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Building an Engineered Complex Stretcher

A Major Qualifying Project Report

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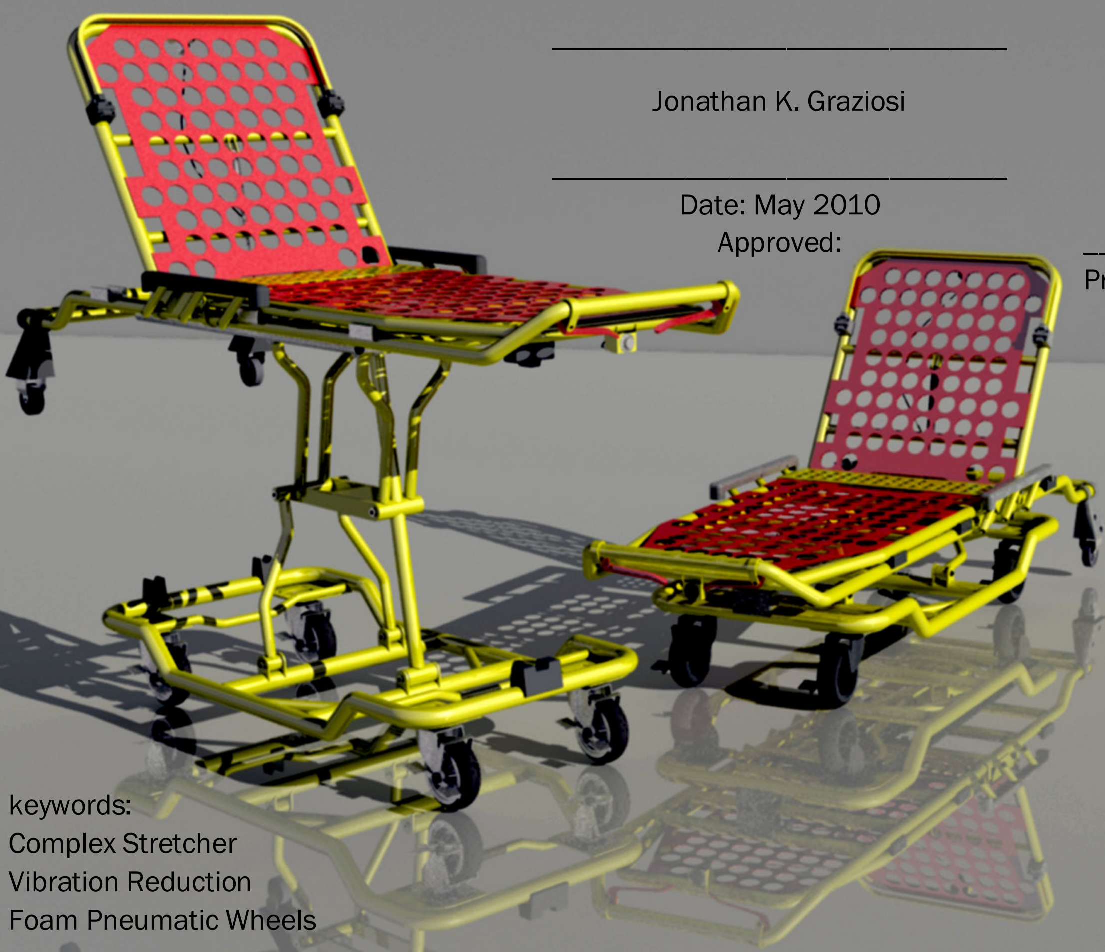

keywords:
Complex Stretcher
Vibration Reduction
Foam Pneumatic Wheels

Abstract

The focus for this project is to design and build a new complex stretcher to be used in standard ambulances. The background research rendered useful information on different types of ambulance stretchers that are found all over the world. The redesigning of the stretcher begins following the specifications and goals set forth by the group, which are to reduce vibrations experienced by the patient, trim down the amount of weight, and simplify user operation while still maintaining a high level of safety, comfort, and patient-centered care. It is decided that the rebuilding of the stretcher will be from the ground up, utilizing lightweight materials, and minimizing the amount of components. The new stretcher employs new designs and features not seen or used on stretches today, while still successfully achieving its objectives.

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Acknowledgements

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CHAPTER 1 - THE PRODUCT REALIZATION PROCESS

1 Introduction

Healthcare is a growing industry that is essential to the longevity of humanity. It is an important aspect of everyday life that is always changing and adapting to compete with the everyday changes of the world. The advances in medicine can be as small as the medications developed for treating deceases to the actual equipment monitoring and caring for people. The ambulance stretcher or gurney is a piece of equipment used in the health field that may be overlooked at times. This item may be overlooked in importance, but it is a necessary step towards recovery. If this device does not fully meet the obligation it is designed for, the likelihood of saving multiple lives per day would drastically decline.

The objectives for this project are to redesign an ambulance stretcher to be more rugged, dependable, and adaptable for use in the field. The particular features that were chosen to concentrate on for redesigning the stretcher are vibrations, number of parts, and easiness of use for the healthcare provider. The thoughts backing these features are to allow the worker to administer more adequate care to the patient whether inserting an intravenous needle or stabilizing a fractured vertebrae with fewer vibrations transmitted during the procedure, allowing a faster assembly time for the stretcher with fewer and simpler parts, and combining simplicity in parts with lower vibrations to allow the stretcher to be managed easily by workers.

Chapter 2 will give information on the background research conducted for identifying the different types of stretchers available. Multiple brands of local and international stretchers were researched to find the best type of stretcher that would later serve as the stepping stone to influence the redesign for the new stretcher. It displays the values set for each type of stretcher ranging from the weight capacity, to standard features, to integrated ideation such as power lifts and intravenous drip bag poles, to where the manufacturing company is located. Each company was examined for qualities that were hoped to be integrated and improved upon in the redesigning of the ambulance stretcher.

Chapter 3 will contain multiple diagrams of the redesigned ambulance stretcher. It will have the arrangement drawings with explanations of major component. The specifications and capacities for the stretcher will be mentioned throughout chapter 3, specifically the weight capacity, the stretcher bulk weight, the material chosen for numerous parts, the height of clearance in the collapsed position, and the unique features developed into the redesign, etc. The main objectives and goals will be examined and explained in further detail in chapter 3 as well as the facilities and equipment utilized during the engineering process. The analysis will include descriptions and explanations of the results in addition to the general observations and obstacles encountered. The constraints following the analysis for proper use out in the field by qualified individuals will be touched upon to conclude the safety aspects of the stretcher.

Chapter 4 will contain the closing remarks from the group members of the project. It will effectively explain the future improvements that can be implemented, a reflection on the obstacles overcome, and lessons learned during the project. The final design shown throughout chapter 3 will not be the conclusion to the stretcher as many sought after features were not evaluated in the goals specified. The main goals were vibration reduction, reducing the number of parts, and allowing easiness of use for the technician.

CHAPTER 2 - BENCHMARKING PROCESS

2 Introduction

Ambulance stretchers are a vital piece of life saving equipment used by paramedic operators. The operator's ability to save a life may falter due to the lack of durability or poor design of a stretcher they are using to transport a patient. In the medical field, this is unacceptable and the potential for accidents must be reduced. Through the new designing of the stretcher's individual parts and sub assemblies, the dependability will increase due to a decreased number of potential failure points. The goal of the new design is to maximize stretcher functionality and stretcher dependability, while increasing comfort for the patient in order to reduce further damage due to vibrations that propagate through the ambulance caused by uneven road surface.

2.1 Background research

2.1.1 Midmark Ambulance Stretcher

All first responders that are called to any emergency situation such as an EMT, a paramedic, or other medical personnel know the importance of having a dependable ambulance stretcher. Stretchers are an important aspect of emergency care and having a sturdy, reliable stretcher built with high quality material is vital to the success of any rescue situation. A stretcher is a medical transport device used in the extensive care of a seriously injured patient. The design of the stretcher can save the paramedic vital time in a situation where every second counts.

Figure 1 Midmark Ambulance Stretcher. ***http://ambulancestretchers.net/midmark-ambulance-stretchers.html***

The purpose of redesigning an ambulance stretcher is to provide better quality of equipment that will aid in the rescue of a seriously injured individual.

Midmark is one of the leading producers and manufacturers of ambulance stretchers (ambulancestretchers.net). Midmark stretchers provide all the necessary services for the patient’s care. They focus all the stretcher designs on the purpose of preventing further injuries until the patient is securely fixed in a hospital bed. The stretcher is an important element in making sure that the patient will be transported safely inside the ambulance until arriving at the hospital.

2.1.2 Stryker Ambulance Stretcher

Stryker manufacturers primarily focus on designing a lighter more durable stretcher (ambulancestretchers.net). The company is a worldwide leader in medical industry and has a reputation for producing innovative products that help the ambulance personnel in several ways. The stretcher has an ergonomic design and an easy operating procedure. It is designed to a specific way that allows it to be both light weight and extremely durable allowing emergency personnel to work more efficiently. A new design of stretcher manufactured by Stryker Incorporated is the MX-PRO R3. Unlike the majority of emergency stretchers, the MX-PRO R3 is electrically powered which dramatically reduces strenuous lifting for the emergency personnel. The stretcher is retrofitted with an electric hydraulic system to raise and lower patients.

Figure 2: The MX-PRO R3 Stretcher.
http://ambulancestretchers.net/stryker-ambulance-stretchers.html

The cot has an easy to use manual backup system necessary in case of battery failure. The power system is operated by a battery and is easily changed in any emergency situation. Stryker has many other stretcher models similar in design to the MX-PRO R3.

2.1.3 Hausted Ambulance Stretcher

Hausted Ambulance Stretchers come in all sizes ranging from universal care to emergency stretchers specifically designed for the youth (ambulancestretchers.net). The stretchers are equipped and ready for critical emergencies. They are retrofitted within the design to have a guard rail on each side, a basket for keeping blankets, and an intravenous rod. Specifically designed Hausted stretchers can carry up to 600 to 700 pounds.

Figure 3: A Hausted Ambulance Stretcher.
http://ambulancestretchers.net/hausted-ambulance-stretchers.html

2.1.4 Gendron Ambulance Stretcher

Gendron Manufacturers focus on the long term travel of bariatric patients to and from hospitals (ambulancestretchers.net). Bariatrics is a branch of medicine that deals with the control and treatment of obesity and allied diseases. The stretchers are designed to hold up to 1000 pounds. Many of the stretchers are retrofitted with air mattresses. Gendron focuses on patient care and the comfort of the patient (dictionary.com).

Figure 4 A Gendron Ambulance Stretcher
http://ambulancestretchers.net/midmark-ambulance-stretchers.html

2.1.5 Defeng Ambulance Stretcher

The DDC-2 Defeng ambulance stretcher is from an international company based out of Jiangsu, China (Jiangsu Defeng Medical Equipment Co., Ltd.). The stretcher is formed from aluminum alloy tubing that is secure and rigid. The size of this stretcher weighs 66 pounds and can handle a maximum loading of 350 pounds. The company has adopted a low-framed structure for this model so that it is simpler for travel. This model is equipped with an intravenous hanger and safety straps that allows it to be more user friendly once it arrives at the hospital.

Figure 5: DDC-2 Defeng Ambulance Stretcher.
http://jsdfylsb.en.alibaba.com/product/267513830-209519236/Multifunctional_Ambulance_Stretcher.html

2.1.6 United Surgical Industries Ambulance Stretcher

The United Surgical Industries, or USI, has a large array of ambulance stretchers available (United Surgical Industries). The model with very unique features is the model 1008. This model has collapsible legs that as the stretcher is pushed into the ambulance the legs collapse at the buckle-point allowing one person to operate this if necessary. The stretcher has safety belts and guard rails to enhance safety of this product. The product weighs 88 pounds so the collapsible legs are a strategic idea as multiple workers would have to lift this into the ambulance. This feature saves a lot of man power that can be saved a later matter. The stretcher can lift 265 pounds which is a moderate weight. This stretcher would mainly have use with children and average sized adults.

Figure 6: The USI-1008 Model Stretcher
http://www.unisurg.com/patient-transfer-trolleys.html

2.1.7 Ferno Ambulance Stretcher

Ferno is a stretcher business with worldwide dealers. The POWERFlexx+ Powered Cot model is the stretcher the company offers (ferno.com). It is enhanced by an unassisted lifting feature that can lift 700 pounds, the highest in the industry, without the workers having to lift a single part of the stretcher. This enables the workers to save energy and not get injured in a high pressure situation. It contains a rechargeable battery pack with 24 volt DC lead-acid batteries. The main frame is made from anodized aluminum which eliminates collection of blood and pathogens on the product. The frame has a lower center of gravity that allows greater stability. The stretcher is also able to withstand very extreme temperatures, -40 degrees Fahrenheit to 150 degrees Fahrenheit, along with many other design specifications. This is a state-of-the-art stretcher that can be applies to a bariatrics situation if needed.

Figure 7: The POWERFlexx+ Powered Ambulance Stretcher
http://www.ferno.com/product_content.aspx

2.1.8 Sitmed Ambulance Stretcher

Sitmed is a company based out of Brazil that makes the MW-39 automatic loading ambulance stretcher (Alibaba Manufacturer Directory - Suppliers, Manufacturers, Exporters & Importers). The design of the automatic loading ambulance stretcher was developed to reduce the effort exerted during the patient's transportation. The ambulance stretcher can be managed by one worker if needed with a buckle-point located on the legs. The stretcher is made from a hard aluminum that is also light weight and durable. The weight capacity of the product can support patients with a weight of 440 pounds. To collapse the legs, there is a red handle that can be pulled horizontal to automatically close the leg systems. There are security belts that secure the patient during travel. There are handles on both sides of the mattress that act as a safety precaution to prevent patients from falling off of the stretcher.

Figure 8: The Sitmed Automatic Loading Ambulance Stretcher
http://www.alibaba.com/product-free/101021657/Ambulance_Stretcher_Automatic_Loading_Stretcher.html

2.2 The Need for Change

A Quality Function Deployment table was constructed to evaluate the need for a redesign on an ambulance stretcher. The customer characteristics on the right are concerns that were raised for the currently designed ambulance stretchers. Table 1 below, shows the top ranked characteristics to be changed in the redesign. The category “Demanded Weight” is a scale based on a hundred percent showing the qualities needing the most attention. The top quality for redesign was a vibration dampening system, with 37.99%. The following qualities were tied for second place with the need for fewer parts and ease of use for the technician, with 12.16%. These qualities are taken into consideration for the development of the stretcher.

Table 1: QFD Chart Used To Evaluate Characteristics For Redesign.

Customer Demands (what) / Quality Characteristics (how)

Customer Demands (what)	Aluminum Alloy Mixture	Reinforced Material	Quick Release Collapse Mechanism	Pneumatic Wheels	Standard Parts	Foam Filled Plastic Mattress	Low Impact Lift Mechanism	
Light Weight	9 0.44	3 0.15	1 0.05	1 0.05	9 0.44	1 0.05	1 0.05	
High Durability	9 0.55	9 0.55	3 0.18	9 0.55	3 0.18	1 0.06	3 0.18	
Easy to Collapse	1 0.05	1 0.05	9 0.41	1 0.05	3 0.14	1 0.05	9 0.41	
Less Vibrations	1 0.38	9 3.42	1 0.38	9 3.42	1 0.38	3 1.14	3 1.14	
Easy to Use	1 0.12	1 0.12	9 1.09	3 0.36	9 1.09	1 0.12	3 0.36	
Comfortable for Patients	1 0.04	3 0.12	1 0.04	9 0.36	1 0.04	9 0.36	3 0.12	
Single Person Operable	3 0.12	3 0.12	9 0.36	1 0.04	1 0.04	1 0.04	3 0.12	
High Weight Limit	9 0.68	9 0.68	3 0.23	3 0.23	3 0.23	1 0.08	1 0.08	
Number of Parts	1 0.12	3 0.36	3 0.36	1 0.12	9 1.09	1 0.12	3 0.36	
Low Maintainance	3 0.19	9 0.58	3 0.19	3 0.19	3 0.19	1 0.06	3 0.19	
TOTAL	2.69	6.16	3.31	5.37	3.83	2.08	3.02	26.47
Percentage	10.18	23.25	12.50	20.31	14.47	7.87	11.43	100.00
Company Now	3	2	2	2	3	3	2	
Midmark Ambulance Stretcher	2	1	1	1	3	4	2	
Hausted Ambulance Stretcher	3	2	1	1	2	3	3	
Gendron Ambulance Stretcher	2	3	3	2	4	4	3	
DDC-2 Defeng Ambulance Stretcher	1	2	1	1	2	1	1	
USI-1008 Model Ambulance Stretcher	4	3	2	1	4	3	2	
Ferno POWERFlexx+ Powered Ambulance Stretcher	4	5	3	3	3	5	4	
Sitmed Automatic Loading Ambulance Stretcher	3	3	4	1	2	3	3	
Plan	3	4	3	5	4	4	4	

Customer Demands (what)	A Rate of Importance	N Company Now	Plan Midmark Ambulance Stretcher	Hausted Ambulance Stretcher	Gendron Ambulance Stretcher	DDC-2 Defeng Ambulance Stretcher	USI-1008 Model Stretcher	Ferno POWERFlexx+ Powered Ambulance Stretcher	Sitmed Automatic Loading Ambulance Stretcher	P Plan	B Ratio of Improvement	C Sales Point	D Absolute Weight	Demanded Weight
Light Weight	3	3	1	2	3	4	5	2	3	4	1.33	1.20	4.80	4.86
High Durability	4	4	3	3	3	2	2	5	3	5	1.25	1.20	6.00	6.08
Easy to Collapse	2	2	3	3	4	2	4	5	3	3	1.50	1.50	4.50	4.56
Less Vibrations	5	1	2	2	3	1	1	3	1	5	5.00	1.50	37.50	37.99
Easy to Use	4	2	3	4	3	3	4	2	3	4	2.00	1.50	12.00	12.16
Comfortable for Patients	3	3	4	3	4	2	1	5	3	4	1.33	1.00	4.00	4.05
Single Person Operable	2	2	4	3	4	3	3	4	3	4	2.00	1.00	4.00	4.05
High Weight Limit	4	4	2	5	5	1	1	5	3	5	1.25	1.50	7.50	7.60
Number of Parts	5	2	3	2	4	3	3	2	4	4	2.00	1.20	12.00	12.16
Low Maintainance	4	3	3	2	4	3	2	1	3	4	1.33	1.20	6.40	6.48
											TOTAL		98.70	100.00

CHAPTER 3 – ENGINEERING REDESIGN AND ANALYSIS

3 Introduction

The goal of the project is to improve the functionality on a current emergency stretcher. Essentially each stretcher is designed specifically for the transportation of a patient from a critical situation to the ambulance. There exist numerous problems with the emergency stretcher design which include the vibrations a patient endures within the ambulance. Paul Cotnoir's work with vibration reduction and retrofitting a force plate into the bottom of an ambulance has proven that a redesign of the stretcher could potentially show significant vibration reduction from what the patient encounters.

3.1 Paul Cotnoir's Research

It has been well established that an ambulance ride has the potential to be a very traumatic and stressful experience for both the patient and the paramedic. The vibrations caused by irregular road surfaces are a previously uncontrollable and virtually unaccounted for problem. Ambulances in the United States are typically built on Ford chassis relying solely on the vehicles stock suspension to isolate the patient compartment from road surface induced vibrations. However, a majority of the vibrations are not suppressed by the suspension system. Paul Cotnoir's research is an understanding of the vibrations that occur within an ambulance and a theoretical plan to reduce them. He has found through extensive data collection that the vibrations are enough to cause harmful damage to the patient and to the emergency personnel. Road surface induced vibrations impact the patients care on two levels; it decreases the ability of paramedics to diagnose and treat as well as having negative effects on the body's vital processes, which may already be compromised.

Figure 9: Ambulance Measurements.

Photographed by Mustapha S. Fofana.

As shown in Figure 10, the frequency increased with the increase in power spectral density or PSD. The PSD graph identifies the frequencies at which the energy due to vibrations is concentrated. This graph identifies the hazardous situations that the body is exposed to while traveling at speeds greater than or equal to 65 miles per hour.

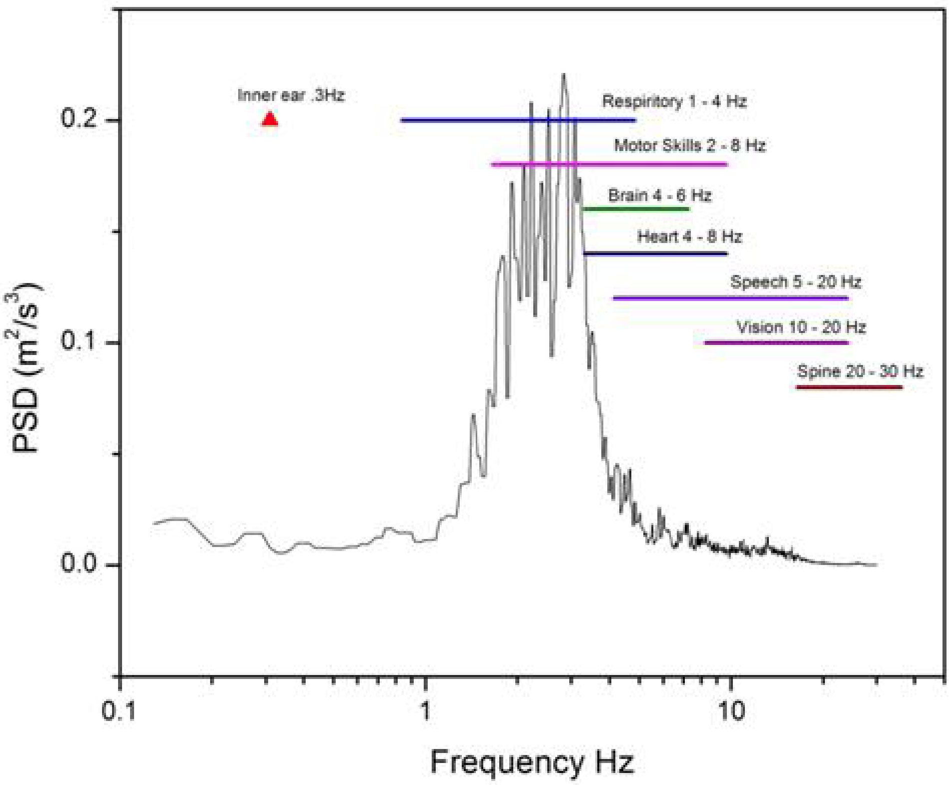

Figure 10: Physiological Effects of Ambulance Whole-Body Vibration.
Frequencies Are Superimposed On PSD Graph Of Z-Axis Power Spectral Density, Amb. #3, >=65 MPH, Highway Surface

In order to reduce vibrations, Paul introduced the theoretical concept of a force plate. The force plate would have a series of springs geometrically spaced on the plate. The force plate would then be retrofitted over the chassis of the vehicle. Paul's computer simulation results concluded that the vibrations from the road to the patient could not be entirely absorbed by the force plate. The source of vibrations that a patient endures is directly related to the stretcher in which they lay on. A redesign of the stretcher could potentially absorb enough vibrations to increase the likelihood of proper diagnosis, proper treatment, and the overall comfort for the patient during travel.

Figure 11: Ambulance Stretcher Technician Space.
Photograph from Paul Cotnoir.

3.2 Objectives of Project

The objectives of the project is to reduce vibrations transmitted through the stretcher into the patient, reduce the number of parts for the redesign, and have a simple “easy to use” system. The vibrations transmitted through the stretcher is the number one priority for the redesigning of the stretcher. The damaging effects from vibrations is quite detrimental to the care a patient can receive, as previously discussed in this chapter, and needs to have full concentration implemented into correcting it. The primary considerations for the number of parts and increasing the likelihood of developing an “easy to use” system for the new design include the following characteristics: overall weight, maximum load capacity, and cost. Cost is more of a secondary concern when headed towards the production phase.

During the designing of the stretcher Pro|Engineer® was used to model the prototype. Since the model was created in Pro|Engineer®, Pro|Mechanica® an add-on to Pro|Engineer®, can be used in the future to determine the stresses on individual parts as well as the entire system. The facilities at Worcester Polytechnic Institute had all the necessary programs and equipment needed to complete the project paper and design model.

3.3 Specifications

The following is a list of design parameters for the stretcher:

- Height of clearance in collapsed position: 15.5 inches
- Height of clearance in raised position: 41.0 inches
- Bulk weight of stretcher: 99 pounds
- Maximum weight capacity: about 500 pounds
- Materials for numerous parts
    - Pneumatic Wheel System: Steel and plastic grey hub
    - Lower Frame: 6061-T6 powder coated aluminum
    - Lift System
        - Mast: 6061-T6 powder coated aluminum
        - Parallel Lift Arms: 6061-T6 powder coated aluminum
        - Yoke: 6061-T6 powder coated aluminum
        - Slider and Bushing: 6061-T6 powder coated aluminum and glass filled nylon
        - Pawl and Ratchet Assembly: Steel
    - Lockable Gas Spring: Steel

- Upper Frame
  - Pipe frame: 6061-T6 powder coated aluminum
  - Auxiliary Wheels: Soft Rubber
  - Perferrated Backing Plate: Polyvinyl chloride (PVC) plastic
  - Mattress: Visco-elastic Polyeurathane foam memory mattress sealed in a neoprene rubber cover.

3.4 Foam Filled Pneumatic Wheel System

The stretcher is equipped with the Algood Casters Limited Foam Pneumatic Wheel. The design specifications provide shock absorption and quiet operation without the use of additional equipment. They are designed specifically for transportation of delicate materials such as sensitive equipment or in this case an injured patient. The foam filled pneumatic wheel is excellent for use on rough terrain and uneven floor surfaces. Each wheel is easily interchangeable with a variety of other styles of wheels suitable for different conditions, as shown below in Figure 12. Essentially the pneumatic wheel is designed to suppress low frequency induced vibrations, between 0.1 Hz and 6.0 Hz (Cotnoir). The tread is specifically designed to reject unwanted debris without manual removal, helping maintain the inside of the ambulance as sanitary as possible.

Figure 12: Various wheel styles to increase the versatility of the stretcher
(faded wheels are not applicable to the design of the stretcher)

The uniqueness of the foam pneumatic wheels allows the stretcher to reduce vibrations while minimizing components, weight, and maintenance. Since the stretcher is being equipped with foam pneumatic wheels, as demonstrated in Figure 13, springs and shock absorbers do not have to be utilized in the vibration dampening system. By not utilizing shock absorbers and spring systems the overall amount of parts, assembly time, weight, and cost is reduced. The wheel system is a compact design that replaces two critical functions and combines them into one. Although the wheels are designed soft enough to absorb large quantities of vibrations each wheel is resilient enough to withstand changes in environmental conditions and is rated to withstand 250 pounds per tire. An Algood Casters Limited MAXX Series caster was selected for its simple design, load rating and its variety of wheel options. The casters are also equipped with independent brakes operated by the user's foot; this allows the user to activate brakes from any position around the stretcher.

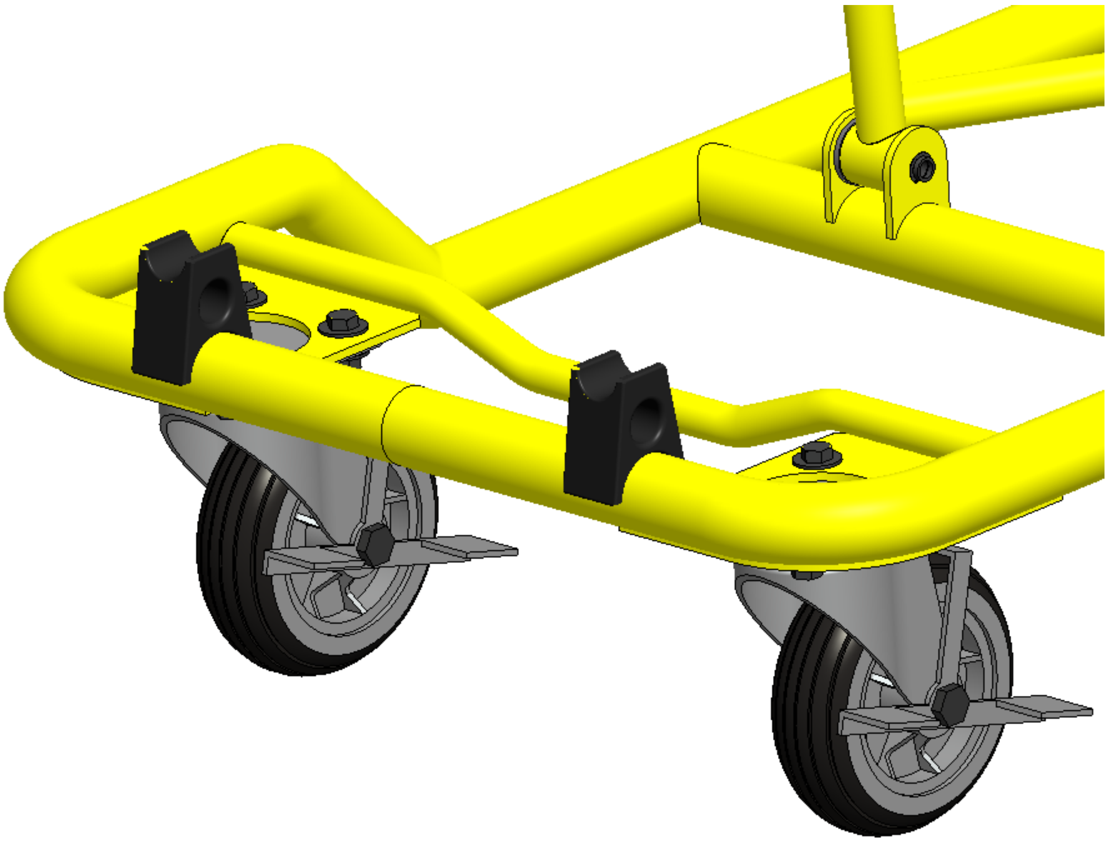

Figure 13: Pro|Engineer® Model of Algood Foam Pneumatic Wheels

The Algood pneumatic tires are desired because they do not rely on an air filled system so they retain the quality of a pneumatic device versus the non-dampened hard plastic tires currently installed on most emergency stretchers, as seen in Figure 14, and since its foam filled it reduces the nuisance of a pneumatic tire draw backs such as flat tires. Casters used in the design are supplied by a manufacturer and allows each individual part to be easily replaced so all the parts involved in the wheel system are standard and always in stock.

This helps with maintenance and overall cost by allowing individual components to be replaces rather than the whole assembly itself.

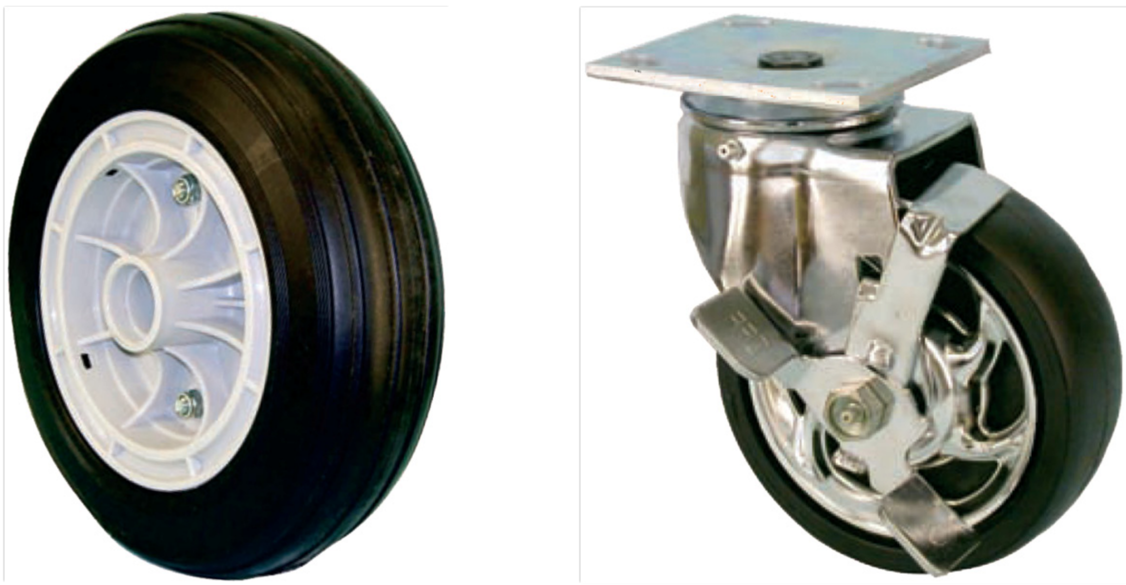

Figure 14: Algood Foam Pneumatic Wheel.
Picture On The Left Is An Algood Foam Pneumatic Wheel And Standard Hard Plastic Wheel On The Right.

3.5 Aluminum Frame[1]

The following sections are detailed figures of the new emergency stretcher. The focus of the design was to increase the comfort of the patient reducing the risk of further injury. The main cause of patient discomfort is directly related to the vibrations transmitted by the uneven road surface to the stretcher and eventually the patient. The choice to use 6061-T6 powder coated aluminum, as shown below in Figure 15, came from research performed in the program CES EduPack 2009. Further explanations for the aluminum alloy chosen are conducted throughout this section.

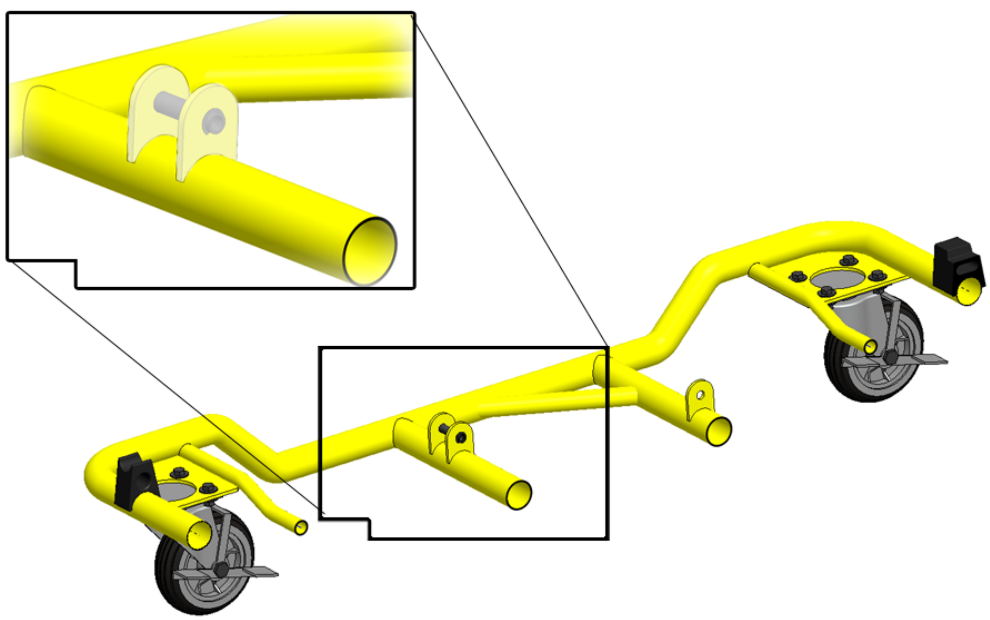

Figure 15: Cross-section of Aluminum Frame to Emphasize Pipe Thickness
Translucent Objects Are To Emphasize The Relationship Between Adjacent Components.

[1] Aluminum material chosen from *CES EduPack 2009*. Vers. 5.1.0. Granta Design Limited, 2009. Computer software.

The new design is a welded tubular device utilizing aluminum 6061-T6 alloy. Overall weight of the stretcher is approximately 99 pounds. Aluminum was chosen not only for its physical strengths but its weight. It costs approximately 71 cents per pound when purchased from a manufacturer. Aluminum is a corrosion resistant and nonflammable metal. Compared to the density of 0.282 lb/in^3 of steel the density of aluminum is 0.097 lb/in^3 which is approximately three times lighter than steel. The typical uses of aluminum alloy are for transportation equipment, heavy duty structures, marine use and pipes. Steel is concentrated more towards heavy duty shafts, axles, crankshafts and gears. Aluminum was chosen for its durability under stressful conditions and the density of the alloy which will lessen the strain the operator endures during lifting and maneuvering of the stretcher. Figure 17 illustrates the level of strength and the complexity of structure one can achieve using aluminum.

Figure 16: Audi Space Age Car Frame
http://www.audiusa.com/us/brand/en/exp/innovation/audi_space_frame.html

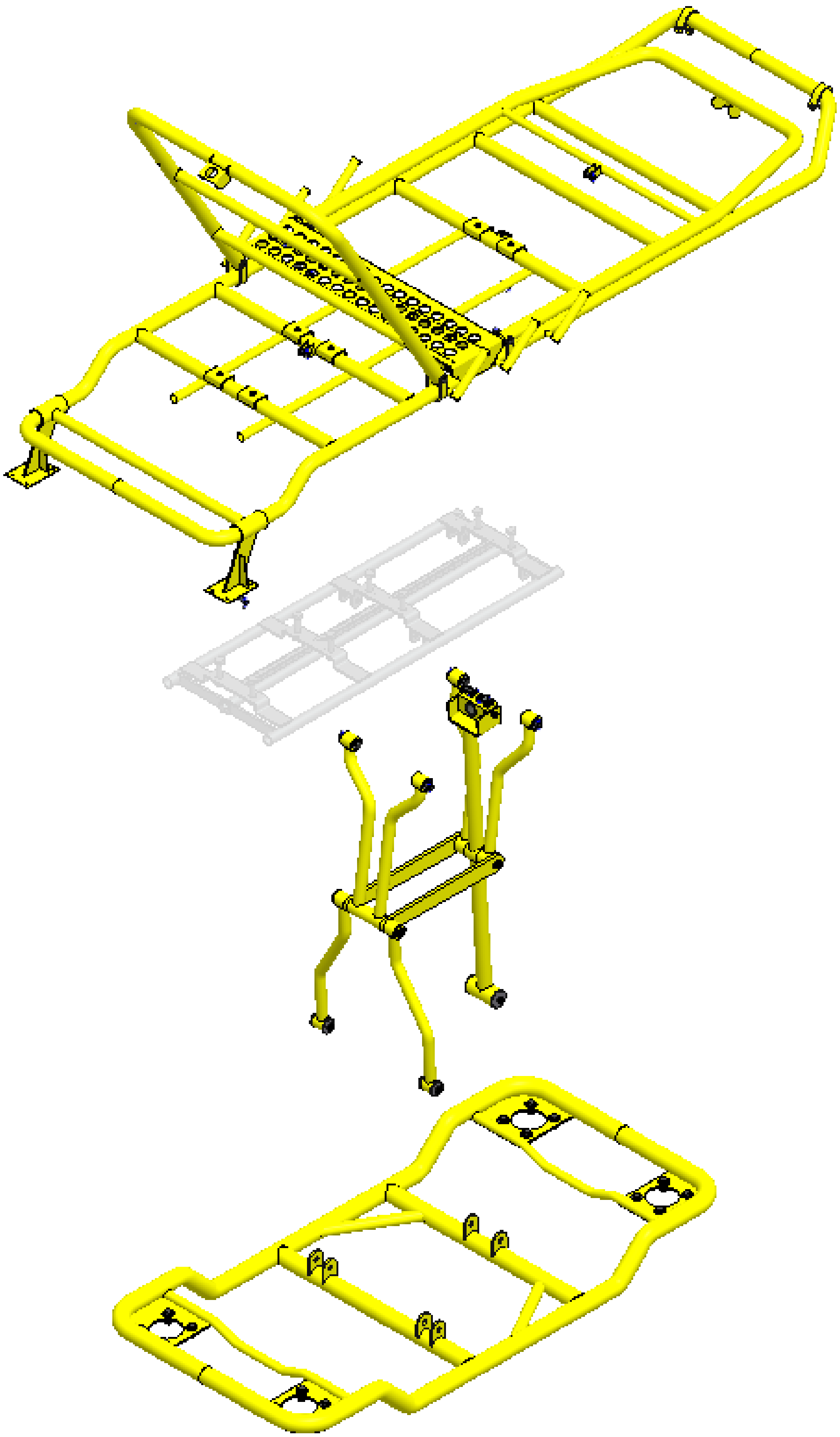

Figure 17: Exploded View of the Stretcher's Aluminum Frame.
Phantom item is made out of steel

The lower frame, lift mechanism, and upper frame are all constructed of the 6061-T6 powder coated aluminum alloy, shown in Figure 17. Powder coating the aluminum alloy has numerous advantages over standard painting. Powder coatings emit nearly zero volatile organic compounds or VOC and a much thicker coating can be applied without running or sagging of the paint. During powder coating the overspray can be recycled, and the finish is much tougher than conventional paints, as well as many other environmentally friendly attributes (Pennisi).

3.6 Lower Frame

The lower frame is a welded tubular design with 1-1/4 schedule 10 aluminum pipe. The pipe provides a strong structure while minimizing weight. It is comprised of two main sections and two cross beams along the bottom for added strength, illustrated by Figure 18 below.

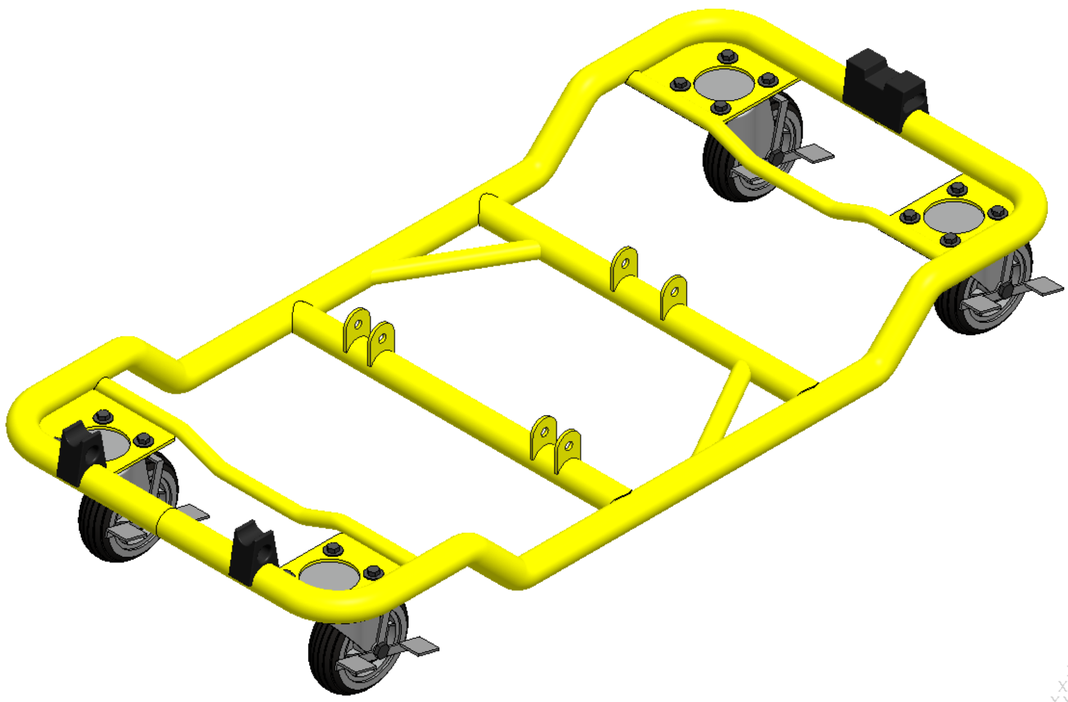

Figure 18: Isometric View of the Lower Frame

The lower frame is designed with a drop in the midsection to maintain the lowest height possible in the collapsed position. This design feature reduces the height required for emergency personnel to lift an incapacitated patient onto the bed. Another benefit of the “drop frame” is that it creates a pocket in which the lifting mechanism is easily stored within the frame. This pocket protects any extremities from pinch points and eliminates protrusions that may become a tripping hazard. The pocket also allows sufficient clearance in the mid section for medical supplies such as oxygen tanks while in the collapsed state without adding to the overall dimensions of the stretcher. Figure 19 and Figure 20 give a suggested idea about the different views of the bottom frame from the redesigned ambulance stretcher.

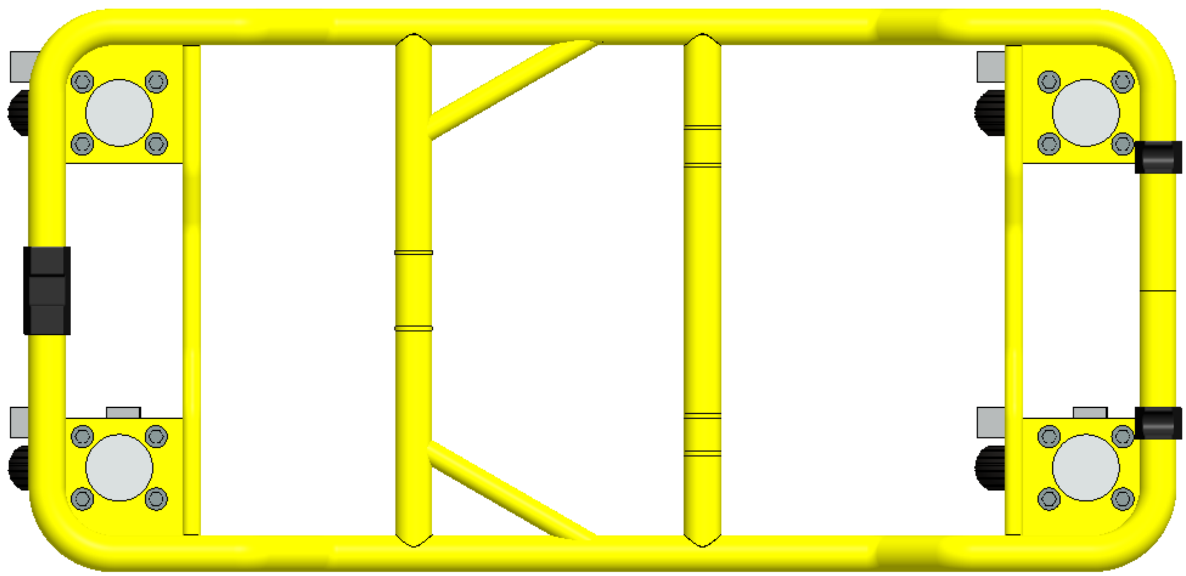

Figure 19: Top View of the Lower Frame

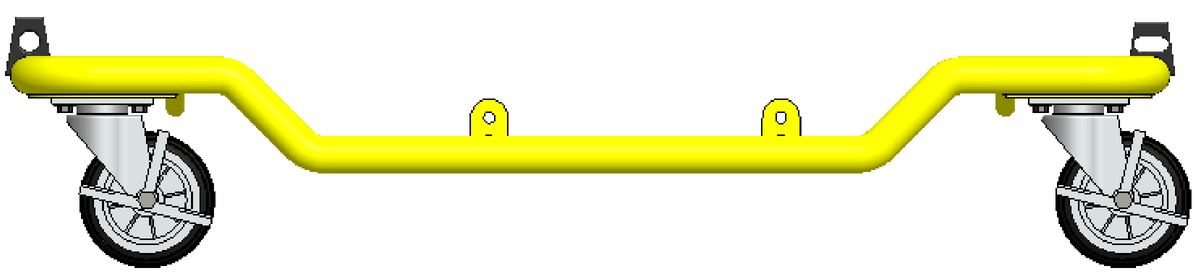

Figure 20: Side View of the Lower Frame

3.7 Medical Equipment Storage

The recessed design in the center of the lower frame, or the pocket, has a unique ability to store oxygen tanks, medical bags, or an automated external defibrillator (AED) while in the raised or lowered position. There is a clearance of 4 inches located toward the foot end of the stretcher between the lower frame and the upper frame when in the collapsed position and 6 inches at the mid-section. While in the raised position, there is 31 inches of clearance that may be used for storage freeing up the technician hands for more adequate care of the patient. Figure 21 demonstrates the space available while operating the stretcher.

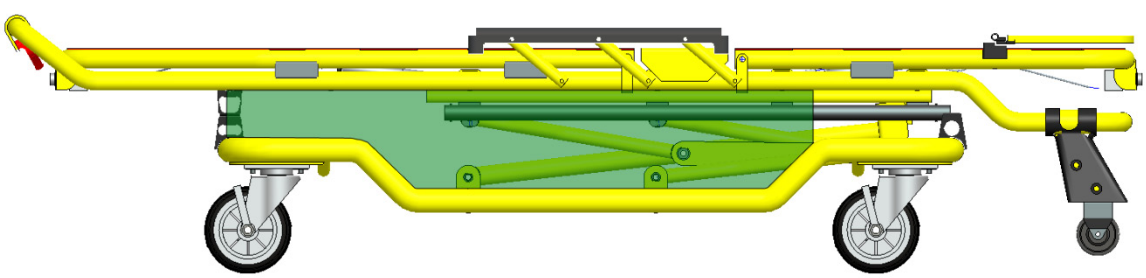

Figure 21: Side View of Six Inch Storage When Collapsed.
The Green Area Represents Available Storage Space.

The medical equipment can be either suspended on the upper frame or placed in the pocket of the lower frame with the addition of some hard plastic molded floor panels. The floor panels will enclose the two large openings in the lower frame located on either side of the lift mechanism. The floor panels will be an additional commodity that can be easily ordered after the ambulance stretcher is purchased if the hospital finds the component necessary. Figure 22 displays the floor panels installed into the stretcher for added storage space.

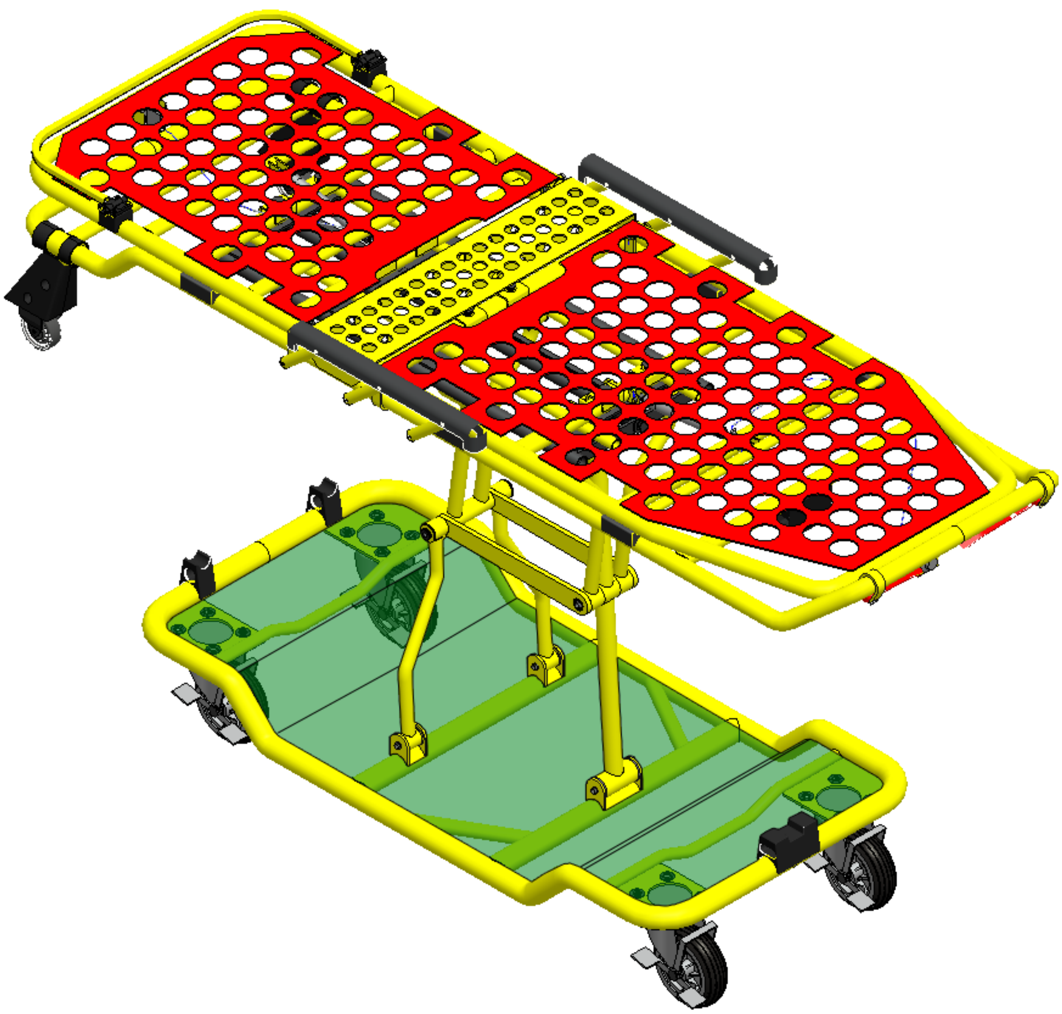

Figure 22: Green Region Represents Available Floor Panels.

3.8 Lift System

During the preliminary stages of designing a variety of lift systems were considered focusing on minimizing parts, minimizing weight, providing ease of manufacturability and minimizing volume, for example the amount of space the lifting mechanism occupies both in the collapsed and extended position. The idea behind the lift originated from a hydraulic floor jack where a horizontal piston is attached to a bell crank which is then attached to two parallel links. The basic idea behind the bell crank is that it converts horizontal motion into vertical motion or vice versa (Blocker). This bell crank is attached to the end of two parallel arms and a lifting pad at the opposite end. Together the parallel arms maintain the lifting pad at a constant horizontal orientation. The advantage with the floor jack is that it provides a low profile in the collapsed state with a reasonable amount of extension; Figure 23 and Figure 24 illustrate the lift mechanism in the collapsed state.

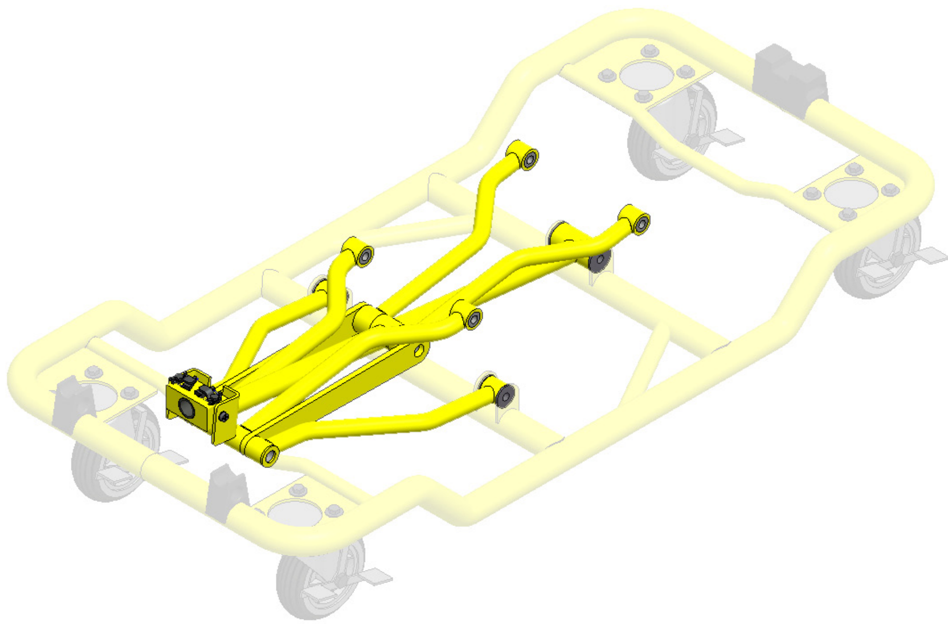

Figure 23: The Lift Mechanism in the Collapsed Position.
The Upper Frame Was Removed To Expose The Lift Mechanism And The Opacity Of The Lower Frame Was Increased To Focus The Attention On The Lift System.

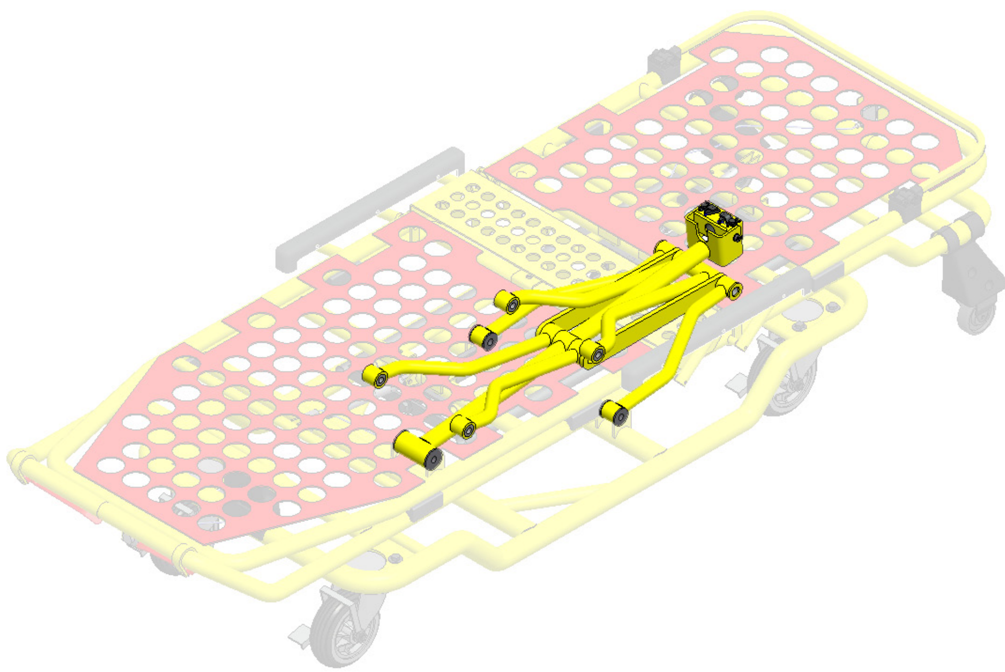

Figure 24: The Lift Mechanism in the Collapsed Position.
Translucent Objects Are To Emphasize The Relationship Between Adjacent Components.

An issue that was discovered is that when the jack is being raised the lifting pad translates the motion not only vertically but horizontally as well. If this was implemented in the new design, the center of gravity of the stretcher would always be changing as the bed is lowered and raised. This unstable system could cause injury to patients and paramedics if it were to ever tip over during proper operation. In order to compensate for that safety issue, a second jack was attached to the top of the first jack, but positioned in the opposite direction to counteract the horizontal motion and prevent the center of gravity from shifting during lifting, this design correctly maintain the center of the bed with no translation is the horizontal direction. After that issue was corrected, a second problem was encountered that was directed toward the synchronization of both lifting mechanisms. Both the lower section and upper would move indecently from each other, making it unstable by allowing then to move opposite direction, making it operation useless. In order to properly synchronize the movement of both lifts so that both would raise and lower in unison while minimizing parts, one of the supports for the bottom lift was extended to reach the same horizontal plane where the upper lift is located. The extended lift arm is characterized as the mast for the lift system. Figure 25 gives a greater sense of the mast support which extends from top to bottom and slides along a shaft in order to synchronize the “floor jacks”.

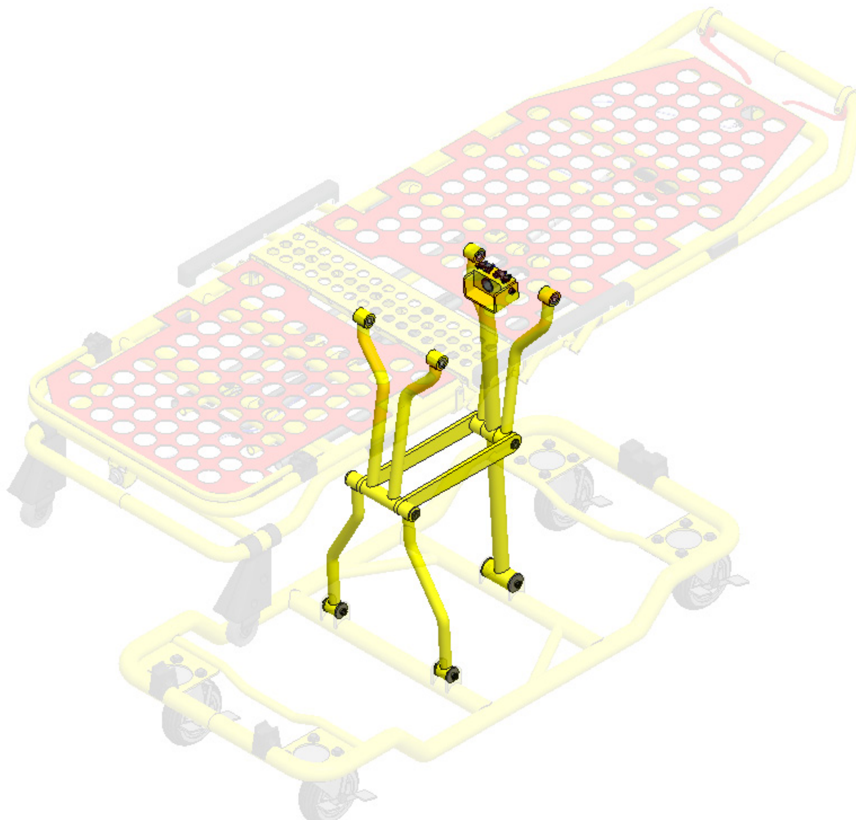

Figure 25: The Lift Mechanism and the Mast Fully Extended
Translucent Objects Are To Emphasize The Relationship Between Adjacent Components.

A slider mechanism is welded to the top of the mast or main lift arm and travels along a horizontal off the shelf linear shaft that runs for most of the length of the stretcher. The slider assembly is composed of a yoke assembly, a bushing and a locking system for the stretcher. This slider system also helps support the extra weight that is added to the system. The sliders main objective is to hold the section of the locking systems as well as provide a smooth guide for the motion for the system.

3.9 Steel Guide Support Frame

The guide support frame is composed out of steel which is located under the bed of the stretcher. The reason that the guide support frame is made out of steel rather than aluminum is for superior yield strength and infinite fatigue life. The guide support frame holds the linear shaft and linear ratchet both of which are also steel and susceptible to high stresses. For this reason the frame was chosen to be made out of steel since aluminum and steel are very hard to weld due to their large differences in melting temperatures. Since the entire frame is composed of steel the components could then be welded together reducing the amount of parts as well as the size of the part since they didn't need to be sized to fit a fasteners helping maintaining a small profile. In order to attach the steel frame to the aluminum frame a bolted connection was added since it doesn't require any welding between the two different metals. An entire steel frame provides the system with a sturdy body capable of withstanding sudden shocks. Figure 26 shows results from a test performed on steel compared to aluminum in high stress situations.

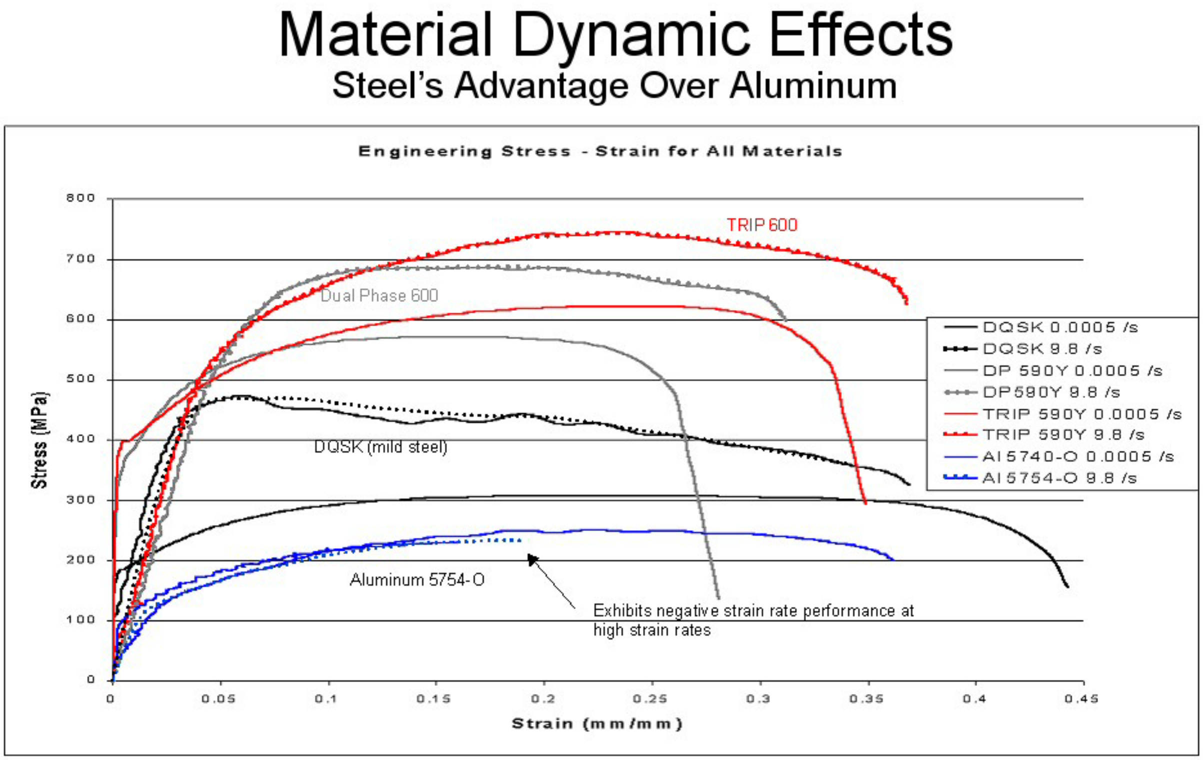

Figure 26: Results From A Study Conducted At The University of Michigan And The Ford Scientific Research Lab. ***Graph Displays the Effects of High Speeds on Aluminum 5754-O, DQSK (Mild Steel), Dual Phase 600, and TRIP 600 Materials.***

3.10 Bansbach Lockable Gas Spring

Attached behind the back rest and leg rest is a Bansbach pneumatic gas spring which is fully adjustable, placing the patient in a variety of position in order to provide a more comfortable ride. Figure 27 provides a visual on the internal components of a gas spring.

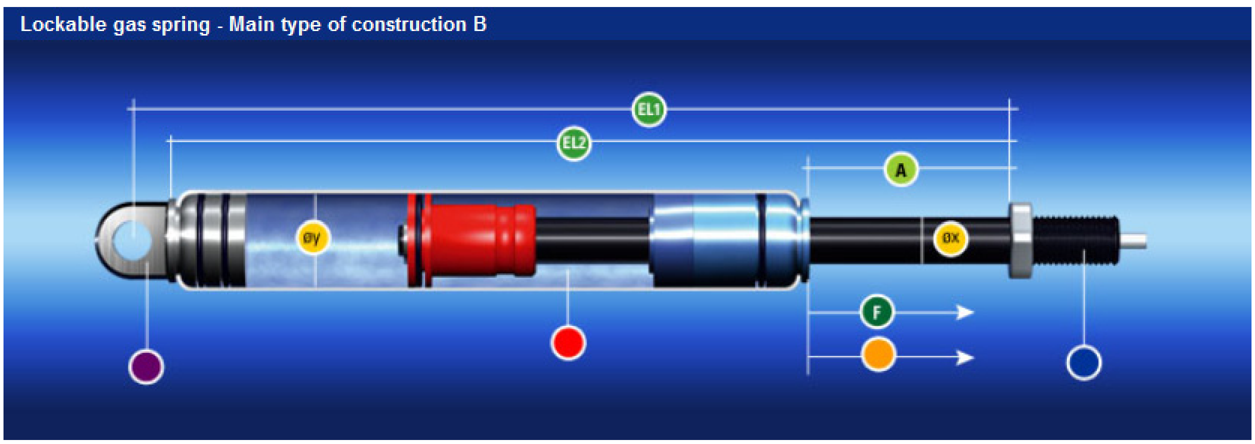

Figure 27: Lockable Gas Spring Type-B

A gas spring system is comprised of a piston that travels along a chamber filled with nitrogen gas. Bansbach produces a range of gas spring for any application. The type B gas spring produced by Bansbach Easy Lift was chosen for the design since it's mostly made of aluminum making it 50% lighter than standard gas springs. Figure 28 is a Pro|Engineer® model of the Bansbach lockable gas spring used in the assembly to check for motion and interferences. Bansbach also provides mechanism that allows the activation of the actuator such levers and buttons. By utilizing these purchase parts it greatly reduces custom components which in turn drastically decrease cost and increase availability of components if replacement is required.

Out of the gas spring provided by Bansbach the type “B” was chosen due to its ability to absorb shock. Even though the gas spring locks in a desired position, the lock is elastic. If a load is applied to the gas spring which exceeds the rated load which is specified by the customer, the gas spring will provided a small amount of “give” similar to a computer desk, which will slight lower if a large weight is applied to the chair. This “give” provides isolated vibration reduction on the back rest and well as foot rest, further decreasing overall vibration experienced by the patient. A detailed table about the features of the Bansbach Type-B Lockable Gas Spring can be found in Appendix A at the back of the report.

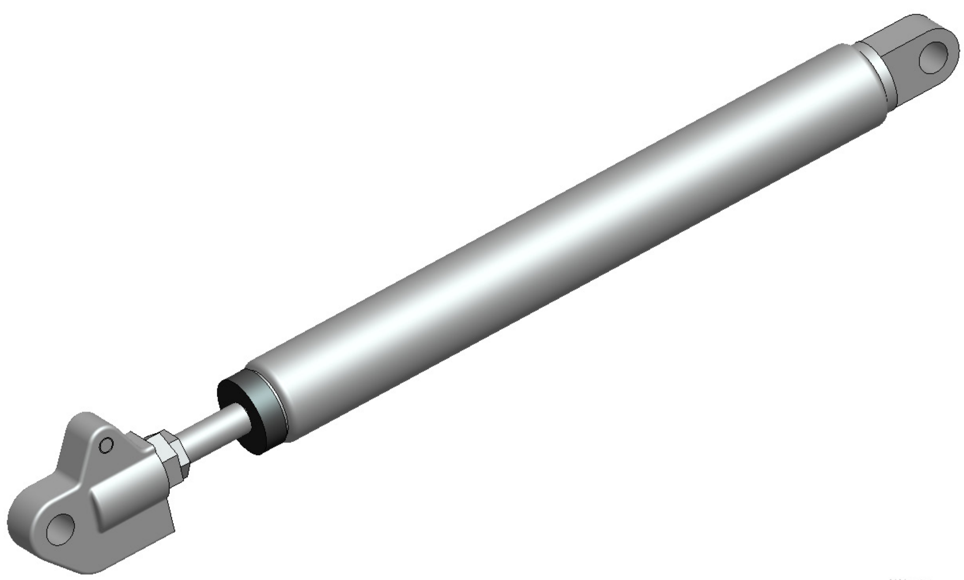

Figure 28: Bansbach Lockable Gas Spring Model Used In the Redesigned Ambulance Stretcher.

The gas springs are actuated by buttons precisely positioned at the ends of both the back and leg rest to allow the paramedic to lift and press the bottom simultaneously with one hand, while leaving the other hand free to apply extra force if need be. The nitrogen gas spring cousin provides an extension force of about 44 Newton or roughly 10 pound-force to further assist the paramedic. Figure 31 and Figure 32 show isometric views of the upper frame assembly in the fully collapsed position and fully extended position, respectively.

3.11 Upper frame “The Bed”

The upper frame bed platform which supports the bed is composed of a hard plastic like PVC with a perforated design to reduce the overall amount of material and weight of the component. The bed frame is approximately 27 inches to accommodate larger patients. Alongside the frame are collapsible railings to prevent the patient from rolling off the bed and causing further injury. The upper frame has adjustable leg and back support both attached to the Bansbach nitrogen gas springs allowing it to be adjusted to an infinite amount of positions between zero and 60 degrees for the back rest and between 0 to 24 degrees for the leg support while still suppressing sudden impacts as seen in Figure 29 below. The auxiliary wheels or the wheels that are used to support the stretcher while the main wheels are raised just before sliding the stretcher on the ambulance a permanently welded to the upper frame, this gives the upper frame a more rigid frame since the aluminum pipes in the structure a significantly smaller compared to the lower frame. The upper frame is designed to be modular. Each section such as the leg rest, back rest can be removed for maintenance, cleaning a replacement without the need to replace the entire system. In between the leg rest and the back rest is the mid-support frame. This frame is placed in the center in order to take a larger load than the rest of the structure since the center of gravity of the patient will be right above it. The mid-support frame is perforated to reduce weight and it also contains two cross members to prevent bowing of the structure as see on Figure 30.

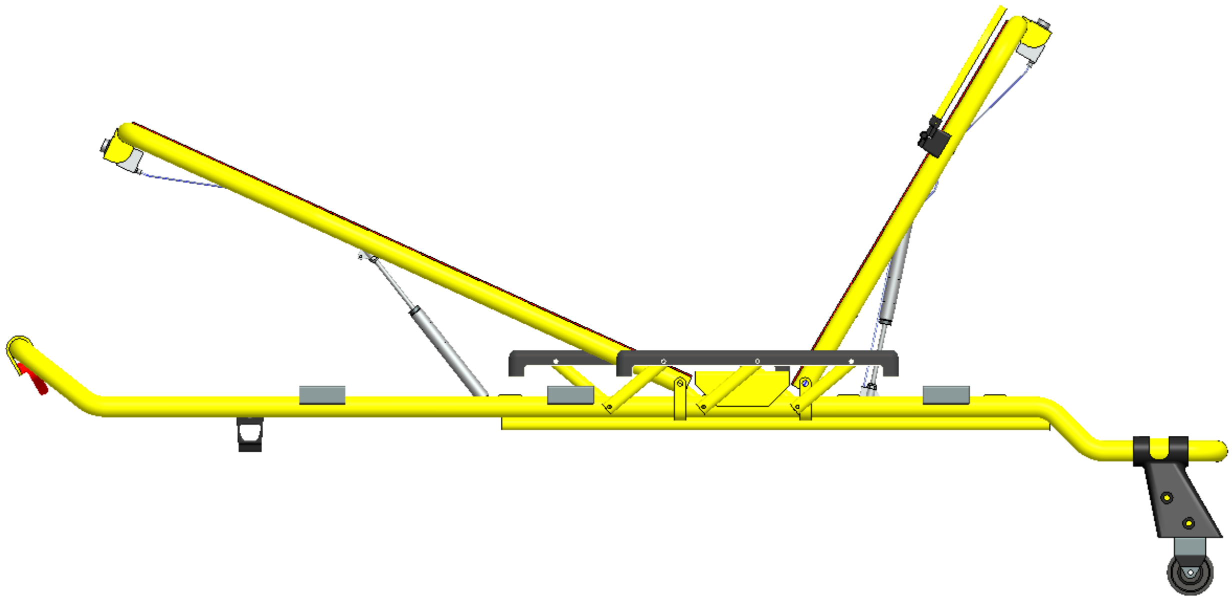

Figure 29: Illustration Of The Bansbach Gas Springs And The Degree Of Inclination Allowed.

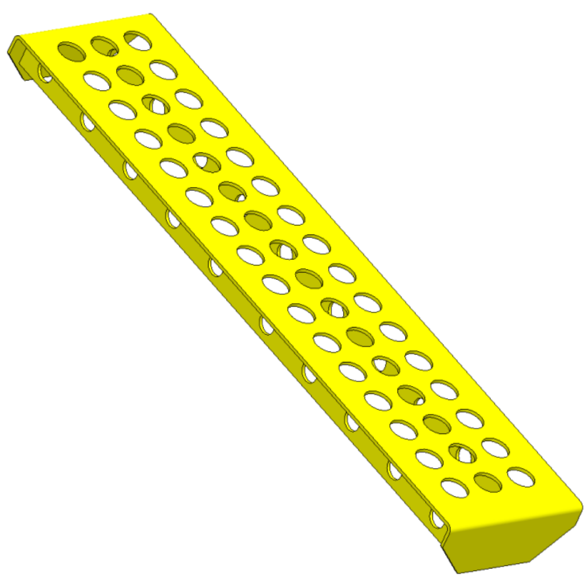

Figure 30: Mid Support Frame.

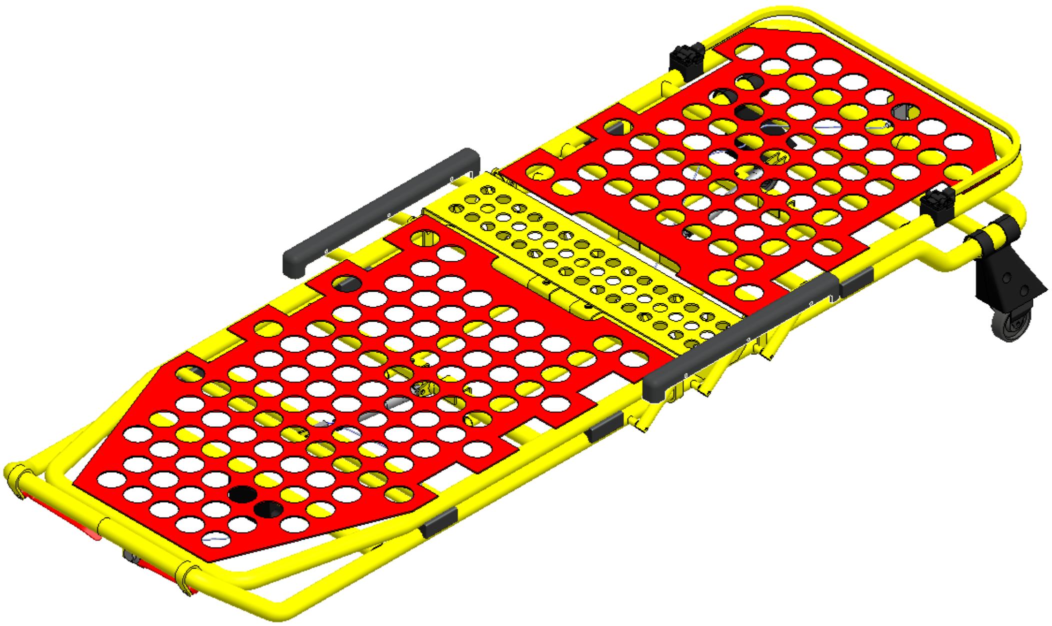

Figure 31: Upper Frame Fully Collapsed.

Figure 32: Upper Frame Fully Articulated

3.12 Bansbach Easytouch™ Button

The Bansbach Easytouch™ Button is a simple device that allows the Bansbach Type-B Lockable Gas Spring to be operated single-handedly. The button was positioned at the centered at the ends of the stretcher on the upper frame to allow the technician easy maneuverability of the back rest and leg rest. This positioning also allows the technician to use the button with ambidexterity if needed. The button in Figure 33 is located at the head of the upper body support.

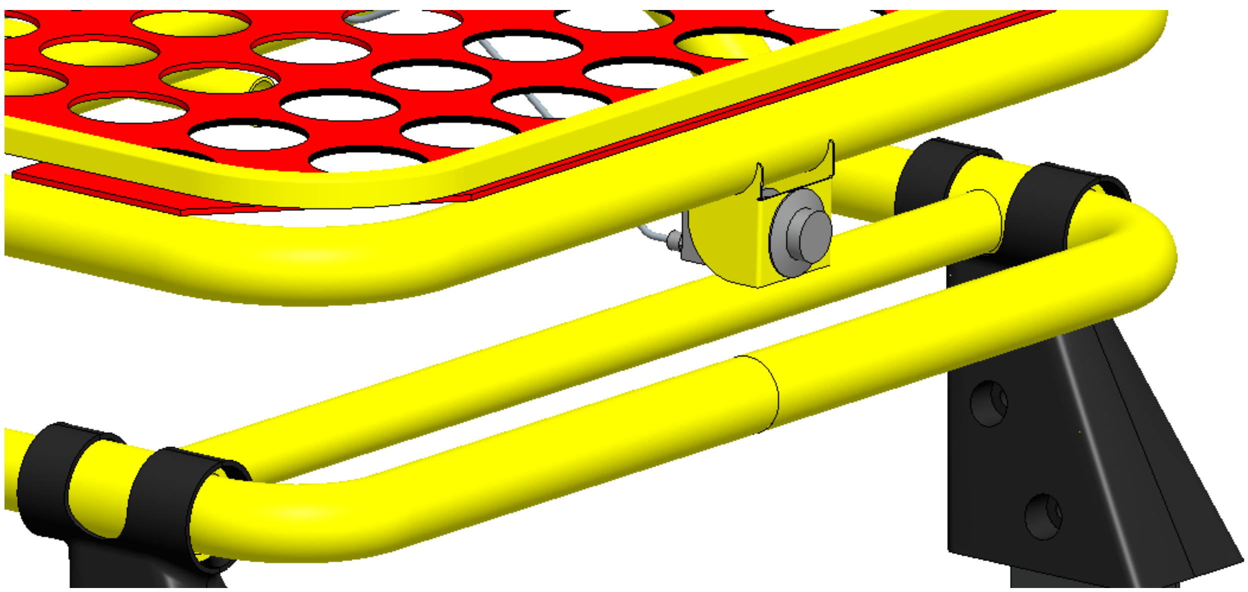

Figure 33: Bansbach Easytouch™ Button Positioned On the Upper Frame.

The button is capable of being activated overhand or underhand with minimal force to relax the piston inside the cylinder. The button is ergonomically designed to provide comfort and increase the ease of use from the technician, which is one of the main priority for the redesign. Figure 34 displays the raised position of the upper body support while highlighting the simple placement of the button.

Figure 34: Bansbach Easytouch™ Button Placement.

3.13 Bumpers

The bumpers employed into the redesign of the stretcher are used to ease the vibrations felt during the operation at the collapsed state. The bumper located toward the foot end of the stretcher has a tooth molded into the rubber that prevents the stretcher from encountering torsion force while inside the ambulance. The bumpers located toward the head of the stretcher are bellowed out to allow the shaft from the steel guide support frame to rest within each recess and prevent torsion. Each bumper is also detailed with hollow cores to allow slight flexing under an increased load. The bumpers are molded from median-soft rubber (See Appendix B) and contribute to the dampening of the vibrations. Figure 35 shows the placement of each bumper on the lower frame assembly. The rubber firmness ratings for different types of rubber that were researched can be found in Appendix B at the back of the report.

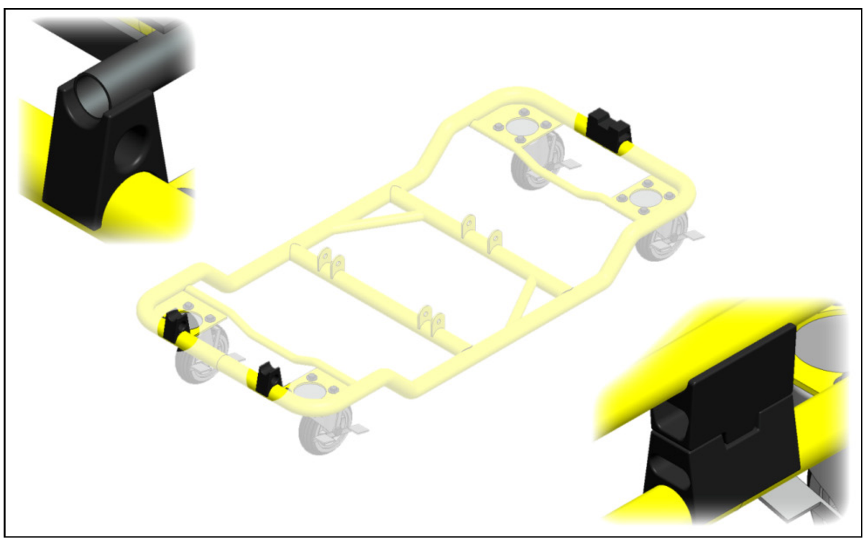

Figure 35: Lower Frame Assembly Showing the Location of the Bumpers.
Translucent Objects Are To Emphasize The Relationship Between Adjacent Components.

3.14 Prototype Head Guard

The head guard is a unique feature considered for the overall comfort of the patient. The idea behind this particular component is to protect the patient's face and head from the natural elements. The head guard is maneuverable with the addition of a friction hinge. The friction hinge contains a screw that applies pressure on the strap which then transfers a pressure onto the pivoting pin. The head guard will improve the comfort of the patient during rain, snow, sleet, hail, bright days, etc. The design is similar to a baby carriage were the carriage has a segmented hood to shield the child from the elements. The increased comfort level in a high stress situation will only benefit a technician's ability to care for that weakened individual. Figure 36 shows the prototype hard guard that will be improving overall comfort of the patient.

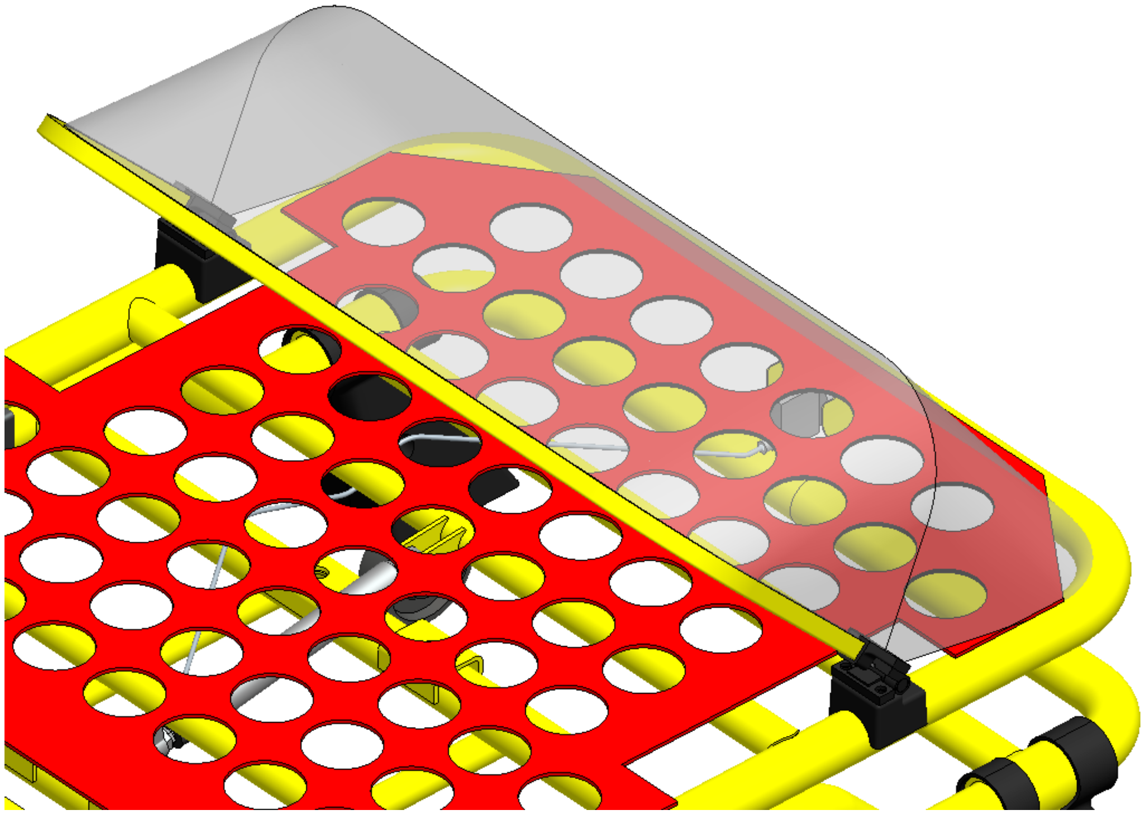

Figure 36: Prototype Head Guard with Translucent Cover to Allow Patient Viewing.

This component may not be viewed as a necessary tool for life saving, but the ideation behind this device could also be used for safe guarding technicians from a fluid transfer. If an individual is coughing or projecting their fluids from forceful actions, a potentially hazardous situation could arise for the technician. The head guard could serve as a physical “wall” between the patient and technician which can protect them if they are distracted while caring for injuries. The degree of closing for the head guard has a maximum of 180 degrees but should only be closed between 120 and 90 degrees, as shown in Figure 37 below.

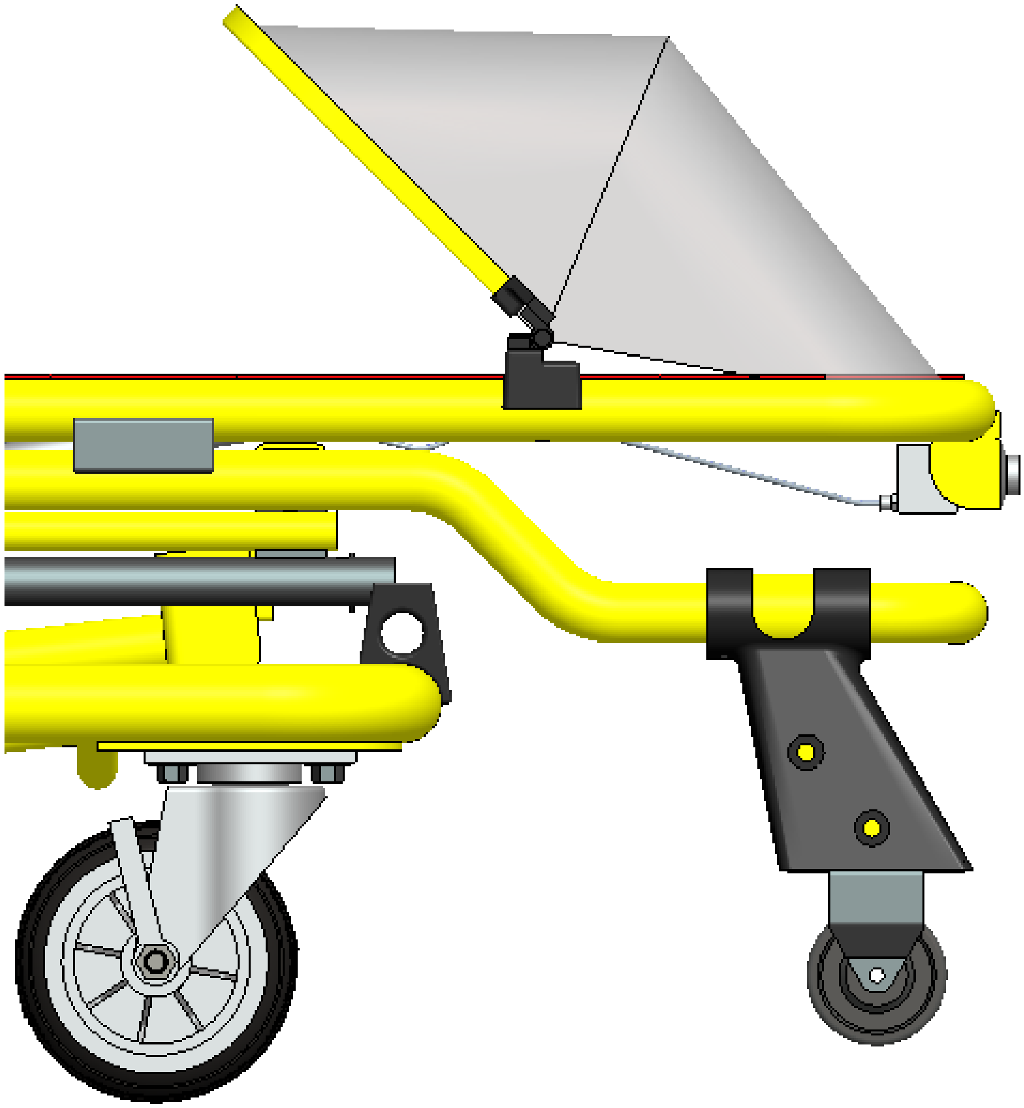

Figure 37: Profile of Head Guard Showing Recommend Degree of Closure.

The head guard is in premature development for use on the stretcher. Further evaluations or situational field tests could be conducted to validate the need for such a device on an emergency stretcher. The theoretical need for the component has merit and could be implemented for standard use on emergency ambulance stretchers.

3.15 Independent Lock System

The stretcher is equipped with an independent lock system. This lock system prevents the upper frame from collapsing on its own. The slider which runs along the shaft attached to the guide support frame is able to lock in place into any fixed position as the bed is lowered and raised. In order to collapse the stretcher the user has to engage both release mechanisms located at the foot of the upper frame to disengage the pawls from the ratchet. The angle of the teeth on the ratchet is approximately 3 degrees (See Appendix C Detail). This angle creates a positive grip on the ratchet when the lock is engaged securing the stretcher in any set position. The more load is applied to the top frame the more it “bites down” on the ratchet. Figure 38 shows the top view for the independent lock system.

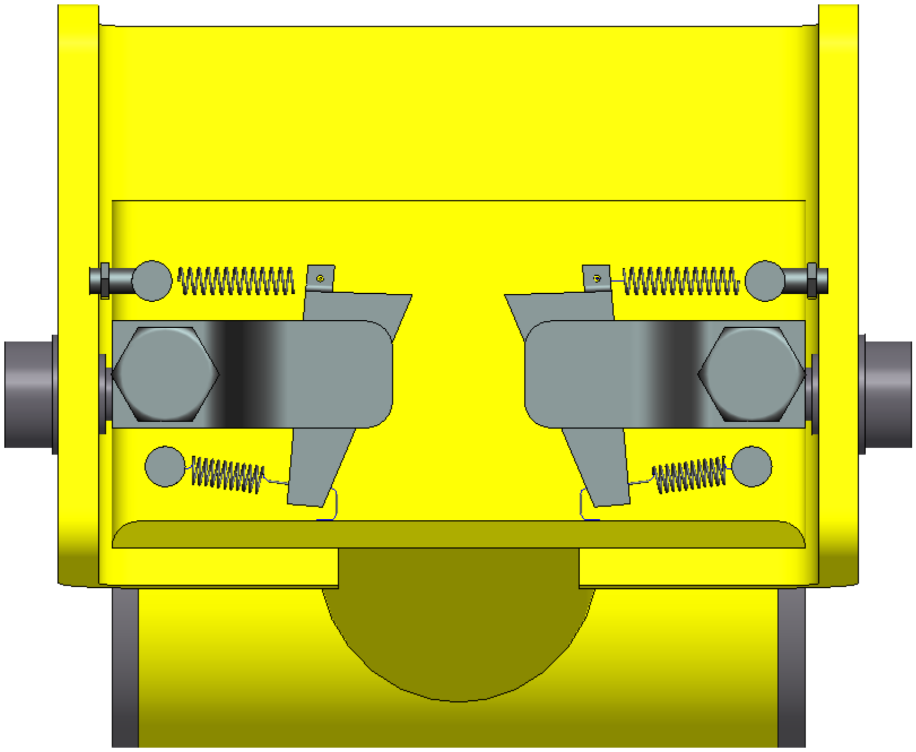

Figure 38: Top View of the Lock System.

Attached to the slider are two sets of extension springs. The tension spring maintains the pawls at a constant contact with the linear ratchet. This contact ensures that the pawl will always engage the linear ratchet if the motion is reversed. Figure 39 shows the interaction between the ratchet and pawl assembly during operation. The other set of extension springs called the release springs stores energy once the user squeezes the release levers, by doing so the lock will not disengage dude to the positive lock. In order to avoid the user attempting to overcome the “positive” grip, the spring system was added to store energy until the bed is slightly lifted reducing this positive grip, or frictional contact force pulling the pawl away from the linear ratchet, thus allowing the slider to move again. This system reduces the amount of motion the user requires i.e. squeezing the lever and lifting the bed at the same time. The paramedic can activate the lever and once confident that his grip is firm he or she can commence lowering the patient. By having two independent systems if one is ever to be tripped accidentally the other lock would still maintain engaged. The linear ratchet contains locking teeth throughout its entire length. This design prevents the stretcher from collapsing through its entire motion if ever the bed is released unintentionally due to user fatigue or other accidents. The system is activated by a steel cable enclosed in a plastic liner which is anchor to the spring as well as the levers. This system is the same type of system that is used in a modern bicycle brake system.

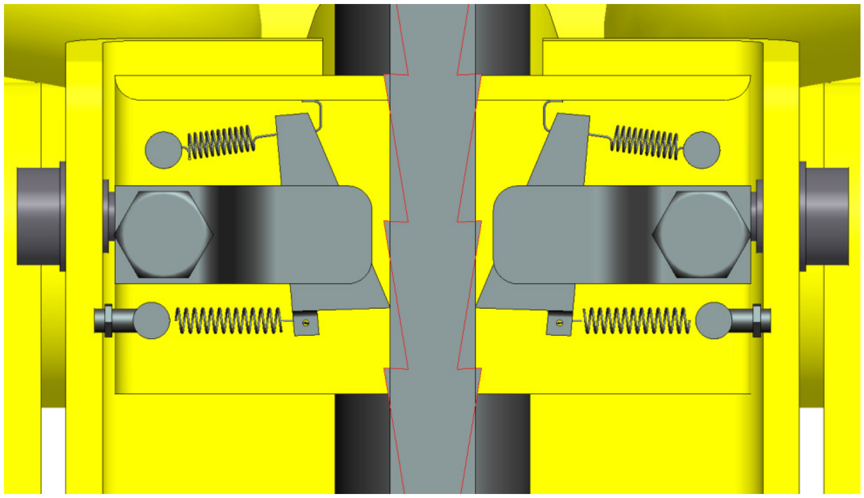

Figure 39: Relationship between the Ratchet and the Pawl
Item out lined in red shows the positive grip the pawls have on the ratchet

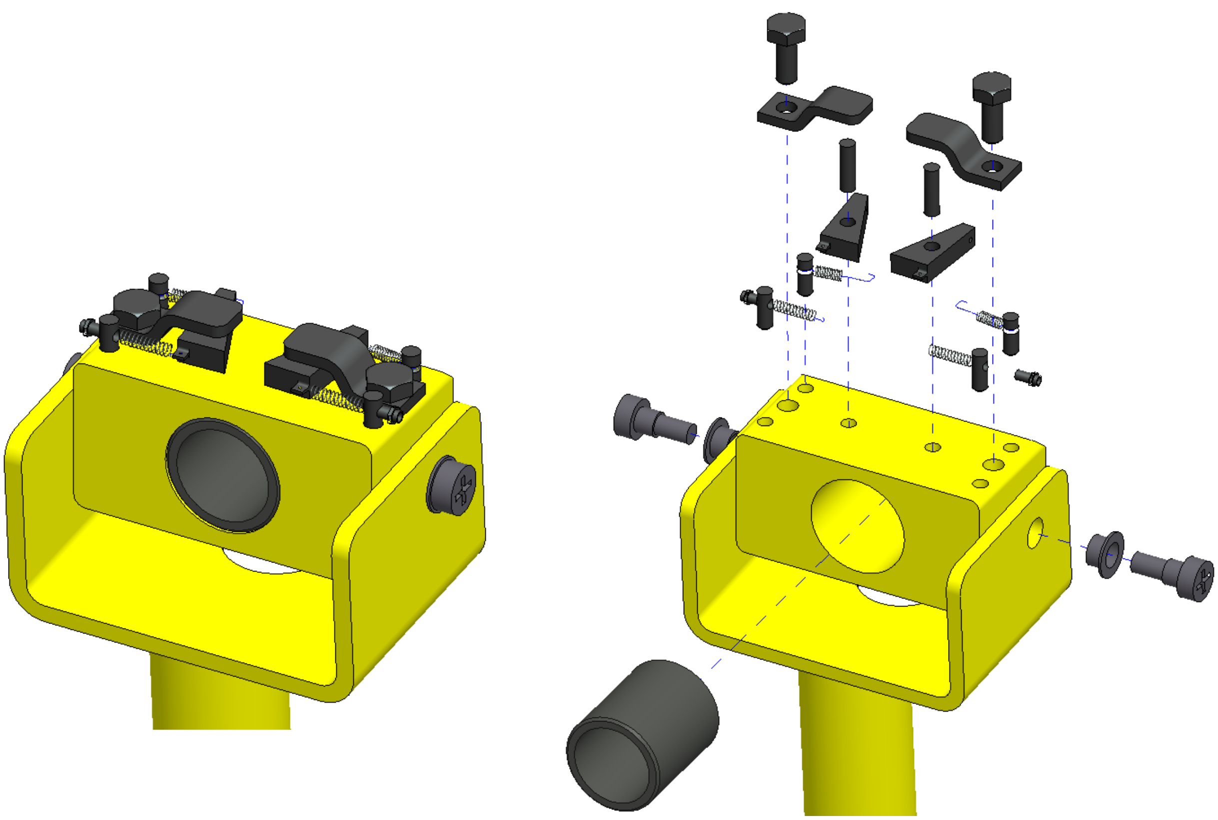

Figure 40: Exploded View of the Independent Lock System.

Chapter 4 - Concluding remarks

4 Summary

The purpose of the project was to design a complex stretcher that could be used in standard ambulances but at the same time reduce significantly that amount of vibrations transmitted to the patient. A fully dimensioned engineering drawing, including the parts list of the final stretcher design can be found in Appendix C. Each component of the new stretcher contributes to the overall comfort and safety for the emergency personnel and patient. Referring to the emergency administration at UMASS Memorial, there are two types of emergency stretchers; one is used for the transportation of patients from one hospital to another or long distances in which time is not too critical and the other is for emergency situations, transporting a patient from a life-threatening situation directly to the hospital. For emergency situations the stretcher has to be light weight and versatile enough to easily transport the patient. However, the stretcher has to be designed in order to provide comfort and safety to the patient.

Reducing low frequency vibrations is essential to the comfort and safety of the patient. The goal was to design a stretcher focusing on reducing vibrations and ultimately preventing further injury to the patient. The stretcher has a light weight design made of aluminum alloy. Aluminum possesses the best strength-to-weight ratio of any metal in common use and weighs about one-third as much as mild steel. Every component of the stretcher focuses on comfort and durability. The lower frame has a unique dip in the mid section to allow paramedics to hold medical supplies and other important equipment. Attached to the lower frame is a lifting mechanism similar to a floor jack capable of holding approximately 500 pounds. The slider which runs along the shaft is able to lock in place into any fixed position as the bed is lowered and raised. If the load increases the grip due to the angle of the pawl and ratchet become tighter making the system more secure (as long as the load does not exceed the maximum capacity).

The bed frame has a wide perforated design to reduce the overall weight of the system. Behind the head and foot rest is a lockable gas spring by Bansbach. The gas spring is a nitrogen filled piston capable of locking in any position required and is 50% lighter than standard gas springs. Each component of the emergency stretcher provides the patient with comfort and the emergency personnel with a simple manual stretcher. A simple design allows the paramedic to respond quickly in life and death situations.

The ambulance stretcher has an aluminum construction and a wheel design that makes the unit easy to roll onto awaiting EMS vehicles. Stretcher mid section can be locked and lowered where the unit can be secured in the travel position for safe movement. The smooth action wheels make it easy to maneuver around hospital facilities as well. The bed consists of a hard plastic frame with a viscoelastic pressure relieving material developed by NASA (McCrum). Figure 41 illustrates the viscoelastic material used to absorb the vibrational energy transmitted throughout the ambulance stretcher. The viscoelastic mattress will also conform to the patient's body preventing the patient from moving laterally while the ambulance performs a turn.

Figure 41: Viscoelastic Polymer
http://ideasformyhome.com/wp-content/uploads/2008/05/foam.jpg

Each component of the unit creates a comfortable and safe experience for the patient preventing further injury.

Along with the features of the design there exists need for improvement and future additions. At the head rest is a prototype for a head guard to shield the patients head from the elements. Often the simplest ideas serve the greatest purpose. Attached to the lower frame could have LED lights retrofitted alongside to increase visibility at night. The purpose of redesign is the challenge of creating a stretcher that is simple to use, that is durable, and that is concentrated at reducing vibrations that cause discomfort to the patient. A dual independent lock above the mast, above of the slider assembly is another potential idea. The purpose of a dual independent lock is to prevent accidental release of the break system. In the closed state are three rubber attachments that limit metal to metal contact and absorb low frequency vibrations. Between the bed frame and the head rest are rubber stops also preventing metal to metal contact ensuring a smooth comfortable ride.

The stretcher could be transformed into a battery powered system. Emergency personnel at UMASS Memorial agree that manual emergency stretchers are more useful. With regards to saving a life where each second counts, paramedics rely on simple designs that have an ergonomic design and an easy operating procedure. However, a battery powered system could be designed to be retrofitted within the new design in order to increase lift capacity for heavier patients. There exist multiple ideas to improve the transportation of a patient from the accident site to the hospital.

The newly designed multi-purpose stretcher is a simple easy to use unit. All the components work together to provide the patient with a comfortable ride to the hospital. The leading causes of discomfort for patients are low frequency vibrations that are transferred through the stretcher into the body. Vibrations can cause further injury to an individual and can be a safety issue. Vibration amplitudes and energy reside in frequency spectrums which are detrimental to human comfort and performance leading to possible effects to both patient safety and standard of care. The primary concern was thus designing a comfortable and durable stretcher. Referring to Paul Cotnoir's work he developed a non-linear ambulance vibration model which can be used to inform the design and manufacture of ambulance vibration attenuation systems and other mobile health care equipment which must operate with precision and accuracy in a vibration environment. Not only does the new stretcher focus on vibration reduction it serves as a durable system capable of hauling over 500 lbs of load. Ultimately all the components function together in the struggle to save a life. Figure 42 displays the Stryker model being applied to save a person's life.

Figure 42: Stryker MX-Pro R3 Being Used In a Critical Situation.
http://francesellenspeaks.wordpress.com/2008/12/01/turn-signals-may-be-detrimental-to-your-health/

4.1 Safety Notifications

4.1.1 During Manufacturing Process

Some important safety aspects for when the components are being manufactured should be mentioned. If the material has to be produced at a higher tolerance and quality then the operator should be aware that some parts might fail due to the stresses from the cutting blade onto the material. A higher quality needed during the bending of the pipes will require normal safety precautions from the operator while being manufactured. The welding of some parts onto the aluminum frame will require the operator to apply a welding helmet, wear leather gauntlet gloves to resist the chance of electric shock and withstand the heat from the welding arc, cover all exposed skin in a non-combustible material to prevent catching on fire and to lessen the chance of sunburns from the light emitted from the welder, and to wear steel toed boots to prevent injury to the feet from falling objects or sparks(MacDonald). Figure 43 shows the end result for some manufactured metal components and the quality of the products.

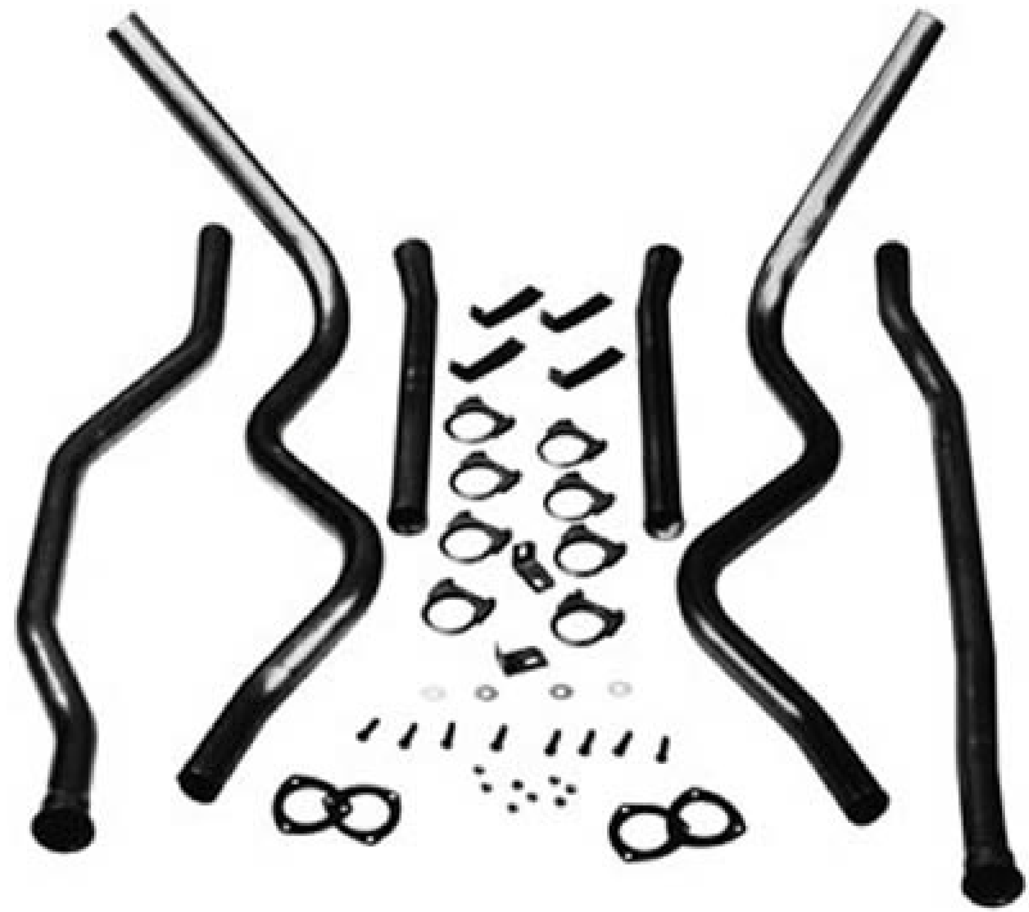

Figure 43: Assorted Bent Pieces of Metal.
http://www.made-in-china.com/showroom/motorbacs/product-detailFqUELQzosAWg/China-CNC-Mandrel-Bending-Tubes-JG86-03-.html

4.1.2 During Assembly Process

During the assembly process, some of the sequence may require the assembler to have to reposition the piece. If the piece needs to be repositioned, the surroundings of the person should be cleared of other workers if the piece is long or awkward to handle to avoid injuring another person. Appendix E shows a chart with different steps of the Design For Manufacturing and Assembly (DFMA) and the score that was achieved for the redesigned stretcher, which was a 52 out of 100. Another safety concern is if a material has a sharp edge or a jagged corner, the assembler should be cautious and if necessary wear a pair of workers gloves. Should pieces be miniature or hard to handle, an inventory sheet of parts needed per subassembly should be made so that each stretcher is assembled properly and has the necessary components specified. A top down assembly chart is the easiest form of tracking the steps necessary to assemble the component. Figure 44 is a simple top down assembly of a mechanical pencil to demonstrate the technique of a top down assembly.

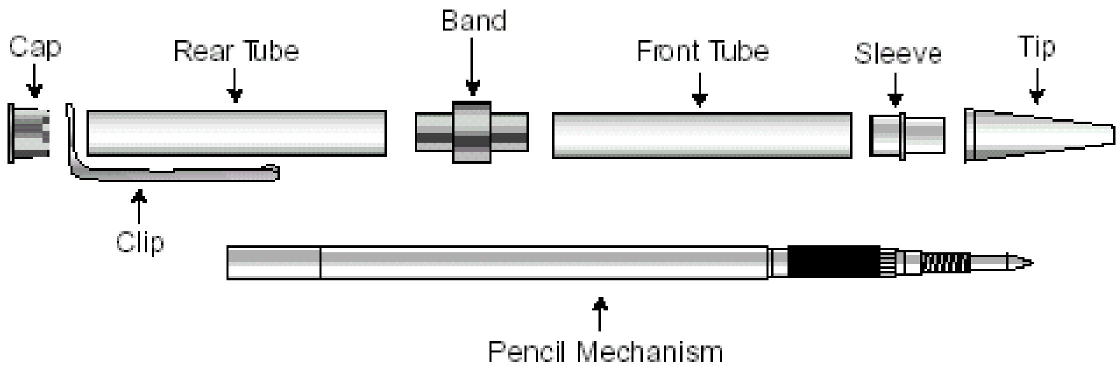

Figure 44: Assembly Of A Mechanical Pencil.
http://www.penmakingsupplies.com/Instruct/SlimInstructions.php

4.1.3 During Operation

While the stretcher is being used by a technician, there are multiple problems that can occur and cause injury to the worker and/ or patient. These situations should be avoided at all costs due to the risk of serious injuries, possible death, or a crippling lawsuit. With safety notifications for proper use in avoiding dangerous circumstances, the longevity of the stretcher can be achieved and proper patient care can be implemented.

Some major problems that should be avoided are tipping over of the stretcher, stretcher weight capacity overloading, and the lift prematurely collapsing. If the stretcher were to tip over, the patient would be at risk of further injury or possible death. This could result in a lawsuit from family members, damages to the stretcher, or prolonged treatments for the patient. If the weight capacity is ignored and the stretcher's lift mechanism fails, serious injury could occur on the patient or the technician. The proper use of the stretcher will be included in the manual when shipped to the owner of the product. Certified technicians will be licensed to use the stretcher properly at all times to insure safety while in operation. Should the lift prematurely collapse due to faults within the design or faults in the parts used to produce it, the owner could be liable for property damages or prolonged care for the patient from increased injuries. All the possible failures are showcased in Appendix D and explained in further detail.

4.1.4 Maintaining and Repairing Product

For an increased lifespan of the stretcher certain guidelines should be followed when regarding maintenance and repairs. Keeping the system clean will require wiping of the components since the product will be used in a variety of sullied locations. If needed, the entire system can be hosed down or pressure washed. The maintenance on the device is minimal, only requiring minor lubrications of bearings when making discordant clamor.

Repairs should be serviced by a professional mechanic or returned to the manufacture for extensive service. If a piece is missing, contact the manufacturer to order another replacement part. A troubleshooting guide will be supplied in the user manual that is packaged with the redesigned ambulance stretcher. Some standard fasteners could be purchased from a local store in needed to replace a part that is missing or damaged.

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Appendix A

Table 2: Details of Lockable Gas Springs Type-B

K0	B1	B	-	3	200	507		001*	550N
thread piston rod	**connecting parts cylinder**	**model**	**push-out speed**	**diameter piston rod / cylinder Øx/Øy mm**	**stroke A (mm)**	**extended length (**see below)**	**progressivity ca. %**	**Index No. (*see below)**	**force F (N)**
K0 =MF10x1x18 **O0** =MF14x1,5x20 **W0** =MF 8x1x16	see connecting parts	**B**	**–** = normal **0** = fast **7** = slow **K** = short release Rel. travel < 1 mm instead of < 3,5 mm	0 = 8/19	10-300	stroke x 2 +75	33		40-700
				1= 8/22	10-300	stroke x 2 +75	23		40-700
				E= 8/28	10-300	stroke x 2 +87	13		40-700
				2= 10/22	10-700	stroke x 2 +81	39		50-1300
				3= 10/28	10-700	stroke x 2 +94	21		50+1300
				A= 10/40	10-700	stroke x 2 +101	8		50-1300
				B= 14/40	30-800	stroke x 2 +101	18		150-2600

Attention: Calculation of extended length

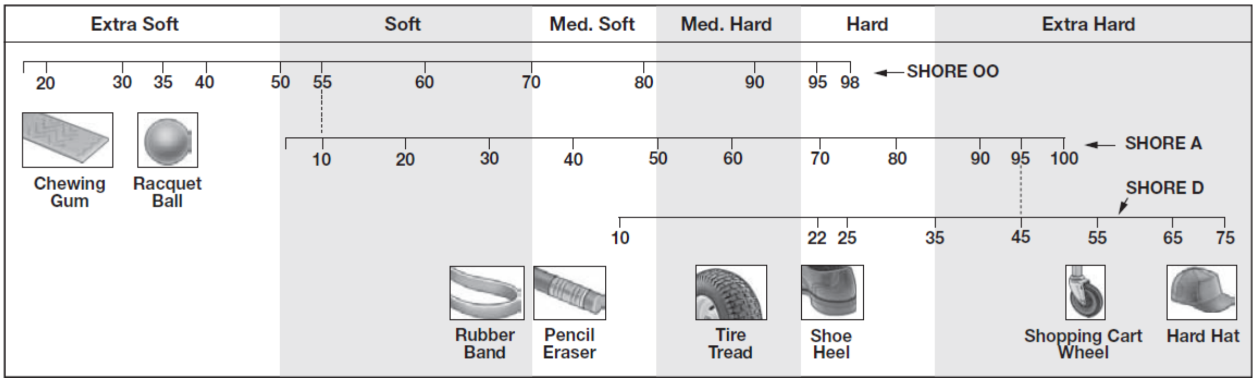
EL1
The total length is calculated when the piston rod is extended. Please add the length of the connecting parts in order to find out the total length.
EL2
length EL2 = measured without hinge eyes and threads

***Index Number**

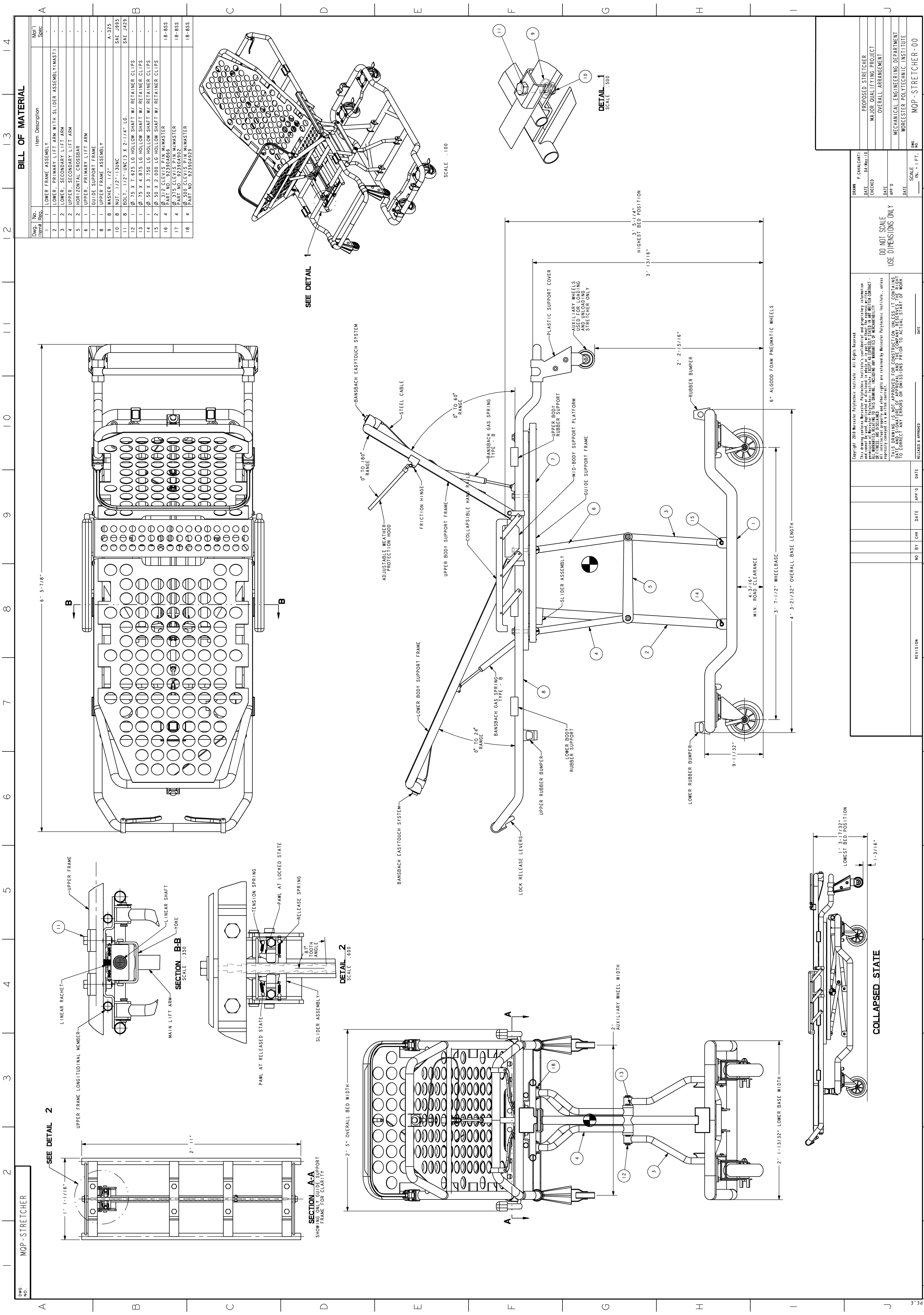
Index No.
With the index no. – only necessary for repeating orders – we can reproduce exactly the same gas spring which has already been produced. You will receive the index no. with the order confirmation / invoice.

Appendix B

Table 3: Rubber Firmness Ratings



Appendix C



BILL OF MATERIAL
SEE DETAIL 1
SEE DETAIL 2
DETAIL 1
DETAIL 2
SECTION B-B
SECTION A-A
COLLAPSED STATE
DO NOT SCALE
USE DIMENSIONS ONLY
PROPOSED STRETCHER
MAJOR QUALIFYING PROJECT
OVERALL ARRANGEMENT
MECHANICAL ENGINEERING DEPARTMENT
WORCESTER POLYTECHNIC INSTITUTE
MQP-STRETCHER-00
MQP-STRETCHER

Appendix D

Table 4: Failure Mode And Effect Analysis Diagram

FAILURE MODE	CAUSES OF FAILURE	EFFECTS OF FAILURE	CORRECTIVE ACTION
Lift Prematurely Collapsing	▪ Weak material ▪ Faulty locking mechanism ▪ Improper use ▪ Worn parts	▪ Pinched extremities ▪ Damaged equipment ▪ Increased patient injuries ▪ Possibility of patient death ▪ Personnel injured ▪ Lawsuits	▪ Reinforced material ▪ Six sigma for parts ▪ Warning labels ▪ Emergency backup locking mechanism
Stretcher Tipping Over	▪ Unbalanced center of mass ▪ Improper use ▪ Low friction factor between wheels and ground	▪ Increased patient injuries ▪ Damaged equipment ▪ Possibility of patient death ▪ Personnel injured ▪ Lawsuits	▪ Warning labels ▪ Change wheel material ▪ Shift center of mass
Loose Hardware	▪ Poor assembly ▪ Wrong Fastener Type	▪ Extra vibrations ▪ Safety problems ▪ Considered cheap product ▪ Parts could break ▪ Parts could be missing	▪ Check tolerances ▪ Six sigma for parts ▪ Employ standard parts
Weight Overload	▪ Unknown weight capacity ▪ Unavoidable circumstance	▪ Frame buckling ▪ Personnel injuries ▪ Parts could break ▪ Increased strain on parts ▪ Risk of tipping over	▪ Warning labels ▪ Reinforce material ▪ Adjust aluminum alloy mixture ▪ Reinforce Structure
Lift Mechanism Stuck In Collapsed Position	▪ Maintenance neglected ▪ Wrong tolerances for lift	▪ Stretcher dropped ▪ Possible improper patient care ▪ Damaged equipment	▪ Check tolerances ▪ Lubricate fittings during assembly
Wheels Locking	▪ Maintenance neglected ▪ Cracked or broken bearing ▪ Object jammed in wheel	▪ Stretcher tipping ▪ Increased vibrations ▪ Increased patient injuries	▪ Lubricate bearings during assembly ▪ Six sigma for parts

Appendix E

Table 5: Design For Manufacturing And Assembly Chart

OVERALL ASSEMBLY										
1 Overall Part Count Minimized		Poor		Fair	●	Good		Very Good		Outstanding
2 Minimum use of separate Fasteners		Poor		Fair		Good	●	Very Good		Outstanding
3 Base Part with Flexible Features (Locating surfaces and Holes)		Poor		Fair	●	Good		Very Good		Outstanding
4 Repositioning Required During Assembly Sequence	●	Two or More Repositions				Reposition Once				No repositions
5 Assembly Sequence Efficiency		Poor	●	Fair		Good		Very Good		Outstanding
PART RETRIEVAL										
6 Characteristics that Complicate Handling (Tangling, Nesting, Flexibility) Have Been Avoided		No Parts		Few Parts		Some Parts		Most Parts	●	All Parts
7 Parts Have Been Designed for a Specific Feed Approach (Bulk, Strip, Magazine)							●			
PART HANDLING										
8 Parts with End-To-End Symmetry		No Parts		Few Parts		Some Parts	●	Most Parts		All Parts
9 Parts with Symmetry about the Axis of Insertion					●					
10 Where Symmetry is Not Possible Parts are clearly Asymmetric					●					
PART MATING										
11 Straight Line Motions of Assembly		No Parts		Few Parts	●	Some Parts		Most Parts		All Parts
12 Chamfers and Features that Facilitate Insertion and Self-Alignment			●							
13 Maximum Part Accessibility			●							
Sum	1	X0	3	X2	5	X4	3	X6	1	X8
								TOTAL		52