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SLATE Ambulance: Designing an Interior Storage System for Improved Sanitation

A Major Qualifying Report

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Abstract

The purpose of this Major Qualifying Project (MQP) is to design a space-efficient, sanitary medical equipment storage system that protects contents from contaminants such as pathogens, waste, organisms, and fumes in the patient compartment. The team evaluates the storage and workspace environment of an ambulance patient compartment and identifies the challenges to protect ambulance occupants and accessories from contaminants. A list containing the quantity, weight and size of all equipment, tools, instrumentation, pharmaceuticals, and consumables in the patient compartment is compiled. This information serves as a framework to determine how pieces of medical equipment can be categorized and stored. Alternative storage systems are identified and evaluated with a "vending machine" style storage compartment chosen as optimal. The proposed design follows the requirements of the Star of Life Federal Regulation KKK-A-1822F and NFPA 1917. The high density polyethylene (HDPE) components of the design are easier to clean and disinfect than the current materials used for the interior surfaces of a typical patient compartment. The proposed vending machine provides an opportunity to protect, clean, and reduce contamination effectively. This new storage system will be an integral part of the modern **SLATE** (**S**afe, **L**ightweight, **A**ffordable, **T**echnology, **E**fficient) ambulance design of MIRAD Laboratory.

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Chapter 1: SLATE AMBULANCE

1. Introduction

In the past 40 years, there have been impressive innovations in medical devices that have been incorporated into the modernization of vehicle ambulance reliability design. The 1973 EMS Systems Act passed by Congress and the accompanied standards, codes, and regulations fostered the increasing improvements in ambulance design. Prior to this act, ambulances were hearses or station wagons that were remodeled for emergency transport [8]. However, these vehicles did not offer enough capacity for a paramedic to treat the patient during a call. As a result of this, the EMS Systems Act stipulated that ambulances built with Federal funding must use one of three approved chassis types, namely: a truck body with a modular patient compartment (Type I), a long wheelbase van (Type II), or a cutaway van with an integrated cab-body (Type III) [3]. The technology integrated into ambulances has improved greatly, but their overall shape and construction had not changed much since the 1973 EMS Systems Act was enacted. Many EMS providers are all too familiar with the challenges facing modern ambulances and the demand for better improvement of patient care. At MIRAD laboratory, effort is being made to address some of these challenges facing EMS providers. This effort includes the creation and development of a SLATE (Safety, Lightweight, Affordable, Technology, and Efficiency) ambulance that can protect pharmaceuticals, consumables, and occupants in the ambulances compartment. There is ample evidence that shows that contaminants in the patient compartment are of great concern for EMS providers. The study by the authors [33] and references cited therein provide excellent information about the concerns of contaminants in the patient compartment.

A look at modern ambulance interior design has shown that there are several locations where contaminants can enter the compartment and entrapped. Many of the cabinets within the patient compartment use sliding glass doors with an aluminum frame. While this may aid the paramedics, it presents a pathway for the spread of contaminants. The current storage cabinets in modern ambulances present a greater challenge to clean contaminants in a sustained way.

The main objective of this project is to create an alternative storage system for the SLATE ambulance that improves storage capacity and workspace environment while attaining the mission of ambulatory care. The MQP team evaluates the current storage systems of a modern ambulance, and classifies pharmaceuticals, consumables, equipment, tools, and other essential medical accessories in the patient compartment. This provides an opportunity for the team to design a vending machine that is dedicated to protecting pharmaceuticals and consumables from contamination. This vending machine is designed to be entirely driven by a mechanical power. The remaining portion of this report is categorized as follows. Chapter 2 contains the developmental stages of modern ambulances in America, Europe, and the rest of the world. It also contains vital information about medical equipment, workspace improvement, and the role of standards in ambulance reliability design. Selected applications of vending machines are documented as well. In Chapter 3, the design process of the vending machine is presented. A list of pharmaceuticals and consumables is presented. The effectiveness of the proposed vending machine is established. Chapter 4 provides an overview of the project objectives, the methodology used to attain the results, and the effectiveness of the vending machine in protecting selected pharmaceuticals and consumables from contaminants in the patient compartment.

Chapter 2: Ambulance and Contamination Research

2. Introduction

Ambulance design and construction have taken on many different forms throughout history. The improvements seen in ambulance design and construction are responsible for faster patient transport and enhanced pre-hospital care. These improvements are largely made possible through the implementation of manufacturing standards, which continue to be a strong impetus for improvements in EMT (Emergency Medical Technician) and patient safety. In order to design a storage system that will dispense medical supplies and protect them from contaminants, it is crucial to possess a strong understanding of the standards that govern ambulance design and construction so that the vending machine may be utilized in American ambulances. The KKK-A-1822f and NFPA 1917 standards specify the amount of storage space required in an ambulance and the properties of the materials from which it is constructed. Ambulances, themselves, are subjected to a number of different contaminants. Blood, vomit, and other bodily fluids may soil the surfaces on the interior of the patient compartment. Routine cleaning reduces the chance of possible bacterial infections, but the cleaning process could be facilitated with the invention of a medical supply vending machine. The creation of a vending machine design eliminates the need to sanitize the inside of ambulance cabinets, thus reducing the overall surface area EMTs need to clean, while also keeping pharmaceuticals and consumables safe from contamination.

2.1 History of Ambulances

Transporting injured or sick people has always been a primary objective for communities and societies. At first, an ambulance was simply a tool to transport a person in medical need from one location to another where he or she could receive medical attention. Oftentimes, the faster a patient can be transported to a hospital or clinic for extended evaluation and treatment, the better the odds are he or can make a full recovery. During the 11th century, these ambulance transportation systems were cots that were carried by men or horses. However, as time progressed the modes of transporting patients became more advanced and eventually led to modern day medical ambulances [10]. During World War I, the Ford Model T automobiles were modified to transport injured soldiers away from the battlefield. The patient compartment of the Ford Model T ambulance was constructed from old wooden boxes, and could hold about three to four injured soldiers. It had a length of 134 inches, and a width of 66 inches. Most of the Ford Model T ambulances were equipped with a four cylinder combustion engine that has an engine power greater than 22 horsepower [11]. Figure 1 shows an example of a Ford Model T ambulance.

Figure 1 World War I Ambulance

This ambulance was archaic, but functional. The Model T was prone to breakdowns on rough terrains because the wheels were only three inches wide. However, this ambulance led to research and growth towards improving automobile ambulances for future endeavors. During World War II, the allied forces adopted a new ambulance. They used the Dodge G502, which was modified into the Dodge WC54. This truck was known for being able to transport a payload of about three quarters of a ton. As seen in Figure 2, the patient compartment was constructed out of metal instead of wood and canvas. The metal used was the same exact steel that was used for military transport vehicles. The steel was able to protect the insides from shrapnel and possible bullet fire. The walls were usually a quarter inch of steel to protect the wounded soldiers from possible harm. The patient compartment was able to hold between four and six patients depending on the severity of their injuries. If patients were able to sit up, six wounded soldiers could be transported in the modified Dodge ambulance. If patients required that they lie down, the truck could carry a maximum of four soldiers [13].

Figure 2 Dodge WC54 WWII Ambulance [13]

During the 1950s, many common and cheap station wagons and hearses were converted for ambulance use. Prior to this period, most ambulance innovation was intended for wartime, instead of civilian use. These vehicles were only 3000 pounds, as opposed to the 6000 pound military ambulances. By being lighter, the converted ambulances were able to achieve better fuel efficiency, and faster travel speeds. The main drawback of switching to a lightweight vehicle was the decrease in volume of the patient compartment. The tight space of the patient compartment left barely enough room for an attending EMT to ride next to the patient. Figure 3 shows an example of a converted ambulance.

Figure 3 Converted Station Wagon

As seen in Figure 4, the station wagon's compartment was modified to fit a gurney. The patient compartment was three feet wide and could hold two separate 75 inch stretchers. Medical consumables were limited only to bandages and essential pharmaceuticals. Although these ambulances were lightweight and consumed limited fuel, however, they did not have enough capacity to provide pre-hospital care [14].

Figure 4 Edsel Amblewagon [14]

Since the Emergency Medical Service Act of 1973, ambulances have become more standardized across the United States. All modern ambulances were built from a preexisting truck or large van chassis like the ambulance in Figure 5. By having a larger patient compartment, more medical supplies and tools were carried onboard the ambulance. A majority of the changes that were made focus on improving safety and reliability of the vehicle. The overall shape of modern ambulances has remained relatively unchanged since the Emergency Medical Service Act. Extruded aluminum is still used to provide the frame and structure for the patient compartment, but the walls and cabinets are now most frequently constructed and reinforced with aluminum instead of plywood.

Figure 5 Modern Ambulance [15]

2.2 Modern Ambulance Design and Technology

When designing an ambulance, the Star of Life Standards need to be considered for determining the size and dimensions of the ambulance. In order for an Emergency Medical Service station to receive federal funding, its ambulances must conform to the star of life specifications. The star of life federal ambulance types are as follows:

TYPE I AMBULANCE (10,001 to 14,000 GVWR)

Type I vehicle shall be a cab chassis furnished with a modular ambulance body.

TYPE I - AD (Additional Duty) AMBULANCE (14,001 GVWR or More)

Type I-AD shall be a Cab-Chassis with modular ambulance body, increased GVWR, storage, and payload.

TYPE II AMBULANCE (9201 – 10,000 GVWR)

Type II ambulance shall be a long wheelbase Van, with Integral Cab-Body

TYPE III AMBULANCE (10,001 to 14,000 GVWR)

Type III shall be a Cutaway Van with integrated modular ambulance body.

TYPE III- AD (Additional Duty) AMBULANCE (14,001 GVWR or More)

Type III-AD shall be a Cutaway Van with integrated modular body, and increased GVWR, storage, and payload.

The Gross Vehicle Weight is one of the defining features that determines the ambulance type. The GVWR is the total amount of weight that the vehicle can support minus the curb weight of the vehicle included. American ambulances are usually built from the chassis of a very large truck. Commonly, the Ford F350, and GMC 3500 are used as the base truck. The chassis is used to support the patient compartment. The patient compartment box is secured directly to the chassis of the vehicle. These large trucks are used so they are able to hold an even larger cabin. The average ambulance is 96 inches wide. This is so there is enough room for paramedics, the very large stretcher, equipment, and sometimes relatives of the patient. However, this large size also poses many issues. With the average city lane being 120 inches wide, ambulances only have a foot of clearance when driving in the center of the lane. This makes travel through crowded city streets especially difficult when civilian cars occupy lanes [1].

2.3 Equipment and Tools in Ambulances

There is a large amount of equipment that is required on an ambulance when EMTs are on a call. This equipment can be broken down into several categories. For basic life support, ambulances must have ventilation and airway devices, monitoring and defibrillation, immobilization devices, bandages, communication, obstetrical, infection control, and injury prevention equipment. Ambulances qualified for advanced life support must include additional equipment for the treatment of patients in critical or severe condition.

2.3.1 Required Equipment

Every state across America has specific regulations for the type of equipment and tools that must be stored within an ambulance. The amount of equipment stored on an ambulance depends on the volume of patients that the ambulance expects to transport during a shift. EMTs must assure that the ambulance is fully-functional and fully-stocked before it leaves the station. This is routinely done by filling out a checklist before the ambulance leaves the station. An example of an ambulance inventory checklist from Bensenville, IL can be seen in Appendix K.

A full inventory of the equipment found in the interior and exterior storage compartments of ambulances at a local EMS center can be seen Appendices B, C, D, and E. These lists were obtained experimentally by counting each piece of equipment that is stored on a fully-stocked ambulance at a local EMS. The weight and size of each object were determined and recorded.

2.3.2 Storage of Pharmaceuticals and Consumables

Ambulances carry a variety of pharmaceuticals. Many counties in California have a specific list of approved medications that are allowed to be stored and preloaded on the ambulance. San Mateo County of California has a list of all medications and the minimum amounts of each that is required to be onboard the ambulances at all times. Table 1 depicts an excerpt of medications and their recommended amounts in a patient compartment [5]. The complete listing can be found at the reference therein.

Table 1: Current Medications Carried on Ambulances

Medication	Minimum Quantity	Standard Quantity
Adenosine	30 mg	60mg
Albuterol .83% solution	1 dose	4 doses
Aspirin: Children's Chewable	1 bottle	2 bottles
Atropine 1.0mg/5ml Preload	4 mg	6 mg
Benadryl 50mg/1ml	100 mg	200 mg
Charcoal Slurry 25grams/ 120ml	1 dose	2 doses
Calcium Chloride 1gm/10ml preload	1 gm	1 gm
Dextrose 50% 25gm/50 ml preload	50 gm	100 gm
Dopamine 400mg vial	400 mg	800 mg
Epinephrine 1:1,000 1mg/ml ampule	2 mg	4 mg
Epinephrine 1:10,000 1mg/10ml preload	4 mg	8 mg
Epinephrine 1:1,000 30 ml vial	1	2

These pharmaceuticals can be divided into narcotics and non-narcotics. The narcotics are kept in a small cabinet within the patient compartment that can only be accessed with a key, in order to maintain inventory control. The non-narcotics, such as epi-pens, albuterol, and aspirin are kept in the storage cabinets.

2.3.3 Temperature Condition in the Patient Compartment

Currently standards dictate that all medication on board an ambulance be stored at room temperature. This means that the temperature in the patient compartment must be maintained between 60 and 80 degrees Fahrenheit at all times. However, when an ambulance engine is shut down, the inside temperatures will match the ambient air temperatures. In warmer places, inside temperatures may reach up to 100 degrees Fahrenheit. In 2003, a study was conducted in the United Kingdom by the Journal of the Royal Society of Medicine [22] where the temperatures were recorded each day for two weeks in August. The paramedics made sure to keep track of which medications degraded over time in the heat, and determined which medications were still usable. It was found that many of the medications stored in gel capsules tended to melt and degrade. The most common form of this was cefalexin, a commonly used antibiotic. As seen in Figure 6, cefalexin comes in a gel capsule.

Figure 6 Cefalexin Pills [17]

This rendered them unusable and they had to be discarded. It was also found that many liquid drugs that need to be injected showed serious degradation during the test. These drugs included ampicillin, erythromycin, and various forms of penicillin. Pressed pill tablets, such as aspirin, were not affected by the heat due to the material properties of the pill [22].

The Biomedical Equipment and Engineering Services Company from Virginia have designed a system for temperature control. The PharmGuard® in Figures 7 and 8 encompasses an air conditioning and heating unit that are meant to keep pharmaceuticals at the Federally specified temperatures, 60 to 80 degrees Fahrenheit. It can fit into most patient compartments. Figures 7 and 8 show the installation of one of these devices in a modern ambulance. The dimensions of the PharmGuard® are 5.75 inches long, 3 inches wide, and 6 inches high. One major flexibility of the device is that it can use a 12 volt battery or a standard wall outlet to operate [21].

Figure 7 PharmGuard® [21]

Figure 8 PharmGuard®Installed [21]

To test the effectiveness of this device the Biomedical Equipment and Engineering Services Company recorded the outside temperatures that the ambulance was subject to during the summer of 2002. Readings were taken from June 1 to August 25 in Virginia. The internal temperatures were recorded as well. All of the readings were recorded in intervals of an hour.

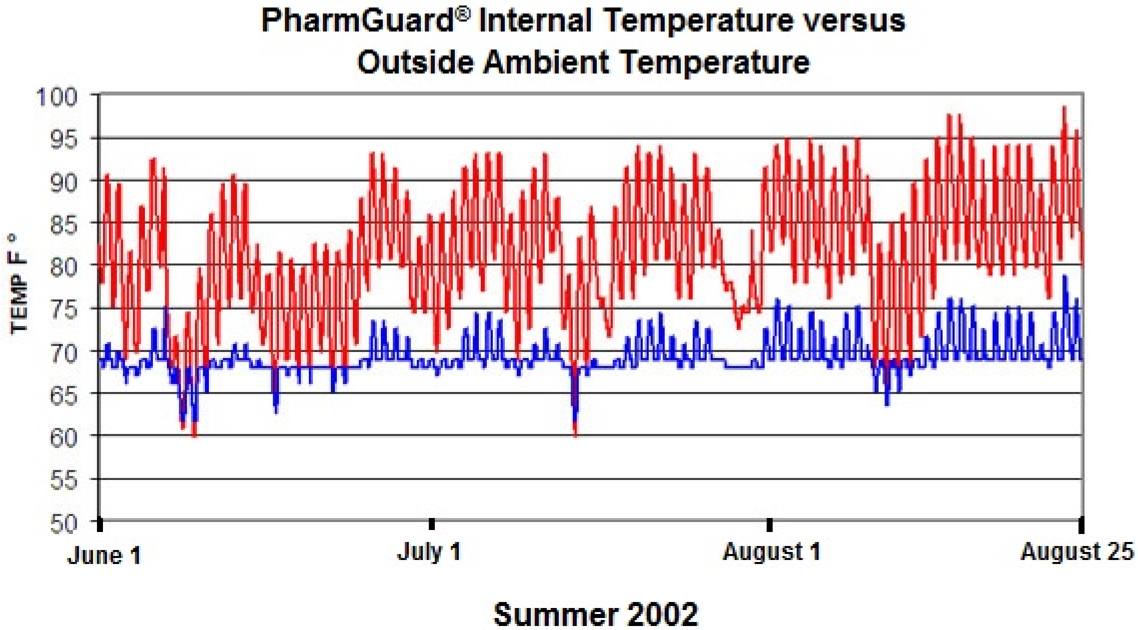


Figure 9 PharmGuard® Test Data

As seen in Figure 9, the red signal represents the external ambient temperatures, and the blue signal represents the readings of the internal temperatures of the PharmGuard® compartment. For a majority of the summer, the PharmGuard® was able to maintain the internal temperature within the nominal range, 60 to 80 degrees Fahrenheit. The temperature in the PharmGuard® storage compartment only exceeded 75 degrees in the month of August, and this was a time when ambient temperatures were 95 degrees or higher [21].

2.3.4 Standards for Ambulance Reliability Design

The two national standards for ambulances that are the most referenced are KKK-A-1822F and NFPA 1917. KKK-A-1822F was published in 2007 and must be followed for an ambulance to have a "Star of Life" certification. NFPA 1917, or the National Fire Protection Association 1917 Standard for Automotive Ambulances, was published in 2013 and is widely regarded as an addition to the KKK-A-1822F.

KKK-A-1822F requires a minimum of 35 cubic feet of storage space as enclosed cabinetry, compartment space or shelf space. No materials that absorb fluids and resist decontamination, such as carpets or fabrics, can be used inside the patient compartment. Cabinets should be made out of lightweight materials, installed in a way that prevents any movement or sagging, and have a maximum depth of 20 inches. They should also be impenetrable for liquids, fire resistant and simple to disinfect. They should not open due to vehicle movement on the road but should open easily for the EMT. Enclosed storage compartments can be located in the squad bench, doors, sidewall, partition, technician seat and overhead. The location of all supplies in the patient compartment is dictated by the use of each supply, with lifesaving equipment stored closest to the patient's head [3].

Table 2 KKK-A-1822f Minimum Volume Standards

		Minimum Volume
Item	Cubic Meters	Cubic Feet
Medicine Dispensary Cabinet	.017	6
Medical Supplies Cabinet	.25	9
Linen Supplies	.11	4
Trash Receptacle Compartment and Sharps Disposal Container	.06	2
Oxygen Installation	.17	6
Oxygen Unit	.06	2
Telemetry Equipment	.06	2
Radio Equipment & Antenna	.03	1
Storage Miscellaneous	.06	2
Vacuum Aspirator Unit	.03	1
Air Conditioning Unit	As Required	
Heating System	As Required	

The NFPA 1917 is very similar to the KKK-A-1822F with few changes in regards to interior storage. The minimum enclosed storage space is decreased to 30 cubic feet. Storage compartments are to be divided into sections and shelves should be removable. All compartments should be firmly attached to the body of the ambulance to prevent excess movement. All supplies and tools stored within the ambulance should be able to withstand temperatures from 95 to 32 degrees Fahrenheit [7].

It is imperative that the materials implemented in the design of the interior storage system meet the requirements established by the KKK-A-1822f and the NFPA 1917. Excerpts that pertain to interior storage from both sets of standards can be found in Appendix F and Appendix G. The NFPA and KKK-A-1822F have similar requirements for interior storage. For example, section 3.10.16 of the KKK-A-1822F requires that "…the finish of the entire patient compartment, including interiors of storage cabinets, shall be:

1. Impervious to soap, water and disinfectants.
2. Mildew resistant.
3. Fire resistant.
4. Easily cleaned/disinfected (carpeting, cloth, and fabrics are not acceptable)" [3].

Section 6.17.3 of the NFPA 1917 reiterates these same points almost verbatim, but requires that the materials must also be impervious to body fluids and that the materials must be fire resistant in compliance with FMVSS 302 (Appendix G) [7].

From this, it can be established that the design of the interior storage system cannot include any cloth, carpeting, or fabrics; the materials must be impervious to disinfectants and contaminants; the materials must be mildew resistant; and the materials must not only be fire resistant, but they must also adhere to FMVSS 302. FMVSS 302 is a code that dictates an allowable degree of flammability to materials located in automobiles. The code specifies the procedure and apparatus for testing materials and has the general requirement that a "Material shall not burn, nor transmit a flame front across its surface, at a rate of more than 4 inches per minute" [30]. Any material that is implemented in the interior storage system must not burn at a faster rate than 4 inches per minute. It is also important to note that the materials must be resistant to disinfectants. Dispatch® wipes contain bleach (sodium hypochlorite) and are used to clean the surfaces on the outside and inside of storage compartments [34]. This is a vital consideration to make when selecting materials for the design because most plastics degrade when exposed to bleach.

Besides the material property requirements, all storage doors must be designed to remain closed during transport according to section 6.16.5 of the NFPA 1917. In addition, section 6.16.4 states that "Storage compartment door handles, where provided, shall not protrude more than 1 in. (25mm) if located 14 in. (356mm) or higher above the floor and shall not protrude more than 2 in. (51mm) if located lower than 14 in. (356mm) or higher above the floor." Any handles included in the design of the interior storage system must not protrude greatly from the surface upon which they are mounted [7].

2.4 Contaminants in the Patient Compartment

Much like a hospital setting, the patient compartment of an ambulance is subject to many forms of contaminants. Considering the main objective of an ambulance is to transport and stabilize sick or injured patients, it is important to make sure that the ambulance is sanitary. Patients may inadvertently get blood or bodily fluids on the interior surfaces of the ambulance. If the contaminated areas are not properly disinfected, or are difficult to disinfect, it may be possible to transmit skin infections or blood-borne pathogens. For these reasons, it is important to protect the occupants and medical supplies from contaminants in the patient compartment and to make the interior surfaces as easy to clean as possible.

2.4.1 Bacterial Contamination

Good cleaning procedures and disinfectants are not always enough to keep an ambulance contaminant-free. During a 2003 study conducted in Wales [25], 82 random ambulances were tested for bacterial contamination before and after a routine cleaning. Before cleaning the ambulances, it was found that 60.97% of the ambulances tested had contaminated interior surfaces. After all the ambulances were cleaned, it was found that 35.37% still showed signs of bacterial contamination. Figure 10 depicts the data gathered from the study. The blue bar represents the 50 ambulances (60.97%) that were found to have contaminated surfaces before cleaning. The red bar represents the 29 ambulances (35.37%) that still showed signs of contamination after they were cleaned. Only 21 out of the 50 contaminated ambulances were successfully disinfected. This is a success rate of 42%.

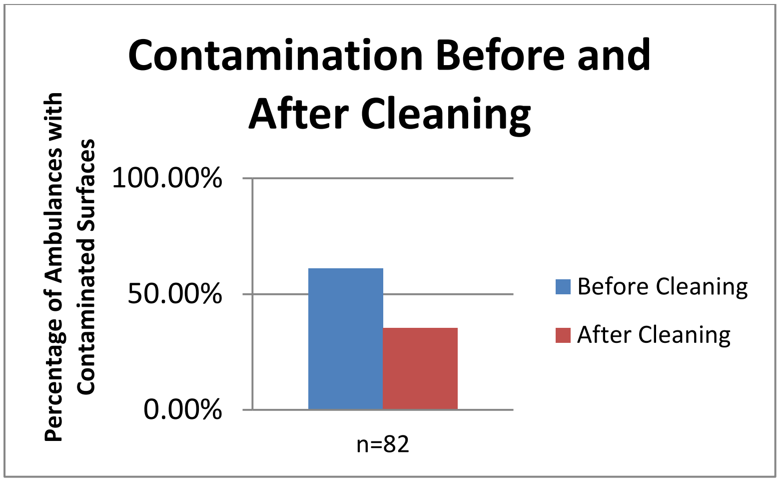


Figure 10 Results of Ambulance Cleansing Test [25]

During this study, specific regions of the ambulances were tested to determine where the highly contaminated areas were within the cabin. According to the tests, the most contaminated areas of the ambulances were the handrails within the ambulance, with 91.7% of the 82 ambulances showing signs of contamination. This was mostly due the paramedics need to use the handrails for support while they are in transit. Any bacteria or contamination they picked up from the patient can easily be transferred to these areas. The walls and the stretcher were the next two most contaminated areas at both at 66.7%. Most stretchers contain many soft surfaces that can easily absorb bodily fluids and other bacterial contamination easily [25].

Another problematic area for contamination is the sliding cabinet doors. Figure 11 shows the inside of a typical patient compartment. These cabinets are where all of the equipment is stored, so it is very crucial that they remain contaminant free. They are just glass that can slide along a metal track. The groove where the glass slides is one of the more difficult areas to clean. This is due to the fact that it is difficult to reach these areas with disinfecting wipes and the felt in the track prevents good disinfectant coverage.

Figure 11 Ambulance Cabinets

One modern issue with bacteria contamination is the increasing resistance to antibiotics. Due to the abundance of modern antibiotics, strains of bacteria have slowly become resistant and immune to these medications. These strains of bacteria present a large problem to most health service systems. MRSA is one of the most problematic antibiotic-resistant bacteria. MRSA stands for Methicillin-resistant Staphylococcus aureus. MRSA is problematic for people that have weakened immune systems, open wounds or sores. It can also be easily spread in locations where large amounts of people are living in close quarters, like residence halls, prisons, or hospitals. Many MRSA infections are a result of human to human cross contamination. If MRSA existed in the back of an ambulance, it would be very easy for a paramedic to transfer the bacteria to the patient. This is the main reason for generating a sterile equipment storage system.

During a study conducted in Chicago by Lewis University [27], it was determined that 69% out of 71 randomly selected ambulances contained *Staphylococcus aureus* bacteria. Of those, 77% showed signs of being antibiotic resistant. Due to the amount of bacteria present in the patient compartment of an ambulance, it is important to fully sterilize the ambulance between uses. It is imperative that proper cleaning procedures be followed so that surfaces in the patient compartment are completely disinfected.

2.4.2 The Cleaning Process of Contaminants

To ensure patient safety, the cleaning process of the ambulance is very thorough. The first step of cleaning the patient compartment of an ambulance is to remove the stretcher or bed the patient rests on. The stretcher is often prone to the most amounts of contaminants. The entirety of the stretcher has to be wiped down with disinfectant wipes to prevent the spread of disease and contamination. After sterilizing the most probable areas of contamination, all of the interior surfaces need to be disinfected. During this process, all disinfectant spray must be applied and wiped dry. After disinfecting the patient compartment, the glass cabinet doors need to be cleaned. The plexi-glass doors are cleaned with glass cleaner instead of disinfectant. The next step of cleaning the ambulance compartment is to secure all small and moveable pieces of equipment. This means securing the bandages and the consumables in their cabinets to ensure organization. This also means placing appropriate pieces of equipment back in their respective locations. The last step of cleaning the patient compartment is to remove the sharps and trash containers. These two containers may contain blood, vomit, or other contaminants. The sharps container must be emptied frequently [35].

In order to test the effectiveness of cleaning procedures, it is possible to use a fluorescent marker such as riboflavin in order to measure the total area covered by the cleaning procedure. Surfaces are covered with a riboflavin solution and then cleaned. After the cleaning is performed, the surfaces are observed under a UV light and checked for the presence of residual riboflavin. This gives the experimenter an idea of how much area the cleaning procedure covers and its effectiveness.

2.4.3 Anti-Microbial Materials and Coatings

One common way to limit the transfer of bacteria within and ambulance is through the use of antimicrobial surfaces. Antimicrobial paint and coatings have been developed so that any type of material or surface can be coated. Bacteria start to multiply exponentially after 15 minutes of contamination. The protective coating is usually contains a metallic ion, like silver and copper. These ions fuse to the bacteria sights, preventing them from being able to reproduce. Another method is to use a titanium dioxide coating in conjunction with UV light to kill bacteria along the material's surface. Figure 12 shows an example diagram of how the protective coating works.

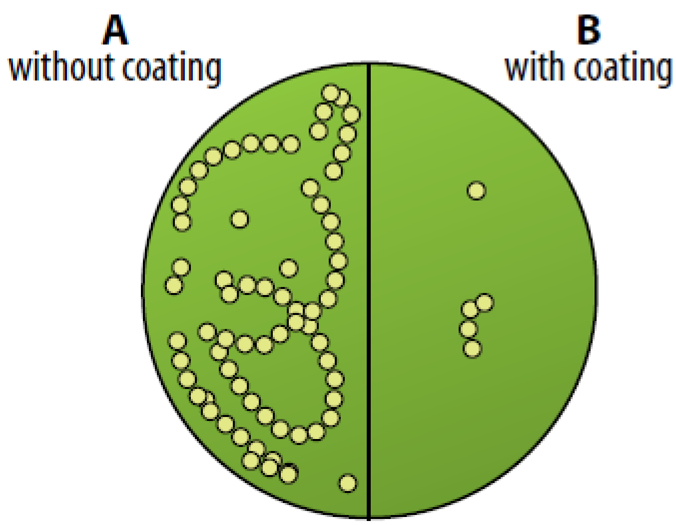


Figure 12 Visual Representation of Antimicrobial Coating Effectiveness

Anti-microbial paints and coatings should not be relied on for disinfection, however. The reason for this is that it is does not kill all of the bacteria, but simply significantly reduces the amount. Antimicrobial paint is most often applied to hand rails and surfaces that the paramedics most often touch [4].

2.4.4 Material Hydrophobicity and Its Effect on Bacterial Adhesion

In biological systems, hydrophobic interactions are usually the strongest of all long-range interactions, excluding covalent interactions [31]. According to the more recent definition, a hydrophobic material is one for which the free energy of interaction (ΔG_{iwi}) is <0

[32]. The free energy of interaction (ΔG_{iwi}) is a measure of the degree to which the polar attraction of two like materials (i) to water is greater or smaller than the polar attraction which water molecules have for each other. The surfaces are determined to be genuinely hydrophobic if the net free energy of interaction between two entities immersed in water is attractive. If ΔG_{iwi} is positive, then the material is hydrophilic. If ΔG_{iwi} is negative, then the material is hydrophobic. Hydrophobicity can also be measured by the contact angle a drop of water makes with the material, but this is less definitive. A sessile drop test determines the droplet's contact angle. Materials with a water droplet contact angle of >90º are generally determined to be hydrophobic, whereas materials with a water droplet contact angle of <90º are generally determined to be hydrophilic.

Since hydrophobic interactions are the strongest of all long-range, non-covalent interactions, their role is crucial in understanding how bacteria adhere to surfaces and spread. In a test performed on various polymeric substances, the bacteria, *Alcaligenes denitrificans*, was applied to clean samples of polypropylene (PP), high-density polyethylene (HDPE), poly-methylmethacrylate (PMMA), and polyvinyl chloride (PVC). It was determined that the more hydrophobic a surface is, the more bacteria adhere to it [29]. This relationship can be seen in Table 3. Note that as the energy of free interaction decreases, the more cells were observed to adhere to the surface.

Table 3 Hydrophobicity and Bacterial Adhesion

Material	Contact Angle with Water [29]	ΔG_{iwi} (mJ/m^2) [26]	Average cell number/mm^2x10^{-3}
Bacteria	15.0 ± 3.3	18.23	N/A
PP	83.0 ± 2.5	-67.2	32.1 ± 1.6
HDPE	79.2 ± 3.1	-59.2	20.0 ± 1.1
PMMA	58.5 ± 1	-16.0	3.1 ± 0.1
PVC	67.7 ± 2.3	-22.0	13.7 ± 1.0

This relationship was linear, with the exception of HDPE, which, when excluded from the results, reveals itself as an outlier. HDPE should exhibit much more cell adhesion than it does in reality. The reason for this is that there is a residual volume of hydration at its surface [29]. This prevents the bacteria from making complete contact with the surface since they are partially suspended in water. This unique property of HDPE is useful because it demonstrates intermediate hydrophobicity, which makes it easy to clean, and its residual water of hydration prevents cells from adhering to it completely.

Inside modern ambulances, most of the interior cabinets are constructed of glass and aluminum framing. Aluminum oxide forms on the exterior of aluminum surfaces. Aluminum oxide has a contact angle with water of 45° [24], which means that it is fairly hydrophilic. According to the findings of P Texiera et al., the advantage to this is that there will be less bacterial adhesion to the surface and disinfectants will coat the surface more easily. However, the disadvantage is that it is more difficult to remove fluid contaminants.

2.5 Vending Machines and Their Applications

Vending machines have been used in many parts of the world in efforts to sell products while saving space. The basic idea of a vending machine is that they contain a large quantity of items which are all uniformly separated and organized. In America, these items usually consist of snack items that are pre-sealed and as a result are safe from external contaminations. Many of these vending machines take up little space and require little user interaction, and keep their contents free from outside contaminations.

In the country of Japan, vending machines are used everywhere as a method for saving precious space in cities. Japan has some of the most densely populated cities in the world. With a growing population, vacant city space has slowly been decreasing. Many buildings in Japan are built very tall and vertical because of the lack of physical land space. One of the biggest differences between Japanese cities and most countries' cities is the abundance of vending machines. Instead of wasting the valuable land space in cities with exuberant amounts of shops and cafes, many of these venues were streamlined. Many products that would normally be purchased in a store can be bought from a vending machine. This includes hot prepared food, magazines, balloons, snacks, alcohol, tobacco, live crabs and many other items. These vending machines line the streets of Japanese cities, allowing much land space to be conserved for other more important businesses. As seen in the picture below, the vending machines are placed in front of other buildings, and take up very little space as seen in Figure 13 [9].

Figure 13 Vending Machines in Japan [9]

In Japan, a person can easily buy a wide variety of items at a vending machine. Unlike most countries, Japan has a number of vending machines that sell perishable items. Because of this a sterile environment must be created. There are two basic thoughts on making sure that the items inside the vending machine do not go bad and perish. One is to individually wrap and seal every single item in the vending machine. This is a very common practice for foods like vegetables and fruits.

There are some instances of certain items that are not individually wrapped in sterile cellophane. One example of this is Japan's lettuce growing vending machine. Because Japan also has limited farm space and considering the land is not fertile to grow lettuce, they have engineered methods of growing it on the streets, as seen in Figure 14. The lettuce growing vending machine has multiple rows of lettuce seeds that are constantly under artificial light. The lettuce is also constantly fed water through a complex system of hoses and mist makers. The exterior of the vending machine is completely sealed off with plastic and glass. The manufacturer does not guarantee that the vending machine is sterile on the inside. However the complicated dispensing mechanism, that uses multiple air locks, works very well at limiting possible contaminants [9].

Figure 14 Climate-Controlled Lettuce Vending Machine [9]

Chapter 3: The Design Process for the Vending Machine

3. Introduction

When first given an engineering design challenge, it is easy to lose track of what the goals and requirements are for the final project. In order to avoid this, the team identifies project objectives of the vending machine and their constraints in terms of materials and intended applications. The design process is started by evaluating vending machines and their applications. The proposed vending machine is intended to protect selected pharmaceuticals and consumables from contaminants in the patient compartment. This chapter discusses the framework that enables the team to better understand the types of equipment, tools, and medical supplies that are carried in a typical basic life support (BLS) ambulance. A number of design iterations based upon the functional operation of the intended vending machine are presented. The determinant of the final design is the ability for the vending machine to protect selected pharmaceuticals and consumables from contaminants in the patient compartment.

3.1 Design and Material Analysis of the Patient Compartment

As discussed in Section 2.3.4 of this report, there are standards set in place that the storage areas of an ambulance must meet. These volume and material requirements affect the overall shape and construction of modern ambulances. Patient and EMT safety are crucial and the standards established by the KKK-A-1822f and the NFPA 1917 ensure that the ambulance patient compartment is built with safety and reliability in mind.

3.1.1 Ambulance Patient Compartment Design

To start this project out, the MQP needed to examine a current ambulance in operation. The interior workspace and layout of the patient compartment needed to be observed and measured to try to determine a more efficient system for storing equipment. The layout of the patient compartment is dependent on which company manufactures it. Most of the compartments are designed to specific regulations or standards to ensure uniformity between Emergency Medical Services. Braun manufacturers the entirety of the patient compartments according to the KKK-A-1822f and NFPA 1917 standards. Drawings of a Braun G3500 ambulance can be seen in figures 15 and 16. As seen in these two figures, the patient compartment is about 95 inches. This is only about 5 inches wider than the goal of the SLATE ambulance. The compartment is then also rests on top of the chassis, at 32.5 inches tall. The overall height of the ambulance is 102.5 inches, being 70 inches of patient compartment. The compartment is then 150 inches in total length, composing more than half of the total length of the ambulance (260 inches). These drawings helped understand the overall space capacity of the ambulance.

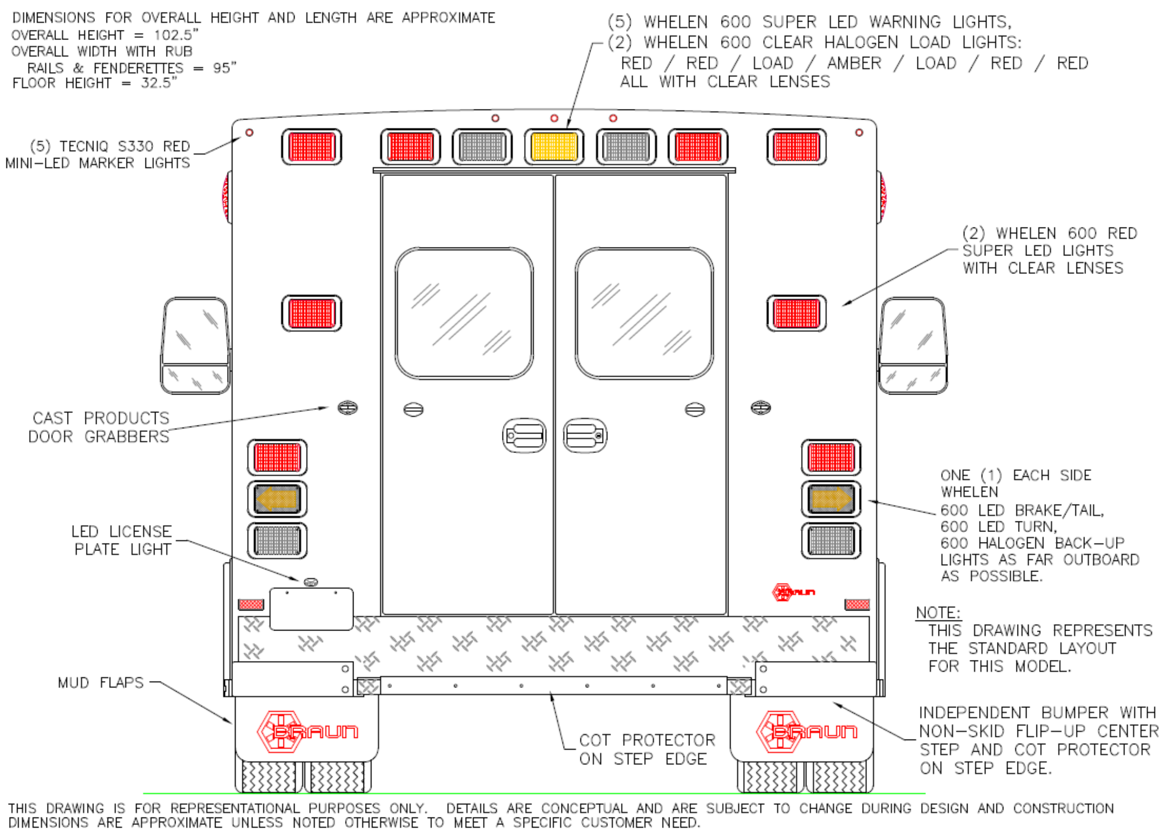


Figure 15 Braun Patient Compartment Back

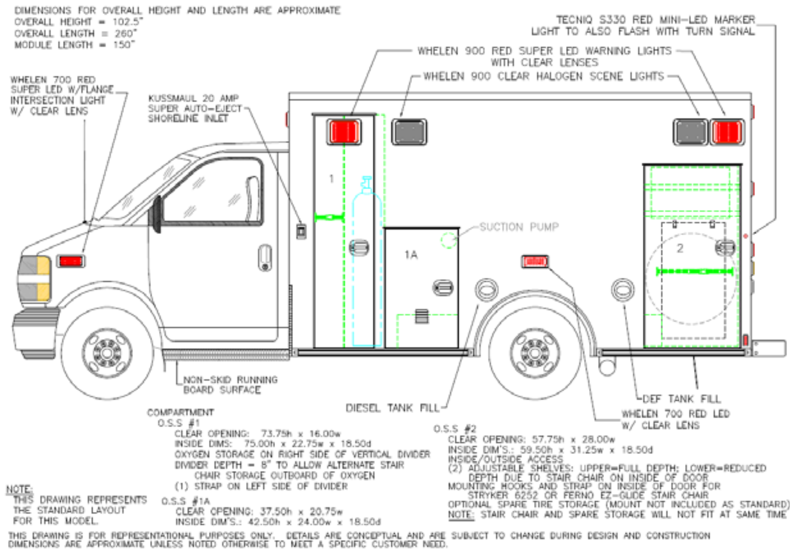


Figure 16 Braun Ambulance Side View

After examining the exterior dimensions of the patient compartment of the ambulance, the team researched the designs and dimensions of the interior workspace needed to be researched. The team found many drawings of the Braun GMS 3500 ambulance including dimensions of the workspace. These drawings can be seen in figures 17 and 18.

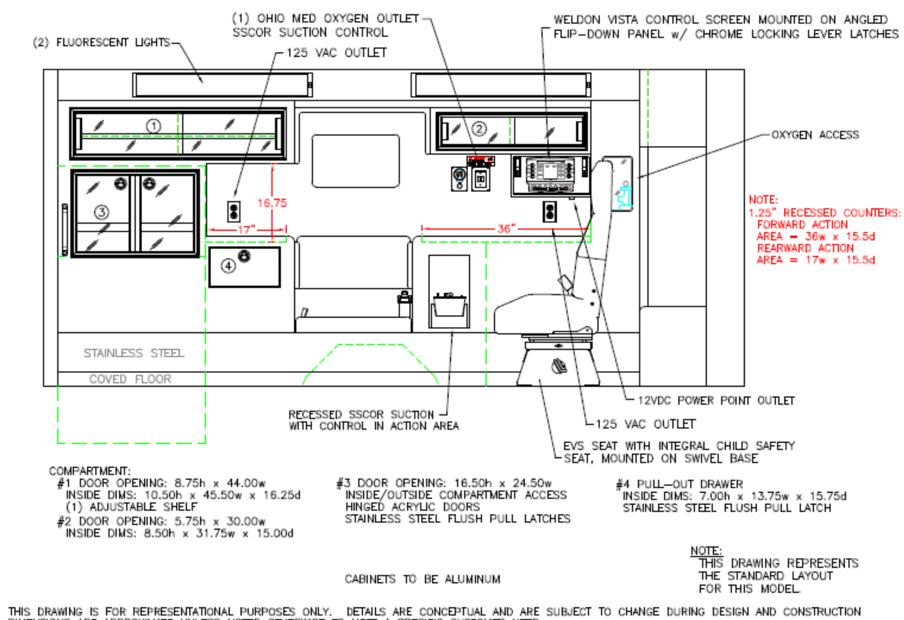


Figure 17 Interior Dimensions

In figure 17, there are four separate storage compartments. Compartments one and two are sliding glass door cabinets. Compartment one contains an adjustable shelf that can also be removed entirely. Compartment three is a cabinet with hinged doors. The doors open outwards, and have a width of 24.5 inches each. Compartment 4 is a cabinet with a pull out drawer. The pull out drawer extends about 15.75 inches. The four compartments can hold up to the following volumes respectively: 4.5cubic feet, 2.3 cubic feet, 3.5 cubic feet, and .88 cubic feet.

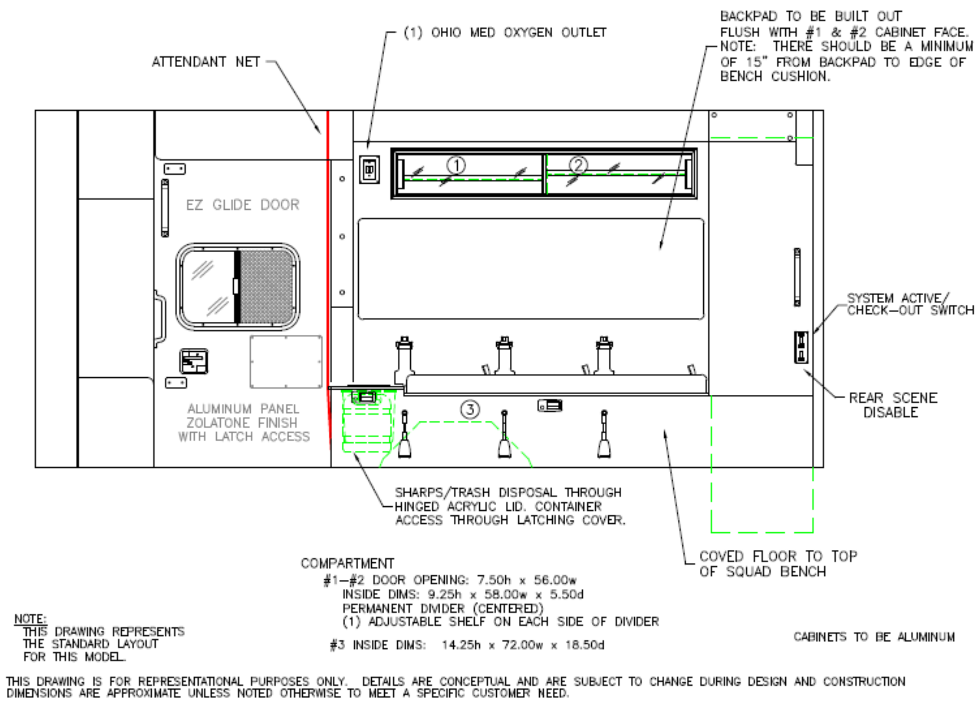


Figure 18 Interior Side 2 Dimensions

Figure 18 shows the opposite side of the patient compartment as the previous figure. This side of the ambulance contains three separate compartments. Compartments 1 and 2 are the same type and dimensions. They are both sliding glass door cabinets that can hold up to 3.4 cubic feet combined. The third compartment is large bench storage. The top of the bench lifts up on a hinge, and larger equipment can be stored beneath it. It can hold up to 11 cubic feet. However, in the overall slate ambulance, the squad bench is going to be removed, eliminating this type of equipment storage as an option.

3.1.2 Patient Compartment Materials and Weight Considerations

While designing a new storage system, the construction of the patient compartment needed to be investigated. The patient compartment of a standard ambulance is mostly made from aluminum sheet metal. The aluminum is usually covered in vinyl to facilitate cleaning. Many surfaces that are touched often in the ambulance are coated in antimicrobial paint. This helps reduce the spread of bacteria and contamination throughout the patient compartment. Many tables and surfaces are covered with stainless steel to help improve cleaning bodily fluids. The floor of the patient compartment is often constructed from plywood to try to keep the weight of the overall compartment less. All of the cabinets onboard an ambulance are constructed from aluminum. The sliding doors are made with Plexiglas. This Plexiglas is used to prevent the doors from shattering, while being clear and easy to see through.

3.1.3 Patient Compartment Workspace and Storage Modifications

Since the goal was to reduce the overall width of a patient compartment, it was vital to assess how much space was available for the medical supplies vending machine. The width of the vending machine is also crucial, because the KKK-A-1822f requires that all ambulances have at least 12" of aisle space for the paramedic to walk through [3]. The outer dimensions of the vending machine were determined to be 80" X 16" X 72". A basic floor layout was constructed to determine the vending machine's outer dimensions as can be seen in Figure 19.

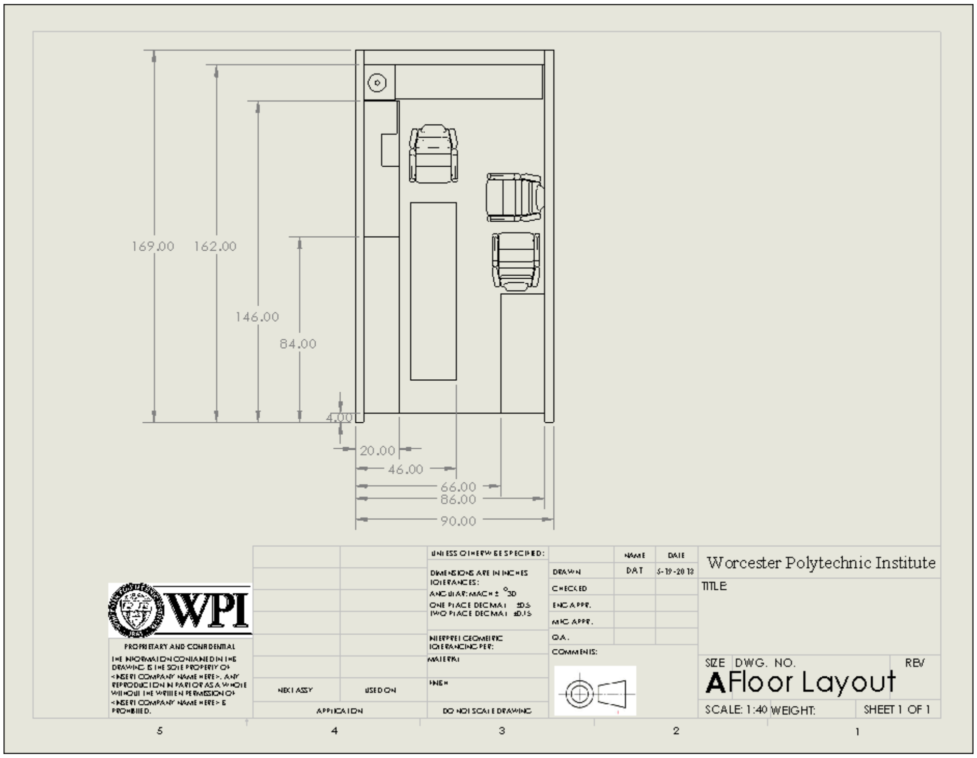


Figure 19 Proposed Patient Compartment Dimensions

In order to obtain accurate dimensions, the outer and interior dimensions of a Type III ambulance on a G4500 Savanna frame were measured at a local EMS facility. The module length was measured to be 166" and the module width was 96". The inside headroom was 72". The workbench next to the captain's chair (the chair positioned behind the stretcher) was found to be 72". The workbench was 22" wide from the edge to the wall.

In order to accommodate a slightly longer storage area, the workbench was shortened to 62" long and the width was shorted from 22" to 16". The overall length of the patient compartment was increased by 3", thus making it 169" in length. These modifications helped to decrease the overall vehicle width and helped give the vending machine adequate space.

3.2 Pharmaceuticals and Consumables in the Patient Compartment

Before being able to redesign the interior storage of an ambulance, the equipment, pharmaceuticals, and consumables needed to be taken into account. This section describes the process the team used to conduct a full inventory of a standard basic life support ambulance. The dimensions and the weights of each medical item were determined and recorded. This spreadsheet was constructed to be able to understand the weights and the capacity each object consumed. From there, the pharmaceuticals and consumables were then categorized by their medical need. The team wanted to reorganize the equipment based on the medical needs and purposes each piece of equipment served. This was to increase the efficiency of the paramedics in expediting patient care. The last part of the medical inventory that needed to be taken into account was the packaging and storage of the medical equipment. Certain pieces of equipment were stored in sterile packaging, while others were packaged to prevent damage or degradation. Each type of packaging and storage had to be taken into account for redesigning how the storage systems would work.

3.2.1 Weight and Size of Pharmaceuticals and Consumables

In order to redesign the storage, an inventory of each piece of equipment and medical supply had to be taken. Using a Model ES100L 20”x16” scale from Ohaus Corporation, the team took the dimensions and weights of everything stored on the exterior and interior of a typical ambulance from a local EMS. The resolution of the device is 0.1lb, so the uncertainty in each weight measurement was ±0.05 lb. The combined weight of all the equipment and tools stored in the exterior storage compartments was 800 ±4.35 lbs. The combined weight of all the pharmaceuticals and consumables in the interior storage compartments was 165.2 ±45.25 lbs (Appendices C and E). The uncertainty for the combined weight of the pharmaceuticals and consumables was relatively large because there were much more items stored in the interior. The items stored in the interior were also much more lightweight and the weights of the objects were.

Figure 20Yellow Pedi Kit

These items were generally large and bulky like, stretchers, splints, EMT equipment, and oxygen tanks. Figure 20 shows a pediatric care bag. This bag had a capacity of about .73 cubic feet, and weighed 5.2 pounds. Most often, these pieces of equipment and consumables are necessary for the paramedics to use at the scene. Oftentimes items stored on the exterior of the ambulance are not needed inside the patient compartment during a call. For example, the stretchers, lift chairs, and braces would exhaust too much capacity to be stored on the interior, as well as being necessary for paramedics to be able to retrieve from the outside of the ambulance. For example, the backboard seen in figure 21 would not be needed inside the patient compartment, however, is a required piece of equipment for the paramedics. The backboard was 12.8 pounds and took up 1.33 cubic feet of space.

Figure 21 Backboard

The interior storage compartments contained 106 different types of equipment, most of which were small and light. Because of this, the total weight of all interior items is much smaller than the exterior total despite there being hundreds of total items. Items stored on the interior of the patient compartment were items that were required for the paramedics to be able to tend to the patient during a call. These items included gloves, bandages, cuffs, splints, sheets, wipes, and certain pharmaceuticals. In total these items measured to be 165.2 pounds.

Figure 22 Saline Solution

Figure 22 shows five bottles of sodium chloride. Sodium chloride is used for disinfecting a patient's wound or open sore. These bottles utilized about half a cubic foot, and weighed 10.4 pounds. Each bottle only weighed about 2 pounds, but because of the increased quantity, the total weight is increased. While most items in the patient compartment were small, a few larger items were able to fit underneath the squad bench seat.

Figure 23 Squad Bench Storage

In Figure 23 there are a few larger items being stored. There was a small blue back board, two sharps containers, and a trash bin under the squad bench.

Certain items on the interior of the ambulance compartment had to be taken special inventory of. Many of the disposable items had to be taken special attention to, as to know how much of each item is usually carried on board the ambulance. These items usually were small and sealed in a special packaging. They are the items that it is essential for them to remain sterile to make sure the patient doesn't contract any illnesses or diseases from the ambulance compartment. These items were usually very small in size and weight. They consisted of bandages, eye pads, burn gauze, swabs, and many others. Figure 24 shows an example of some of these consumables.

Figure 24 Eye Pads and Pressure Cuffs

Most of these consumables used very little space, and weighed very little. For example, one eye pad used 1.5 cubic inches of space, and had a negligible weight. Other examples of consumables found on board the ambulance were sheets and disinfectant wipes. These items were sealed in plastic bags in other cabinets. The items seen in the figure 25 used about .5 cubic feet and weighed about 12 pounds.

Figure 25 Linens and Cleaning Supplies

The dimensions and weights of all the items found on board the ambulance were recorded into multiple excel spreadsheets. Appendixes B, C, D, and E contain this information. An excerpt from the interior storage capacity of the equipment can be seen below.

Table 4 Excerpt Interior Storage

Item #	Name	Quantity	Length (L) ±0.125 (in.)	Width (W) ±0.125 (in.)	Height (H) ±0.125 (in.)	Storage Space Occupied (LxWxH) ±0.217 (in.^{3})	Total Storage Space Occupied (Quantity x Space Occupied) (in.^{3})	Uncertainty (± Value)
45	Box of Gloves	6	9.75	4.75	3	138.90	833.63	1.302
46	Baxter .9% NaCl	2	2.75	2.75	7.25	54.80	109.66	0.434
47	Large Bottle of Baxter .9% NaCl	4	3.75	3.25	9	109.70	438.75	0.868
48	Bladder Irrigation Set	2	9	7.5	1	67.50	135.00	0.434
49	Sterile Burn Sheet	5	10.5	8	1	84.00	420.00	1.085
50	Continu-Flo Solution Set	1	7.5	3	1	22.50	22.50	0.217
51	IV Bags	8	10.75	4.5	3	145.10	1161.00	1.736
52	BP Cuff	1	6	5	1	30.00	30.00	0.217
53	KED Bag (Green)	1	33	10.5	5.5	1905.80	1905.75	0.217
54	Backboard (Blue)	1	23.75	16.5	3	1175.60	1175.63	0.217
55	Small Sharps Container	3	9	5	5.75	258.80	776.25	0.651
56	Bag of Splints	1	55.75	8.5	3.5	1658.60	1658.56	0.217
57	Femur Traction Splint	3	31	10	2.5	775.00	2325.00	0.651
58	Transfer Sheet	1	21	15	2	630.00	630.00	0.217
59	Pillow	1	23	17	5	1955.00	1955.00	0.217
60	Fire Extinguisher	1		4.25 diameter	15		14.19	0.217
61	Bed Pan	1	14.5	12.5	3	543.80	543.75	0.217
62	Cardboard Bin	51	11	4.75	5	261.30	13323.75	11.067

The dimensions were measured in increments of ¼". The storage space that each object occupies is determined by its length x width x height. According to uncertainty analysis, the uncertainty in the volume can be calculated using the following, where ω is the uncertainty in the volume value:

$$\omega = \sqrt{0.25^2 + 0.25^2 + 0.25^2} \quad (1)$$

Through this equation, the uncertainty in each volume measurement is found to be 0.217 in^3. The total uncertainty for each item is then calculated by multiplying 0.217 in^3 by the item's quantity.

3.2.2 Classification of Items According to Medical Application

Of all the items inventoried, about 40 of the interior items are able to work in the vending machine. This is due to size constraints as well as the amount stored in the ambulances. Equipment, such as a blood pressure cuff, would not be in the vending machine since it is an item used multiple times and usually there is only one needed on an ambulance. Therefore the cuff would remain in a drawer or other storage container. Other equipment, such as Band-Aids or finger pricks for taking blood glucose levels, also would not be vended. Both items are very small and light in size and since there were more than 200 of each, vending would not be a logical approach.

In Appendix H, the items are categorized by use and type of equipment. The oral airways and catheters have many different sizes and therefore would have separate groups. The gauze, tape, and wrap groups should be placed close to one another. When caring for a patient, the EMT or paramedic will utilized items in these three groups together. The same idea should be applied to the oxygen supplies for an adult and a pediatric patient as well as the oral airways. This equipment should be located near the head of the patient to provide easy access for the EMT or paramedic.

After all of the exterior and interior equipment was measured and weighed, each piece had to be categorized based on its function. The focus for this was to try to find a method of storing equipment so that it could be more efficiently accessed based on its function. After reviewing all of the equipment, nine different categories were created. These groups were gauze, wraps, tape, medications (non-narcotic), Pedi-oxygen, Adult Oxygen, oral airways, catheters, and bags. Table 6 is an example of these classifications. A full list can be seen in Appendix H.

Table 5 Classification of Pharmaceuticals and Consumables for the Vending Machine

Item #	Gauze	Quantity
64	Eye Pads	
81	5x9 Gauze, Small	
82	5x9 Gauze, Large	
84	Kendall Conform Bandage	
85	4x4 Sponges	
86	Petrolium Gauze	

Item #	Wraps	
67	Cravats	
78	Coban Wrap	
79	Large Ace Wrap	
80	Small Ace Wrap	
83	Kerlix	
87	Over Wraps	

Item #	Tape	
107	Cloth Tape	
108	Cloth Tape, Large	
109	Transparent Tape	
110	Transparent Tape, Large	

Item #	Medications (non-narcotic)	
70/77	Albuterol	
71	Insta-Glucose	
73	Epi-Pen	
74	Naloxone Hydrochloride	
75	MAD Nasal	
76	Asprin	

Item #	Pedi O2	
124	Pedi Nasal Airways	
132	Pedi NRB Mask	
140	Pedi Nasal Cannula	
141	Pedi NRB	

3.2.3 Storage of Pharmaceuticals and Medical Consumables

One major piece of information noted was how the medical equipment and items were stored in the cabinets of the ambulance. Certain items were packaged specifically to protect them from any contaminants present in the patient compartment. The types and sizes of the cabinet spaces were also noted. Certain cabinets were designed to form a tight seal to isolate the equipment from contaminants, while other cabinets were open to the outside air.

Figure 26 Interior/Exterior cabinet on the passenger side

Figure 26 shows the exterior cabinet on the passenger side of the ambulance. The items seen in this picture are a backboard, a chair lift, a PED bag, and a suction bag. While these items were large, the current storage cabinet for them contains a large portion of unused space. This specific cabinet could store up to 5.6 cubic feet of equipment. As seen in the picture, about 50% of the space is unused.

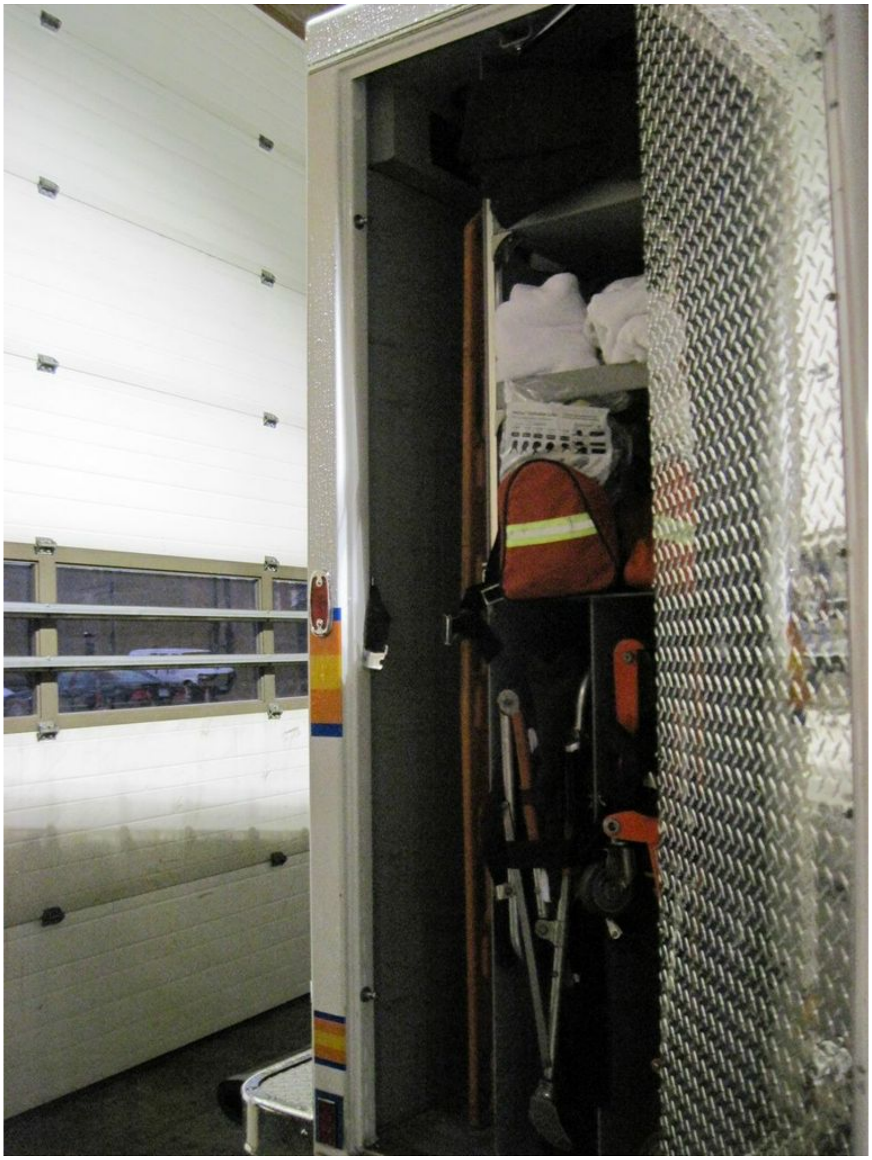


Figure 27 Stretchers and extra linens exterior compartment

Figure 27 shows an exterior cabinet that was used to house the stretcher and extra linens. There is minimal space being wasted in this cabinet. However, by being in an exterior cabinet, the extra linens are very prone to contaminants. These linens are exposed to all of the contaminants from the outside of the ambulance. This cabinet contains 14.5 cubic feet of storage capacity.

Figure 28 Driver's side exterior compartment

Figure 28 shows the exterior cabinet on the driver's side of the door. It contains an EMS trauma, and other braces. This cabinet was able to hold up to 17.4 cubic feet. As seen in the picture, only about half of the space is being used. One major drawback to exterior storage, was that any item stored on the outside of the ambulance, was subject to airborne contamination from the air.

Figure 29 Large oxygen tank storage

After the exterior components were examined for their storage, the interior medical equipment and consumables were examined. The pharmaceuticals and consumables onboard the ambulance were subject to contamination from paramedics, the patient, or bacteria already present in the cabinets or surfaces of the ambulance. Most of the equipment inside the patient compartment of the ambulance was individually wrapped and disposable, to prevent transmission of any contaminations and diseases to other pieces of equipment. Most of the consumables were wrapped in paper wraps, like in figure 30.

Figure 30 Wraps and Gauze

The figure seen above is a cabinet that contained mostly wraps and burn gauze. These consumables were wrapped in wax paper. By being wrapped in wax paper, the items were protected from potential bodily fluids contaminating the wraps. For organizational purposes, the wraps were arranged and stored inside cardboard boxes. The cardboard boxes however, were not covered in a protective coating. This meant that the boxes were able to absorb any type of contamination that might have been spread to it. The boxes would then contaminate any of the consumables that were not properly sealed in the cabinet.

Figure 31 Airway Tubing stored above the Squad Bench

Currently airway tubing is stored above the squad bench, as seen in Figure 31. It has to be stored in plastic bags to protect it from contaminants within the patient compartment. However, the tubing is stored directly next to a set of linens that are not wrapped in plastic. These linens could easily absorb contaminants transferred from the packaging of the air tubes, or the cabinets.

Figure 32 Storage in the Squad Bench

Figure 32 shows the squad bench storage area. This area could store up to about 12.5 cubic feet. As seen in the picture, the items stored in the squad bench are larger and not individually wrapped. The squad bench also contained a receptacle for trash and for sharp objects. This presented an area for possible contamination. Oftentimes, sharps containers hold used needles that could contain other bodily fluids. Because the blue backboard is not plastic wrapped, it was not safe from contaminants.

3.3 Design Objectives, Concepts, and Iterations

Before being able to start the design process, the team needed to evaluate the four possible design paths for the interior storage. The initial design concepts were to incorporate ceiling storage, removable storage, sliding glass cabinets, or to use an equipment vending machine. These initial design options were ranked according to nine different parameters. These parameters were clean-ability, volume reduction, ease of use, safety, adherence to federal specifications, basic life services, safety for the paramedic and safety for the patient, and keeping cost low. Table 4 displays the decision matrix of the initial design paths considered.

Table 6 Design Decision Matrix

	Clean-ability	Volume Reduction	Quick & Easy to Use	Safe	Federal Specs	BLS	Safe – Paramedic	Safe - Patient	Cost	TOTAL
Multiplier	*1*	*1.5*	*1.5*	*2*	*C*	*C*	*C*	*C*	*C*	*N/A*
Ceiling Storage	40	80	60	20	Y	Y	Y	**N**	Y	***290**
Removable Storage	80	40	60	100	Y	Y	Y	Y	Y	430
Vending Machine	90	60	30	100	Y	Y	Y	Y	Y	425
Sliding Glass	60	50	80	70	Y	Y	Y	Y	Y	395

The decision matrix determined that using a vending machine or a removable storage system would be the best option. The team wanted to be able to create a new storage system that favored safety and volume reduction. It was initially conceived that these would be the two most important factors in creating a new design. Once the initial design concepts were established, the team needed to determine what qualities and specifications to include in the design iterations. The team created a Pairwise Comparison Chart (Table X) to help decide what objectives were most important to the interior storage system. The objectives were ranked against each other to determine their order of significance to the final design. The team decided that the potential objectives were to make the storage system able to auto disinfect, hydrophobic, easy to clean, limit the contaminants, easy to use, and limit the volume use.

Table 7 Pairwise Comparison Chart

	Auto Disinfect	Hydrophobic	Easy to clean	Limit Contaminants	Easy to use	Reduce volume	Total
Auto Disinfect	x	0	0	0	0	0	**0**
Hydrophobic	1	x	0	0	1	0	**2**
Easy to clean	1	1	x	0	1	1	**4**
Limit Contaminants	1	1	1	x	1	1	**5**
Easy to use	1	0	0	0	x	0	**1**
Reduce Volume	1	1	0	0	1	x	**3**

By comparing the objectives against each other, the team was able to clarify which objectives were the highest priorities. After creating the Pairwise Comparison Chart, it was established that the two most important objectives to achieve were that the interior storage systeme limit the equipment's exposure to contaminants and that the interior storage system be easy to clean. The main purpose of the vending machine is to improve the overall sanitation within the ambulance, so it must be effective at limiting the spread of contaminants to the medical equipment and consumables. The storage system must be easy to clean in order to ensure adequate disinfectant coverage and soil removal. It was determined that the storage system's ability to reduce the volume was the third highest priority, followed by it incorporating hydrophobic materials, ease of use, and it having the ability to self-clean.

3.3.1 First Iteration

By using the Table 4 Design Option Matrix, the team decided that the two main areas to focus a design on were removable storage racks, or a vending machine. The removable storage design was advantageous over the vending machine design for a few reasons. Using removable storage racks was considered to be efficient to and more intuitive to use than a vending machine. By having less dynamic parts, there would be a significantly less of a chance for malfunction. The removable storage design also allowed for total disinfection of the storage area. The individual storage containers were designed so that the lid is completely removable and only held in by a half-inch groove. The containers would be watertight so that contaminants cannot enter the container unless it has been used during that patient transport. At the end of every day, the storage containers would be disassembled and emptied so that they may be completely disinfected. The containers are made of polypropylene so that they can be easily disinfected. The polypropylene will also make the containers durable, which is ideal for any piece of ambulance equipment.

Figure 33 Removable Storage Concept

There are few main drawbacks to using a removable storage system. According to standards all of the equipment has to be able to be secured to the wall of the ambulance during travel, as to prevent injuries. As a result, the team was not able to design a removable storage rack for that would be able to be implemented into a star of life ambulance.

3.3.2 Second Iteration

After realizing the drawbacks to the removable storage concept, the design was reconsidered. Due to the manufacturing capabilities of the team, the vending machine design was ultimately selected. There were several reasons to back this decision:

1. The removable storage design required injection molding and could not be prototyped easily.
2. The removable storage design would require a timely cleaning process every day.
3. The removable storage design would be prone to contamination when equipment was being retrieved.

The team designed a few different design iterations while trying to construct a final design. One of the designs was to create a revolving pharmaceutical dispenser (Figure 34). The equipment would be stored in cylindrical tubes. There would six tubes per unit. The entire unit would be spun freely. Even with the six tubes holding equipment, there would only be one dispensing area. By pressing the button, a single unit of equipment or medication would be dispensed. This design would help conserve space with medication storage, while keeping it mostly contaminant free. This design was entirely mechanically driven, and only uses the force of the user and gravity to vend medication. The paramedics would have to spin the unit by hand to obtain the equipment or medicine desired. There were many good qualities of using the revolving pharmaceutical dispenser. Most of it came down to the fact that equipment can be easily categorized into its use and therefore keeping it stored better. A good way to save space would be to stack multiple revolving pharmaceutical dispensers on top of one another. However, the design's use and application are limited because all of the ambulance equipment cannot fit into such a tight space or slide out of the tube due to gravity alone.

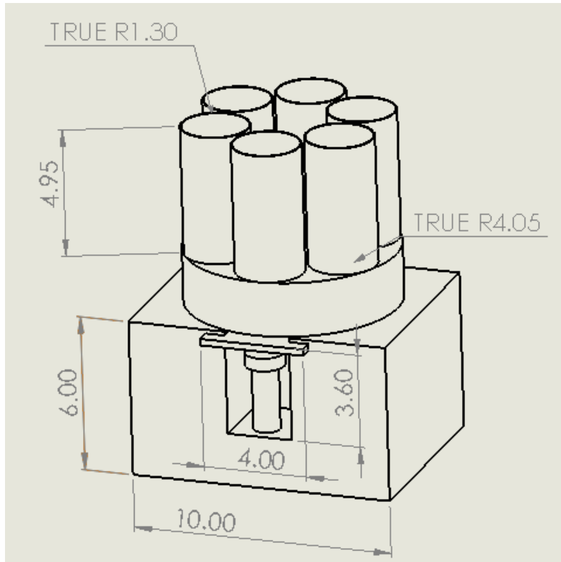


Figure 34 Lazy Suzan Drawing with Dimensions

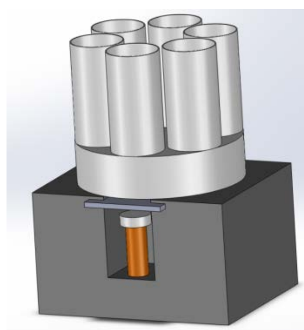
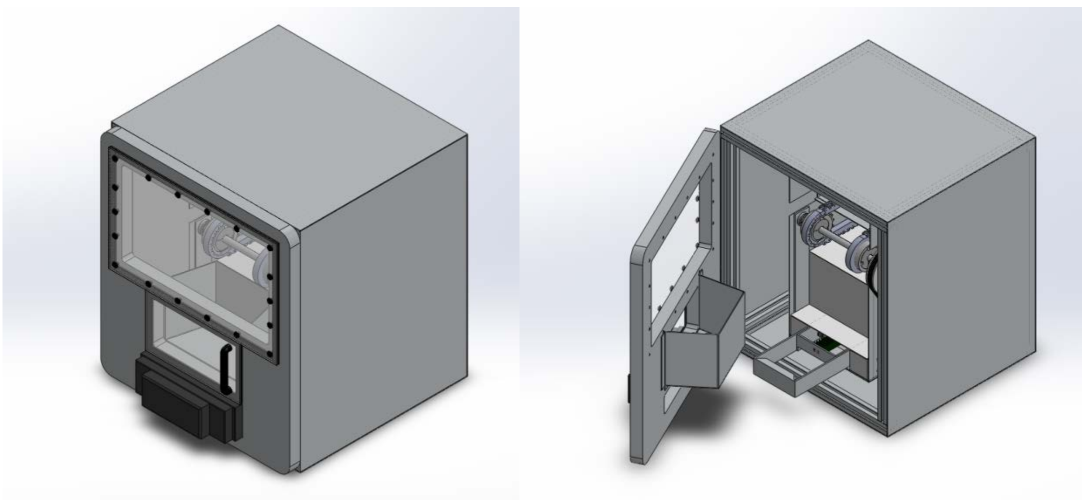


Figure 35 Revolving Pharmaceutical Dispenser Concept Image

Dimensions of the device can be seen in Figure 34. As seen in the figure, the revolving dispenser was very small. The entire unit is about 10 inches wide by 8 inches long and 12 inches tall. Its best intended use was to store medicine. The medicine would fit into one of the six cylindrical tubes. The tubes are able to fit one vial each of sealed medicine. A vial of medicine is usually a cylindrical tube that is 1.5 inches in diameter, and 4 inches in length. This design was only useful for dispensing medicine that was in pill form. As seen during the inventory process, there are certain medicines that are stored as a liquid solution, like albuterol, that would not be able to be stored in this machine.

3.4 Final Design: Mechanical Vending Machine

The final design is a fully mechanical vending unit. The design is modular so that it can be utilized as either wall-mounted storage towards the rear of the ambulance or as storage above the squad bench or work bench. An example of a single one of these vending units in an enclosure can be seen in Figure 36A. In a real world application, a single enclosure would house several vending units. The front face of the enclosure is hinged so that it can be opened when restocking supplies, as seen in Figure 36 B. The governing principle behind the design is that a large volume of the ambulance is protected from potential contamination. This results in faster cleaning times for paramedics and a more sanitary patient compartment.



A B

Figure 36 A Single Vending Unit Enclosure Opened and Closed

The enclosure consists of two main parts: the frame and the front face. The frame is constructed of extruding aluminum T-framing so that a prototype could be easily constructed and is enclosed by 1/16" aluminum sheet metal. The front face is made of high density polyethylene (HDPE), which is useful from a manufacturing standpoint because it can be drilled and tapped without the need to breach the front face and use jam nuts to fasten it in place. An acrylic glass window pane is fastened to the HDPE with ¼-20 cap head screws. Half inch strips of EPDM (ethylene propylene diene monomer) rubber are pressed between the acrylic glass and

HDPE in order to form a tight seal at the edge of the acrylic. The front face of the enclosure has a dispensing area fastened to it made from 1/16” folded aluminum. This dispensing area is slightly V-shaped so that it does not interfere with the vending mechanism upon closing the front face (Figure 36 B). The dispensing area is accessed via an acrylic glass door with EPDM rubber around its outer edge. Mechanical latches hold the dispensing door and the front face closed during patient transport, in accordance with NFPA 6.16.5. A rubber boot is attached to the front face of the enclosure with rubber adhesive, which prevents the paramedic from making direct contact with the vending mechanism. A detailed drawing of the front face assembly is depicted in Figure 37. A full size drawing is located in Appendix J.

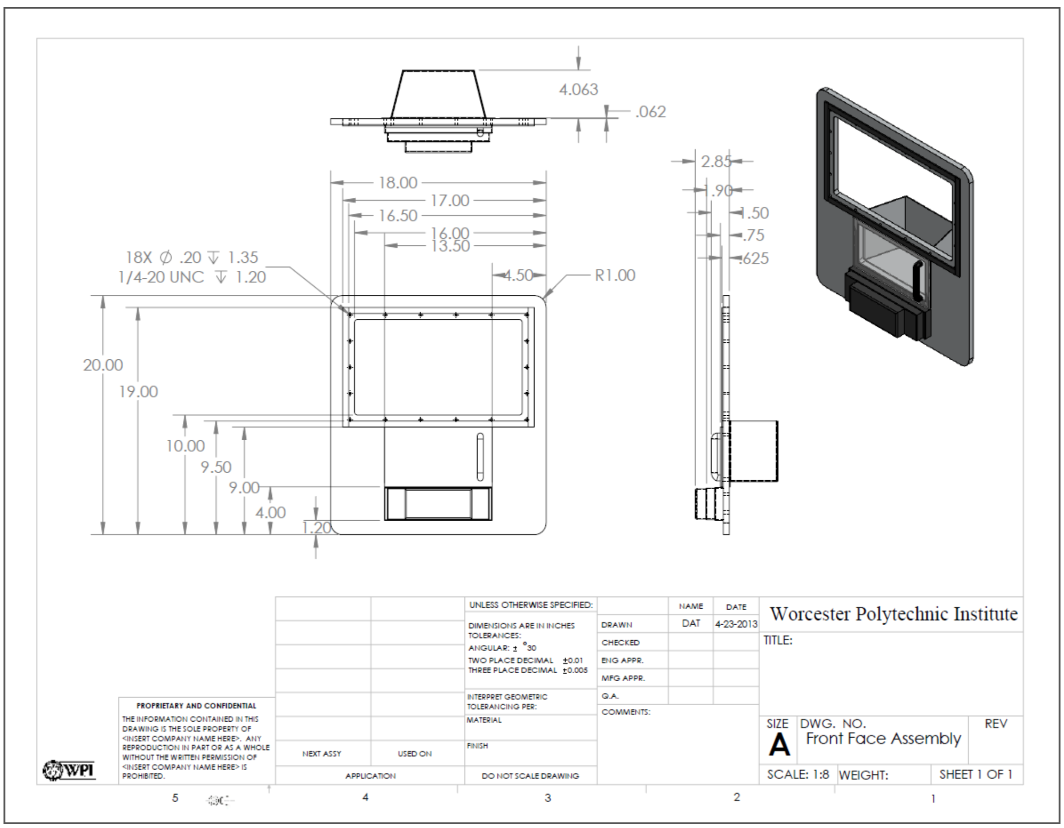
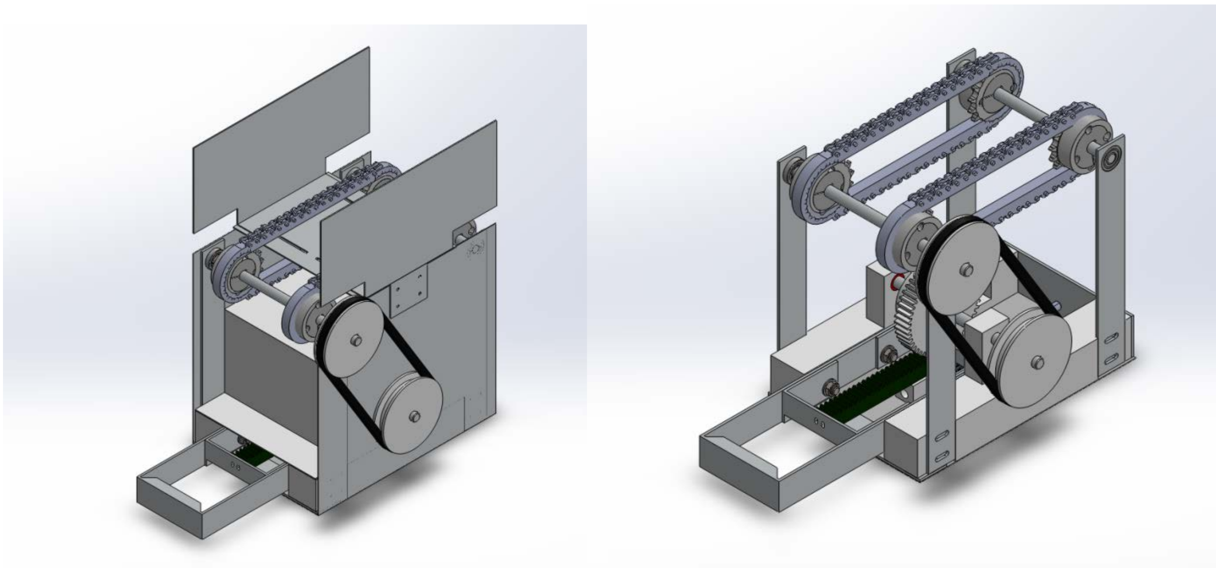


Figure 37 Front Face Detailed Drawing

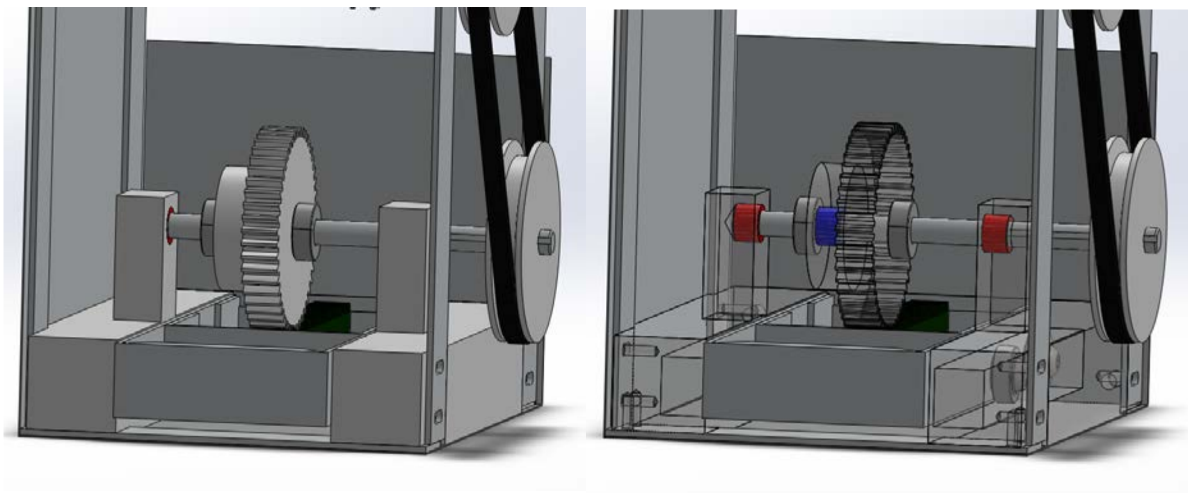
The vending mechanism itself works by pressing a spring-loaded button, which causes the medical supplies loaded on top of the chains to vend. The mechanism is partially contained in an aluminum sheet metal housing in order to protect the gear and gear rack from excessive contact with bleach. Since the gear rack and gear are made of nylon, they will degrade if exposed to bleach for too long. The pulleys hold a 27” rubber belt, which rotates the front shaft. The vending mechanism can be seen with and without its sheet metal housing in Figures 38 A and 38 B.



A **B**

Figure 38 The Vending Mechanism with and without its Housing

The aluminum frame is fastened to a high density polyethylene base. HDPE was selected as a material because it is nonreactive with bleach, it can be drilled and tapped, and it provides a smooth and quiet running surface for the rollers on the spring-loaded button. The spring-loaded button holds a 7” long 12 pitch machined nylon gear rack that mates with a 4” pitch diameter machined nylon spur gear. The spur gear is retained by two shaft collars. When the spring-loaded button is depressed, the chains feed items forward, but when the button retracts, the chains do not move. This feat is accomplished by opposing one-way needle roller bearings. The HDPE base holds two one-way needle roller bearings by interference fit. These bearings are highlighted in red in Figure 39 B. These two bearings are mounted so that they allow the drive shaft to spin when the button is depressed, but they lock when the button is pushed back to its starting position and the drive shaft remains stationary. A single one-way roller bearing lies at the center of the 4” pitch diameter machined nylon spur gear. This bearing is mounted opposite of the two that are mounted on the HDPE base. This allows the spur gear to lock onto the shaft when the button is depressed and to spin freely as the button returns to its starting position.



A **B**

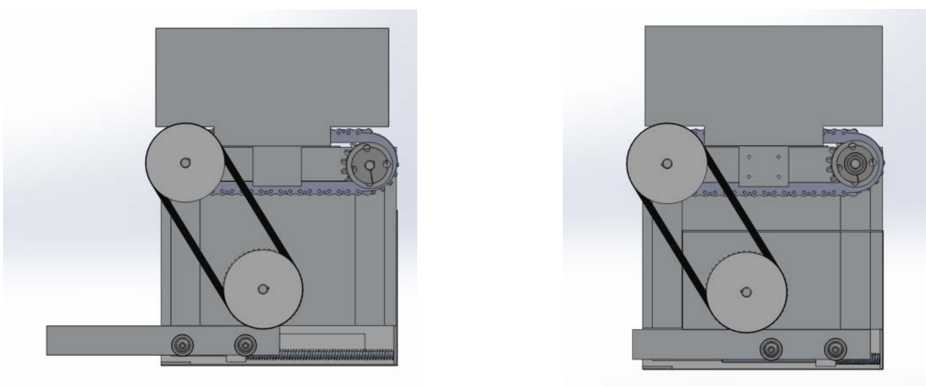
Figure 39 Opposing One-Way Needle Roller Bearings

The spring-loaded button is designed for repetitive use and for low resistance. The uncompressed length of the spring is 8” and the compressed length is 2.6”. The spring constant is 0.45 lb/in. In order to better utilize space and material, the compressed length of the spring was determined so that the spring shaft guide can be mounted as close to the back plate of the vending unit’s frame as seen in Figure 40. The purchased spring length is 20” and has 136 revolutions. This means that an 8” spring would have 54.4 revolutions. Namely,

$$\frac{8\,in\ \ x\,136\,rev}{20\,in} = 54.4\,rev. \qquad (2)$$

The compressed length can then be determined by multiplying the number of revolutions by the diameter of the spring. The spring shaft guide is placed at a distance of 2.23” away from the frame’s back plate when the button is fully depressed (Figure 40 B). The 8” spring is slightly preloaded when it is installed. The actual length of the spring in its uncompressed position while installed is 7.63”. This is done so that the spring can push upon the rubber boot attached to the outer surface of the vending machine. Since the spring is already pre-loaded and compressed a distance of 0.37”, it allows the button to push slightly on the rubber boot with a force of 0.167 lb in order to fully extend the boot. The total force required to compress the spring 5.4”, and to fully depress the button, is 2.43 lb.

This force could be reduced if the initial cut length of spring was longer, but this would require a longer spring guide shaft and a waste of material. The spring guide shaft has a single tapped end, which is fastened to the back plate of the frame by a countersunk 10-24 screw. The spring-loaded button can be viewed in Figures 40 A and 40 B in both the compressed and uncompressed position, respectively.



A **B**

Figure 40 The Spring-Loaded Button, Uncompressed and Compressed

One useful feature of the vending mechanism is that the positions of the sprockets and the sidewalls can be adjusted to suit the width of the object being dispensed. This allows objects as thin as 2” and as wide as 8.5” to be dispensed. The maximum length of a dispensed object is determined by the length of chain upon which it can rest. This sets the maximum length at 8.5”. The minimum length of an object is set by the minimum distance between pusher dogs on the chain. The chain is 0.5” pitch so the minimum width of a dispensed object is

0.5”. The maximum width is determined by length of the vending tray (12”) and the vending tray’s maximum width (8.5”). The maximum height of an object is determined by the supporting sidewalls (6”). As convenient as this design is, its main drawback is that each vending unit requires a dispensing area. This adds unnecessary height to each vending mechanism, and while the design does not stick out from the wall as much as ordinary cabinets (17” compared to 22.5”) it takes up drastically more vertical space and is almost 17.5” tall with the side walls attached. Detailed drawings of the mechanism can be viewed in Figures 41 and 42. Figure 41 depicts the mechanism without its sheet metal housing and Figure 42 depicts it with the housing. Full size drawings can be found in Appendix J.

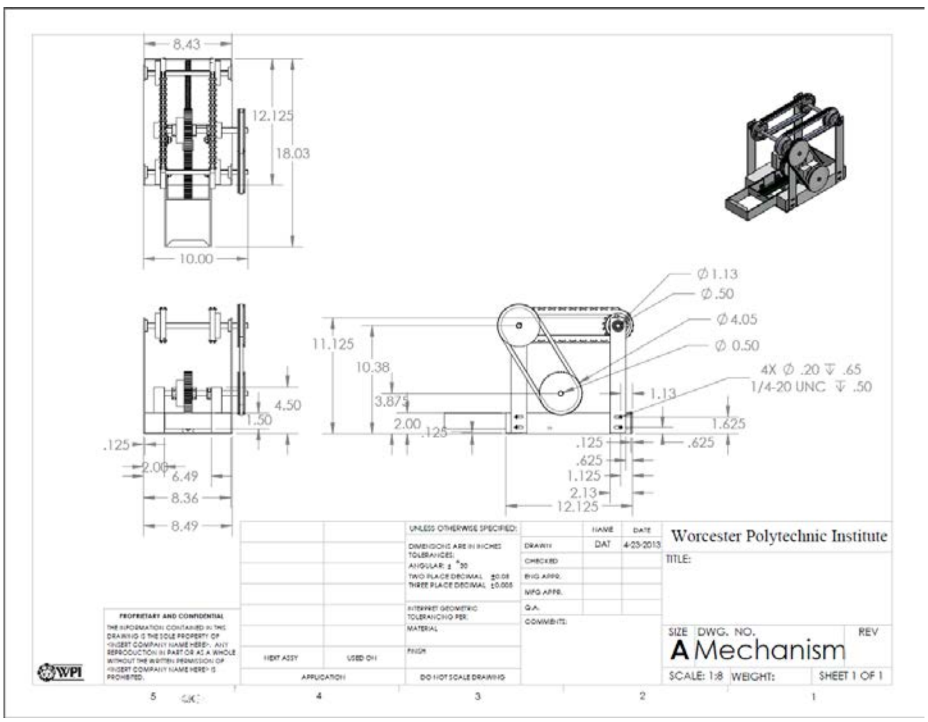


Figure 41 Mechanism without Sheet Metal Housing

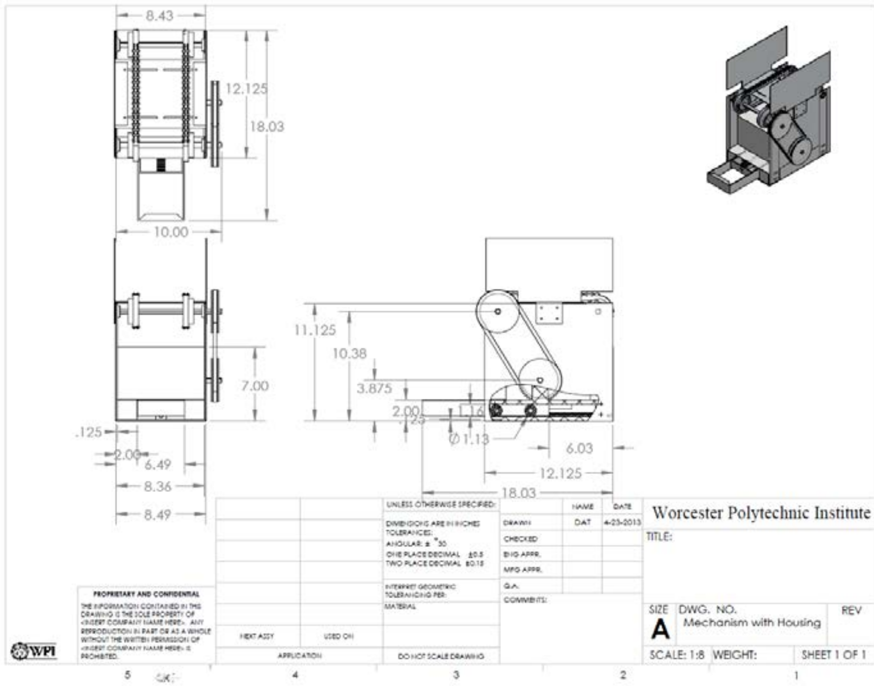


Figure 42 Mechanism with Sheet Metal Housing

The overall outer dimensions of the ambulance are used to determine the number of vending mechanisms, and number of items, that can be dispensed by this design. Seven vending mechanisms can sit side-by-side within the 80” maximum length of the vending machine and still allow room for a 1” X 1”, 0.125” thick extruded aluminum frame. The mechanisms were placed next to each other in groups of two or three. The front panel to each group can be hinged upwards (top row) or downwards (bottom two rows) during restocking. The arrangement of vending mechanisms can be viewed in Figure 43.

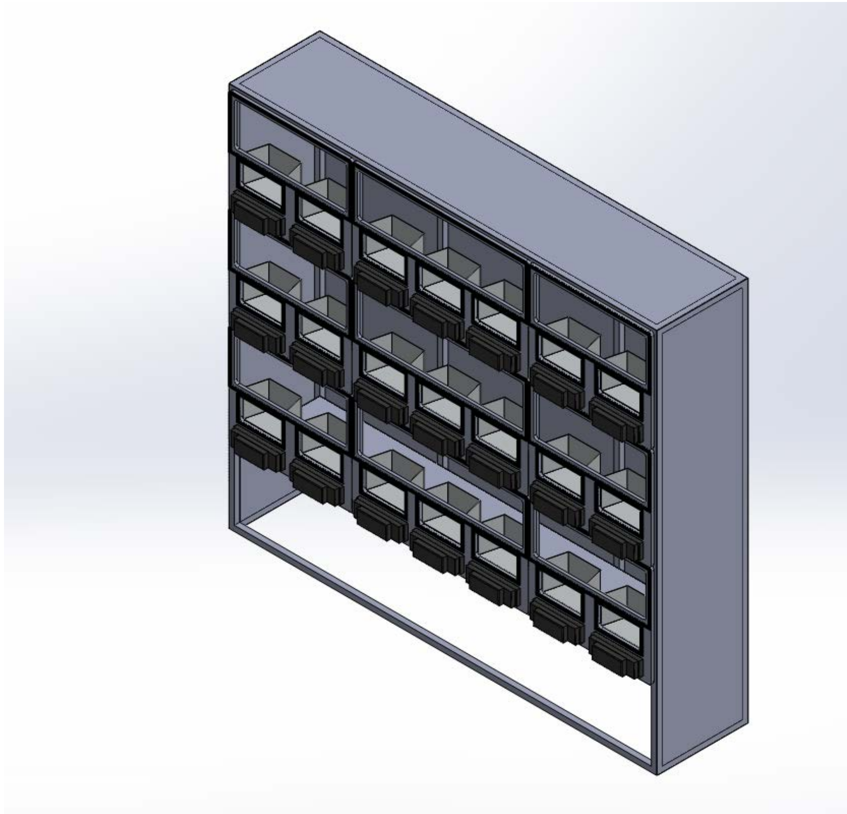


Figure 43 Full-Sized Vending Machine

Since space does not allow for another row of vending mechanisms, the bottom of the vending machine may be used for the storage of linens or larger items such as leg braces and arm braces. A view from the interior of the patient compartment can be seen in Figure 44. This design is advantageous to the EMT because he can access equipment at the touch of a button, thus improving the speed and quality of patient care. The overall sanitation of the patient compartment is improved because the interior of the vending machine can be cleaned easily once the vending trays are removed. A single vending mechanism is depicted in the center of the machine. More than one could not be depicted due to graphics processing limitations. The dimensions for the vending machine and the other storage cabinets can be seen in Figures 45 and 46.

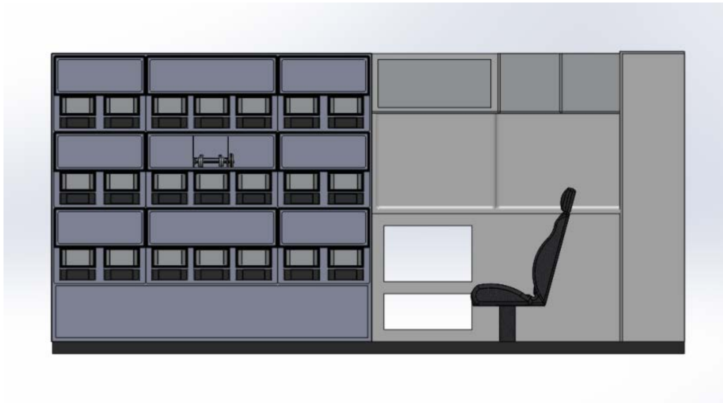


Figure 44 Patient Compartment Interior View

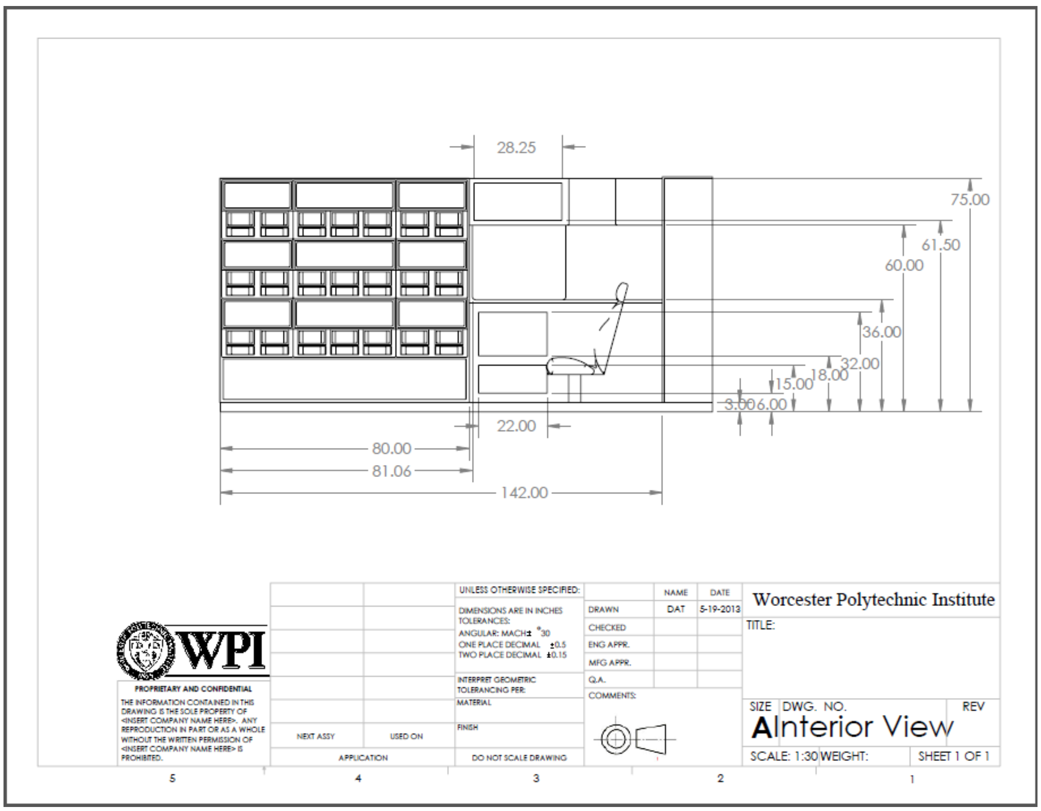


Figure 45 Patient Compartment Interior View Drawing

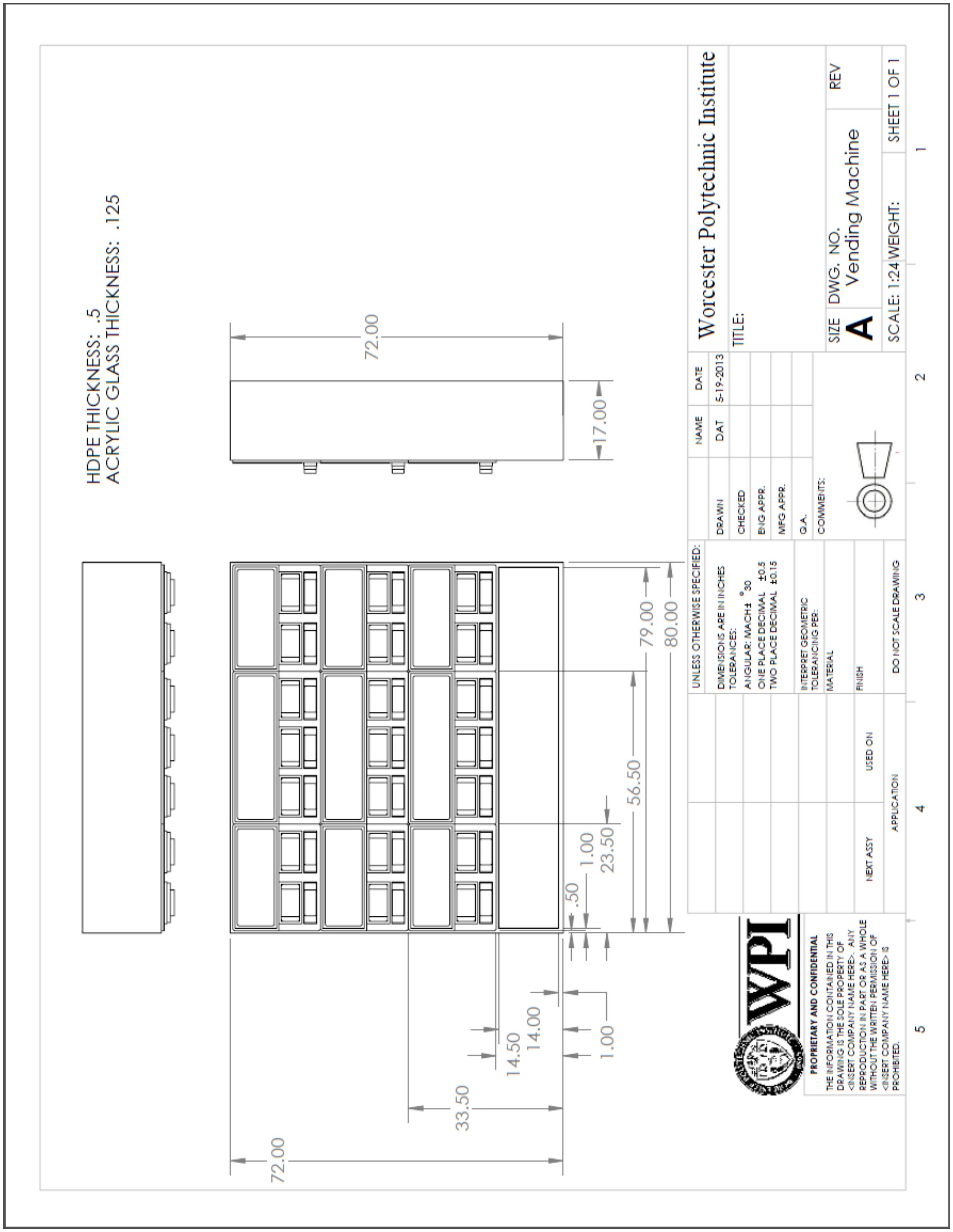


Figure 46 The Vending Machine

Finally, the weights and dimensions of the inventory were used to create a list of items that were recommended or discouraged for vending. This list can be seen in Appendix B. Not all items should be vended. Some items are too large and will not fit in the vending machine. Also, since each vending unit has a dispensing area, storage space is limited. Storage space in the vending machine should be allocated to items that may come in close contact with open wounds, mucous membranes, or children (because they are more susceptible to infection.)

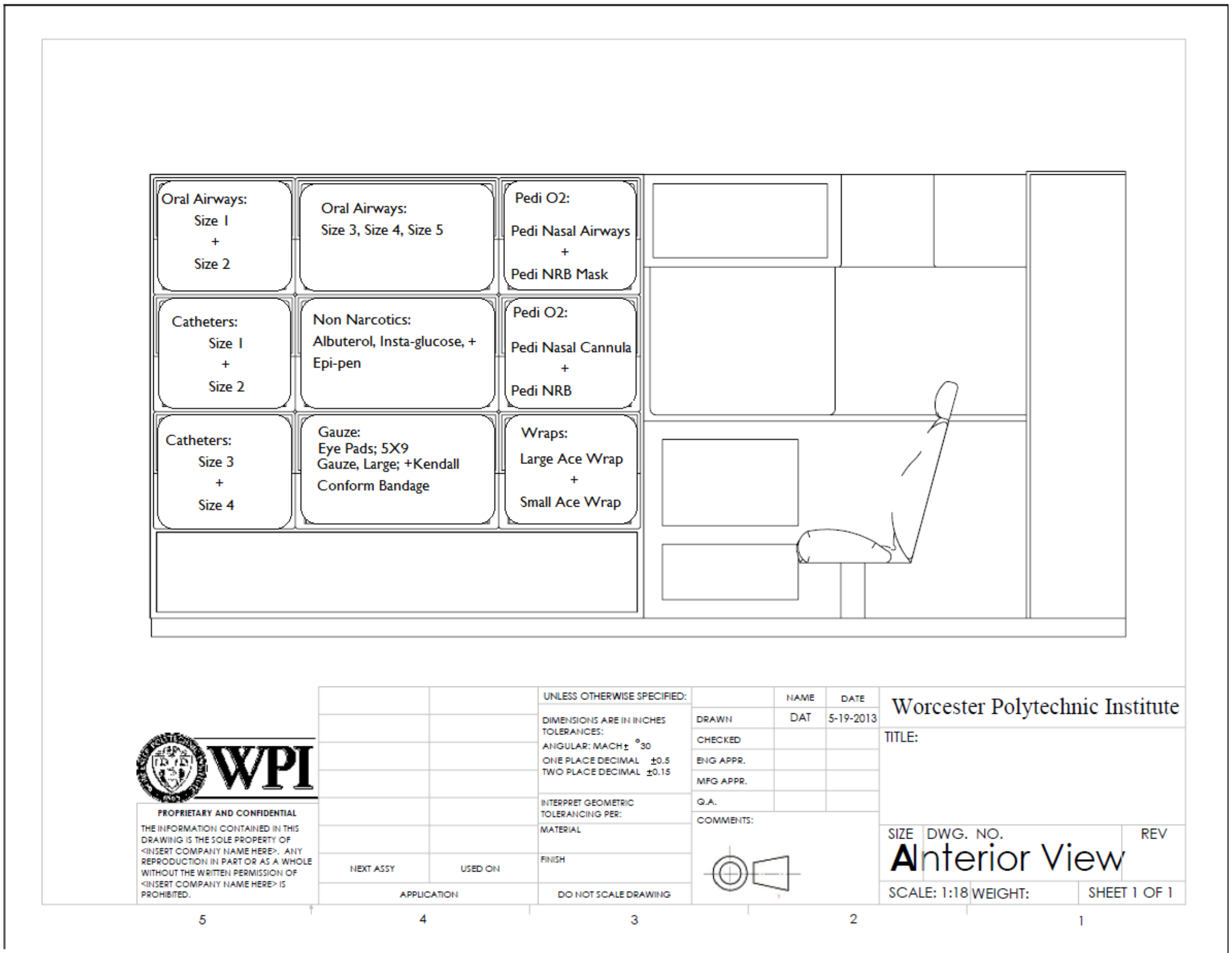


Figure 47 Interior View of the Patient Compartment with Equipment Sorted

From the list that was arranged in Appendix H, an organization method was proposed (Figure 47). Items that come into contact with open wounds or mucous membranes received the highest priority for being stored in the vending machine. For this reason, oral airways and catheters were stored in the vending machine. Oral airways and catheters are sterile when they are placed in their plastic packaging, but if the packaging itself is not protected from contaminants, it is possible for an EMT to transfer bacteria on the packaging onto the item itself during handling. According to the same logic, the pediatric O_2 equipment should be put into the vending machine. This equipment was prioritized higher than the adult O_2 equipment because adults can fight off infection easier than children and because the non-rebreather mask is not particularly invasive. The albuterol, insta-glucose, and epi-pen were selected for vending because they would benefit from a faster means of retrieval. These items can save someone's life if they have asthma, diabetes, or extreme allergic reactions and it is crucial that the EMT be able to retrieve them quickly. The dimensions of these objects can all be found in Appendix B. The Item numbers for these objects are 64, 70, 71, 73, 77, 82, 84, 79, 80, 121, 122, 124, 132, 140, and 141.

3.4.1 Cost Analysis

One of the major downsides to designing the entire vending machine to be mechanical is the cost. The vending machine requires a large amount of material compared to the current standard, since each piece of equipment must have its own vending tray. The amount of material used in this design could be significantly reduced if the design is modeled after a typical electronic vending machine, instead. Since the design is fully mechanical, it requires a large amount of material to operate, which drives the cost up. The amount of material could also be reduced if an aluminum track with rollers was used instead of the high density polyethylene for the vending tray, but it was a priority to minimize the amount of noise that the vending machine would produce.

The prices for the parts of the vending tray are obtained from McMaster-Carr. As shown in Table 8, the total cost for the parts necessary to construct the vending tray alone is over $1100. Some of these materials could be used to construct multiple vending trays in order to reduce cost, though. For example, the 4' gear rack could be used in the construction of 4 vending trays, since each requires only 1' of gear rack. However, this would only reduce the cost of the 3 subsequent vending trays to $917.

Table 8 Bill of Materials

Quantity	Product		Unit Price ($)	Total ($)
1	9663K57	302 SS Cut-to-Length Compression Spring 20" Length, .562" OD, .041" Wire Diameter	5.88	5.88
4	57095K131	Taper-Lock Bushing Size 1210, 1/2" Bore	15.36	61.44
4	2590K32	Taper-Lock Bushing-Bore Steel Sprocket for #40 Chain, 1/2" Pitch, 17 Teeth, Uses 1210 Bushing	34.64	138.56
2	1570K42	Fully Keyed Aluminum Drive Shaft 1/2" OD, 1/8" Keyway Width, 12" Length	20.85	41.70
2	6435K14	One-Piece Clamp-on Shaft Collar for 1/2" Diameter, Black-Oxide Steel	1.97	3.94
1	6191K19	4L Rubber V-Belt Trade Size 4L270, 27" Outer Circle	5.45	5.45
2	6274K26	UHMW Plain-Bore V-Belt Pulley 4.05" OD, 3.80" Pitch Dia, 3/4" Width, 1/2" Bore	20.73	41.46
2	8671K79	Rigid HDPE Polyethylene Rectangular Bar 2" Thick, 4" Width	23.15	46.30
1	60435K62	Machined Nylon 14-1/2 Deg Pressure Gear Rack 12 Pitch, 3/4" Face Width, 3/4" H O'all, 4' Length	115.03	115.03
1	60455K51	Machined Nylon 14-1/2 Deg Angle Spur Gear 12 Pitch, 48 Teeth, 4" Pitch Diameter, 1/2" Bore	77.85	77.85
4	2780T57	High-Load Steel Ball Bearing Dbl Sealed, for Shaft Dia 3/8" X 1-1/8" OD X 3/8" W	12.31	49.24
4	2780T59	High-Load Steel Ball Bearing Dbl Sealed, for Shaft Dia 1/2" X 1-3/8" OD X 7/16" W	14.54	58.16
2	2326K12	Add-and-Connect Link for #40 Stainless Steel Hollow-Pin ANSI Chain	13.96	27.92
1	2326K1	Stainless Steel Hollow-Pin ANSI Chain #40,	212.32	212.32
1	8377T6	Partially Keyed Type 303 SS Drive Shaft 1/2" OD, 1/8" Keyway Width, 24" Length	85.30	85.30
1	98535A130	Spring Steel Standard Key Stock 1/8" X 1/8", 12" Length	2.07	2.07
1	8975K15	Multipurpose Aluminum (Alloy 6061) 1/8" Thick X 3" Width X 6' Length	25.56	25.56
2	89015K39	Multipurpose Aluminum (Alloy 6061) Sheet, .063" Thick, 24" X 24"	49.71	99.42
3	2489K24	One-Way Locking Steel Needle-Roller Bearing Plastic Cage, 1/2" Shaft Dia, 3/4" OD, 1/2" Width	10.92	**32.76**
		Total		**1130.36**

Another reason why the design is so costly is the choice in materials. Machined nylon spur gears and racks were chosen over molded nylon, because they are more resistant to wear and potential corrosion from bleach vapors. The machined nylon spur gear can also be bored out to the necessary 3/4” inner diameter so that it can be mounted onto the one-way roller bearing. Since most plastic chains are composed of acetal, an expensive stainless steel chain system is used instead. The reason for this is that the acetal would degrade when exposed to bleach.

3.5 Biomedical Considerations and Impact

The vending machine is intended to limit and reduce the equipment's exposure to contaminants. This is accomplished by eliminating the cracks and crevices of current storage methods. The main objective was to keep the medical equipment isolated from the rest of the patient compartment until it is needed by the EMT. The current design houses all of the equipment behind a door, and features rubber seals to prevent the spread of contamination. The secondary objective was to promote a thorough cleaning by ensuring that the material used in the design were easy to clean.

To test the cleanliness of the design, the team prototyped the front door of the vending machine. This was determined to be the number one area where bacteria would be present in an actual ambulance. The team conducted a riboflavin test to determine how easy it was to clean our prototype, and compared it to a cabinet door that commonly found on a normal ambulance. To start, the team put a riboflavin solution on gloved hands and opened and touched the cabinet as if we were trying to retrieve a piece of equipment from inside of it. The team used a black light to expose the contaminated, and a ruler to measure the area of contamination. The test left an area of about 20 square inches contaminated, about 60% of the front face.

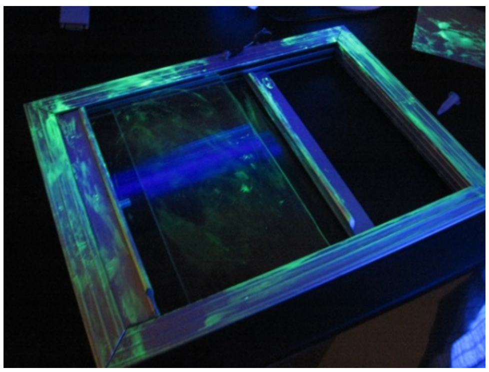


Figure 48 Simulated Contamination

The team then used dispatch hydrogen peroxide to clean the cabinet. The cleaning removed 75% of the contamination on the front surface, leaving about 5 square inches on the surface. However, the team was not able to clean track that the glass slides along.

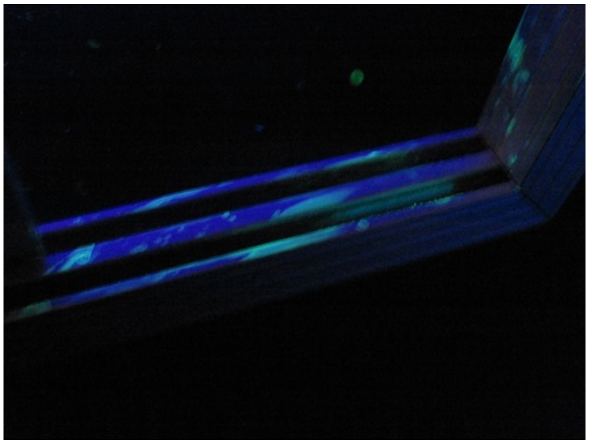


Figure 49 Residual Contaminants After Cleaning

The same procedure was repeated with the prototype of the door. After contamination, there was only an area of about 10 square inches appeared under the black light. The door was then wiped down with fresh dispatch wipes to clean the contamination. After cleaning, only an area of about 3 square inches was present. The door of the vending machine was made from high density polyethylene, which is an intermediately hydrophobic material. This would explain why it had half the amount of contaminated areas as the aluminum cabinet. During cleaning, because aluminum is hydrophilic, it was more difficult to remove the contaminants. The hydrophobic properties of the polyethylene allowed for 70% of the contaminated surface to be cleaned. As a result of this test, the team can conclude that an intermediately hydrophobic material like high density polyethylene should be used for outer surface of the vending machine.

There were limitations to this test, however. This test revealed that the HDPE was easier to clean due to its semi-hydrophobic nature, but soil removal is not the only step in disinfecting surfaces. In the future, it would be opportune to test for the amount of bacterial adhesion on each type of material. The materials would be coated in benign bacteria, cleaned, and then swabbed for contaminants. The cleanliness testing performed showed that good disinfectant coverage could be obtained by utilizing HDPE for the outer surface, but this does not necessarily imply that the surface will be more bacteria-free.

Chapter 4: Conclusion

The vending machine design exhibited an ability to improve ambulance sanitation and patient quality care. The design was capable of keeping medical equipment removed and isolated from contaminants present in the ambulance, which would also ideally reduce the amount of illnesses acquired during patient transport. The vending machine would increase the efficiency of EMTs by dispensing equipment at the touch of a button. However, due to the high cost and large space requirements, the team recommended that the vending machine only be used for a few items in each ambulance instead of replacing all the cabinet storage. The team created a list of recommended pieces of equipment that would easily fit on a vending tray and would benefit from being vended, which can be seen in Appendix D. However, each piece of equipment would require its own vending unit and dispensing area, which added to the weight and volume of the final design. The team recommended that medical consumables that come in close contact with the patient's face or mucous membranes be stored in the vending machine. These items included, but were not limited to airway tubing, catheters, tracheotomy kits, and pediatric non-rebreather masks.

If the SLATE ambulance were going to keep the concept of using an equipment vending machine, the future designers might want to consider using an electric machine. Our team followed the design constraint of trying design an entirely mechanical system. During our research, we found that energy conservation was a key factor in ambulance design. However, the main issue with our design is that the mechanical system that dispenses the equipment takes up more space than originally expected. A vending system that was electrically powered would be able to store equipment in a much more space-efficient manner. Any future designers should consider using only a single dispensing area for equipment, as this took up an egregious amount of vertical space. This would be an important tradeoff for future design engineers to consider.

In the future, a weight test done with the team's inventory data can be used to evaluate the current layout of the interior and exterior storage in an ambulance. This would help reduce the strain on the structure and suspension of an ambulance which ultimately extends its working life. Using the volumes of each item, which can be seen in Appendix D, alternative storage methods can be conceived. Overall one can get the final weight, dimensions, and weight distribution of the entire ambulance.

To increase security of the medical supplies a keypad lock or RFID scanner could be added into the vending machine design. This would require the EMTs to use a personalized code or badge to access the supplies, which can be recorded and stored in a computer. This may help reduce problems with medications and supplies disappearing as each access would be recorded with an identifying code or badge, leading to the person responsible.

The team has submitted an entire inventory of a standard ambulance from a local EMS service. All of the equipment on the interior and exterior were examined, measured, weighed, and categorized. This list of equipment will be vital to the engineers that further continue working on the SLATE ambulance. With this list, they will be able to help organize the future storage system based on the functions each piece of equipment would serve. This information has the potential to greatly increase the efficiency for paramedics to retrieve equipment for specific patient needs.

References

[1] U.S. Department of Transportation, "Mitigation Strategies for Design Exceptions," *U.S. Department of Transportation,* vol. Chapter 3, 13 Controlling Criteria, pp. , July 2007.

[2] "Ambulance Crashes While Transporting Patient," *WSVN,* March 14, 2013.

[3] General Services Administration,"Federal Specification for the Star-of-Life Ambulance," *KKK-A-1822f,* August 28, 2012.

[4] "Antimicrobial Solutions How, where and why to choose antimicrobial coated door hardware." *Ingersoll Rand Security Technologies, IR,* pp. 1-4, 2008.

[5] "Paramedic emergency ambulance staff, medications, equipment, and supplies," County of San Mateo, San Mateo, CA, April 1, 2002.

[6]General Services Administration, "Federal Specification for the Star-of-Life Ambulance," *General Services Administration, GSA,* pp. 1-110, June 1, 2002.

[7] National Fire Protection Agency, "Standard for Automotive Ambulances," *National Fire Protection Agency. NFPA,* 1917.

[8] (September 17, 2012). *Evolution of the Ambulance*. Available: http://firehistory.weebly.com/evolution-of-the-ambulance.html. DOI: Firehistory.weebly.com.

[9] (October 29, 2010). *Dentsu Green Vending Machines Grow Veg Without Sun*. Available: http://www.apartmenttherapy.com/dentsu-green-vending-machines-131012.

[10] (2010). *The History of Ambulances*. Available: http://www.emt-resources.com/History-of-Ambulances.html.

[11] (2007). *The Model T Specifications*. Available: http://www.barefootsworld.net/ford-t-specs.html.

[12] (June 25, 2007). *1916: Ambulances - World War I* [EMS History]. Available: http://www.emsmuseum.org/virtual-museum/timeline/articles/398194-1916-Ambulances-World-War-I.

[13] (March 1, 2002). *Dodge WC- 54 3/4 Ton Ambulance*. Available: http://www.mtaofnj.org/content/WWII%20Combat%20Medic%20-%20Dave%20Steinert/dodge_wc.htm.

[14] (2013). *Specialty Edsels*. Available: http://www.edsel.com/pages/special.htm.

[15] (). *The 2013 Braun Ambulance Lineup* [Braun]. Available: http://www.braunambulances.com/. DOI: 2013.

[16] (2013). *The BMW X6 Ambulance is Not Your Regular Aid Vehicle*. Available: http://www.autoevolution.com/news/the-bmw-x6-ambulance-is-not-your-regular-aid-vehicle-6690.html.

[17] (November 18, 2011). *Cefalexin Capsule*. Available: http://sanatate.bzi.ro/cefalexin-capsule-8010.

[18] (2008). *Antimicrobial Solutions*. Available: http://w3.securitytechnologies.com/IRSTDocs/Brochure/105307.pdf.

[19] (July 7, 2012). *Japan- The Land of Vending Machines*. Available: http://www.kuriositas.com/2012/07/japan-land-of-vending-machines.html.

[20] (2013). *U.S. WW1 Ambulance Comes to Life*. Available: http://www.ww1history.com/Model_T_Project.php.

[21] (2007). *PharmGuard, An Environmental Control System for EMS Pharmaceutical Storage*. Available: http://www.pharmguard.com/pharmguard.htm.

[22] B. Crichton, "Keep in a cool place: exposure of medicines to high temperatures in general practice during a British heatwave," *Jrsm,* vol. 97, pp. 328-329, 2004.

[23] C. L. Lai, J. H. Harwell, E. A. O'Rear, S. Komatsuzaki, Arai, J., Nakakawaji, T. and Y. Ito, "Adsorption isotherms of perfluorocarbon surfactants from aqueous and non-aqueous solutions and friction measurementsof perfluorosurfactant-adsorbed alumina," *Colloid and Surfaces A : Physicochemical and Engineering Aspects,* vol. 104, pp. 231-241, 1995.

[24] K. Lazar, "Boston EMS paramedic suspected of drug tampering may have affected 57 patients," *The Globe Newspaper Company,* pp. March 22, 2013, September 30, 2012, 2012.

[25] Y. Nigam and J. Cutter, "A Preliminary Investigation into Bacterial Contamination of Welsh Emergency Ambulances," *Emerg Med,* vol. 479, January 20, 2003, 2003.

[26] Oliveira. R, Azeredo. J, Teixeria. P and Fonseca. A. P., "The Role of Hydrophobicity in Bacterial Adhesion," *Bioline,* pp. 1-22, 2001.

[27] J. Rago, K. Buhs, V. Makaorvite, E. Patel, M. Pomeroy and C. Yasmine, "Detection and analysis of *Staphylococcus aureus* isolates found in ambulances in the Chicago metropolitan area," *Ajic,* vol. 40, pp. 201-205, April 2012, 2012.

[28] M. Swaroop, D. C. Straus, O. Agubuzu, T. J. Esposito, C. R. Schermer and M. L. Crandall, "Pre-hospital transport times and survival for Hypotensive patients with penetrating thoracic trauma," *Journal of Emergencies, Trauma, and Shock,* vol. 6, pp. October 15, 2012-16-20, January 22, 2013, 2013.

[29] Teixeira. P and Oliveira. R, "Influence of surface characteristics on the adhesion of Alcaligenes denitrificans to polymeric substrates," *J. Adhesion Sci. Techmol,* vol. 13, pp. 1287-1294, March 30, 1999, 1999.

[30] U.S. Department of Transportation National Highway Traffic Safety Aministration, "Laboratory Test Procedure fr FMVSS 302, Flammability of Interior Materials," *U. s. Dot,* pp. 1-32, 1995.

[31] C. J. Van Oss, "Hydrophobicity and hydrophilicity of biosufaces." *Current Opinion in COlloid Interface Science,* pp. 503-512, 1997.

[32] C. J. Van Oss, "Hydrophobicity of biosurfaces- origin, quantitative determination of interaction energies. Colloids and Surfaces B." *Biointerfaces,* pp. 91-110, 1995.

[33] K. Zachary and et. al., "Comtamination of gowns, gloves, and stethoscopes with Vancomycin-resistant Enterococcus," *Iche,* vol. 22, pp. 560-564, 2001.

[34] "MSDS." *The Clorox Company*. N.p., n.d. Web. 20 May 2013.

[35] (2013). *Decontaminating the Ambulance*. Available: http://carsrescue.org/wp-content/uploads/2012/Downloads/deconambo.pdf.

[36] "Engineering properties of marlex resins," Chevron Phillips Chemical Company LP, The Woodlands, TX, September, 2002. 2002.

[37] P. Kittle, "Flammabilitiy of plastics & polymers used as alternate daily covers," Rusmar incorporated, West Chester, PA, April, 1993. 1993.

[38] (September, 2013). *Bensenville Fire Protection District #2*. Available: http://www.bensenvillefpd.org/.

[39] (September, 2010). *How Ambulance is Made*. Available: http://www.madehow.com/Volume-5/Ambulance.html.

Appendix A: Excerpts from the Star of Life Specifications [3]

Acceleration: Vehicle shall have a minimum average acceleration, at sea level, of 0-55 mph within 25 seconds.

Fuel Range: The ambulance shall be capable of being driven for at least 250 miles without refueling.

Fording: The vehicle shall be capable of three fordings, without water entering patient and equipment compartments while being driven through a minimum of 8" of water, at speeds of 5 mph, for a distance of at least 100'.

Wheels: Types I, I AD, III & III AD ambulances shall be equipped with dual rear wheels and single front wheels. Type II ambulances shall be equipped with single, front and rear wheels.

Dimensions

Length: The overall length of the ambulance (OAL) shall be specified by the purchaser, including bumpers, rear step and bumper guards.

Width: The overall width of the ambulance bodies having dual rear wheels shall be a maximum of 96”, excluding mirrors, lights, and other safety appurtenances.

The ambulance body sides, on a chassis with dual rear wheels, shall be symmetrical and within +/- 2.5” of the overall width of the tires (outside sidewalls). The 2.5” allowance is not cumulative; it applies individually to each side. Tires shall not extend beyond the fenders.

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

Floor Height: The finished floor (loading) height shall be a maximum of 34".

Weight

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

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

Appendix B: Storage Capacity of Equipment and Tools

Item #	Name	Quantity	Length (L) ±0.125 (in.)	Width (W) ±0.125 (in.)	Height (H) ±0.125 (in.)	Storage Space Occupied (LxWxH) ±0.217 (in.^{3})	Total Storage Space Occupied (Quantity x Space Occupied) (in.^{3})	Uncertainty (± Value)
1	Pediatric Kit (Yellow)	1	11.5	10.0	11.0	1265.00	1265.00	0.217
2	Latex Free Gloves (Purple)	1	13.5	6.5	11.5	1009.13	1009.13	0.217
3	Burn Kit (Blue)	1	13.0	10.0	8.0	1040.00	1040.00	0.217
4	Hudson RCI CPR Board	1	23.0	17.0	3.0	1173.00	1173.00	0.217
5	Flare Kit	1	18.0	5.0	5.0	450.00	450.00	0.217
6	Jumper Cables	1	15.5	15.5	5.0	1201.25	1201.25	0.217
7	Step Stool	1	14.5	11.5	9", legs. 1" thick	166.75	166.75	0.217
8	Tire Block, triangular	2	8.5	8.5	7.5	541.88	1083.75	0.434
9	Backboard (Orange)	4	72.0	16.0	2.0	2304.00	9216.00	0.868
10	Backboard (Metal)	1	65.0	17.0	3.0	3315.00	3315.00	0.217
11	EMSAR Stair Chair	1	46.0	16.0	6.0	4416.00	4416.00	0.217
12	Ferno Stair Chair	1	36.0	20.0	9.5	6840.00	6840.00	0.217
13	EMS Trauma Bag (Orange)	1	22.0	8.0	12.0	2112.00	2112.00	0.217
14	White Towel	11	9.0	6.0	3.0	162.00	1782.00	2.387
15	White Sheets	4	9.0	9.0	1.0	81.00	324.00	0.868
16	Small EMS Bag (Orange)	1	12.0	4.5	5.0	270.00	270.00	0.217
17	Germicidal Wipes	1	5 dia.		6.5	127.63	127.63	0.217
18	Foam Pad	4	12.0	6.0	4.0	288.00	1152.00	0.868
19	White Blanket	2	17.0	10.0	1.0	170.00	340.00	0.434
20	Hypothermia Blanket (Green)	1	17.0	11.0	6.0	1122.00	1122.00	0.217
21	Blanket (Blue)	3	12.0	9.0	2.5	270.00	810.00	0.651
22	Neckbrace	10	12.0	7.0	2.5	210.00	2100.00	2.17
23	Box of Tape	1	7.0	4.5	2.5	78.75	78.75	0.217
24	Medical Waste Basket	1	10.0	7.0	10.5	735.00	735.00	0.217
25	Orange Strap	7	4.0	2.0	2.0	16.00	112.00	1.519
26	EMS Minilator	1	8.5	6.5	11.0	607.75	607.75	0.217
27	Small Oxygen Tank	3	4.5 dia.		20.0	318.09	954.26	0.651
28	Ferno Stretcher	1	36.0	19.0	3.5	2394.00	2394.00	0.217
29	Small Brace	2	11.5	5.0	3.5	201.25	402.50	0.434
30	Medium Brace	1	21.0	9.0	4.0	756.00	756.00	0.217
31	Large Brace	1	28.0	12.0	4.0	1344.00	1344.00	0.217
32	Hazmat Suit	1	11.0	16.0	8.0	1408.00	1408.00	0.217
33	Advanced Limb Support	1	18.0	7.0	9.0	1134.00	1134.00	0.217
34	KED	1	33.0	9.0	6.5	1930.50	1930.50	0.217
35	To-go BLS Bag (Orange)	1	22.0	16.0	10.0	3520.00	3520.00	0.217
36	EMS Bag (Orange)	1	18.0	10.0	9.0	1620.00	1620.00	0.217
37	Priority Tags Bag	1	9.0	7.0	5.0	315.00	315.00	0.217
38	12V Car Battery	3	6.5	12.5	8.5	690.63	2071.88	0.651
39	Suction	1	13.0	8.5	12.0	1326.00	1326.00	0.217
40	AED	1	10.5	10.5	6.5	716.63	716.63	0.217
41	O2 Bag	1	24.0	13.0	9.5	2964.00	2964.00	0.217
42	WMD Response Case	1	18.0	7.5	16.0	2160.00	2160.00	0.217
43	Small WMD Response Case	1	15.5	12.5	6.5	1259.38	1259.38	0.217
44	Main O2 Tank	1	8.0 dia.		47.0	2362.48	2362.48	0.217
	TOTAL:						**71487.61**	**18.879**

Appendix C: Weights of Equipment and Tools

Item #	Name	Quantity	Weight (lb)	Total Weight (Quantity x Weight) (lb)	Uncertainty (± Value)
1	Pediatric Kit (Yellow)	1	5.2	5.2	0.05
2	Latex Free Gloves (Purple)	1	3.3	3.3	0.05
3	Burn Kit (Blue)	1	11.8	11.8	0.05
4	Hudson RCI CPR Board	1	4.6	4.6	0.05
5	Flare Kit	1	12.8	12.8	0.05
6	Jumper Cables	1	14.8	14.8	0.05
7	Step Stool	1	6.0	6.0	0.05
8	Tire Block, triangular	2	13.2	26.4	0.10
9	Backboard (Orange)	4	12.8	51.2	0.20
10	Backboard (Metal)	1	16.4	16.4	0.05
11	EMSAR Stair Chair	1	25.0	25.0	0.05
12	Ferno Stair Chair	1	34.5	34.5	0.05
13	EMS Trauma Bag (Orange)	1	8.5	8.5	0.05
14	White Towel	11	0.6	6.6	0.55
15	White Sheets	4	1.1	4.4	0.20
16	Small EMS Bag (Orange)	1	2.5	2.5	0.05
17	Germicidal Wipes	1	0.7	0.7	0.05
18	Foam Pad	4	0.3	1.2	0.20
19	White Blanket	2	1.5	3.0	0.10
20	Hypothermia Blanket (Green)	1	2.8	2.8	0.05
21	Blanket (Blue)	3	0.9	2.7	0.15
22	Neckbrace	10	0.4	4.0	0.50
23	Box of Tape	1	0.6	0.6	0.05
24	Medical Waste Basket	1	0.8	0.8	0.05
25	Orange Strap	7	0.2	1.4	0.35
26	EMS Minilator	1	3.3	3.3	0.05
27	Small Oxygen Tank	3	7.3	21.9	0.15
28	Ferno Stretcher	1	14.8	14.8	0.05
29	Small Brace	2	0.9	1.8	0.10
30	Medium Brace	1	3.1	3.1	0.05
31	Large Brace	1	3.6	3.6	0.05
32	Hazmat Suit	1	7.5	7.5	0.05
33	Advanced Limb Support	1	9.4	9.4	0.05
34	KED	1	6.4	6.4	0.05
35	To-go BLS Bag (Orange)	1	12.9	12.9	0.05
36	EMS Bag (Orange)	1	10.9	10.9	0.05
37	Priority Tags Bag	1	2.1	2.1	0.05
38	12V Car Battery	3	53.0	159.0	0.15
39	Suction	1	8.6	8.6	0.05
40	AED	1	8.6	8.6	0.05
41	O2 Bag	1	18.4	18.4	0.05
42	WMD Response Case	1	14.4	14.4	0.05
43	Small WMD Response Case	1	11.4	11.4	0.05
44	Main O2 Tank	1	118.7	118.7	0.05
151	O2 Lift	1	112.0	112.0	0.05
	TOTAL:			**800**	**4.35**

Appendix D: Storage Capacity of Pharmaceuticals and Consumables

Items that are not recommended for storage in the vending machine are shaded in grey.

Item #	Name	Quantity	Length (L) ±0.125 (in.)	Width (W) ±0.125 (in.)	Height (H) ±0.125 (in.)	Storage Space Occupied (LxWxH) ±0.217 (in.^{3})	Total Storage Space Occupied (Quantity x Space Occupied) (in.^{3})	Uncertainty (± Value)
45	Box of Gloves	6	9.75	4.75	3	138.90	833.63	1.302
46	Baxter .9% NaCl	2	2.75	2.75	7.25	54.80	109.66	0.434
47	Large Bottle of Baxter .9% NaCl	4	3.75	3.25	9	109.70	438.75	0.868
48	Bladder Irrigation Set	2	9	7.5	1	67.50	135.00	0.434
49	Sterile Burn Sheet	5	10.5	8	1	84.00	420.00	1.085
50	Continu-Flo Solution Set	1	7.5	3	1	22.50	22.50	0.217
51	IV Bags	8	10.75	4.5	3	145.10	1161.00	1.736
52	BP Cuff	1	6	5	1	30.00	30.00	0.217
53	KED Bag (Green)	1	33	10.5	5.5	1905.80	1905.75	0.217
54	Backboard (Blue)	1	23.75	16.5	3	1175.60	1175.63	0.217
55	Small Sharps Container	3	9	5	5.75	258.80	776.25	0.651
56	Bag of Splints	1	55.75	8.5	3.5	1658.60	1658.56	0.217
57	Femur Traction Splint	3	31	10	2.5	775.00	2325.00	0.651
58	Transfer Sheet	1	21	15	2	630.00	630.00	0.217
59	Pillow	1	23	17	5	1955.00	1955.00	0.217
60	Fire Extinguisher	1		4.25 diameter	15	212.79	212.79	0.217
61	Bed Pan	1	14.5	12.5	3	543.80	543.75	0.217
62	Cardboard Bin	51	11	4.75	5	261.30	13323.75	11.067
63	Medline Tissue Box	6	5.75	3.75	1	21.60	129.38	1.302
64	Eye Pads	17	3	2	0.25	1.50	25.50	3.689
65	Adult BP Cuff	1	8	6	4	192.00	192.00	0.217
66	Child and Infant Cuffs	2	11	4.75	5	261.30	522.50	0.434
67	Cravats	20	4	3.5	1	14.00	280.00	4.34
68	Padded Boards	10	9.75	3.75	0.25	9.10	91.41	2.17
69	OB Pads	7	3.75	3.75	0.75	10.50	73.83	1.519
70	Albuterol	1	3	3.5	2.5	26.30	26.25	0.217
71	Insta-Glucose	4	4.75	6	1	28.50	114.00	0.868
72	Tubing	5	6.75	1.0 diameter		5.30	26.51	1.085
73	Epi-Pen	3	6.25	1.25 diameter		7.70	23.01	0.651
74	Naloxone Hydrochloride	8	4.75	1.5	0.75	5.30	42.75	1.736
75	MAD Nasal	12	4	3	0.25	3.00	36.00	2.604
76	Aspirin	2	3	1.75	1.75	9.20	18.38	0.434
77	Albuterol Tube	41	3.5	0.25 diameter		0.20	7.04	8.897
78	Coban Wrap	5	2	2.5 diameter		9.80	49.09	1.085
79	Large Ace Wrap	8	6	2.0 diameter		18.80	150.80	1.736
80	Small Ace Wrap	4	3.25	1.25 diameter		4.00	15.95	0.868
81	Small 5X9 Gauze	12	7.25	3.75	0.5	13.60	163.13	2.604
82	Large 5X9 Gauze	19	7.25	6.25	0.5	22.70	430.47	4.123
83	Kerlix	6	7	4	2.75	77.00	462.00	1.302
84	Kendall Conform Bandage	10	5	2.75	1.25	17.20	171.88	2.17
85	4X4 Sponges	44	6.5	5.75	0.25	9.30	411.13	9.548

86	Petroleum Gauze	5	8.25	5.25	0.25	10.80	54.14	1.085
87	Over Wraps	7	10.5	6.25	0.25	16.40	114.84	1.519
88	Mattress Porta Warm	2	9.75	6	3	175.50	351.00	0.434
89	Multi-trauma Dressing	6	14.25	10	1.75	249.40	1496.25	1.302
90	Disposable Obstetrics Kit	3	10.5	10.5	3	330.80	992.25	0.651
91	Trauma Numbers	20	9.25	4.25	0.25	9.80	196.56	4.34
92	Poison Kits	2	8.25	6.25	1.25	64.50	128.91	0.434
93	Stretcher Straps	3	5.5	2.25	2.25	27.80	83.53	0.651
94	Dispatch Wipes	1	9.5	4.5	2	85.50	85.50	0.217
95	Alcohol Bottles	2		2.75 diameter	7	11.88	23.76	0.434
96	Tubing and Scissors	3	9.75	5.5	1	53.60	160.88	0.651
97	Hydrogen Peroxide Bottles	2		2.25 diameter	6	7.95	15.90	0.434
98	Heat Packs	24	6.75	6	0.75	30.40	729.00	5.208
99	Kimberly Clark Cold Packs	11	8.75	6	1.75	91.90	1010.63	2.387
100	Vomit/Urine Bag	17	10	6	0.5	30.00	510.00	3.689
101	Swivel Adapter	5	4	4	1	16.00	80.00	1.085
102	Scissors	16	7.5	3.5	0.25	6.60	105.00	3.472
103	Pupil Gauges	10		0.5 diameter	4.5	0.88	8.80	2.17
104	Trauma Shears	2	6.25	2	1.75	21.90	43.75	0.434
105	B and F	4	4.5	1.25	0.25	1.40	5.63	0.868
106	Baby Shampoo	2	1.75	0.75	3.5	4.60	9.19	0.434
107	Cloth Tape	2		2.25 diameter	1	3.98	7.96	0.434
108	Cloth Tape, Large	2		2.25 diameter	2	7.95	15.90	0.434
109	Transparent Tape	4		2 diameter	1	3.14	12.56	0.868
110	Large Transparent Tape	4		2 diameter	2	6.28	25.12	0.868
111	Seatbelt Guard	3	2.25	1.25	2.5	7.00	21.09	0.651
112	Trash Bag	1	8	2 diameter		25.13	25.13	0.217
113	Suction Bags	2	8	5.25 diameter		173.18	346.36	0.434
114	Red Hazard Bags	2	6	2.5 diameter		29.45	58.90	0.434
115	Purell Refill	1	3.75	6.5	3.25	79.20	79.22	0.217
116	AirLife Bubble Humidifier	1		3.25 diameter	8	66.37	66.37	0.217
117	Blue Trash Bag	1	11.5	1.5 diameter		20.32	20.32	0.217
118	Dispatch Wipes	1		5 diameter	8	14.14	14.14	0.217
119	Suction Tube	2	9.25	6.25	1	57.80	115.63	0.434
120	Suction Handle	3	11.75	2.75	1	32.30	96.94	0.651
121	Catheter	7 of varying sizes; 1,2,2,2	8.5	4.5	1.5	57.40	401.63	1.519
122	Oral Airways	37of varying sizes; 3,5,5,5,6,4,9	4.5	2	1	9.00	333.00	8.029
123	Adult Nasal Airways	10	8.25	4	0.5	16.50	165.00	2.17
124	Pediatric Nasal Airways	1	8.25	4	0.5	16.50	16.50	0.217
125	Alcohol Wipes	1	6	2.5	0		0.00	0.217
126	Tracheotomy. Mask	5	7.75	5	2	77.50	387.50	1.085
127	Bandaids	full bin	3	1.5	0	0.00	0.00	0
128	Finger Pricks	225	2	0.1 diameter		0.02	4.50	48.825
129	Probe Covers	42	3.25	1.25	1	4.10	170.63	9.114

130	Glucose Kit	1	4	5.75	1	23.00	23.00	0.217
131	Test Strips	3	2.75	1.75	1.75	8.40	25.27	0.651
132	Pediatric Non-Rebreathing Mask	1	6.5	7	2.5	113.80	113.75	0.217
133	Allergic Reaction	3	8.5	5.75	2.25	110.00	329.91	0.651
134	Airway Tubing	2	5	5.5	1	27.50	55.00	0.434
135	Adult Breathing Kit	5	5.5	5	3.5	96.30	481.25	1.085
136	Adult Aerosol Mask	3	5.5	3	3	49.50	148.50	0.651
137	O2 Tubing	7	1	4.0 diameter		12.57	87.99	1.519
138	Adult NRB	5	2.25	5.5 diameter		53.46	267.30	1.085
139	Adult Nasal Cannula	4	0.75	5.0 diameter		14.73	58.92	0.868
140	Pediatric Nasal Cannula	8	1	4.0 diameter		12.57	100.56	1.736
141	Pediatric NRB	5	1	5.0 diameter		19.63	98.15	1.085
142	Particulate Respirator	2	5.5	5.25	8	231.00	462.00	0.434
143	Procedure Mask	1	9	8	3.75	270.00	270.00	0.217
144	Epinephrine Tubing	1	8.5	5	2.75	116.90	116.88	0.217
145	Resuscitator	1	8	10	4	320.00	320.00	0.217
146	Infection Control Kit	3	11.5	9.5	1.5	163.90	491.63	0.651
147	Speed Sheet	1	12	8	0.25	24.00	24.00	0.217
148	Disposable Cups	1 tube	13.75	3.0 diameter		97.19	97.19	0.217
149	Plastic Wrap	1	18.5	5	2	185.00	185.00	0.217
150	Emergency Blanket	2	10	14	2	280.00	560.00	0.434
	TOTAL:						**44026.25**	**196.168**

Appendix E: Weights of Pharmaceuticals and Consumables

Item #	Name	Quantity	Individual Weight ±0.05 (lb)	Total Weight (Quantity x Weight) (lb)	Uncertainty (± Value)
45	Box of Gloves	6	1.1	6.6	0.30
46	Baxter .9% NaCl	2	1.3	2.6	0.10
47	Large Bottle of Baxter .9% NaCl	4	2.6	10.4	0.20
48	Bladder Irrigation Set	2	0.2	0.4	0.10
49	Sterile Burn Sheet	5	0.3	1.5	0.25
50	Continu-Flo Solution Set	1	0.1	0.1	0.05
51	IV Bags	8	2.3	18.4	0.40
52	BP Cuff	1	0.4	0.4	0.05
53	KED Bag (Green)	1	6.9	6.9	0.05
54	Backboard (Blue)	1	3.1	3.1	0.05
55	Small Sharps Container	3	0.6	1.8	0.15
56	Bag of Splints	1	3.6	3.6	0.05
57	Femur Traction Splint	3	5.8	17.4	0.15
58	Transfer Sheet	1	6.9	6.9	0.05
59	Pillow	1	1.3	1.3	0.05
60	Fire Extinguisher	1	8.9	8.9	0.05
61	Bed Pan	1	0.4	0.4	0.05
62	Cardboard Bin	51	0.2	10.2	2.55
63	Medline Tissue Box	6		0.5	0.30
64	Eye Pads	17		N/A	0.85
65	Adult BP Cuff	1	0.7	0.7	0.05
66	Child and Infant Cuffs	2		1.0	0.10
67	Cravats	20		1.1	1.00
68	Padded Boards	10		0.5	0.50
69	OB Pads	7		0.5	0.35
70	Albuterol	1	0.1	0.1	0.05
71	Insta-Glucose	4	0.2	0.8	0.20
72	Tubing	5		N/A	0.25
73	Epi-Pen	3		N/A	0.15
74	Naloxone Hydrochloride	8		N/A	0.40
75	MAD Nasal	12		N/A	0.60
76	Aspirin	2		N/A	0.10
77	Albuterol Tube	41		0.4	2.05
78	Coban Wrap	5		0.3	0.25
79	Large Ace Wrap	8		0.9	0.40
80	Small Ace Wrap	4		0.2	0.20
81	Small 5X9 Gauze	12	0.3	0.3	0.60
82	Large 5X9 Gauze	19	0.3	0.3	0.95
83	Kerlix	6		0.6	0.30
84	Kendall Conform Bandage	10		0.1	0.50
85	4X4 Sponges	44		0.5	2.20
86	Petroleum Gauze	5		0.4	0.25
87	Over Wraps	7		0.4	0.35
88	Mattress Porta Warm	2		3.5	0.10
89	Multi-trauma Dressing	6		0.2	0.30
90	Disposable Obstetrics Kit	3		0.6	0.15
91	Trauma Numbers	20		0.6	1.00
92	Poison Kits	2		1.0	0.10
93	Stretcher Straps	3		1.9	0.15
94	Dispatch Wipes	1		0.8	0.05
95	Alcohol Bottles	2		1.2	0.10
96	Tubing and Scissors	3		1.0	0.15
97	Hydrogen Peroxide Bottles	2		0.9	0.10
98	Heat Packs	24		5.1	1.20
99	Kimberly Clark Cold Packs	11		5.5	0.55
100	Vomit/Urine Bag	17		0.7	0.85
101	Swivel Adapter	5		0.7	0.25
102	Scissors	16		2.2	0.80

103	Pupil Gauges	10		0.6	0.50
104	Trauma Shears	2		0.3	0.10
105	B and F	4		0.2	0.20
106	Baby Shampoo	2		0.2	0.10
107	Cloth Tape	2		0.2	0.10
108	Cloth Tape, Large	2		0.2	0.10
109	Transparent Tape	4		0.4	0.20
110	Large Transparent Tape	4		0.4	0.20
111	Seatbelt Guard	3		0.0	0.15
112	Trash Bag	1		0.8	0.05
113	Suction Bags	2		0.4	0.10
114	Red Hazard Bags	2		1.5	0.10
115	Purell Refill	1		1.7	0.05
116	AirLife Bubble Humidifier	1		0.2	0.05
117	Blue Trash Bag	1		0.4	0.05
118	Dispatch Wipes	1		1.7	0.05
119	Suction Tube	2		0.2	0.10
120	Suction Handle	3		0.0	0.15
121	Catheter	7; 1,2,2,2		0.5	0.35
122	Oral Airways	37; 3,5,5,5,6,4,9		1.5	1.85
123	Adult Nasal Airways	10		0.3	0.50
124	Pediatric Nasal Airways	1		0.0	0.05
125	Alcohol Wipes	1		0.4	0.05
126	Tracheotomy. Mask	5	0.1	0.5	0.25
127	Bandaids	full bin		0.7	0.05
128	Finger Pricks	225		0.9	11.25
129	Probe Covers	42		0.1	2.10
130	Glucose Kit	1		0.3	0.05
131	Test Strips	3		0.3	0.15
132	Pediatric Non-Rebreathing Mask	1		0.2	0.05
133	Allergic Reaction	3	0.2	0.6	0.15
134	Airway Tubing	2	0.3	0.6	0.10
135	Adult Breathing Kit	5	0.2	1.0	0.25
136	Adult Aerosol Mask	3		0.0	0.15
137	O2 Tubing	7		0.7	0.35
138	Adult NRB	5	0.2	1.0	0.25
139	Adult Nasal Cannula	4		0.5	0.20
140	Pediatric Nasal Cannula	8		0.8	0.40
141	Pediatric NRB	5	0.2	1.0	0.25
142	Particulate Respirator	2		0.4	0.10
143	Procedure Mask	1		0.8	0.05
144	Epinephrine Tubing	1		0.2	0.05
145	Resuscitator	1		0.8	0.05
146	Infection Control Kit	3	0.4	1.2	0.15
147	Speed Sheet	1		0.4	0.05
148	Disposable Cups	1 stack		0.4	0.05
149	Plastic Wrap	1		1.1	0.05
150	Emergency Blanket	2	1.1	2.2	0.10
	TOTAL:			**165.2**	**45.25**

Appendix F: KKK-A-1822f Standards for Interior Storage [3]

3.10.16 INTERIOR SURFACES.

The interior of the body shall be free of all sharp projections. All hangers or supports for equipment and devices shall be mounted as flush as possible with the surrounding surface. Interior body lining and cabinetry materials, excluding the cab compartment, shall be selected to minimize dead weight. The finish of the entire patient compartment, including interiors of storage cabinets, shall be:

1. impervious to soap, water and disinfectants.

2. mildew resistant.

3. fire resistant.

4. easily cleaned/disinfected (carpeting, cloth, and fabrics are not acceptable).

3.11 STORAGE COMPARTMENTS.

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

3.11.1 INTERIOR STOWAGE ACCOMMODATIONS.

The interior of the patient compartment shall provide a minimum volume of 35 cubic feet of enclosed stowage cabinetry, compartment space, and shelf space which shall be conveniently located for medical supplies, devices, and installed systems as applicable for the service intended. The 35 cubic feet of enclosed stowage cabinetry requirement does not apply to type II ambulances. Enclosed compartments and spaces shall be located at, in, or on the partition, sidewalls, overhead, seating areas, and doors. Compartment(s) under the floor, with opening panel(s) inside the patient compartment, shall not be acceptable. When furnished, top opening squad bench lids shall be fitted with an automatic hold open device and a quick release slam type latching device when closed.

3.11.1.1 LOCATION OF MEDICAL EQUIPMENT AND SUPPLIES.

Supplies, devices, tools, etc., shall be stored in enclosed compartments and drawers designed to accommodate the respective items. All medical devices and equipment shall be stowed or properly fastened in/on the action area according to the medical device manufacturer's directions.

Appendix G: NFPA 1917 Interior Storage Requirements [7]

6.16* Interior Storage.

6.16.1 The interior of the patient compartment shall provide enclosed storage cabinetry, compartment space, and shelf space.

6.16.2 Compartment(s) under the floor that have opening panel(s) inside the patient compartment shall not be acceptable.

6.16.3 When furnished, top opening squad bench lids shall be fitted with an automatic hold open device and a quick release slam-type latching device when closed.

6.16.4 Storage compartment door handles, where provided, shall not protrude more than 1 in. (25mm) if located 14 in. (356mm) or higher above the floor and shall not protrude more than 2 in. (51mm) if located lower than 14 in. (356mm) or higher above the floor.

6.16.5 Doors shall be designed to remain closed during transport.

6.16.6 Storage compartments shall be firmly fastened to the body structure.

6.17 Interior Surfaces

6.17.1 The interior of the body shall be free of all sharp projections and sharp corners.

6.17.2 All hangers or supports for equipment and devices shall be mounted as flush as possible with the surrounding surface.

6.17.3 The finish of the entire patient compartment and exterior storage, including interiors of storage cabinets, shall be as follows:

(1) Impervious to soap, water, body fluids, and disinfectants
(2) Mildew resistant
(3) Fire resistant in compliance with FMVSS 302
(4) Able to be cleaned and disinfected

6.17.4 Counter top horizontal surface shall be seamless and impervious to contaminates.

6.17.5 All edges that meet vertical cabinets shall be sealed.

Appendix H: Categorized List of Vendible Items

Items are listed in groups, categorized by type. The numbers refer to those listed in Appendix B for more specific information.

Group 1	Gauze
64	Eye Pads
81	5x9 Gauze, Small
82	5x9 Gauze, Large
84	Kendall Conform Bandage
85	4x4 Sponges
86	Petrolium Gauze

Group 2	Wraps
67	Cravats
78	Coban Wrap
79	Large Ace Wrap
80	Small Ace Wrap
83	Kerlix
87	Over Wraps

Group 3	Tape
107	Cloth Tape
108	Cloth Tape, Large
109	Transparent Tape
110	Transparent Tape, Large

Group 4	Medications (non-narcotic)
70/77	Albuterol
71	Insta-Glucose
73	Epi-Pen
74	Naloxone Hydrochloride
75	MAD Nasal
76	Asprin

Group 5	Pedi O2
124	Pedi Nasal Airways
132	Pedi NRB Mask
140	Pedi Nasal Cannula
141	Pedi NRB

Group 6	Adult O2
123	Adult Nasal Airways
135	Adult Breathing Kit
138	Adult NRB
139	Adult Nasal Cannula

Group 7	Oral Airways
122	Size 1
	Size 2
	Size 3
	Size 4
	Size 5
	Size 6
	Size 7

Group 8	Catheters
121	Size 1
	Size 2
	Size 3
	Size 4

Group 9	Bags
100	Vomit/Urine Bag
112	Trash Bag
113	Suction Bags
114	Red Hazard Bags
117	Blue Trash Bags

Appendix I: Material Safety Data Sheet for Dispatch® Wipes [34]

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **DISPATCH® HOSPITAL CLEANER DISINFECTANT TOWELS WITH BLEACH**
PRODUCT NUMBER: **69101-Singles** **DATE: September 9, 2011**
69150-150 Piece Canister
69240-40 Piece Soft Pack
69260-60 Piece Soft Pack

TRADE NAME: **Dispatch® Hospital Cleaner Disinfectant Towels With Bleach** GENERAL USE: Hospital Disinfectant CHEMICAL FAMILY: Sodium Hypochlorite PRODUCT DESCRIPTION: Bleach disinfectant formula absorbed on towels.	**DISPATCH® HOSPITAL CLEANER DISINFECTANT TOWELS WITH BLEACH**
MANUFACTURER **Clorox Professional Products**	DATE PREPARED: **September 9, 2011** SUPERSEDES: **July 10, 2009**
ADDRESS (NUMBER, STREET, P.O. BOX) 1221 Broadway	TELEPHONE NUMBER FOR INFORMATION/Customer Service **(510**
(CITY, STATE AND ZIP CODE) CO UNTRY Oakland, CA 94612	**For Medical Emergencies, call: (800) 446-1014** **For Transportation Emergencies, call Chemtrec:**

SECTION 2 - HAZARDOUS INGREDIENTS

Hazardous Components	% (by Weight)	C
Sodium hydroxide	**<0.**	**1310**
Sodium metasilicate	**<0.**	**6834**
Sodium hypochlorite	**<1. 0%**	**7681 -52-9**

Notes: * The balance of ingredients not listed above are non-hazardous as defined in the OSHA hazard communication standard 29CFR

SECTION 3 - HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Avoid contact with eyes, skin, and clothing as this product may produce irritation. Do not allow this product to contact acidic materials as hazardous chlorine gas may be released.

POTENTIAL HEALTH EFFECTS

INHALATION:
No adverse effects are anticipated from inhalation.

SKIN:
Normal exposure (contact) is not likely to cause significant skin irritation.

EYES:
Causes moderate eye irritation.

INGESTION:
May cause gastrointestinal irritation and upset.

CARCINOGENICITY:
NTP? No IARC MONOGRAPHS? No OSHA REGULATED? No
CALIFORNIA, Prop. 65? No

SECTION 4 - FIRST AID MEASURES

INHALATION:
No specific treatment, suspected hazard by this route is minimal. **Note to Physician:** No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of

EYES:
If in eyes, hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first five minutes, then continue rinsing eyes. Seek medical attention if irritation persists.

SKIN:
Wash with soap and water, no further first aid should be required.

INGESTION:

No specific treatment, suspected hazard by this route is minimal.

PRODUCT NAME: **DISPATCH® HOSPITAL CLEANER DISINFECTANT TOWELS WITH BLEACH**

PRODUCT NUMBER: **69101-Singles** **DATE: September 9, 2011**

69150-150 Piece Canister

SECTION 5 - FIREFIGHTING MEASURES

GENERAL HAZARDS:
Product is minimally flammable FP ≥101ºC (215ºF). Chlorine may be released from this product in the presence of acids.

EXTINGUISHING MEDIA:
Water fog, carbon dioxide and dry chemical to fight surrounding fire.

FIREFIGHTING PROCEDURES:
Wear SCBA when fighting fires involving this product as a precaution.

UNUSUAL FIRE AND EXPLOSION HAZARDS:
None.

HAZARDOUS COMBUSTION PRODUCTS:
Carbon monoxide, Carbon Dioxide, smoke, organic vapors from dried and heated towels in fire conditions.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:

Isolate damaged goods. Spills should be diluted with water, then absorbed with sand, clay, or earth. Dispose of saturated absorbent materials appropriately since spontaneous heating may occur.

SECTION 7 - HANDLING AND STORAGE

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:

Ventilation: Good general ventilation should be sufficient for most conditions. Respiratory Protection: No respiratory protection should be needed.

SECTION 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

HAZARDOUS COMPONENTS	N				ACGIH			OSHA
	TWA ppm	TWA	STEL ppm	STEL	TLV/TWA	TWA	STEL ppm	STEL
Sodium hydroxide				10 IDLH		2		2
Sodium metasilicate	N	N	N	N	N	N	N	N
Sodium hypochlorite	N	N	N	N	N	N	N	N

PERSONAL PROTECTION

RESPIRATORY PROTECTION:
A respiratory protection program that meets OSHA's 29 CFR 1910.134, ANSI Z88.2 requirements must be followed whenever workplace concentrations of this product in air exceed the published TLVs.

PROTECTIVE GLOVES:
Impervious rubber or nitrile gloves are advised if prolonged or repeated exposure is likely.

EYE PROTECTION:
Use safety glasses with protective side shields to avoid eye contact.

OTHER PROTECTIVE
CLOTHING OR

WORK/HYGIENIC PRACTICES:
Wash with soap and water after contact.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR Solution on a synthetic fabric towel with a mild bleach	VAPOR PRESSURE 17.5mmHg at 20°C
pH 12.2	SPECIFIC GRAVITY (WATER = 1) 1.015 @25ºC.
BOILING POINT/BOILING RANGE 100°C (212°F)	SOLUBILITY IN WATER

FLASH POINT >101ºC (>215ºF)	V I
FLAMMABLE LIMITS LEL: NE UEL: NE	VAPOR DENSITY
AUTO IGNITION TEMPERATURE NE	EVAPORATION RATE (WATER = 1)

PRODUCT NAME: **DISPATCH® HOSPITAL CLEANER DISINFECTANT TOWELS WITH BLEACH**
PRODUCT NUMBER: **69101-Singles** **DATE: September 9, 2011**

69150-150 Piece Canister
69240-40 Piece Soft Pack
69260-60 Piece Soft Pack

SECTION 10 - STABILITY AND REACTIVITY

STABILITY	STABLE X	CONDITIONS TO AVOID: Excessive heat and light exposure. Avoid contact with incompatible materials listed in the following section:

INCOMPATIBILITY (MATERIALS TO AVOID):

Avoid contact with acids, reducing agents, ammonia or heavy metals such as nickel, cobalt, copper, and iron.

HAZARDOUS DECOMPOSITION OR BYPRODUCTS:

Carbon Monoxide, Carbon Dioxide (from burning dried towels), and chlorine in the presence of acids.

HAZARDOUS POLYMERIZATION:	CONDITIONS TO AVOID: None related to polymerization.

SECTION 11 - TOXICOLOGICAL INFORMATION

Hazardous Components	C	LD50 of Ingredient	LC50 of Ingredient (Specify Species)
Sodium hydroxide	1310-73-2	Oral, rat: LD50 ≥90 mL/kg (in this product)	N E
Sodium metasilicate	6834-92-0	Oral, rat: LD50 ≥90 mL/kg (in this product)	N E
Sodium hypochlorite	7681-52-9	Oral, mouse: LD50 = 5800 mg/kg	N E

SECTION 12 - ECOLOGICAL INFORMATION

No information is available for this blended product.

SECTION 13 - DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD:

Isolate damaged goods. Spills should be diluted with water, then absorbed with sand, clay, or earth. Dispose of saturated absorbent materials appropriately since spontaneous heating may occur. Landfill in a permitted waste disposal facility in accordance with all local, state and federal regulations.

SECTION 14 - TRANSPORT INFORMATION

PROPER SHIPPING NAME: **Not Regulated**

DOT HAZARD CLASS/Pack Group: **Not Regulated** REFERENCE: **49CFR172, 49CFR173** UN/NA IDENTIFICATION NUMBER: **Not Regulated** LABEL: **Not Regulated** HAZARD SYMBOLS: **NONE**	IATA HAZARD CLASS/Pack Group: **Contact Manufacturer** IMDG HAZARD CLASS: **Contact Manufacturer** RID/ADR Dangerous Goods Code: **Contact Manufacturer** UN TDG Class/Pack Group: **Contact Manufacturer** Hazard Identification Number (HIN): **Contact Manufacturer** **Refer to 49CFR172 and 49CFR173 for pertinent regulations.**

Note: Transportation information provided is for reference only. Client is urged to consult CFR 49 parts 100 - 177, IMDG, IATA, EU, United Nations TDG and WHMIS (Canada) TDG information manuals for detailed regulations and exceptions covering specific container sizes, packaging materials and methods of shipping.

Appendix J: Solidworks Drawings

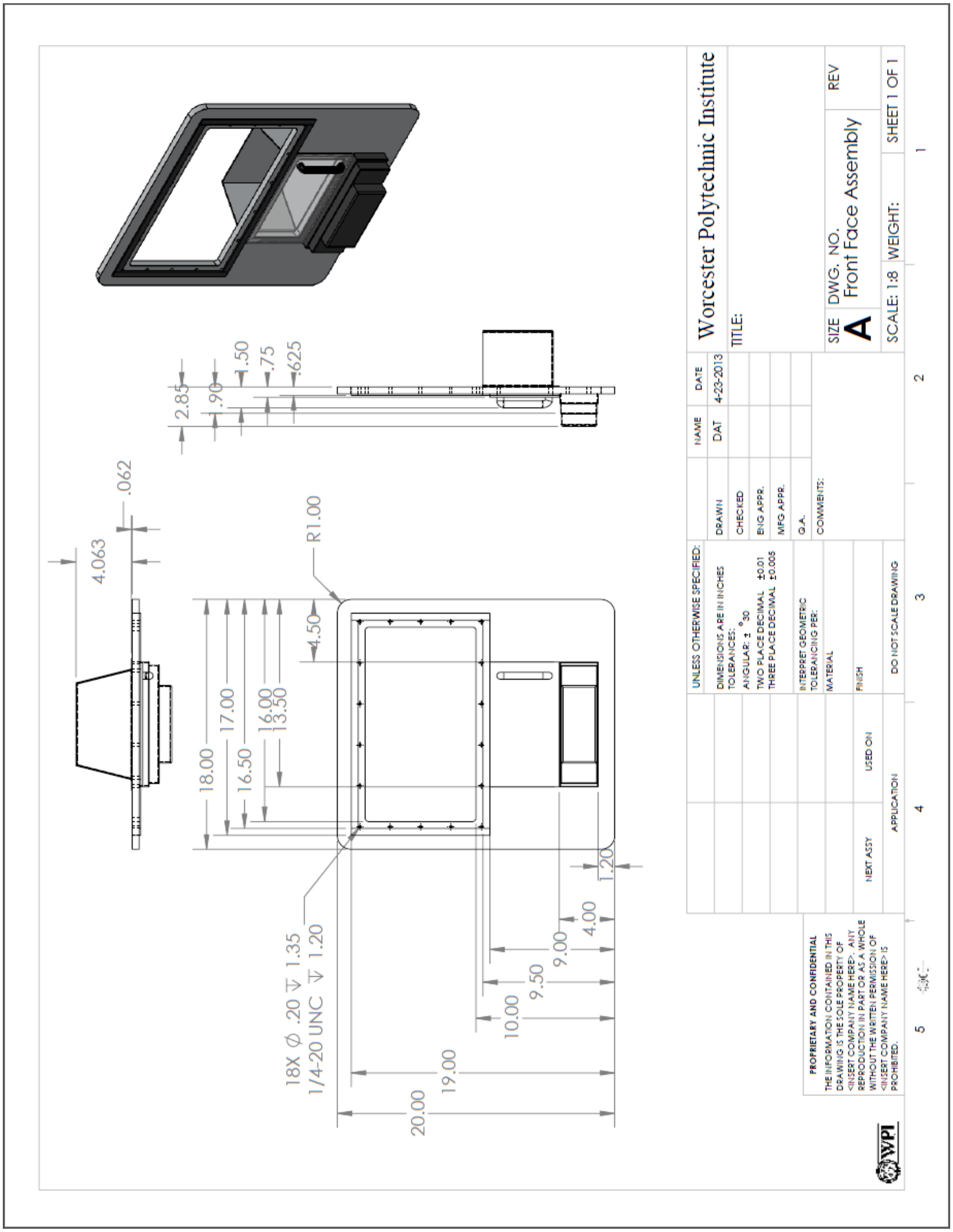


Figure 50 Outer Surface Design of the Vending Machine

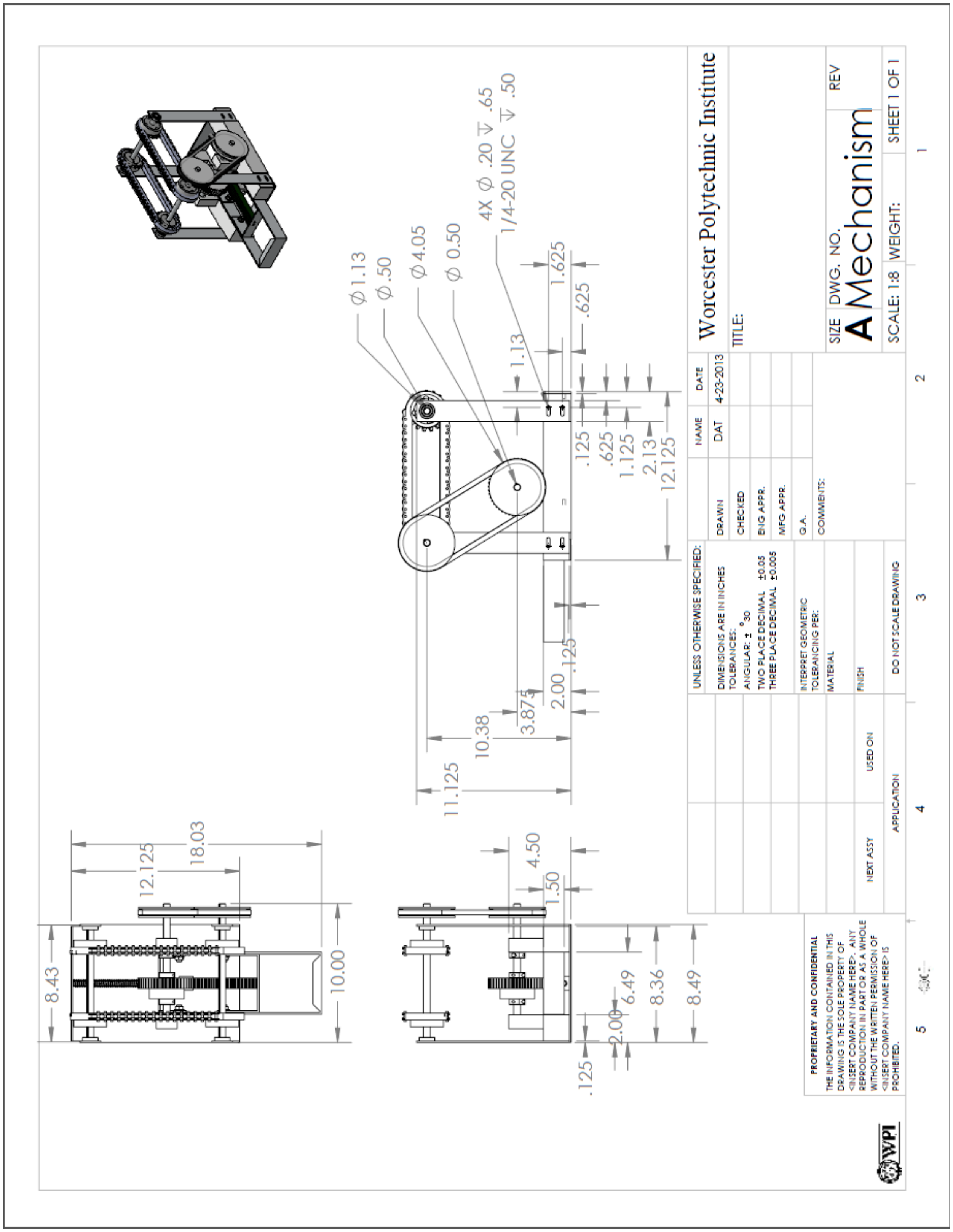


Figure 51 Vending Tray Without Sheet Metal Housing

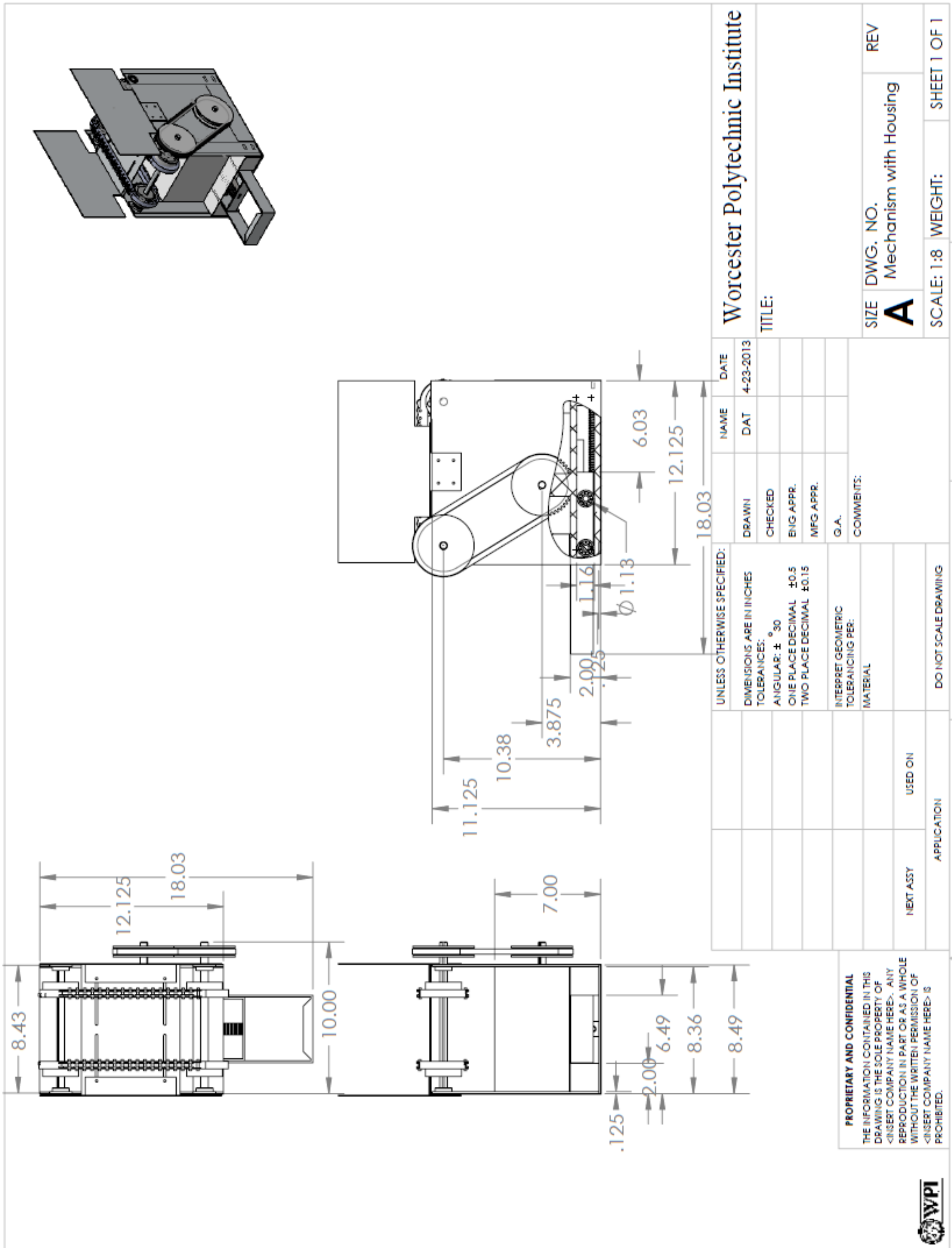


Figure 52 Vending Tray With Sheet Metal Housing

Appendix K: Example Inventory Checklist: Bensenville, IL [38]

Cab Area
Ambulance/ Knox Keys
Door Opener
Mobile Radio
Portable Radios (2)
Seat Covers (2)
Gloves (L)
Gloves (M)
ERG Book
Vehicle Manual (glove box)
Passports
Road Safety Vests (2)
ABC Extinguisher
Maps (Bensenville, Elmhurst, Wood.)
Wood Dale Street Routing Book
Chicago Mabas Book
Area Hospitals and Routing Binder
Clipboard
GPS

Clipboard
10 Loyola Run Sheets
Multiple Patient Release Forms
Patient Assist Forms
Rehab Info
Loyola SMO Book
BFPD Fire Reports
Box Cards
Anchorage, Bridgeway, Fenton Maps

Action Area
Onboard Suction (test)
Canister, Tubing & Yankauer
Oxygen Flowmeter
Cell Phone & Charger
Camera & Dock (78 only)
Mobile Radio
Poison Control # 800-222-1222

Top Drawer
Spare Zoll Paper (3)
Adult Pads (2) Exp Date:
Peds Pads Exp Date:
Spare Zoll Battery (charged)
Penlight
Trauma Shears
EKG Electrodes

Bottom Drawer
N95 Respirator
Face Masks
CPR Masks
Safety Glasses
Spare Bulbs for Laryngoscope Blade
Lancets

Slim Drawer
Pens and Sharpies
Websters Medical Speller
Keys for Cabinets
Flight for Life Reference
Loyola SMO Book
Spare AA and AAA Batteries

Cabinet by Captain's Chair
Spare Suction Canister
Wrist and Ankle Restraints
Psych Strap
Spare 3 Lead Cable & Telemetry Patch
Flashlight
Tray of Narc Tags
BP Mulyi Cuff Set

Area Behind Captains Chair
Cavicide Wipes/Disinfectant Spray
ABC Extinguisher

Airway Cabinet-Top Left
Combitubes 41fr & 37fr
V-Vac Canister (2)
Decompression Kit
Needle Cric Kit
Surgical Cric Kit
ET Equip: EDD
V-Vac tip and Catheter
Inline Adapter
14 fr Stylet
6 fr Stylet
ET Tubes: 3.0-9.0 (1 each)

Airway Cabinet - Bottom Left
Oral Sets (2 Sets)
Nasal Airways - 12 fr to 32 fr
3 Packs Surgilube
Yankauers (3)
Suction Catheters 14fr kits (2)
10 fr Kits (2)
8 fr Kits (2)
Suction Tubing (2)

Airway Cabinet - Top Right
Adult BVM (2)
Peds BVM (2)
Infant BVM (2)

Airway Cabinet - Bottom Right
Peds and Infant NRB - Peds(2), inf (1)
Nebulizer kits(2), Inline Neb Kits (1)
Nasal Cannula (3)
Oxygen Tubing (1)
Adult NRB (4)

Cabinet Above CPR Seat
Trauma Teddy (2)
Box Small Gloves
Box XL Gloves
Box of N95 Respirators

Bottom Cabinet Near CPR Seat
Garbage Can
Sharps Container

Above Back Door
Medium Gloves
Large Gloves

Trauma Cabinet - Top Shelf
Adult Slings (2)
Child Slings (2)
1000cc Bottles of Saline (3)
Burn Sheets (2)
Multi Trauma Dressings (5)

Trauma Cabinet - Bottom Shelf
Hot Packs (4)
Cold Packs (4)
Tape 2" (1), 1" (1)
Band Aids
Kerlix (7)
4x4's (20)
Abdominal Pads (4)
Petroleum Gauze (2)
Box of Alcohol Preps

OB Cabinet - Top Shelf
OB Kits (2)
Emesis Basin (3)

OB Cabinet - Bottom Shelf
Rolls of Aluminum Foil (2)
Box of 1 Gal Bags
Biohazard Bags
Baby Bottle
Morgan lends
Bulb Syringe
Meconium Aspirator
Cabinet Above Bench Seat
Macro Drip Tubing (3)
Micro Drip Tubing (2)
IV Start Kits (4)
.9 NS 1000cc (6)
Head Rolls (2)
Adult C Collars (2)
Peds C Collars (2)

Under Bench Seat
Jack
Urinal
Bed Pan

Top Compartment By Side Door
Extra Sheets, Towels, and Blackets
Drivers Side Front
Oxygen Tank Psi:
Irons
FDNY Hook

Driver Side Back
2 SCBA's PSI: /

Driver Side Middle
Triage Kit
Ked
Traction Splint
Pro Splints
Case of Water
Rehab Kit

Passenger Side Front
IV Tray
EZ/IO
Spare Oxygen Bag
Peds Bag
Jump Bag
Oxygen Bag

Passenger Side Middle
PFD's (2)
Mark 1 Kit

Passenger Side Back
Backboards With Straps (3)
Stair Chair
Head Rolls
Crash Bag