the EMSP to reach the patient and equipment and supplies in order 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 patients who are infants and children, as well as the needs of any additional riders in the patient compartment.

There are a number of tradeoffs that need to be considered 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 EMSP safety should be the highest priority, the EMSO and/or manufacturer may need to tradeoff the costs of the seats against costs associated with EMSP injury or 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.

c. **Mission.** The longer the typical patient transport, the more critical is it that the seats provide good ergonomic and injury protection to the EMSP. For shorter transports, a lower degree of comfort and adjustability that still maintains safety may be sufficient.

The following paragraphs provide detailed design criteria 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 EMSPs, 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 6. This includes a male patient who is 95th percentile in stature.
4.0 Seating and Restraints

4.1.2 Optimum Patient Care Reach

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

a. Seats and restraints should preferably be designed to allow EMSPs, 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 who is 95th percentile in stature.

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

These guidelines allow EMSPs 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

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

This guideline ensures that the 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

If the EMSP has to perform cardiopulmonary resuscitation (CPR) when the ambulance is in motion, the restraint system has to allow the EMSP to perform it while restrained. A restraint system that allows the EMSP to perform CPR while restrained needs to be used only in conjunction with a seat that protects the EMSP in the event of an accident or evasive maneuver.

Manual CPR requires the EMSP to stand over the patient’s chest in order to perform compressions with adequate force, which places the 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 the EMSP from potential injury and support proper CPR technique for the safety of the patient.

4.4 Accessing Equipment

Seats and restraints should be designed to allow EMSPs 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. Maximum functional reach is defined in the Definitions and Acronyms section. Figure 7 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 the EMSP has 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 7. 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 the diverse EMSP populations. These aspects of ergonomic seat design are illustrated in Figure 8.

a. The seat height should be a maximum of 21 inches (533 mm), measured from the floor or surface where the EMSP will place his or her feet. The seat height should be adjustable in 1 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 should be 18-20 inches (460-510 mm).

e. Both the backrest and headrest should accommodate the range of EMSPs 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).

f. The backrest and seat should be cushioned with at least 1 inch (25 mm) of compressible material for comfort.

A seat that properly supports the full range of EMSPs, 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 the EMSP in the event of an accident or evasive maneuver.
4.0 Seating and Restraints

4.5.2 Restraint Systems

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

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:
   - Seated height range of 32.9-38.8 inches (836-986 mm).
   - Weight range of 129-263 pounds (lbs) (58.5–119.3 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 and/or tactiley 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 criteria to ensure that all EMSPs and other caretakers are restrained while the ambulance is in motion.

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

4.7 Ensure Quick Donning and Doffing of Restraints

The 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.

4.8 Design Seating for Safety

Seating needs to minimize injury to the 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 the 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° throughout the range of the seat rotation to secure the seat when rotated in the event of an accident or evasive maneuver.
4.0 Seating and Restraints

d. The headrest should be contoured to provide energy absorption qualities to minimize whiplash injuries. The headrest should fit the full range of EMSPs 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’s hips and buttocks.

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

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 92.8lbs (42.1 kg)
- 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 EMSPs, 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 section discusses the equipment used by EMSPs 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. Therefore 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 EMSPs and patients. The patient compartment should be designed for easy access to, and 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), will need to be determined by each individual EMS organization based on the type and frequency of calls that the organization performs as well as state and local regulatory requirements.

There are a number of tradeoffs that need to be considered regarding equipment and supplies. These 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. The EMS organization should determine its equipment needs for each type of ambulance in the fleet prior to design 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 the EMSP to access that equipment or those supplies. The EMS organization should determine its list of common and critical equipment and supplies prior to design.

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, which 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, less equipment and supplies may need to be duplicated on the ambulance.

The following paragraphs provide detailed design criteria and best practices for ambulance patient compartment equipment and supplies.
5.0 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, the 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 one EMSP without having to bear the full weight of the cot.

The patient compartment floor height must be low enough to allow EMSPs 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. If a cot loading mechanism is used, it 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, the EMSP.

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

This prevents EMSPs 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 the EMSP to secure the cot with minimal physical effort.

c. A cot loading mechanism should require minimal number of steps to deploy.
5.0 Equipment and Supplies

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, the EMSP.

a. The cot guidance and securing mechanism should incorporate a universal locking and mounting system that is able to secure cots of all models and from all vendors.

| This ensures that all cots can be safely transported and will save costs if switching cot models in the future. It will also ensure that in a multiple ambulance response, cots can be loaded into any of the responding ambulances. |

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).

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

d. The EMSP should be able to engage the guidance and securing mechanism without 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.

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

f. The EMSP should be able to immediately verify, either visually and/or tactiley, if the cot has been properly secured.

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

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 avoid or minimize pressure on sensitive areas, including large blood vessels, nerves, and areas lacking muscular or skeletal protection.

b. The length of the cot restraints should be adjustable to fit all 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)
   - 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.

c. 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.

d. Cot restraints should be designed such that it can be verified visually and/or tactiley that restraints are in place and connected.

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

f. 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 EMSPs to safely access areas of the patient’s body necessary for performing patient care while the patient remains safely restrained.

g. Child cot restraints should fit all male and female child body types from a newborn to a 90th percentile 8 year old, including by not limited to the following representative body dimensions:
5.0 Equipment and Supplies

- Height of 54.8 inches (1392 mm)
- Weight of 92.8lbs (42.1 kg)
- 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

Cots need to ensure that equipment and supplies transported with the cot do not become potential projectiles during an accident or evasive maneuver.

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.
   - 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. An intravenous (IV) pole should be available on the cot to secure IV bags during transport.

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 a charging power cord should be provided for charging.

   This ensures that powered cots can be charged within the patient compartment.
5.0 Equipment and Supplies

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 the 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 EMSPs 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 EMSPs 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 EMSPs to install.

c. The length of the backboard restraints should be adjustable to accommodate 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 111.2-270.3 lbs (50.4-122.6 kg)
- 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° (0.79 radians) from the normal line of sight and within a viewing distance of 28 inches (710 mm) (see Figure 9 below).
5.0 Equipment and Supplies

Figure 9. Orientation of Patent Compartment Displays

b. Equipment that requires EMSP interaction should be located to allow EMSPs, from a 5th percentile female through a 95th percentile male, to reach it with either hand at a maximum functional reach\(^6\) from a seated and restrained position. Figure 10 illustrates a maximum functional reach for a 5th percentile female.

Figure 10. Illustration of Maximum Functional Reach for a 5th Percentile Female

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

d. Equipment that requires EMSP interaction 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.

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\(^6\) See Definitions and Acronyms section
5.3 Labeling and Text Displays

Visible and readable labels and text allow EMSPs 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 the EMSP’s 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 (D) with a minimum character height of .4 inches (10 mm).

   • Character height for critical labels with variable positions (e.g., numerals on dials) can be calculated using the following formula:

     \[ CH = \{0.12'' \leftrightarrow 0.20''\} \times \frac{D}{28''} \text{ or } \{3mm \leftrightarrow 5mm\} \times \frac{D}{710mm} \]

   • Character height for all other labels can be calculated using the following formula:

     \[ CH = \{0.10'' \leftrightarrow 0.20''\} \times \frac{D}{28''} \text{ or } \{2.5mm \leftrightarrow 5mm\} \times \frac{D}{710mm} \]

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., l, 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 11).

![Figure 11. Character Width](image)
5.0 Equipment and Supplies

g. The stroke width of text (see Figure 12) 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 high 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 12. Character Stroke Width](image)

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 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 on the page they are.

5.4 First-In Kits

First-In Kits include the equipment and supplies that are carried out of the ambulance to the patient. EMSPs typically work directly out of these kits to initiate treatment of a
5.0 Equipment and Supplies

patient at the scene and therefore need to be able to locate, access, and use equipment quickly and easily.

a. 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.

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

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

d. First-In Kits should be secured within maximum functional reach\(^7\) of EMSPs, from a 5\(^{th}\) percentile female through a 95\(^{th}\) percentile male, from a restrained position.

First-In-Kits will be accessed frequently and it is ideal to locate them close to the EMSP if possible.

\(^7\) See Definitions and Acronyms section

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

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

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

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

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

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

These design attributes allow the EMSP to easily lift and transport the First-In Kit without putting undue physical stress on the EMSP.

5.5 Reduced Injury Risk

Equipment and supplies must not pose an injury risk to EMSPs 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.

\(^7\) See Definitions and Acronyms section
b. The design of the patient compartment should provide routing such that cords, leads, and tubing, when in use, do not cross any walking paths, present entanglement hazards, or protrude into aisles.

This allows EMSPs to safely traverse the patient compartment safely.

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 EMSPs 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 EMSPs from striking hazards.

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

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

g. 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 the EMSP at risk for injury. It is imperative that the 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.

h. 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.
This section discusses enabling EMSPs to safely store and access 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. A designated storage location with consistent organization and labeling allows EMSPs to locate and retrieve required items quickly and easily. A secure storage location protects EMSPs and patients from potential projectiles in the event of an accident or evasive maneuver. EMSPs need safe access to common and critical equipment and supplies while seated and restrained. They also need safe access to all storage locations, both interior and exterior, while standing in a stationary ambulance. These factors allow EMSPs to quickly and easily locate, access, and retrieve items necessary to perform patient care.

There are a number of tradeoffs that need to be considered regarding storage. These include:

- **Working out of First-In Kits versus on-ambulance storage.** If First-In Kits are used as the primary source for immediate patient care equipment and supplies during transport, then First-In Kit storage will need to be designed to be secured within reach of the primary patient care seat(s). If First-In Kits are not used as the primary source of patient care equipment and supplies during transport, then storage will need to be designed within reach of the primary workstation(s) for immediate patient care items, especially common and critical equipment and supplies.

- **Minimum versus maximum equipment and supplies.** The number of supplies and equipment that the ambulance carries will have a direct impact on the amount and configuration of storage. Deciding to typically carry the minimal amount of supplies and equipment required for patient care will allow for a potentially more efficient compartment layout as well as less weight but will require more frequent resupply and vice versa.

The following paragraphs provide detailed design criteria and best practices for ambulance patient compartment storage areas.

### 6.1 Adequate Storage Space Available

The size and location of interior storage areas needs to be determined 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.

- **Interior storage cabinets, shelves, and/or drawers should have adequate space to store the equipment and supplies designated for that storage location.**
6.0 Storage

b. Interior storage cabinets, shelves, and/or 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 as well as reduce the risk of those items becoming potential projectiles upon opening the storage area.

6.2 Accessibility While Standing

EMSPs 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/or drawers should be within reach of EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, while standing (see Figure 13).

b. The securing mechanism of interior storage cabinets and/or drawers and exterior storage compartments should be within reach of EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, while standing.

c. Standing EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, should be able to retrieve the contents of all interior storage cabinets, shelves, and/or drawers.

Measured from the shoulder blade to the tip of the thumb

Figure 13. Illustration of 5\textsuperscript{th} Percentile Female’s Functional Reach while Standing
d. The lowest cabinets, shelves, and/or drawers should be reachable by EMSPs from a 5th percentile female through a 95th percentile male.

6.3 Accessibility While Seated and Restrained

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

a. Interior storage cabinets, shelves, and/or drawers whose contents include common and critical equipment and supplies should be within maximum functional reach of EMSPs, from a 5th percentile female through a 95th percentile male, while seated and restrained. Figure 14 illustrates a maximum functional reach for a 5th percentile female.

Figure 14. Illustration of Maximum Functional Reach for 5th Percentile Female

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

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8 See Definitions and Acronyms section
6.4 Storage Cabinet Doors and/or 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/or drawers should be operable with one hand.

One-handed operation allows EMSPs 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 doors to open in a way that doesn’t present a striking hazard or hinder patient care activities.

c. There should be a means to keep the interior storage compartment lid, door, or drawer or exterior storage compartment door in an open position while in use.

This enables quick retrieval of items and protects the EMSP from potential injury resulting from a lid, door, or drawer closing on the EMSP’s hand. It also allows EMSPs to quickly and easily restock storage areas without the doors closing.

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. If the storage area contains items that are required to be secured by a lock (e.g., pharmaceuticals), the storage cabinet or drawer locking mechanism should be within maximum functional reach\(^9\) of EMSPs, from a 5\(^{th}\) percentile female through a 95\(^{th}\) percentile male.

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

One-handed operation allows EMSPs 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 EMSPs to quickly and easily locate equipment and supplies.

\(^9\) See Definitions and Acronyms section
6.0 Storage

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

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

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

> Consistency allows EMSPs 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 EMSPs when storing and retrieving items.

a. The design should allow for items greater than 31lb (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 EMSPs from potential lifting injuries.

![Figure 15. Maximum Lift Heights](image-url)
b. If twisting motion is required to store or remove an item, it should be limited to a maximum of 30° left or right of the body centerline.

c. If the body has to twist through more than 15° while lifting an object, the recommended acceptable weight for that lift height (Refer to 6.6.a) should be reduced by 20% (Figure 16). The design should allow for items greater than 24.8lb (11.2 kg) to be stored no higher than 60 inches (1520 mm) from the floor and for items greater than 35.2 lbs (16.0 kg) to be stored no higher than 36 inches (910mm) from the floor.

![Figure 16. Maximum Twisting Motion](image)

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

Maximum twist 15°, without reducing lifting weight

Maximum twist 30°, reduce lifting weights for maximum lifting heights

![Reduced lift heights](image)

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.
6.0 Storage

Figure 17. Hand Clearance

6.7 Labeling and Identification

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

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

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

c. The character height (CH) of text used on labels should be appropriate for the viewing distance (D). The minimum character height is .4 inches (10 mm). Character height can be calculated using the following formula:

\[ CH = \left\{ \frac{.10''}{28''} \times \frac{D}{28''} \right\} \quad \text{or} \quad \left\{ \frac{2.5mm}{710mm} \times \frac{D}{710mm} \right\} \]

d. The characters used on the label should be readable against the background (Refer to Chapter 5.0 Section 5.4).

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

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

Properly sized text and contrasting text and label coloring allow EMSPs to quickly and easily read labels.
6.0 Storage

6.8 Secure Personal Belonging Storage

EMSP and patient personal belongings 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 EMSP's performance or safety.

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

b. EMSP's personal storage space should be lockable to protect belongings from theft.
This section discusses the workspace environment and patient compartment layout that support the 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 EMSPs in a timely, safe, effective, and comfortable manner. EMSPs 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 the EMSP to treat both patients. The patient compartment workspace must not introduce injury risks to EMSPs or patients.

There are a number of tradeoffs that need to be considered regarding workspace. These 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 for the securing of a backboard in the patient compartment and that the EMSP is able to monitor and/or provide care to both patients while remaining safe.

b. **Accessibility versus striking hazards.** The closer an object is to the EMSP's workstation, the easier it is for EMSPs to access the items yet the greater the risk of the object becoming a striking hazard.

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/or secondary workstations in the patient compartment. While additional workstations allow EMSPs to work from more than one location or for multiple EMSPs 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 criteria and best practices for the ambulance patient compartment workspace.

**7.1 Comfortable and Appropriate Working Environment**

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

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 within 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 68° Fahrenheit (F) to 76°F (20° Celsius [C] – 24°C) throughout the patient compartment. These temperature constraints ensure that the patient compartment is maintained in a temperature zone to keep the patient comfortable and not interfere with patient care while supporting the EMSP in working comfortably and safely.

c. The temperature of the air at floor level and at head level at any EMSP position should not differ by more than 10 °F (5.5 °C). A temperature difference of less than 6 °F (3.0 °C) is preferred. Side walls of the compartment should be kept at equal temperatures insofar as possible; however, temperature differences of 20 °F (11 °C) or less do not significantly degrade comfort. Consistent temperatures throughout the patient compartment ensure that the EMSP is 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 EMSPs 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 EMSPs or patients.

e. The HVAC system should be capable of providing and maintaining a relative humidity within a range from 30% minimum to 70% maximum, with 40% to 45% preferred. The temperature/humidity design goal should be between 70°F and 77°F (21°C and 25°C) and 45% humidity.
f. The ventilation system should be capable of maintaining either positive or negative pressure in accordance with the following specifications to keep contaminants out of the ambulance or to keep the ambulance quarantined, dependent on the needs of the EMSPs (see Table 4).

Positive pressure protects EMSPs and patients from outside contaminants entering the patient compartment while negative pressure keeps contaminants in the ambulance from escaping and having negative effects on the public or outside environment.

Table 4. Positive and Negative Pressure Levels Required for Safety

<table>
<thead>
<tr>
<th>Positive Pressure Areas (e.g.; protective environments [PE])</th>
<th>Negative Pressure Areas (e.g., airborne infection isolation [AII])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Differentials</td>
<td>&gt; +2.5 Pascal (Pa) (0.01&quot; water gauge)</td>
</tr>
<tr>
<td>Air Changes per Hour (ACH)</td>
<td>&gt; 12</td>
</tr>
<tr>
<td>Filtration Efficiency</td>
<td>Supply: 99.97% @ 0.3µm Dioctylphthalate particles (DOP) Return: none required *</td>
</tr>
<tr>
<td>Room Airflow Direction</td>
<td>Out of the patient compartment</td>
</tr>
<tr>
<td>Clean-to-Dirty Airflow in Room</td>
<td>Away from the patient (high-risk patient, immunosuppressed patient)</td>
</tr>
<tr>
<td>Ideal Pressure Differential</td>
<td>&gt; +8 Pa</td>
</tr>
</tbody>
</table>

* If the patient requires both PE and AII, return air should be High Efficiency Particulate Air (HEPA) filtered or otherwise exhausted to the outside.
** HEPA filtration of exhaust air from AII rooms should not be required, providing that the exhaust is properly located to prevent re-entry into the building.

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

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

i. If the enclosure volume is 150 cubic feet [ft³] (4.25 cubic meters [m³]) or less per person, a minimum of 30 ft³ (0.85 m³) of ventilation air per minute per person should be introduced into the enclosure; approximately two-thirds should be outdoor air. For larger enclosures, the air supply per person should be in accordance with both curves in Figure 18 below.

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

Figure 18. Ventilation Requirements for Patient Compartments

j. 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 EMSPs or patients is provided. In these cases, air should be moved past personnel at a velocity not more than 200 feet (60m) 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 the 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), preferred 100 fc (1076 lux), 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 allow the 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, 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.

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

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

g. Lights should turn on automatically when the door is opened.

- 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) and preferably not exceed 65 dBA to ensure successful communication between EMSPs and the patient. If noise levels exceed 85 dBA, appropriate hearing protection should be provided.

- Limiting the noise level protects EMSPs’ and patients’ 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 laptop dock or portable radio storage).

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

### 7.2 Equipment Accessibility While Seated and Restrained

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

#### 7.2.1 IV bag Accessibility

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

- The IV bag hook should allow the EMSP to hang an IV bag while seated and restrained.
7.0 Workspace

b. The cot IV pole, if installed, should be within maximum functional reach\textsuperscript{10} of EMSPs, from a 5th percentile female through a 95th percentile male, while seated and restrained. Figure 19 illustrates a maximum functional reach for a 5th percentile female.

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

![Illustration of Maximum Functional Reach for a 5th Percentile Female](image)

**Figure 19. Illustration of Maximum Functional Reach for a 5\textsuperscript{th} Percentile Female**

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

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

d. The flow control should be within maximum functional reach\textsuperscript{11} of EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, while seated and restrained.

e. Metal IV hooks should not be used unless they are recessed. This will eliminate a striking injury hazard.

7.2.2 Oxygen (O\textsubscript{2}) and Suction Port Accessibility

EMSPs need to administer and monitor oxygen (O\textsubscript{2}) and suction without risk of injury.

\textsuperscript{10} See Definitions and Acronyms section
\textsuperscript{11} See Definitions and Acronyms section
7.0 Workspace

a. \( \text{O}_2 \) and suction ports should be located within line of sight of the EMSP such that he/she does not have to reach behind themselves, a structure, and/or any equipment to access the ports.

b. \( \text{O}_2 \) and suction ports should be within maximum functional reach\(^\text{11} \) of EMSPs, from a \( 5^{\text{th}} \) percentile female through a \( 95^{\text{th}} \) percentile male, while seated and restrained.

This allows EMSPs to safely access \( \text{O}_2 \) 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. EMSPs should be provided space within maximum functional reach\(^\text{12} \) of EMSPs, from a \( 5^{\text{th}} \) percentile female through a \( 95^{\text{th}} \) percentile male, for placing equipment and supplies while in use.

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 the EMSP, if possible.

b. Controls should be located within maximum functional reach\(^\text{13} \) of EMSPs, from a \( 5^{\text{th}} \) percentile female through a \( 95^{\text{th}} \) percentile male, while seated and restrained or operable through a remote control stored within this reach envelope.

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

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

d. Controls should be visually and/or tactiley distinct from each other (i.e. can't confuse temperature controls with lights) and designed and arranged such that the probability of using the wrong control is minimized.

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

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\(^{11}\) See Definitions and Acronyms section

\(^{12}\) See Definitions and Acronyms section

\(^{13}\) See Definitions and Acronyms section
e. Redundant controls, such as lighting and HVAC, should be provided at all primary (most frequently used) workstations.

Redundant controls allow EMSPs 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 EMSPs 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.

Consistency allows EMSPs 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.

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

7.4 Maintainability

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

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 EMSPs 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.
7.0 Workspace

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 EMSPs 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 EMSPs to distinguish clean from soiled surfaces.

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

f. Potentially exposed surfaces should be reachable and accessible for sanitization and cleaning.

This protects patients with latex allergies from an adverse reaction.

g. Restraints should be fully exposable for sanitation and cleaning.

This allows the entire seat belt, including portions that retract into the seat or other housing, to be cleaned and sanitized.

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. 15 inches (381 mm) is preferred.

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

This allows EMSPs to traverse around the cot and through the patient compartment without the risk of striking injuries in their path.

c. Objects that pose a potential head strike risk to EMSPs while seated should be padded.

An area around seating that is clear of obstacles, or has padding around obstacles when they cannot be avoided, reduces EMSPs’ risk of injury in the event of an accident or evasive maneuver.
d. Clearance under a workstation overhang, as illustrated in Figure 20, should be at least 25.5 inches (647.7 mm) to accommodate the thighs and knees of a seated 95th percentile male EMSP.

![Minimum overhang height 25"

Figure 20. Workstation Overhang Clearance for EMSP Knees

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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 the EMSP’s back by allowing him or her to stand up straight inside of the patient compartment as well as reduces the risk of the head striking the ceiling.
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f. Ceiling handholds should be recessed and installed over 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 and/or their padding should have a high contrast with background surfaces.

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h. Handholds should have a nonslip surface. Handholds help EMSPs to safely traverse the patient compartment and to help reduce the risk of injury from slips and falls.
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7.0 Workspace

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 EMSPs 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 the EMSP’s body parts, clothing, or gloves.

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

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

7.6 Trash and Sharps Disposal

EMSPs need unobstructed access to trash and sharps disposal from all workstations that does not require reaching over the patient’s body.

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 EMSPs 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 EMSPs from contamination.

e. Containers for contaminated sharps should be easily accessible by EMSPs, 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 EMSPs to dispose of contaminated sharps while remaining safely seated and restrained while limiting the amount of time that EMSPs and other riders are exposed to contaminants.

f. Sharps disposal containers should have warning labels affixed to the container.

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

h. Sharps disposal container labels should be fluorescent orange or 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 EMSPs from accidental contact with the contents of the container and allow EMSPs to quickly and easily identify the proper disposal area for contaminated sharps.

7.7 Second Patient Transport

If the patient compartment is configured to transport a second patient, the design needs to ensure that both patients and the EMSPs remain safe and patient care can be provided.

a. Requirements in Chapters 4.0 – 9.0 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 the 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.
8.0 Ingress and Egress

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

Considerations for Ingress and Egress

EMSPs 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. They should also be usable in various weather conditions and while wearing gloves so that they do not present a safety hazard resulting in injury to the EMSP or further injury to their patient. Ingress and egress paths need to accommodate the anthropometric dimensions of the various EMSPs. In addition to the primary door, a secondary exit ensures that EMSPs and their patients can safely and effectively exit the ambulance in a situation where the primary door is damaged or blocked, prohibiting normal egress.

One tradeoff that needs to be considered regarding ingress and egress is:

a. **Step height versus vehicle clearance.** Lower steps are better for EMSPs 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 raise while the vehicle starts in motion.

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

8.1 Ingress and Egress in Various Weather Conditions

EMSPs 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.

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

This allows all EMSPs, 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.
8.0 Ingress and Egress

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

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

d. Ingress/egress doors should provide positive feedback that the door is secured in the full open or closed position. This will prevent EMSPs from entering or exiting and inadvertently being struck by a moving door.

e. 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.

8.1.2 Steps

Steps need to accommodate safe movement of EMSPs 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 21).

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 21).

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.
8.0 Ingress and Egress

**Figure 21. 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 EMSPs to move closer when loading and unloading a cot.

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

> Open stair treads allow ice to melt thus preventing the risk of slips and falls due to ice buildup.

f. 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 EMSPs 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. Handrails, if used in stairwells, should be placed 34-37 inches (864-940 mm), with 35 inches (889 mm) recommended, above the standing surface and should include an intermediate guardrail on open sides.
8.0 Ingress and Egress

8.1.4 Windows

Windows provide visibility of the area past ingress and egress doors.

a. Windows on egress doors should allow for adequate viewing of the door opening or egress path.

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

b. If a window is vented, it should be equipped with a screen and be lockable.

8.2 Emergency Egress

Egress out of a secondary door (other than the main loading/unloading door) with a patient on a patient transport device 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 EMSPs and a patient loaded on a patient transport device.
This section discusses communication in the patient compartment, a vital part of an EMSPs’ role in providing patient care. Communication systems utilize various methods and technologies to enable EMSPs 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 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. The EMSP in the back of the ambulance must be able to communicate with the ambulance driver. If a patient’s condition worsens, the EMSP may need to ask the driver to expedite the transport to the hospital or stop to allow the patient to be stabilized. If the EMSP must remove his or her 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 or reduce their driving speed. 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 hospital or physician. EMSPs 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 hospital of the patient’s condition so that the hospital medical team can accurately prepare the requisite medical equipment. The more awareness the EMSPs, dispatch, and the hospital 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 the EMSP and the patient.

There are a number of tradeoffs that need to be considered regarding communication. These include:

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, limit freedom of movement if wired, and pose a sanitation concern. Portable communications systems, such as hand radios or cell phones, when in use, limit the EMSP to performing other actions with only one hand.

b. **Existing versus emerging technologies.** Advanced technologies, such as wireless radios or headsets, text-based communication, 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 the EMSP is spending on patient care.

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

9.1 Easily Understood Communication between EMSP, Drivers, Third Parties

Communications between the EMSP in the patient compartment, the driver, the patient, and third parties, such as the hospital, 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 5 below.

**Table 5. Intelligibility Criteria for Voice Communication Systems**

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MRT</td>
</tr>
<tr>
<td>Exceptionally high intelligibility</td>
<td>97%</td>
</tr>
<tr>
<td>Normal acceptable intelligibility</td>
<td>91%</td>
</tr>
<tr>
<td>Minimally acceptable intelligibility</td>
<td>75%</td>
</tr>
</tbody>
</table>

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.

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. The user should have a volume control for adjusting the output level.

The EMSP needs 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.
9.0 Communication

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

A volume minimum prevents the 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\(^{14}\) of EMSPs, from a 5\(^{th}\) percentile female through a 95\(^{th}\) percentile male, from a restrained position. Figure 22 illustrates a maximum functional reach for a 5\(^{th}\) percentile female.

Figure 22. Illustration of Maximum Functional Reach for 5\(^{th}\) Percentile Female

9.3 Facilitation of Effective Patient Care by Communication Devices

Communication systems, when in use, need to allow the 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 EMSPs to operate equipment and controls easily and to do so while keeping one hand free for performing other patient care activities.

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

The EMSP and patient need to easily communicate verbally so that the patient can be monitored and calmed.

\(^{14}\) See Definitions and Acronyms section
9.0 Communication

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

d. EMSPs 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, hospitals, and dispatch.

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

9.4 Notifications from the Driver Compartment

Notifications from the driver compartment alert EMSPs in the patient compartment to any driving hazards that could impact EMSP or patient safety or any additional information received from dispatch or the receiving hospital.

a. Notifications received from the driver should be noticeable by EMSPs.

b. Notifications in the patient compartment should not be distracting to EMSPs.

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

```
Visual notifications that are salient 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.
```
Definitions

**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
- Monitor
- Nasal Cannula
- Trauma Bag

This list may differ between ambulance stations and ambulance mission.

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

**Cot Loading Mechanism** The mechanical component that supports the loading and unloading of cots.

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

**Design Criteria** 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** Commonly called jump bags. Bags and/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 (HFE) A systems engineering process that focuses on incorporating human performance and safety considerations into the design of systems.

Lateral Directed towards the side(s).

Link Analysis An analysis of the relationships and connections between elements of design, mapped out as links between entities. A link analysis depicts the pathways and frequencies of interaction within a diagram of the physical space.

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 Maximum functional reach is measured from the center point of the junction of the seat pan and seat back to the thumbtip where the arm is fully extended parallel to the floor and the torso is leaning forward at a 45° angle. Maximum functional reach is calculated using the following formula, where $F$ = functional reach and $S$ = seat to shoulder sitting height.

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

As an example using anthropometric data from MIL-STD-1472G, the maximum functional reach for a 5th percentile female, illustrated in Figure 23, is calculated using the seat (bottom of buttocks) to shoulder torso length (20.0 inches [508 mm]) leaned forward at a 45° degree angle and a functional reach as measured from the shoulder blade to thumbtip (26.7 inches [677 mm]) for a maximum functional reach of 43.2 inches (1097 mm).

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

**Figure 23. Maximum Functional Reach for a 5th Percentile Female**

**Neutral Seated Position** The seated position where an EMSP is 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° angle. An example of a non-neutral position would be when an EMSP is 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 and/or parts of those structures.

**Primary Workstation** Most frequently used, 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 and/or seat belts, designed to secure all riders (EMS and other passengers) against harmful movement that may result during and accident or evasive maneuver.

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

**Repetitive Strain Injury (RSI)** 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. RSIs 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 (ex. 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.

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 (also called performance shaping factors).

Tipping Hazard  The hazard arising from the possibility of unsecured objects falling over on EMS personnel, patients, and/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 EMSPs perform primary tasks.

### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACH</td>
<td>Air Changes per Hour</td>
</tr>
<tr>
<td>AI</td>
<td>Articulation Index</td>
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<tr>
<td>AII</td>
<td>Airborne Infection Isolation</td>
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<tr>
<td>ALS</td>
<td>Advanced Life Support</td>
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<td>BLS</td>
<td>Basic Life Support</td>
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<td>C</td>
<td>Celsius</td>
</tr>
<tr>
<td>CPR</td>
<td>Cardiopulmonary Resuscitation</td>
</tr>
<tr>
<td>D&amp;P</td>
<td>BMT Designers &amp; Planners</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>dB</td>
<td>Decibel</td>
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<tr>
<td>dBA</td>
<td>A-weighted Decibel</td>
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<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
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<tr>
<td>DOP</td>
<td>Diocylphthalate Particles</td>
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<tr>
<td>EKG</td>
<td>Electrocardiogram</td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
</tr>
<tr>
<td>F</td>
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</tr>
<tr>
<td>FC</td>
<td>Foot-candle</td>
</tr>
<tr>
<td>FMVSS</td>
<td>Federal Motor Vehicle Safety Standards</td>
</tr>
<tr>
<td>Ft³</td>
<td>Cubic Foot</td>
</tr>
<tr>
<td>GSA</td>
<td>General Services Administration</td>
</tr>
<tr>
<td>HEPA</td>
<td>High Efficiency Particulate Air</td>
</tr>
<tr>
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<td>Human Factors Engineering</td>
</tr>
<tr>
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<td>intravenous</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>lb</td>
<td>Pound</td>
</tr>
<tr>
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<td>Meter</td>
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<td>Millimeter</td>
</tr>
<tr>
<td>M&amp;S</td>
<td>Modeling &amp; Simulation</td>
</tr>
<tr>
<td>m³</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>MRT</td>
<td>Modified Rhyme Test</td>
</tr>
<tr>
<td>N</td>
<td>Newton</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Agency</td>
</tr>
<tr>
<td>NIOSH</td>
<td>National Institute of Occupational Safety and Health</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Science and Technology</td>
</tr>
<tr>
<td>O₂</td>
<td>Oxygen</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>Pa</td>
<td>Pascal</td>
</tr>
<tr>
<td>PE</td>
<td>Protective Environments</td>
</tr>
<tr>
<td>RSI</td>
<td>Repetitive Strain Injury</td>
</tr>
<tr>
<td>S&amp;T</td>
<td>Science &amp; Technology</td>
</tr>
<tr>
<td>UCD</td>
<td>User Centered Design</td>
</tr>
</tbody>
</table>


Kibira, D, Lee, Y. T., Marshall, J., Barnard Feeney, A., Avery, L., and Jacobs, A., Simulation-based design concept evaluation for redesigned ambulance patient compartments. (draft)


Index


## Index

<table>
<thead>
<tr>
<th>Accessibility</th>
<th>Cot Height</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common and critical equipment and supplies</td>
<td>Powered</td>
<td>32</td>
</tr>
<tr>
<td>Communication device</td>
<td>Restraints</td>
<td>31</td>
</tr>
<tr>
<td>Equipment and supplies</td>
<td>Secure equipment storage</td>
<td>32</td>
</tr>
<tr>
<td>Seated</td>
<td>Cot guidance and securing</td>
<td>30</td>
</tr>
<tr>
<td>Sharps containers</td>
<td>Cot guidance mechanism</td>
<td>67</td>
</tr>
<tr>
<td>Standing</td>
<td>Force required to secure and release</td>
<td>30</td>
</tr>
<tr>
<td>Storage</td>
<td>Mechanism for proper placement</td>
<td>30</td>
</tr>
<tr>
<td>Advanced life support (ALS)</td>
<td>Universal locking and mounting</td>
<td>30</td>
</tr>
<tr>
<td>Ambulance</td>
<td>Verification if properly secured</td>
<td>30</td>
</tr>
<tr>
<td>Type I</td>
<td>Cot loading</td>
<td>29</td>
</tr>
<tr>
<td>Type II</td>
<td>Cot loading</td>
<td>29</td>
</tr>
<tr>
<td>Type III</td>
<td>Center of gravity</td>
<td>29</td>
</tr>
<tr>
<td>Backboard</td>
<td>Cot loading mechanism</td>
<td>29, 67</td>
</tr>
<tr>
<td>Basic life support (BLS)</td>
<td>Patient compartment floor height</td>
<td>29</td>
</tr>
<tr>
<td>Build phase</td>
<td>CPR</td>
<td></td>
</tr>
<tr>
<td>Cabinets and drawers</td>
<td>Automated</td>
<td>38</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Restraints</td>
<td>23</td>
</tr>
<tr>
<td>Adequate space</td>
<td>Deployment phase</td>
<td>15</td>
</tr>
<tr>
<td>Doors</td>
<td>Design concepts</td>
<td>12, 13</td>
</tr>
<tr>
<td>Sealing</td>
<td>Design criteria</td>
<td>3, 9, 11, 12, 14</td>
</tr>
<tr>
<td>Children</td>
<td>Definition</td>
<td>10, 67</td>
</tr>
<tr>
<td>Restraints</td>
<td>Design tradeoffs</td>
<td>12, 13, 14</td>
</tr>
<tr>
<td>Transport</td>
<td>Display orientation</td>
<td>33</td>
</tr>
<tr>
<td>Color</td>
<td>Doors</td>
<td></td>
</tr>
<tr>
<td>Common and critical equipment and supplies</td>
<td>Handles</td>
<td>60</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Ingress and egress</td>
<td>59</td>
</tr>
<tr>
<td>Adequate space</td>
<td>Operating force</td>
<td>59</td>
</tr>
<tr>
<td>Design concepts</td>
<td>Windows</td>
<td>62</td>
</tr>
<tr>
<td>Design criteria</td>
<td>Emergency egress</td>
<td>62</td>
</tr>
<tr>
<td>Cot loading</td>
<td>Equipment and supplies</td>
<td>28</td>
</tr>
<tr>
<td>Center of gravity</td>
<td>Accessibility</td>
<td>33, 51</td>
</tr>
<tr>
<td>Max functional reach</td>
<td>Consistent design and organization</td>
<td>54</td>
</tr>
<tr>
<td>Cots, leads, and tubing</td>
<td>Consistent stored location</td>
<td>54</td>
</tr>
<tr>
<td>Hangers or supports</td>
<td>Cords, leads, and tubing</td>
<td>38</td>
</tr>
<tr>
<td>Cots, leads, and tubing</td>
<td>Maximum functional reach</td>
<td>34</td>
</tr>
<tr>
<td>Routing</td>
<td>Securing</td>
<td>34, 37</td>
</tr>
<tr>
<td>Cords, leads, and tubing</td>
<td>Ergonomics</td>
<td>3, 6, 13, 24</td>
</tr>
<tr>
<td>First-In Kits</td>
<td>Seating</td>
<td>24</td>
</tr>
<tr>
<td>Maximum functional reach</td>
<td>Maximum functional reach</td>
<td>37</td>
</tr>
<tr>
<td>Seating</td>
<td>Storage</td>
<td>37</td>
</tr>
<tr>
<td>Maximum functional reach</td>
<td>Weight</td>
<td>37</td>
</tr>
<tr>
<td>Maximum functional reach</td>
<td>Flooring</td>
<td>57</td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
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</table>
Index

Functional reach 67
Guidebook
   Designing a new ambulance 4
   Evaluating a patient compartment design 4
How to Use 3
Intended Audience 3
Purpose 2
Retrofitting an existing ambulance 4
Handholds 56, 61
Handrails 61
Human factors engineering 2, 3, 5, 8, 68
   Design goals 6
   Objectives 6
   Principles 5
HVAC 48
   Air discharge direction 48
   Air velocity 49, 50
   Humidity control 48
   Positive or negative pressure 49
   Temperature control 48
   Ventilation 49
Ingress and egress 59
   Door design 59
Interior layout 55
   Head strike obstacles 55
   Height 56
   Object storage 55
   Safety features 57
   Workstation clearance 56
IV bag 51
   Accessibility 51
   Drip chamber visibility 52
   Flow control accessibility 52
Labeling 35
   Character height 35
   Character width 35
   Digital display 36
   Orientation 35
   Reading distance 35
   Sharps containers 58
   Stroke width 36
   Style 36
   Text color 35
Lighting 50
Maintenance 54
Maximum functional reach 23, 34, 37, 41, 52, 53, 65, 68
Modeling and simulation 13
Needs 9, 11
   Definition 10, 67
NFPA 1917 2, 74, 4
   Noise 51
   Oxygen (O₂) accessibility 52
   Power receptacles 51
   Requirements 9, 11, 12, 13, 14
      Definition 10, 67
   Requirements development phase 9
      Methods 10
   Restraints 21, 25
      Accessing equipment 23
      Adjustability 25
      Anthropometrics 25
      Children 27
      Cot 31
      CPR 23
      Donning and doffing 26
      Facing the patient 22
      Minimum patient care reach 21
      Optimum patient care reach 22
      Verification of connection 25
      Rounded exposed edges 57
Seating 21, 26, 57
   Accessing equipment 23
   Backrest 24
   Cushioning 24
   Ergonomics 24
   Facing the patient 22
   Headrest 27
   Minimum patient care reach 21
   Optimum patient care reach 22
   Rotating 26
   Seat height 24, 69
   Seat pan 24, 70
   Seat pan molding 27
   Securing infants and children 27
   Stationary 26
   Transport of additional passengers 27
   Second patient transporting 58
   Sharps disposal 57
   Specification development phase 14
   Steps 60
   Storage 39
      Accessibility, Seated and restrained 41
      Accessibility, standing 40
      Adequate space 39
      Cabinet doors and drawers 42
      Hand clearance 44
      Labeling 45
      Lifting height 43, 44
      Organization 42
      Personal 46
      76
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction accessibility</td>
<td>52</td>
</tr>
<tr>
<td>System-level design</td>
<td>19</td>
</tr>
<tr>
<td>Design tradeoffs</td>
<td>12, 13, 19</td>
</tr>
<tr>
<td>Functional requirements</td>
<td>19</td>
</tr>
<tr>
<td>Systems integration processes</td>
<td>20</td>
</tr>
<tr>
<td>Trash disposal</td>
<td>57</td>
</tr>
<tr>
<td>User-centered design</td>
<td>1, 8</td>
</tr>
<tr>
<td>Core user group</td>
<td>8, 11</td>
</tr>
<tr>
<td>Design team</td>
<td>8</td>
</tr>
<tr>
<td>Design tradeoffs</td>
<td>12, 13</td>
</tr>
<tr>
<td>Goals</td>
<td>8</td>
</tr>
<tr>
<td>Process</td>
<td>3, 8</td>
</tr>
<tr>
<td>Process phases</td>
<td>8</td>
</tr>
<tr>
<td>Requirements development</td>
<td>9</td>
</tr>
<tr>
<td>Tailoring the process</td>
<td>15</td>
</tr>
<tr>
<td>User-centered evaluation</td>
<td>15</td>
</tr>
<tr>
<td>Methods</td>
<td>16</td>
</tr>
<tr>
<td>Windows</td>
<td>62</td>
</tr>
<tr>
<td>Workspace</td>
<td>47, 53</td>
</tr>
<tr>
<td>Maximum functional reach</td>
<td>53</td>
</tr>
<tr>
<td>Workstation</td>
<td>47</td>
</tr>
<tr>
<td>Overhang clearance</td>
<td>56</td>
</tr>
<tr>
<td>Primary</td>
<td>69</td>
</tr>
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</table>
Chapter 3 presented the user centered design (UCD) and evaluation processes, which are the application of human factors engineering to design, from a high level perspective. This appendix will provide a more detailed discussion of the UCD process as applied to the design and building of an ambulance and how the Guidebook can be used in this process. Figure A-1 illustrates the ambulance UCD process, which is described in more detail in Sections A-1.2 through A-1.7. This process is flexible and can be tailored to each ambulance design effort.

A-1.1 Design Drivers

The following are basic drivers for design that will have a significant influence on the design of the ambulance and how the UCD process and Guidebook are applied. Decisions associated with these design drivers should be finalized prior to the design effort.

A-1.1.1 Manufacturer or EMS Provider Organization

Different users of this Guidebook may focus on different sections of the Guidebook and may approach patient compartment design differently.

Manufacturers may focus less on developing requirements and will instead evaluate how well their standard models currently meet the requirements in this Guidebook, how they want to modify their offerings to be compliant with the Guidebook, and how they might integrate UCD methods into their design practices. Their methods for understanding end user requirements and working with the customer should embrace UCD practices.
EMS provider organizations (EMSPOs) may want to evaluate their current fleet using the Guidebook as well as analyze what aspects of their current or past ambulances have worked and what have not worked and why. Understanding current issues will help to determine design needs for a future ambulance as well as retrofits to existing ambulances. EMSPOs should also implement a UCD design process that engages their EMS providers (EMSPs) throughout the process to understand EMSPs’ unique requirements that are not otherwise addressed. For example, a location with a large elderly population may have a greater need to accommodate patients’ walkers, wheelchairs, or oxygen tanks, whereas this may be a lesser need in a college town.

A-1.1.2 Mission

The intended missions of the ambulance will influence the tasks to be performed inside of the patient compartment and what equipment and resources are needed to perform those tasks.

Ambulances used for Advanced Life Support (ALS) or Basic Life Support (BLS) patient care require a variety of equipment and supplies. ALS ambulances typically need seating for more EMSPs or other first responders. They may also need more space for equipment and supplies, requiring a Type I or III ambulance.

Ambulances used for inter-facility patient transport only, where fewer patient interactions are required, may require less equipment and supplies be stocked since transported patients are typically stable and therefore require only one EMSP in the patient compartment to monitor the patient. Since less space and equipment are required to care for the patient, a smaller ambulance may be better suited for transport only missions. However, transport time can range from short trips, such as from a hospital to a rehab facility, to very long trips, such as transporting a patient between hospitals, which may influence the storage requirements as well as the comfort of EMSP seating.

A-1.1.3 Distance to Hospital

The typical length of transport from the patient’s pickup location to the hospital will affect the extent of the care to be performed in the patient compartment.

Areas that are closer to a hospital, such as urban environments, typically have shorter transport times. Due to the shorter amount of time available to provide patient care, less equipment and supplies or fewer pieces of specialty equipment may be needed.
Appendix A–UCD Application to Patient Compartment Design

Areas that are not within close proximity to a hospital, such as rural environments, typically have longer transport times. Due to the longer amount of time that the patient will be receiving care in the patient compartment, more equipment and supplies and/or more complex or specialty equipment may be needed. This additional equipment may be considered common and critical and therefore should be within EMSPs’ maximum functional reach from their workstations. EMSPs may need to be able to access and treat two patients while remaining seated and restrained if a second ambulance is not able to respond in a timely manner to a call with multiple patients. EMSPs that typically run calls with longer transport times may need seats that have a higher degree of adjustability in order for the seat to remain comfortable and to be ergonomically supportive during longer periods of sitting.

A-1.2 Develop Design Plan

In order to apply a UCD process to patient compartment design, the user of this Guidebook should first develop a patient compartment design plan. 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, as well as the design drivers discussed in Section A-1.1. This plan should include an identification of the objectives of the design effort, a schedule for applying the design process, and any potential barriers or risks that will need to be managed.

The plan should also identify a group of representative users who will be involved in the design process from start to finish, often called a “core user group.” This group will be instrumental in developing and evaluating the requirements and design concepts. This group of users should include EMSPs and other first responders that 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.

The plan should describe the UCD methods to be used (listed in section 3.1.1) that are most appropriate to the time, funding, and manpower available to the design effort, as well as expected complexity of the effort. Interviews or focus groups with the selected group of users and observations of patient care are simple and highly effective methods for determining user needs and are recommended as a basis for the requirements development phase (section A-1.3). Observations of EMSPs performing patient care scenarios during a ride along or in a static ambulance with a human patient training simulator, if available, are also highly informative and recommended for this process but may not be necessary if the group defining the requirements includes EMSPs.

15 See Definitions and Acronyms section
A-1.3 Phase 1—Requirements and Criteria Development Phase

The requirements and criteria development phase should start with a review of the requirements and criteria contained in this Guidebook in Chapters 4.0 – 9.0. These criteria are common to all Type I and III style ambulance patient compartments and many will also apply to Type II ambulances. The Guidebook user should review the criteria contained in this Guidebook to determine which, if any, are not applicable to the operations of that EMSPO and expected mission of the ambulance. For example, the requirement to have an IV bag hook within reach of a seated and restrained EMSP may not be relevant for an EMSPO that has a policy to prep IV bags before a call. Those requirements and criteria from the Guidebook that are relevant will form the basis for the initial EMS organizations requirements list.

This initial requirements list should be validated, enhanced, and finalized using the process illustrated in Figure A-2.

![Figure A-2. Process for Developing Requirements](image)

This process relies heavily on the involvement of EMSP end users for the ambulance. This involvement should include the core user group but also, at specific intervals, additional potential users of, and stakeholders in, the ambulance to ensure inclusiveness of all ideas and validate the core user group’s perspective. Methods that can be used for involving the user include interviews, patient care task performance observations, and focus groups. For larger EMSPOs, questionnaires can be administered to elicit input from a wide group of users. As an example, the following methods were employed to iteratively develop the requirements and criteria contained in this Guidebook:

a. Focus groups composed of EMSPs and manufacturers conducted at an EMS conference.

b. Interviews of EMSPs conducted at EMS conferences and in their station houses.
Appendix A—UCD Application to Patient Compartment Design

d. A web-based survey that surveyed the opinions of EMSPs across the country.
e. Review and validation of needs, requirements, and criteria by a core user group.
f. A workshop conducted at an EMS conference to prioritize requirements.

New requirements beyond those included in the Guidebook will typically be evolved through the definition of needs, requirements, and criteria.

A-1.3.1 User Needs Definition

Needs are defined as “high level user performance and safety goals identified by the user community.” For example, during the development of the Guidebook, the needs presented in Table A-1 were identified. These needs evolved over the course of the Guidebook development process through iterative interaction with EMSPs as well as during Phase 2—Concept Development and Evaluation.

Table A-1. Ambulance Design Needs Identified in the Development of the Guidebook

<table>
<thead>
<tr>
<th>Need</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to provide safe and effective patient care from a seated and restrained position in the ambulance patient compartment.</td>
<td>Patient compartments are able to accommodate more than one passenger.</td>
</tr>
<tr>
<td>Patient compartments are able to accommodate more than one passenger.</td>
<td>Cots and cot locking mechanisms are designed to allow the EMSP to safely and effectively treat the patient.</td>
</tr>
<tr>
<td>Equipment is designed to allow the EMSP to safely and effectively treat the patient.</td>
<td>Equipment and patient compartment design allows EMSPs to safely and readily access secured first-in kits while providing patient care.</td>
</tr>
<tr>
<td>Equipment and patient compartment design allows EMSPs to safely and readily access secured first-in kits while providing patient care.</td>
<td>Storage supports the ability of the EMSP to safely and effectively perform patient care.</td>
</tr>
<tr>
<td>Storage supports the ability of the EMSP to safely and effectively perform patient care.</td>
<td>Ability of EMSPs to perform inventory management.</td>
</tr>
<tr>
<td>Ability of EMSPs to perform inventory management.</td>
<td>Ability to stow personal equipment/belongings.</td>
</tr>
<tr>
<td>Ability to stow personal equipment/belongings.</td>
<td>Workspace supports the ability of the EMSP to safely and effectively perform patient care.</td>
</tr>
<tr>
<td>Workspace supports the ability of the EMSP to safely and effectively perform patient care.</td>
<td>Ambulance needs to be easily maintainable.</td>
</tr>
<tr>
<td>Ambulance needs to be easily maintainable.</td>
<td>The patient compartment includes safety measures to reduce hazard risks.</td>
</tr>
<tr>
<td>The patient compartment includes safety measures to reduce hazard risks.</td>
<td>Provide sufficient sharps and trash disposal.</td>
</tr>
<tr>
<td>Provide sufficient sharps and trash disposal.</td>
<td>Ability to transport more than one patient.</td>
</tr>
<tr>
<td>Ability to transport more than one patient.</td>
<td>Ability to quickly and safely ingress/egress the ambulance patient compartment.</td>
</tr>
<tr>
<td>Ability to quickly and safely ingress/egress the ambulance patient compartment.</td>
<td>Ability to communicate efficiently and effectively between the patient compartment, the driver, patient, and others.</td>
</tr>
<tr>
<td>Ability to communicate efficiently and effectively between the patient compartment, the driver, patient, and others.</td>
<td>EMSP awareness of driver intentions and actions.</td>
</tr>
</tbody>
</table>

A-1.3.2 Requirements Decomposition

Identified needs should be decomposed into requirements, where a requirement is defined as the “functions, capabilities, or support that will satisfy or fulfill the need.” This decomposition should be done by the core user group taking the need, which is a goal end state, and determining at a
high level how to achieve that need. An example of the requirements decomposed from a need is provided in Table A-2.

As requirements are defined, the Guidebook user should review and revise, if necessary, the needs. Additionally, any state, local, or other organizational requirements should be identified in this step and incorporated into the list of requirements.

Table A-2. Example of a Need Decomposed into Requirements

<table>
<thead>
<tr>
<th>Need</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>EMSPs are able to provide safe and effective patient care while in a restrained position within the ambulance patient compartment.</td>
<td>The EMSP is able to quickly put on and take off a restraint system (includes all restraints and seat belts).</td>
</tr>
<tr>
<td></td>
<td>The restraint system (includes all restraints and seat belts) incorporates ergonomic/anthropometric design to minimize risk of injury and support safe and comfortable use by the diverse EMSP populations.</td>
</tr>
<tr>
<td></td>
<td>Each working position is equipped with its own restraint system (includes all restraints and seat belts).</td>
</tr>
<tr>
<td></td>
<td>The restraint system allows the EMSP to perform CPR while restrained.</td>
</tr>
</tbody>
</table>

A-1.3.3 Criteria Definition

The list of requirements will need to be decomposed into design criteria where a design criterion is defined as “specific elements of design that support the fulfillment of a design requirement.” This is done by taking the requirement and determining the details of how the requirement can be achieved through the design of the patient compartment. Criteria are specific and, to the extent possible, measureable attributes that describe all aspects of design that together satisfy the requirement and meet the overarching need. An example of the criteria associated with a requirement is presented in Error! Reference source not found..esign of a patient compartment.
Appendix A–UCD Application to Patient Compartment Design

<table>
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<tr>
<th>Requirement</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>The EMS provider is able to quickly put on and take off a restraint system.</td>
<td>The restraint system’s fastening mechanism should require minimal steps to operate.</td>
</tr>
<tr>
<td></td>
<td>The restraint system’s unfastening mechanism should require only one motion or click to operate.</td>
</tr>
<tr>
<td></td>
<td>The restraint system’s unfastening mechanism should be operable with only one hand.</td>
</tr>
</tbody>
</table>

As criteria are defined, the Guidebook user should review and revise, if necessary, the requirements and needs.

Chapters 4.0 through 9.0 of this Guidebook provide design criteria and Appendix B presents a table of issues, requirements, and criteria that were used to develop the Guidebook and that can be used for the design of a patient compartment.

Throughout the entire design requirements and criteria development process, representative users and other relevant stakeholders should remain engaged and review the developed needs, requirements, and criteria. The feedback from these reviews should be used to improve and validate the design requirements and criteria, which will be used to develop design concepts.

A-1.4 Phase 2-Concept Development and Evaluation Phase

The purpose of this phase is to use the requirements and criteria 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 criteria. During this phase, tradeoffs will be performed to determine the ideal implementation of the criteria, and to narrow down design options into one finalized design concept. Figure A-3 illustrates the concept development process.
Concept development is an iterative process, with each iteration providing better definition of, and details on, the patient compartment design.

**A-1.4.1 Develop and Assess Initial Concepts**

The first step is to develop a visualization of basic layout concepts for the patient compartment. These will most likely be hand-drawn sketches but can be computerized drawings as well. The core user group should review these low-level design concepts for compliance with the design criteria defined in the previous phase, as well as to identify any criteria that are incompatible with the design goals and assess feasibility of implementation. For example, during the development of the Guidebook, several initial concepts were developed and assessed with the design team selecting one to move forward. Figure A-4 illustrates these initial concepts with the third concept pictured being selected for more detailed design.
A-1.4.2 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 should be developed. These more detailed design concepts should be used to explore tradeoffs in one implementation versus another in order to determine which concepts best meet the criteria and what, if any, constraints exist with the concepts. These tradeoffs should compare types and brands of equipment as well as different design concepts. The tradeoff process should also ensure that the design concept selected complies with not only the design criteria but also meets any other constraints such as financial limitations and technical incompatibilities.

Where possible, easy to use drawing tools such as Google SketchUp© can be used to provide low fidelity 3D models for better visualization and assessment of the design concepts. As the concept(s) are refined, the requirements and criteria should also be refined as required. Figure A-5 presents a refined design concept from the Guidebook development process.

Figure A-5. Illustration of a Refined Design Concept
A-1.4.3 Concept Modeling and Evaluation

Using the refined concepts, more detailed models should be developed and evaluated. These models should have as much detail on the size and location of storage, workspace, seating, and other elements as possible given the time, funding, and technology available to the Guidebook user. It is recommended to use a Computer Aided Design (CAD) program, such as Google SketchUp©, to determine feasibility of the layout and to investigate various implementations of the design criteria. The more realistic the design concepts, the better able the Guidebook user will be to assess the usefulness and feasibility of the concepts, as well as their adherence to the design criteria. These detailed concepts should be evaluated through reviews by the super user group, measurements to ensure compliance with the design criteria, visual design walkthroughs of the modeled spaces, and human modeling & simulation, to the extent possible. Some of the issues that should be explored include reach distances, workflow, integration of the patient compartment with the chassis components such as wheel wells, external compartments, and the driver compartment.

For the Guidebook development, the team used both Google SketchUp© and Jack to develop and evaluate detailed design concepts. Jack (http://www.plm.automation.siemens.com/en_us/products/tecnomatix/assembly_planning/jack/index.shtml) is a modeling and simulation program that allows one to place a human mannequin in a work environment to assess ergonomics and workflow. Figure A-6 illustrates a Jack model.

![Figure A-6. Illustration of a Jack Model for Assessing Reach in a Design Concept](image-url)
Evaluations of the concepts by the user group should continue until one ideal design concept is chosen that is best able to incorporate all of the design requirements and criteria while minimizing design complexity and stays within any cost or manufacturing constraints. This final design concept should include either drawn or written details about the size, layout, function, and materials of as many elements of the patient compartment as possible in order to facilitate the creation of a build specification.

**A-1.4.4 Finalize the Design Concept**

Based on the results of the modeling and evaluation, the concept for the ambulance patient compartment design should be finalized along with the requirements and criteria. These will be used for the next phase. Figure A-7 presents a final design concept from the Guidebook development.

![Figure A-7. Illustration of a Final Design Concept](image)

**A-1.5 Phase 3-Specification Development**

The next phase in the patient compartment design process is to develop an ambulance build specification from the selected design concept and the design requirements and criteria. This should specify the design of the patient compartment in as much detail as possible and be integrated in with the full vehicle specification. During this integration, any remaining incompatibilities between the patient
compartment and the rest of the ambulance should be evaluated and any changes that need to be made should be reviewed for compliance with the design criteria. Changes to the requirements and concept should be documented. The specification should be reviewed to ensure compliance with Federal Motor Vehicle Safety Standards (FMVSS). The specification should be at a level of detail that will allow a manufacturer to fully understand what to build and estimate the costs for building the vehicle. Where the manufacturer has already been selected, feedback on the design specification should be elicited.

A-1.6 Phase 4–Build

The build phase is conducted by a manufacturer that is selected by the EMS organization, either before, during, or after specification development as described above. This manufacturer will use the build specification to manufacture the ambulance.

Once build specifications are finalized and a manufacturer is selected, that manufacturer will create a series of drawings and models. The EMSPO should review these drawings and models with the manufacturer to ensure compliance with the design concept and the design criteria and any time and cost constraints. The selected user group should conduct a final visual walkthrough of the patient compartment design and submit a final acceptance of the design. Once the EMSPO approves the manufacturer’s drawings and models, the manufacturer will develop blueprints and engineering drawings.

Next, the manufacturer will produce a build order that includes all details of the ambulance (upholstery color, etc.). The EMSPO should review the build order for compliance to their design needs. Additionally, the EMSPO may choose to conduct inspections during the build process to stay engaged with the manufacturer. Throughout the build process the EMSPO or the manufacturer may initiate changes. These changes should be evaluated to ensure compliance with design needs and the specification, design concept, and criteria should be updated.

A-1.7 Phase 5 – Deployment

During use of the completed ambulance, EMSPs and other users of the ambulance patient compartment should be asked to document any noticed benefits from the design, any issues with the design, and any suggestions for future ambulance builds. This “lessons learned” documentation will be used to refine the requirements and criteria for future ambulance designs as well as modifications to the existing design.
Appendix B - Patient Compartment Needs, Requirements, and Criteria
### Categories

<table>
<thead>
<tr>
<th>Categories</th>
<th>Needs</th>
<th>Requirements</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seating &amp; Restraints</td>
<td>The EMSP is able to provide safe and effective patient care from a seated and restrained position in the ambulance patient compartment.</td>
<td>The EMSP is able to reach the patient’s body from head to knee while in a seated and restrained position.</td>
<td>Seats and restraints should be designed to allow EMSPs, 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 a male patient who is 95th percentile in stature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The EMSP is able to reach the patient’s full body length while in a seated and restrained position.</td>
<td>Seats and restraints should preferably be designed to allow EMSPs, 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 who is 95th percentile in stature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In addition to accessing the full length of the body, the seating should allow the EMSP access to either side of the patient's body from a seated and restrained position.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The EMSP is able to face and interact with the patient while in a seated and restrained position.</td>
<td>The EMSP should be able to face and interact with the patient while seated and restrained.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The restraint system allows the EMSP to perform CPR while restrained.</td>
<td>The restraint system should allow the EMSP to perform CPR while restrained when the ambulance is in motion. A restraint system that allows the EMSP to perform CPR while restrained should be used only in conjunction with a seat that protects the EMSP in the event of an accident or evasive maneuver.</td>
</tr>
<tr>
<td>Categories</td>
<td>Needs</td>
<td>Requirements</td>
<td>Criteria</td>
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</tr>
<tr>
<td></td>
<td>The EMSP is able to reach common and critical equipment and supplies from a seated and restrained position.</td>
<td>Seats and restraints should be designed to allow EMSPs 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.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seating incorporates best practices in ergonomic/anthropometric design to support safe and comfortable use by the diverse EMSP populations.</td>
<td>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 1 inch (25mm) increments from 15 inches-21 inches (381mm-533mm).</td>
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<td></td>
<td>The seat pan width should be a minimum of 18 inches (460mm).</td>
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<td>The seat pan depth should be a maximum of 15.9 inches (405mm).</td>
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<tr>
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<td></td>
<td>A supporting backrest with lumbar support should be provided for each seat. The preferable width should be 18 inches-20 inches (460mm – 510mm).</td>
<td>Both the backrest and headrest should accommodate the range of EMSPs from a 5th percentile female through a 95th percentile male with seated heights (seat to top of head) between 32.9 inches (836mm) and 38.8 inches (986mm).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The backrest and seat should be cushioned with at least 1 inch (25mm) of compressible material for comfort.</td>
</tr>
</tbody>
</table>
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

<table>
<thead>
<tr>
<th>Categories</th>
<th>Needs</th>
<th>Requirements</th>
<th>Criteria</th>
</tr>
</thead>
</table>
|            | The restraint system (includes all restraints and seat belts) incorporates ergonomic/anthropometric design to minimize risk of injury and support safe and comfortable use by the diverse EMSPs populations. | Restraints should fit all body types of a 5th percentile female through a 95th percentile male, including but not limited to the following representative body dimensions:  
- Seated height range of 32.9 inches (836mm) – 38.8 inches (986mm)  
- Weight range of 129 pounds (lbs) (58.5 kilograms [kg]) – 263lbs (119.3kg)  
- Waist circumference range of 38 inches (965mm) – 56 inches (1422mm). | The restraint system should be adjustable to prevent pressure on the throat or other sensitive areas to accommodate from a 5th percentile female through a 95th percentile male. |
|            | Restraints should be designed such that it can be verified visually and/or tactiley that restraints are in place and connected. | Restraints should be designed to ensure that once secured, the passenger will remain restrained. | |
|            | Each working position is equipped with its own restraint system (includes all restraints and seat belts). | Each working position should be equipped with its own restraint system that meets all other restraint criteria to ensure that all EMSPs and other caretakers or riders are restrained while the ambulance is in motion. | |
|            | The EMSP is able to quickly put on and take off a restraint system (includes all restraints and seat belts). | The restraint system's fastening mechanism should require minimal steps to operate. | The restraint system's unfastening mechanism should require only one motion or click to operate. |
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

<table>
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<tbody>
<tr>
<td></td>
<td>The seating minimizes injury to the EMSP in all working positions from the forces and energy imparted during an accident or evasive maneuver.</td>
<td>Seats should have resilient material under the cushion to absorb shocks.</td>
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</tr>
<tr>
<td></td>
<td>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.</td>
<td>Seats that rotate should have a locking detent at a minimum of every 45° throughout the range of the seat rotation to secure the seat when rotated in the event of an accident or evasive maneuver.</td>
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<tr>
<td></td>
<td>The headrest should be contoured to provide energy absorption qualities to minimize whiplash injuries. The headrest should fit the full range of EMSPs from a 5th percentile female through a 95th percentile male with seated heights between 32.9 inches (836mm) and 38.8 inches (986mm), taking into account any headsets or helmets that may be worn by EMSPs.</td>
<td>Seats should be designed so that the seat pan is molded to reduce the likelihood of side slippage of the EMSP hips and buttocks during transport or accidents.</td>
<td>Seat design should not hinder ingress and egress paths while loading or unloading a patient.</td>
</tr>
</tbody>
</table>
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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| Patient compartments      | are able to accommodate more than one passenger.                       | Seats should be capable of securing children of any age for transport.         | 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 (1392mm)  
  - Weight of up to 92.8lbs (42.1kg)  
  - Waist circumference of up to 31.9 inches (810mm)  
  The child seat restraints 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 |
|                           |                                                                        |                                                                               | Child car seats, if used, should be compliant with state car seat laws.                                                               |
| Riders other than the     | other than the primary EMSPs have a seat with a restraint system (includes all restraints and seat belts) that incorporates ergonomic/anthropometric design to minimize risk of injury and support safe and comfortable use by the diverse rider populations. |                                                                               | The ambulance design should incorporate seats and restraints for all riders, including those other than the primary EMSPs, that are based on an ergonomic and anthropometric design to minimize risk of injury and support safe and comfortable use by diverse rider populations. |
|                           | primary EMSPs                                                          |                                                                               |                                                                               |
| Equipment and Supplies    | Cots and cot locking mechanisms are designed to allow the EMSP to safely and effectively treat the patient. | Cot allows for loading and unloading without risking injury to the EMSP.        | The center of gravity of the cot should be low to reduce the risk of a tipping hazard during loading and unloading.                        |
## Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<tbody>
<tr>
<td></td>
<td></td>
<td>The floor height and design of the patient compartment should allow for the cot to be inserted into the compartment by one EMSP without having to bear the full weight of the cot.</td>
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<tr>
<td></td>
<td></td>
<td>Ingress and egress doors and paths should be designed for safe patient loading on a cot or other patient loading device. If a cot loading mechanism is used, it should be compatible with rear doors and steps.</td>
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</tr>
<tr>
<td></td>
<td>The cot loading mechanism, if used, allows the patient to be loaded safely to minimize the risk of injury to the patient or EMSP.</td>
<td>A cot loading mechanism should allow use only if all of its parts are in the proper position. The EMSP should be able to immediately verify that the cot loading mechanism is in the proper configuration for use.</td>
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<td></td>
<td></td>
<td>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.</td>
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<td></td>
<td>A cot loading mechanism should require minimal steps to deploy.</td>
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<td></td>
<td>The cot loading mechanism should not sag or flex during cot loading or unloading.</td>
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<td></td>
<td>The cot loading mechanism should be free of pinch points and sharp projections or edges.</td>
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</tr>
<tr>
<td></td>
<td>The cot guidance and securing mechanism is compatible with all cots.</td>
<td>The cot guidance and securing mechanism should incorporate a universal locking and mounting system that is able to secure cots of all models and from all vendors.</td>
<td></td>
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</table>
## Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<tr>
<td></td>
<td>The cot guidance and securing mechanism allows for the cot to be safely secured and released.</td>
<td>The cot guidance and securing mechanism should be free of pinch points and sharp projections or edges.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The cot allows for the patient to be comfortably restrained on the cot.</td>
<td>The cot guidance and securing mechanism should facilitate proper placement of the cot such that the cot can be guided in and locked in one motion.</td>
<td>The cot guidance and securing mechanism should be able to accommodate specialty (e.g. bariatric) cots.</td>
</tr>
<tr>
<td></td>
<td>The cot guidance and securing mechanism should be free of pinch points and sharp projections or edges.</td>
<td>The force required to secure and to release the cot from the cot securing mechanism should be no greater than 23 Newtons (N).</td>
<td>The cot restraint system should avoid or minimize pressure on sensitive areas, including large blood vessels, nerves, and areas lacking muscular or skeletal protection.</td>
</tr>
<tr>
<td></td>
<td>The cot restraint system should avoid or minimize pressure on sensitive areas, including large blood vessels, nerves, and areas lacking muscular or skeletal protection.</td>
<td>The EMSP should be able to engage the guidance and securing mechanism without lateral (side to side) movement of the cot.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The cot restraint system should avoid or minimize pressure on sensitive areas, including large blood vessels, nerves, and areas lacking muscular or skeletal protection.</td>
<td>The EMSP should be able to immediately verify, either visually and/or tactically, if the cot has been properly secured.</td>
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</table>
## Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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|            |       | The length of the cot restraints should be adjustable to fit all body types from a 5th percentile female through a 95th percentile male, including but not limited to the following representative body dimensions:  
  - Height range of 59.3 inches (1506mm)-74.3 inches (1887mm)  
  - Weight range of 111.2lbs (50.4kg)-270.3lbs (122.6kg)  
  - Waist circumference range of 28.3 inches (719mm)-50.3 inches (1278mm). | Cot allows for the patient to be securely restrained on the cot. | The cot design should allow for additional restraints to be installed. |
|            |       | Cot restraints should be designed such that it can be verified visually and/or tactiley that restraints are in place and connected. | Cot restraints should be designed to ensure that once secured, the patient will remain restrained. |
|            | Child cot restraints should fit all male and female child body types from a newborn to a 90th percentile 8 year old, including by not limited to the following representative body dimensions:  
  - Height of 54.8 inches (1392mm)  
  - Weight of 92.8lbs (42.1kg)  
  - Waist circumference of 31.9 inches (810mm). | Cots are capable of securing children of any age for transport. | |
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<tr>
<td></td>
<td>All equipment required to be carried with the cot and patient is securely stored on cot.</td>
<td>Secure storage should be available on the cot for equipment that may be carried on the cot, such as:  - A portable oxygen tank.  - The monitor.  - The laptop (if used).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If an ambulance carries a powered cot, the powered cot or its battery can be charged in the ambulance.</td>
<td>The powered cot or battery should have a dedicated storage and charging system within the patient compartment.</td>
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</tr>
<tr>
<td></td>
<td>Cot allows for the EMSP to perform patient care while seated and restrained.</td>
<td>The height of the cot should be adjustable up to 29.9 inches (759mm) above the floor.</td>
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</tr>
<tr>
<td></td>
<td>Equipment is designed to allow the EMSP to safely and effectively treat the patient.</td>
<td>Backboard allows for quick and safe securing and transport of the patient.</td>
<td>The backboard should have handholds located around its full perimeter for stability when transporting a patient.</td>
</tr>
<tr>
<td></td>
<td>An IV pole should be available on the cot to secure IV bags during transport.</td>
<td></td>
<td>Restraints used to secure the patient to the backboard should require no more than two EMSPs to install.</td>
</tr>
<tr>
<td>Categories</td>
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<tr>
<td></td>
<td>The length of the backboard restraints should be adjustable to accommodate a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, including but not limited to the following representative body dimensions:</td>
<td>The length of the backboard restraints should be adjustable to accommodate a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, including but not limited to the following representative body dimensions:</td>
<td>The length of the backboard restraints should be adjustable to accommodate a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, including but not limited to the following representative body dimensions:</td>
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<td>· Height range of 59.3 inches (1506mm)-74.3 inches (1887mm)</td>
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<td></td>
<td>· Waist circumference range of 28.3 inches (719mm)-50.3 inches (1278mm).</td>
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<td>· Waist circumference range of 28.3 inches (719mm)-50.3 inches (1278mm).</td>
</tr>
<tr>
<td></td>
<td>The cot patient restraints do not hinder the ability of the EMSP to provide safe and effective patient care.</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Placement of equipment that requires EMSP interaction should allow EMSPs to complete this interaction while seated and restrained.</td>
<td>Frequently used display faces (e.g., patient monitor) should be perpendicular to the user's normal line of sight, not less than 45° (0.79 radians) from the normal line of sight, and within a viewing distance of 28 inches (710mm).</td>
<td>Frequently used display faces (e.g., patient monitor) should be perpendicular to the user's normal line of sight, not less than 45° (0.79 radians) from the normal line of sight, and within a viewing distance of 28 inches (710mm).</td>
</tr>
<tr>
<td></td>
<td>Equipment that requires EMSP interaction should be located to allow EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, to reach it with either hand at a maximum functional reach from a seated and restrained position.</td>
<td>Equipment should not be secured so that it precludes physical or visual access to common and critical equipment and supplies or their storage locations.</td>
<td>Equipment should not be secured so that it precludes physical or visual access to common and critical equipment and supplies or their storage locations.</td>
</tr>
</tbody>
</table>
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<td></td>
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<td></td>
<td>Equipment that requires EMSP interaction should be secured or mounted with the equipment controls accessible to EMSP while in a normal restrained working position.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Equipment securing mechanisms should not impede use of that equipment by obscuring equipment controls, openings, or other critical areas of the equipment.</td>
</tr>
<tr>
<td></td>
<td>Equipment and control labels are easily identifiable and readable.</td>
<td>Labels should be oriented horizontally and read left to right.</td>
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<td></td>
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<td></td>
<td>Labels should not be located where a user's normal hand or arm position will obscure the label or where the label obscures any other information.</td>
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<td></td>
<td></td>
<td></td>
<td>Labels should be easy to read accurately from the operational reading distances and in the anticipated vibration, motion, and illumination environments.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Text should be written with black characters on a light background.</td>
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<tr>
<td>Categories</td>
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<td>Criteria</td>
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</tbody>
</table>
|            |       | The character height (CH) of text should be appropriate for the viewing distance (D) with a minimum character height of .4 inches (10mm). Character height for critical labels with variable positions (e.g., numerals on dials) can be calculated using the following formula: CH = \{0.12"±0.20"\} \times \frac{D}{20} \text{ or } \{3mm ± 5mm\} \times \frac{D}{70mm}
|            |       | Character height for all other labels can be calculated using the following formula: CH = \{0.10"±0.20"\} \times \frac{D}{20} \text{ or } \{2.5mm ± 5mm\} \times \frac{D}{70mm}
|            |       | 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. |
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<td></td>
<td>The stroke width of text should meet the following: 1) 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. 2) For transilluminated characters (backlit), the stroke width should be 0.1 of the height. 3) The stroke width ratios should apply regardless of how high 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.</td>
<td>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”).</td>
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<tr>
<td></td>
<td></td>
<td>For text on a digital display or monitor, variable length lines should be avoided by use of hyphenation of words at line breaks to improve readability on small screens.</td>
<td>For digitally displayed text, scrolling markers should be provided when content cannot be displayed in one screen to enable users to identify where on the page they are.</td>
</tr>
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<tr>
<td></td>
<td>When being used for patient care, the placement of secured First-in-Kits allows EMSPs to quickly and safely access them.</td>
<td>First-In Kits should be able to be opened and closed quickly.</td>
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<td></td>
<td></td>
<td>First-In Kits should remain closed once closed.</td>
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<tr>
<td></td>
<td></td>
<td>First-In Kits should be secured within maximum functional reach of EMSPs, from a 5th percentile female through a 95th percentile male, from a restrained position.</td>
<td></td>
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<tr>
<td></td>
<td>First-In Kit allows the EMSP to access supplies and equipment.</td>
<td>The interior compartments of the First-In Kits should allow EMSPs to organize and identify the location of different supplies and equipment.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>First-In Kit allows EMSPs to quickly transport them to and from the patient care scene and the patient compartment while minimizing their risk of injury.</td>
<td>First-In Kits should be lightweight and optimally no more than 25 pounds (11.3kg) when fully loaded.</td>
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<td>First-In Kits should be packed with the weight of its contents evenly distributed throughout the kit.</td>
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<td>The handles of the First-In Kits should be located to evenly distribute the weight of the kit and its contents.</td>
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<tr>
<td></td>
<td></td>
<td>The handles of the First-In Kits should be accessible while the bag is in use and in storage.</td>
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<td></td>
<td>The location of equipment while in use in the patient compartment does not introduce additional risks to EMSP and patient safety.</td>
<td>The design of the patient compartment should allow for cord routing such that cords, leads, and tubing do not cross any walking paths, present entanglement hazards, or protrude into aisles.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The EMSP is able to perform CPR with minimal risk of injury to the patient and him/herself.</td>
<td>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.</td>
<td>All hangers or supports for equipment, lighting, controls, and other devices should be mounted as flush as possible with the surrounding surface.</td>
</tr>
<tr>
<td></td>
<td>Equipment stored outside of a cabinet that is required for patient care is secured such that it does not become a hazard to the EMSP or patient.</td>
<td>An automated CPR device, if available, should allow the EMSP to remain seated and restrained after setting up the device.</td>
<td>Sufficient secure storage space should be provided for the automated CPR device, if device is used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If an automated CPR device is not available, the restraint system should allow for proper CPR technique.</td>
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<tr>
<td></td>
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<td></td>
<td>Securing and unsecuring equipment should require minimal steps.</td>
</tr>
</tbody>
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<td>Storage</td>
<td>Storage supports the ability of the EMSP to safely and effectively perform patient care.</td>
<td>Interior storage cabinets, shelves, and/or drawers and exterior storage compartments provide adequate storage space for all required equipment and supplies.</td>
<td>Interior storage cabinets, shelves, and/or drawers should have adequate space to store the equipment and supplies designated for that storage location.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interior storage cabinets, shelves, and/or drawers should have adequate space to store the equipment and supplies designated for that storage location.</td>
<td>Interior storage cabinets, shelves, and/or drawers and exterior storage compartments should be designed to preclude movement of contents due to vehicle motion or vibration.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interior storage cabinets, shelves, and/or drawers are accessible while standing.</td>
<td>Interior storage cabinets, shelves, and/or drawers should be within reach of EMSPs, from a 5th percentile female through a 95th percentile male, while standing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The securing mechanism of interior storage cabinets and/or drawers and exterior storage compartments should be within reach of EMSPs, from a 5th percentile female through a 95th percentile male, while standing.</td>
<td>Standing EMSPs, from a 5th percentile female through a 95th percentile male, should be able to retrieve the contents of all interior storage cabinets, shelves, and/or drawers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The lowest cabinets, shelves, and/or drawers should be reachable by EMSPs from a 5th percentile female through a 95th percentile male.</td>
<td>The lowest cabinets, shelves, and/or drawers should be reachable by EMSPs from a 5th percentile female through a 95th percentile male.</td>
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<tr>
<td></td>
<td>Interior storage cabinets, shelves, and/or drawers whose contents include common and critical equipment and supplies are accessible while seated and restrained.</td>
<td>Interior storage cabinets, shelves, and/or drawers whose contents include common and critical equipment and supplies should be within maximum functional reach of EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, while seated and restrained.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The securing mechanism of interior storage cabinets and/or drawers whose contents include common and critical equipment and supplies should be within maximum functional reach of EMSPs, from a 5\textsuperscript{th} percentile female through a 95\textsuperscript{th} percentile male, while seated and restrained.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interior storage cabinet, shelf, and/or drawer or exterior storage compartments remain closed and latched while in transit unless opened by an EMSP.</td>
<td>The securing mechanism of interior storage cabinets and/or drawers should be operable with one hand.</td>
<td></td>
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<td></td>
<td></td>
<td>Interior storage cabinet doors should not intrude on working space.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>There should be a means to keep the interior storage compartment lid, door, or drawer or exterior storage compartment door in an open position while in use.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

<table>
<thead>
<tr>
<th>Categories</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>If required, a lockable storage cabinet and/or drawer are provided.</td>
<td>If the storage area contains items that are required to be secured by a lock (e.g., pharmaceuticals), the storage cabinet or drawer locking mechanism should be within maximum functional reach of EMSPs, from a 5th percentile female through a 95th percentile male.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If required, the locking mechanism should be operable with one hand.</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Where possible, the storage of equipment and supplies is consistent across same purpose ambulances within a given fleet.</td>
<td>Interior storage cabinets, shelves, and/or drawers should not be obscured by other equipment or structures.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The location and arrangement of storage cabinet, shelves, and/or drawers should be as consistent as possible across same purpose ambulances within a given ambulance fleet.</td>
<td>The location and arrangement of items within storage cabinets, shelves, and/or drawers should be consistent across same purpose ambulances within a given ambulance fleet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment is stored to minimize the risk of injury when stowing or unstowing.</td>
<td>The design should allow for items greater than 31lb (14kg) to be stored no higher than 60 inches (1520mm) from the floor and for items greater than 44lbs (20kg) to be stored no higher than 36 inches (910mm) from the floor.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>If twisting motion is required to store or remove an item, it should be limited to a maximum of 30° left or right of the body centerline.</td>
<td></td>
</tr>
</tbody>
</table>
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<tr>
<td></td>
<td>If the body has to twist through more than 15° while lifting an object, the recommended acceptable weight for that lift height should be reduced by 20%. The design should allow for items greater than 24.8lb (11.2kg) to be stored no higher than 60inches (1520mm) from the floor and for items greater than 35.2lbs (16.0kg) to be stored no higher than 36 inches (910mm) from the floor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage should be designed with hand clearance in mind, with a recommended 5.9 inches (150mm) clearance for items that require a two-handed grip.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interior storage cabinet or drawer or exterior storage compartment handles should not pose a risk of injury, especially for the finger.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMSPs need the ability to perform inventory management.</td>
<td>EMSPs are able to easily determine the content of interior storage cabinets, shelves, or drawers.</td>
<td>Interior storage cabinets, shelves, and/or drawers should be labeled with the contents.</td>
<td></td>
</tr>
<tr>
<td>EMSPs are able to easily determine the content of interior storage cabinets, shelves, or drawers.</td>
<td></td>
<td>Labels should be visible when the storage compartment door is closed.</td>
<td></td>
</tr>
</tbody>
</table>
| The character height (CH) of text used on labels should be appropriate for the viewing distance (D) with a minimum character height of .4 inches (10mm). | The character height (CH) of text used on labels should be appropriate for the viewing distance (D) with a minimum character height of .4 inches (10mm). | \[
\text{CH} = \frac{D}{2.8} \quad \text{or} \quad \frac{D}{7.10}\text{mm}
\] | |

Character height can be calculated using the following formula:

\[
\text{CH} = \{.10^{"} \leftrightarrow .20^{"}\} \times \frac{D}{2.8} \quad \text{or} \quad \{2.5\text{mm} \leftrightarrow 5\text{mm}\} \times \frac{D}{7.10\text{mm}}
\]
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ability to stow personal equipment/belongings.</td>
<td>Patient compartment design allows for patients’ belongings (walkers, etc.) to be secured without compromising EMS performance and safety.</td>
<td>The characters used on the label should be readable against the background.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Personal belongings should be secured in a location where the contents are not exposed to pathogens or compromise EMSP's performance or safety.</td>
</tr>
<tr>
<td>Workspace</td>
<td>Workspace supports the ability of the EMSP to safely and effectively perform patient care.</td>
<td>A secured space is provided to accommodate EMSP's personal belongings without compromising EMSP performance and safety.</td>
<td>EMSP's personal storage space should be lockable to protect belongings from theft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HVAC system maintains a comfortable and appropriate environment.</td>
<td>The heating and air conditioning systems should have the capacity to reestablish the set temperature within 30 minutes of closing the patient compartment doors.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The heating and air conditioning systems should provide controls to maintain a temperature in the range of 68°F Fahrenheit (F) to 76°F (20°C – 24°C) throughout the patient compartment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The temperature of the air at floor level and at head level at any EMSP position should not differ by more than 10 °F (5.5 °C). A temperature difference of less than 6 °F (3.0 °C) is preferred. Side walls of the compartment should be kept at equal temperatures insofar as possible; however, temperature differences of 20 °F (11 °C) or less do not significantly degrade comfort.</td>
</tr>
</tbody>
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### Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<tr>
<td></td>
<td></td>
<td>Cooling and heating air should be designed such that cool or hot air discharge is not directed on EMSPs or patients, with the option to direct air discharge onto patients if deemed medically necessary.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The HVAC system should be capable of providing and maintaining a relative humidity within a range from 30% minimum to 70% maximum, with 40% to 45% preferred. The temperature/humidity design goal should be between 70°F and 77°F (21°C and 25°C) and 45% humidity.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B—Patient Compartment Needs, Requirements, and Criteria Matrix

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<tbody>
<tr>
<td></td>
<td></td>
<td>The ventilation system should be capable of maintaining either positive or negative pressure in accordance with the following specifications to keep contaminants out of the ambulance or to keep the ambulance quarantined, dependent on the needs of the EMSPs.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positive Pressure Areas (e.g.; protective environments [PE])</th>
<th>Negative Pressure Areas (e.g., airborne infection isolation [AII])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Differentials</td>
<td></td>
</tr>
<tr>
<td>&gt; +2.5 Pascal (Pa) (0.01&quot; water gauge)</td>
<td>&gt; -2.5 Pa (0.01&quot; water gauge)</td>
</tr>
<tr>
<td>Air Changes per Hour (ACH)</td>
<td></td>
</tr>
<tr>
<td>&gt; 12</td>
<td>&gt; 12 (for renovation or new construction)</td>
</tr>
<tr>
<td>Filtration Efficiency</td>
<td></td>
</tr>
<tr>
<td>Supply: 99.97% @ 0.3µm Dioctylphthalate particles (DOP)</td>
<td>Supply: 90% (dust spot test)</td>
</tr>
<tr>
<td>Return: none required *</td>
<td>Return: 99.97% @ 0.3µm (DOP)**</td>
</tr>
<tr>
<td>Room Airflow Direction</td>
<td></td>
</tr>
<tr>
<td>Out of the patient compartment</td>
<td>In to the patient compartment</td>
</tr>
<tr>
<td>Clean-to-Dirty Airflow in Room</td>
<td></td>
</tr>
<tr>
<td>Away from the patient (high-risk patient, immunosuppressed patient)</td>
<td>Towards the patient (airborne disease patient)</td>
</tr>
<tr>
<td>Ideal Pressure Differential</td>
<td></td>
</tr>
<tr>
<td>&gt; +8 Pa</td>
<td>&gt; -2.5 Pa</td>
</tr>
</tbody>
</table>

Adequate ventilation should be assured by introducing outside air into any personnel enclosure.

Air vents should be located where they will not be obscured by interior storage cabinet doors, other equipment storage, or EMSPs.
<table>
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<tr>
<td></td>
<td></td>
<td>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; approximately two-thirds should be outdoor air. For larger enclosures, the air supply per person should be in accordance with both curves on the figure below.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air velocities should not exceed 100 feet (30m) per minute at any measured position in the space. An exception would be in locations where spot cooling of EMSPs or patients is provided. In these cases, air should be moved past personnel at a velocity not more than 200 feet (60m) per minute. Where manuals or loose papers are used, air velocity past these items should be not more than 65 feet (20m) per minute, to preclude pages in manuals from being turned by the air or papers from being blown off work surfaces.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lighting system provides appropriate illumination to support task performance.</td>
<td>Lighting system should be able to fully illuminate all patient care areas at a minimum of 75 foot-candles (fc) (807 lux), preferred 100fc (1076 lux), as measured at the work surface or 29.5 inches (750mm) below the light.</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

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<tr>
<td></td>
<td></td>
<td>Once set, the lighting system should maintain consistent lighting levels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The lighting system should include the capability to dim the lights.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lighting should not cause a change in the patient's perceived skin color.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overhead lights should be recessed to eliminate a striking hazard.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lighting controls should be available adjacent to each entry door as well as at each EMSP workstation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lights should turn on automatically when the door is opened.</td>
</tr>
<tr>
<td></td>
<td>Noise levels do not interfere with safety or task performance.</td>
<td>Patient compartment noise levels in moving ambulances should not exceed 75 A-weighted decibels (dBA) and preferably not exceed 65 dBA to ensure successful communication between EMSPs and the patient. If noise levels exceed 85 dBA, appropriate hearing protection should be provided.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power receptacles (outlets) in the patient compartment meet the needs of the EMSP with respect to powering equipment or recharging batteries during patient care and transport.</td>
</tr>
<tr>
<td></td>
<td>Power receptacles should be located near open counterpace or equipment that requires power (such as near laptop dock or portable radio storage).</td>
<td></td>
</tr>
<tr>
<td>Categories</td>
<td>Needs</td>
<td>Requirements</td>
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</tr>
<tr>
<td></td>
<td>IV bags, while being administered, can be secured within visual and physical reach of the restrained EMSP while not introducing risks to the safety of the patient or EMSP.</td>
<td>The IV bag hook should allow the EMSP to hang an IV bag while seated and restrained.</td>
</tr>
<tr>
<td></td>
<td>The cot IV pole, if installed during transport, should be within maximum functional reach of EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, while seated and restrained.</td>
<td>The bag and drip chamber should be visible from a seated and restrained position.</td>
</tr>
<tr>
<td></td>
<td>The flow control should be within maximum functional reach of EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, while seated and restrained.</td>
<td>Metal IV hooks should not be used, which will eliminate a striking injury hazard.</td>
</tr>
<tr>
<td></td>
<td>O&lt;sub&gt;2&lt;/sub&gt; and suction port allows for the restrained EMSP to readily access and use O&lt;sub&gt;2&lt;/sub&gt; and suction for patient care while not introducing risks to the safety of the patient or EMSP.</td>
<td>O&lt;sub&gt;2&lt;/sub&gt; and suction ports should be located within line of sight of the EMSP such that he/she does not have to reach behind themselves, a structure, and/or any equipment to access the ports.</td>
</tr>
<tr>
<td></td>
<td>O&lt;sub&gt;2&lt;/sub&gt; and suction ports should be within maximum functional reach of EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, while seated and restrained.</td>
<td></td>
</tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Workspace provides appropriate space to allow the EMSP to securely and safely place and use equipment and supplies.</td>
<td>EMSPs should be provided space within maximum functional reach of EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, for placing equipment and supplies while in use.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment and controls are operable by the EMSP while seated and restrained.</td>
<td>Controls should be located within maximum functional reach of EMSPs, from a 5&lt;sup&gt;th&lt;/sup&gt; percentile female through a 95&lt;sup&gt;th&lt;/sup&gt; percentile male, while seated and restrained or operable through a remote control stored within this reach envelope.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment and controls should be operable by one hand.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls should be visually and/or tactiley distinct from each other (i.e. can't confuse temperature controls with lights) and designed and arranged such that the probability of using the wrong control is minimized.</td>
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</tr>
<tr>
<td></td>
<td>Redundant equipment controls such as lighting and HVAC should be provided at all primary (most frequently used) workstations.</td>
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</tr>
<tr>
<td></td>
<td>Patient compartment controls should remain operable when subjected to extreme temperatures, vibration, mechanical shock, dust and dirt contamination, electromagnetic and electrostatic interference, and moisture.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls and equipment storage are consistent across same purpose ambulances within a given fleet.</td>
<td>The location of controls should be consistent across same purpose ambulances within a given fleet.</td>
<td></td>
</tr>
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<tr>
<td></td>
<td></td>
<td>The size and shape of controls should be consistent across same purpose ambulances within a given fleet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The stored location of equipment and supplies should be consistent across same purpose ambulances within a given fleet.</td>
<td></td>
</tr>
<tr>
<td>Ambulance needs to be easily maintainable.</td>
<td>Consumable supplies (e.g. light bulbs, filters) should be quickly identifiable to allow for the quick replacement of these items.</td>
<td>The numbers, types, and complexity of tools required for maintenance should be minimized.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The interior of the patient compartment and its contents can be sanitized and cleaned.</td>
<td>All surfaces, edges, corners and joints that can be exposed to any fluid should be sealed by a liquid proof bonding material.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface materials and their color should allow EMSPs to distinguish clean from soiled surfaces.</td>
<td></td>
</tr>
</tbody>
</table>
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<tr>
<td></td>
<td>Potentially exposed surfaces should be reachable and accessible for sanitization and cleaning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restraints can be sanitized and cleaned.</td>
<td>Restraints should be fully exposable for sanitization and cleaning.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interior patient compartment allows EMSPs to safely and effectively treat patients.</td>
<td>Pathways are clear of obstacles.</td>
<td>No objects should be stored or located within a minimum of 12 inches (305mm) around a standard size cot and ingress/egress doors. 15 inches (381mm) is preferred.</td>
</tr>
<tr>
<td></td>
<td>There should be no head strike obstacles in movement pathways or around the cot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Objects that pose a potential head strike risk to EMSPs while seated should be padded.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clearance under a workstation overhang should be at least 25 inches (635mm) to accommodate the thighs and knees of a seated 95th percentile male EMSP.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patient compartment ergonomically supports task performance.</td>
<td>Interior height of the patient compartment should be at least 76 inches (1930mm) to accommodate a 95th percentile male standing in boots.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The patient compartment includes safety measures to reduce hazard risks.</td>
<td>Patient compartments aid the EMSP in moving around the space safely.</td>
<td>Ceiling handholds should be recessed and installed over and run the full length of each walking path in the patient compartment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Handholds and their padding should have a high contrast with background surfaces.</td>
</tr>
<tr>
<td>Categories</td>
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</tr>
<tr>
<td></td>
<td>Handholds should have a nonslip surface.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td>Exposed edges that could come in contact with an occupant’s body during normal use should be rounded.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The patient compartment should be designed without small crevices, cracks, protrusions, or other structures which may trap or catch the EMSP’s body parts, clothing, or gloves.</td>
<td>If seats can rotate or otherwise move, the workspace should allow EMSPs to access equipment and supplies necessary for patient care from multiple orientations of that seat.</td>
<td></td>
</tr>
<tr>
<td>Provide sufficient sharps and trash disposal.</td>
<td>Disposal containers are secure.</td>
<td>Wall mounted trash or sharps disposal containers should remain attached to the wall in the event of an accident or evasive maneuver.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disposal containers are accessible from a restrained position.</td>
<td>Disposal of trash and sharps into disposal containers should require only one hand.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disposal container and its securing system minimize the risk of exposure.</td>
<td>Securing mechanism for sharps and trash disposal containers should allow for containers to be removed and emptied without the use of tools.</td>
<td></td>
</tr>
<tr>
<td>Categories</td>
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<td>Requirements</td>
<td>Criteria</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Contaminated sharps should be discarded in containers that are closable, puncture resistant, leak-proof on sides and bottom, and maintained upright throughout use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Containers for contaminated sharps should be easily accessible by EMSPs, 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.</td>
</tr>
<tr>
<td></td>
<td>Sharps container labels are secure and identifiable.</td>
<td>Sharps containers should have warning labels affixed to the container.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sharps container labels should include the biohazard legend.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sharps container labels should be fluorescent orange or orange-red or predominantly so, with lettering and symbols in a contrasting color.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than one patient can be transported.</td>
<td>When required by state or other regulations or desired, a second patient can be transported.</td>
<td>Requirements that address patient access and patient care should be met for both patients.</td>
</tr>
<tr>
<td></td>
<td>Common and critical equipment and supplies should be accessible from the primary workstation when a second patient is being transported.</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Requirements</td>
<td>Criteria</td>
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<tr>
<td>Ingress &amp; Egress</td>
<td>Ability to quickly and safely ingress/egress the ambulance patient compartment.</td>
<td>Individuals are able to safely ingress and egress the ambulance patient compartment in dry, wet, and wintry weather conditions.</td>
<td>All egress doors should have a failsafe method of opening the door and should not be lockable in a way that precludes egress.</td>
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<td>Doors should require 44 to 133 N (10 to 30 pounds of force) of operating force to open.</td>
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<td></td>
<td>Door handles should accommodate hand sizes ranging from 5(^{th}) percentile female to 95(^{th}) percentile male represented by the following body dimensions:</td>
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<td></td>
<td>• Hand length (6.5-8.3 inches [165-211mm])</td>
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<td></td>
<td></td>
<td>• Hand breadth (2.7-3.9 inches [69-98mm])</td>
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<td></td>
<td></td>
<td>• Circumference (6.6-9.0 inches [168-229mm])</td>
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<td></td>
<td></td>
<td></td>
<td>• Palm length (3.5-4.6 inches [90-117mm])</td>
</tr>
<tr>
<td>Categories</td>
<td>Needs</td>
<td>Requirements</td>
<td>Criteria</td>
</tr>
<tr>
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<td></td>
<td>A safety grating step at the rear door opening should pivot to permit EMSPs to move closer when loading and unloading a cot.</td>
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<td></td>
<td>Where practical, exterior stair treads should be open.</td>
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<td></td>
<td>Step surfaces should be lit by a minimum of 10fc (107.6 lux) with 20fc (215.3 lux) preferred.</td>
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<td></td>
<td>Handholds should be mounted on the inside of entrance doors and immediately inside each entrance to the patient compartment.</td>
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<td></td>
<td>Handrails, if used in stairwells, should be placed 34 inches (864 mm) to 37 inches (940 mm), 35 inches (889 mm) recommended, above the standing surface and should include an intermediate guardrail on open sides.</td>
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<td></td>
<td>Windows on egress doors should allow for adequate viewing of the door opening or egress path.</td>
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<td></td>
<td>If a window is vented, it should be equipped with a screen and be lockable.</td>
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<td></td>
<td>EMSPs are able to egress the patient compartment with a patient loaded on a patient transport device from the main loading/unloading doors and one other door.</td>
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<td></td>
<td>Egress out of a secondary door (other than the main loading/unloading door) with a patient on a patient transport device 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.</td>
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</tbody>
</table>
### Categories

<table>
<thead>
<tr>
<th>Categories</th>
<th>Needs</th>
<th>Requirements</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications</td>
<td>Ability to communicate efficiently and effectively between the patient compartment, the driver, and others.</td>
<td>Communications between EMSP, the driver, and third parties, such as the hospital, are easily and quickly established, intelligible, and understandable within the operational environment of a patient compartment and driver’s cab regardless of modality.</td>
<td>Speech should be understandable in accordance with the table below.</td>
</tr>
</tbody>
</table>

#### Communication Requirement

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceptionally high intelligibility</td>
<td>97%</td>
</tr>
<tr>
<td>Normal acceptable intelligibility</td>
<td>91%</td>
</tr>
<tr>
<td>Minimally acceptable intelligibility</td>
<td>75%</td>
</tr>
</tbody>
</table>

The communication system should be capable of power output at least 15 dB higher in sound intensity than the anticipated ambient noise. The user should have a gain control for adjusting the output level.

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

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

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

Means for communicating between the EMSP, the driver, the patient, and third parties, such as the hospital, are provided and accessible from all EMSP workstations.

Communication devices should be secured within maximum functional reach of EMSPs, from a 5th percentile female through a 95th percentile male, from a restrained position.
## Appendix B–Patient Compartment Needs, Requirements, and Criteria Matrix

<table>
<thead>
<tr>
<th>Categories</th>
<th>Needs</th>
<th>Requirements</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication systems, when in use, allow the EMSP to continue providing safe and effective patient care.</td>
<td>Built-in communication devices should allow one-handed or hands free operation.</td>
<td>Communication devices should not hinder verbal communication within the patient compartment.</td>
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<tr>
<td>Awareness of the driver’s activity in the patient compartment.</td>
<td>The driver’s actions are communicated to the EMSPs in the patient compartment non-verbally.</td>
<td>Notifications received from the driver should be noticeable by EMSPs.</td>
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<td></td>
<td>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, hospitals, and dispatch.</td>
<td>Notifications in the patient compartment should not be distracting to EMSPs.</td>
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<td></td>
<td>Visual notifications, when used, should be visible from all primary workstations.</td>
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