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Redesign of Medical Stretcher for Special Operation Pararescue Jumpers

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Interim Report

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14. ABSTRACT
The AFRL developed a prototype medical stretcher for use by the Air Force Special Operations Command based on a crowd-sourced concept that would reduce the time to remove an injured soldier from the battlefield to improve his surviability. This concept was for a small lightweight inflatable stretcher with wheels that uses material in commercial inflatable kayaks. Problems were identifed with this approach and several redesigns were made with the intention of building a prototpye system that could be tested by the user community for acceptabiltiy and ease of use.

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PREFACE

In March 2011 a workshop was conducted at the Wright Brothers Institute to examine the needs for the Air Force Special Operations Pararescue Jumpers (PJs). During this workshop the PJs were able to demonstrat an operational situation that showed the kind of activities that they have to perform while accomplishing their mission. These missions are often conducted in extreme locations, under harsh conditions and it situations where every second counts. During the workshop it was determined that a need existed for a better way to get wounded soldiers off the battlefield. We would like to expess our appreciation to the Guardian Angel System Program Office for their assistance in providing access to operational PJs that was critical in understanding what would be needed to create a better "special operations stretcher". MSgt Robbie Bean was of invaluable help on this project and we greatly appreciate his eagerness to help and the professional insights that he brought to the task. His experience from years of field operations helped to define the capability, ruggedness and versitailty that this system must meet to be acceptable for real world operations.

1. Summary

The Air Force Research Lab used a crowd-sourcing platform to openly solicit ideas and concepts for improving the extraction of injured personnel from the battlefield. In December of 2011 they posted an Award Challenge and within 60 days had 243 concepts from 36 different countries around the world. A concept of building a small wheeled inflatable stretcher with material used in inflatable Kayaks was selected as the best idea to meet the needs of our special operations Pararescue Jumpers (PJs). The original overriding considerations for a casualty extrication technology were keeping the weight and size to a minimum, improve the ease of use so a single rescuer could extract an injured soldier, be able to operate in all terrains (mud, snow, swamp, hard surface, rocky terrain, etc), and require minimum time for setup, loading and securing the patient. The testing on the inflatable concepts showed that the material was not stiff enough to support the weight of a 200Lb patient and still maintain the small wheel size of the original design. Also the inflatable polyurethane would not be rugged enough to survive unde some conditions that the PJs are required to operate in. This finding led to a brainstorming session that separated the harness function from the transport function to create options for that could be used for operational testing. These design options and detailed work environment for the PJs are presented in this report for protoype development and testing. Due to budget cuts and reassingments, the current design team was unable to get to a prototype system and wanted to document the progress for later development.

2. Introduction

2.1. Operational Use

Figure 1: PJ operation

Modern combat rescue relies on a rescuer's ability to brave enemy fire and stabilize injured individuals for transportation to a field hospital. After the rescuer arrives at the combat site, the injured person is located and removed from immediate danger. The "hot" zone may be quite large (up to 500 meter radius). After locating the injured person, the rescuer may quickly stabilize any emergency injuries, such as heavy bleeding or trauma, in place at the "hot" site. Then the injured person (who is sometimes unconscious) must be loaded onto a stretcher system for transport to a secondary site away from immediate danger. At this location, the injured person is stabilized and prepared for evacuation by helicopter. When the helicopter arrives, the rescuer may have to transport (by foot) the injured person on the stretcher up to 2 km to the helicopter zone. In the helicopter zone, the stretcher must be quickly connected to a rope to hoist the patient in the stretcher or a subpart of the stretcher (in either a vertical or horizontal orientation) into the helicopter for evacuation. Not all situations will require hoisting the stretcher or transportation device, but all devices must be capable of safely hoisting the patient by rope to a helicopter in either the horizontal or vertical postion if needed. The rescuer is often under threat of enemy attack throughout the rescue operation. When under fire, the rescuer may carry the injured person or load them into a stretcher/sled/litter--whichever can get them to safety the fastest. Sometimes, the injured person must be loaded onto a spine board to stabilize their head and neck and prevent further injury, however, the size and inability of these spine boards to fold down to a reasonable size prevents these from being carried into the field on most occasions by the rescuers. Also in a case of multiple personnel being injured the PJ team usually has only one stretcher. Therefore once the persons is brought to the safe zone they must be unloaded to get to the next patient. Multiple handling of the patient can exasperate their injuries. Existing medical stretcher systems have several key problems: they take too long to set up before an injured person can be loaded, they are too cumbersome (especially when an injured person is being transported), and the many straps used to secure the injured person are too slow to use and prone to tangling.

Versitility and speed are also important to the operators. The PJs are often called on to treat civilian's that have have been injured in the conflict or for humanitarian missions. Therefore the equipment must be able to secure a large man as well as a small child. The injuries could include missing legs or arms so the securing straps have to be able to attach from various points on the stretcher. This equipment must operate in every imaginable environment that the PJs will encounter. The Guardian Angel System Program Office (GA-SPO) provided some estimates of baseline operations for setting up and using the current stretcher systems. The times provided varied greatly dependent on the patients injuries. In the swamp and other waterways the second person is needed to make sure the patient's head is above water.

Table 1: Current Operational times for stretcher use

Operation	# Operators	Surface	Time
Unload and setup stretcher	1	Flat Ground	30-60 Sec
Load and secure Patient	2	Flat Ground	5 Min
Unload patient to helicopter	2	Flat Ground	60-90 Sec
Drag patient over 500 meters	2	Flat Grassy Field	4-6 Min
Drag patient over 500 meters	2	Rocky Terrain	8-10 Min
Drag patient over 500 meters	2	Swamp	15-30 Min
Drag patient over 500 meters	2	Woods and Brushy area	20-30 Min

2.2. Current Stretcher systems

Medical personnel must carry everything they need with them to the combat site. Heavy, bulky, or cumbersome items are especially dangerous because they prevent the rescuer from reaching the site quickly and put them at risk of taking fire themselves. After the injured person is loaded onto a stretcher or sled, they move very low to the ground and present a low profile, reducing the risk of

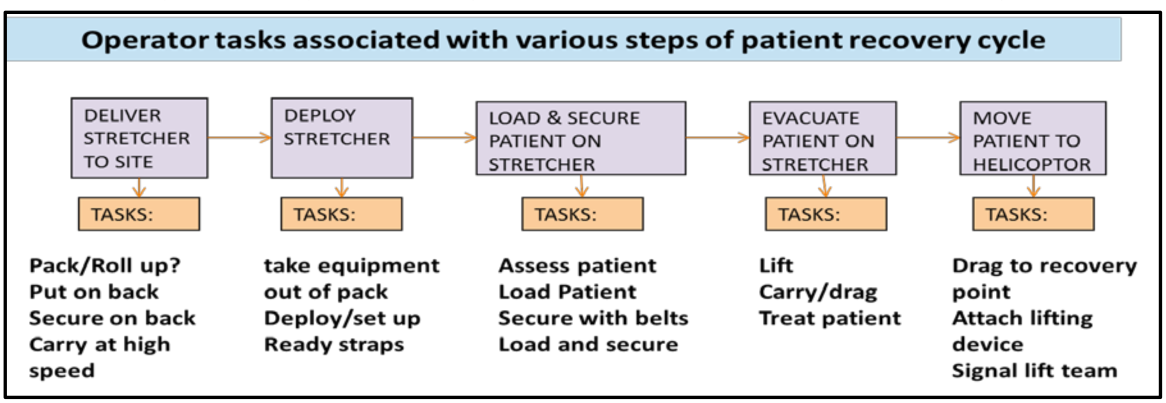

Figure 2: Tasks associated with stretcher use in operation

taking direct fire. However, shrapnel and ricochet are serious threats, especially when an injured person has had their body armor removed so the rescuer can access the injury. While body armor is usually replaced for transport, this is not necessarily an effective solution. In addition, existing medical stretcher systems are passive devices--beyond providing mechanical support, they do little to actually enable the rescuer to stabilize an injury or support vital body functions. An ideal medical transport system would make it as easy as possible for a rescuer to access the site of injury on the injured person's body and staunch bleeding, would provide for thermostasis (i.e., heat/cool the injured person as necessary), and would protect the injured person and/or rescuer from ballistic fire. A litter could also serve as a sensor platform to feed real-time medical stats to the rescuer. Currently the two main "stretchers" used by the PJs are the Talon II and the Skedko systems

2.2.1. Talon II Stretcher system

Figure 3: Talon II Stretcher

The Talon II is a traditional concept type stretcher consisting of two poles with a fabric for holding the patient. This has been modified for PJ use by making it foldable to fit in a backpack that can be carried into hostile areas. The Talon II is made by North American Rescue and currently has wide use in military operations. The system folds down to an area about 21x10x9 in space. It weighs about 16 ½ pounds and can carry a load of 1200 pounds. It is designed with small feet on the handles to give it a ground clearance of 1 ½ inches to keep the patient off the ground[1]. The Talon II has a foldable bar the stretches out the fabric and extends the poles to their operational seperation. This usually requries a strong kick by the operator to secure the stretcher in the locked position. The handles have egonomic grips so it is easy for the operator to lift one end of the stretcher. Securing straps are placed around the patient and attached to the poles to keep the patient in place for transporting. Typically two or more people are required to transport a patient but one operator can lift one end and drag the patient to a safer area.

2.2.2. Skedco

The Skedco is a tough sheet of E-Z glide polyethylene plastic that is used to wrap the patient and drag them out of the battlefield. This system was designed and built by Skedco Inc. The Sked comes equipped for horizontal hoisting by helicopter or vertical hoisting in caves or industrial confined spaces. When the patient is packaged the stretcher becomes rigid. The durable plastic provides protection for the patient while allowing extrication through the most demanding confined spaces. The stretcher is rolled for storage in a tough cordura backpack which is included with the system.[2] The basic Sked rescue system weighs 17 lbs and can be rolled into a 8"x 30" roll that is attached to the PJ backpack (See Figure 4). There are many attachments that can be added to the Skedco system including the Oregon Spine Splint (10 lbs) and several floatations devices to assist in water rescues. The inflatable float logs each weight 1 lb and are inflated with a CO2 cartridge. One complaint of this sytem is that when these systems are dragged quickly through difficult terrain (i.e., at altitude, over swampy ground, etc.) it can roll, resulting in the patient being dragged facedown and causing abrasions. If the patient is dragged on the ground for an extended time, the friction can cause "hot spots" that lead to burns and bruises for the patient. This system is excellent

Figure 4: Skedco

[1] Talon II model 90C product description, http://www.narescue.com/Talon_II_Model_90C_Collapsible_Handle_Litter-CNB06BC8635AF5.html
[2] Sked Basic Rescue system product description, http://www.skedco.com/Military/sked-rescue-stretchers/sk-200-gr

for getting a patient out of a confinded space since it pulls the patients extremities into a protective case that can be vertically lifted through small openings that are found in damaged buildings and caves.

2.3. Preliminary Design

The open innovation challenge was posted on the AFRL Tec^Edge pavilion on 28 December 2011 and was closed out on 28 March 2012. Over the next month the evaluation team consisting of AFRL researchers and representative from the Guardian Angel Systems Program Office, responsible for all PJ equipment procurement, evaluated the 243 concepts and selected the most promising concept that could be built and demonstrated. The winning selection was from Sergey Logvinov, an engineer, from St. Petersburg, Russia. Figure 5 is the drawing of his concept of using the Kayak material to build an inflatable stretcher.

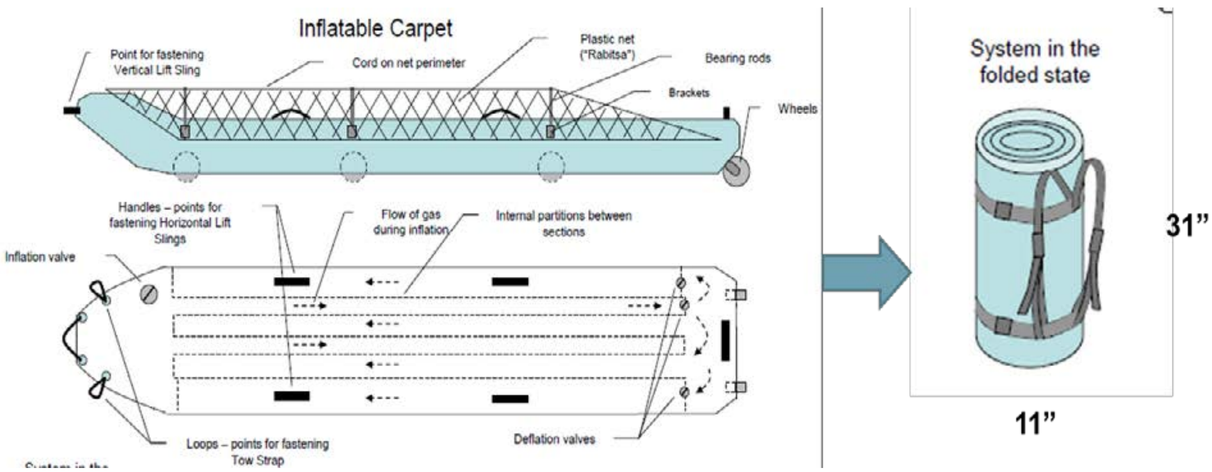

Figure 5: Inflatable raft with wheels concept

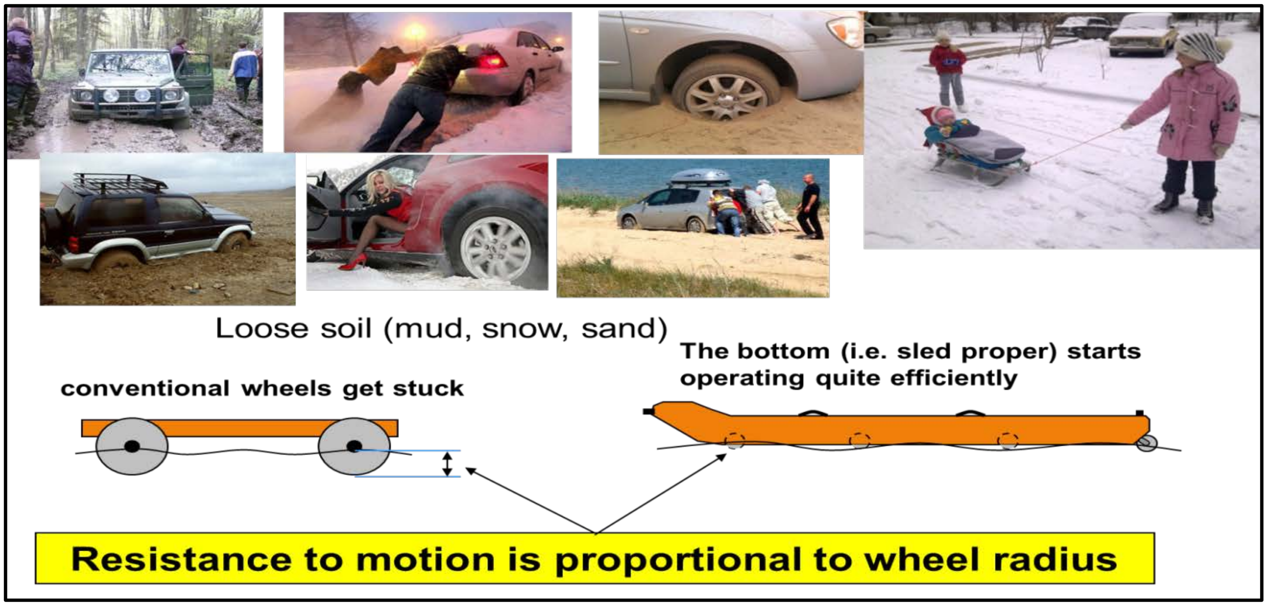

Figure 6: Dual Transport system advantage for soft ground

The raft concept uses two principles to reduce the energy of transporting the patient. The small wheel reduce friction for hard surfaces and the back wheels provide a hand truck like system in hard to get at locations allowing the patient to be lifted up and rolled out in a vertical position. The small

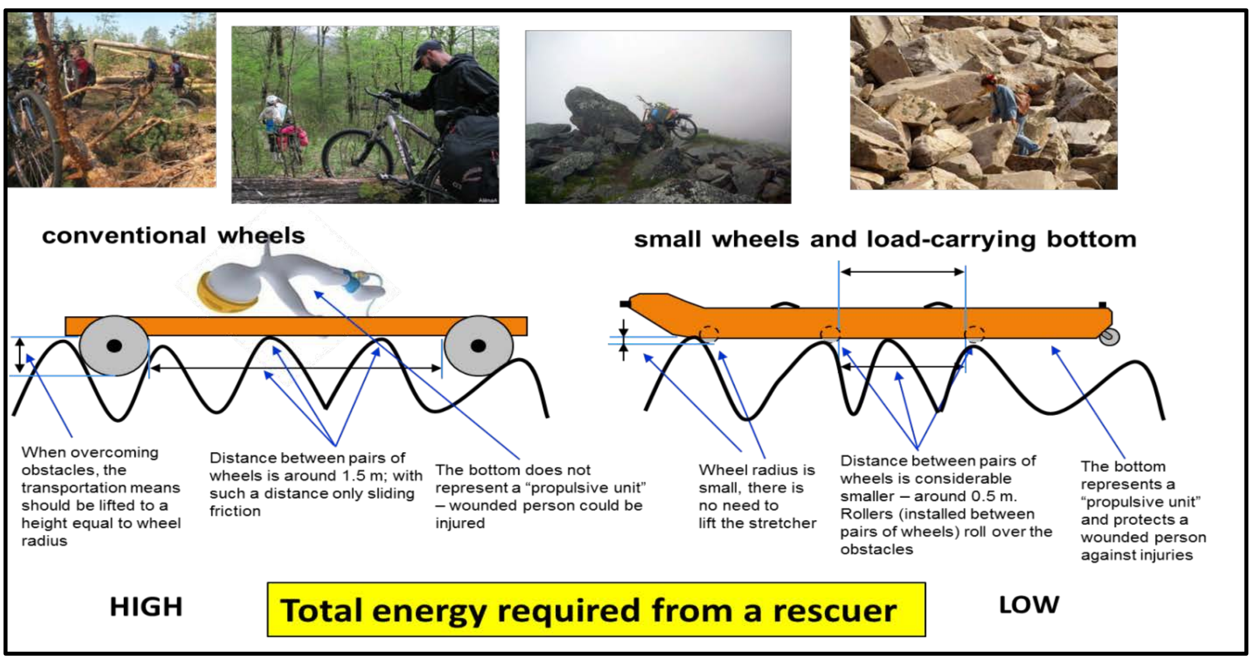

Figure 7: Dual Transport system advantage for rocky surfaces

wheels will not get stuck in soft ground and not create much added resistance in this terrain. The small wheels will also not jar the patient like large wheels would in uneven ground. The raft acts like a sled over soft terrain and is buoyant enough to float over water and swamp terrains. This concept assumes that the inflatable structure will be stiff enough to support the weight of a large soldier along with his gear (approx. 300 lbs) without flexing more than the wheel radius of the small wheels. Without this, the system would still drag on the ground and would lose the advantage of having wheels for hard or rocky terrains. Without the wheels this system would be like an inflatable Skedco that may not prove tough enough to stand up to the scraping and abrasion expected in many urban settings and other types of rugged terrain. Another assumption is that the raft will be able to be

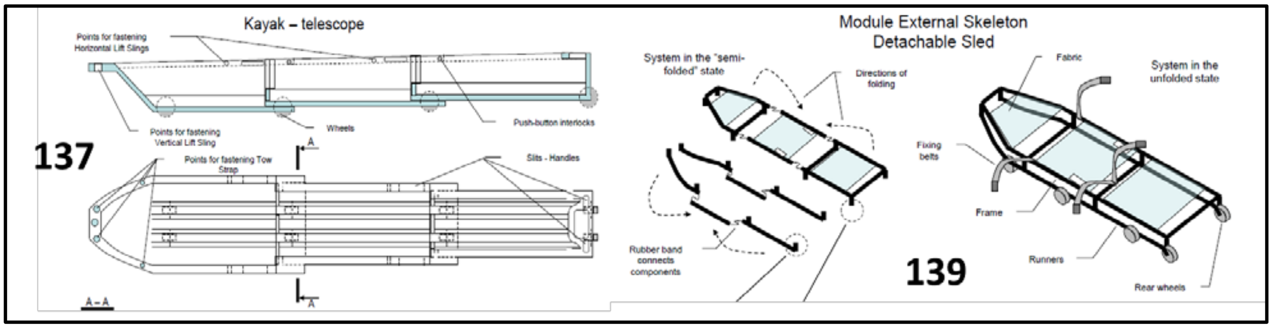

Figure 8: Alternate design concepts for dual transport system

compressed easily into the backpack size that is indicated while being rugged enough to support this expected abrasion. If this system works it can be seen that the advantages of keeping the patient afloat in swamp and water rescues would be an improvement on the current litter designs. This concept assumes that the reduced force required to pull will allow a single rescuer to quickly get an injured soldier to safety. In addition to this inflatable concept the solver proposed two other methods of transporting the patient based on the dual transport concept. The first was a telescoping frame that locked when expanded. The second was a foldable frame with a canvas fabric to hold the patient.

3. Methods, Assumptions, and Procedures

3.1. Analysis of Inflatable Alternatives

For this concept to work, it was necessary to characterize the types of materials and design methods used to build modern rugged inflatables. Primarily, it was desireable to compare weights, toughness, and rigidity of various designs. Structurally, modern inflatables use one of two types of designs, either ribbed or drop-stitch. Ribbed designs are characteristic of conventional pool lounges and are built constructed with multiple long bladders aligned in parallel. Drop stitch designs have a single bladder, where the top and bottom surfaces are kept flat by many small threads of identical length that connect the surfaces. This is typically used in higher end products such as inflatable surf boards.

AFRL procured three inflatable products for analysis. All were roughly the same dimensions, 36 x 72 x 4 inches. One product was made entirely from polyurethane drop stitch material, another was a poly-vinyl-chloride (PVC) dropstitch, and the third was a ribbed bladder encased in an outer shell with a polyurethane bottom and a nylon canvas top.

Based on assurances from manufacturers, the design team was confident that compatible wheel assemblies could be designed. The primary interest was in validating the ability of the inflatables to resist deflection under load. To test this the polyurethane inflatables were bridged lengthwise across a 36 inch span. Varied weights ranging from 45 to 125 lbs were applied across the center of the spanned distance. The deflection from the unweighted configuration was measured at the center point. The weight and size of the bladders were measured and are shown in the following table.

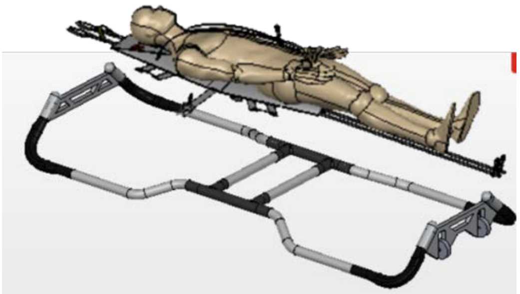

Figure 9: Dual function stretcher-transport and hoist

Figure 10: Foldable stretcher option

Table 2: Weights and measurements of the inflatable test articles

Inflatable Test Article	Weight (lbs)	Inflated Height (in.)	Inflated Width (in.)	Inflated Depth (in.)
Urethane Dropstitch	9	3	30.5	72
Ribbed with Urethane shell	10	3.75	31	72
PVC Dropstitch	16	3	32	72

The PVC construction, while seemingly durable, was more rigid when not inflated, and heavier than the polyurethane construction. The ribbed and dropstitch design using polyurethane were similar in weight and ridigity when not inflated. One advantage of the ribbed design is that its depth is not constant across the surface. The result of this is that it will take less total gas to reach the same internal pressure as a dropstitch design.

3.2. Prototype design

After analyzing the inflatable samples made from both polyurethane and polyvinyl chloride (PVC) materials of both drop-stitch and ribbed structures, it became obvious that the materials were acceptable in terms of rigidity, weight, and packed volume. Then, the team was invited to watch the PJs, in a training exercise, draging a patient in a Skedco over rough concrete. After the exercise the team could see the wear on this ¼ inch thick polyethylene plastic was quite severe. This led the team to conclude that the durability of the vinyl or Polyurethene would not stand up to the rigors of the operational need. This led the team to look for other options to address the wear issue. During a brainstorming session the team separated the two functions of the stretcher (secure and transport). This allowed them to come up with a method of securing the patient with a 5 or 6 point harness attached to a small inflatable pouch and then dropping that into a transport system. This could be used with the skedco for user acceptability or with a new design if it proves to be better in field testing. Several different systems were examined including the foldable concept provided by the solver (see Figure 10). During feedback sessions the users wanted a double strap around each leg to better secure the patient for hoisting. Also they indicated that if the stretcher could provide multiple functions it would lead to better acceptablily by the PJ community. By looking at the results of another contest for a portable bridge the team was able to merge their modular design with the stretcher requirements to build a composite material that would float and have multiple uses. Using two of the four sections of this 20 foot span bridge system the team designed a modular system that could also be used as a ladder, the stretcher, and a floatation device for carrying equipment, the PJ, or a backpack across a swamp or waterway.

3.3. New Stretcher systems

Figure 11: RiteRescue system

During the development of the stretcher prototype two new stretcher designs were found that are availble on the commercial market. The first system is called the RiteRescue and it was designed by firemen in New York City. This system is a “harness in a bag” that has a five point strapping system that is very much like the one that we designed. This system has an attachable plastic sliding device so a single operator can slide the patient off the battlefield much like the SKEDCO system. This system also has a pouch that holds an inflatable bag that helps to stablize the spine after the patient is harnessed into the system. This inflatable bag also acts as a floatation device and can keep the patients head above water. This airbag also provides a limited amount of protection against the shock of being dragged off the battlefield. This harness system allows the patient to be secured in seconds and has been tested to handle up to 1500 lbs for immediate hoisting of the patient to a helicopter. The system has six location points for both vertical or horizontal hoisting of the patient. Since the legs, torso, and arms are secured the patient cannot slide out while hoisting in a vertical position. This system will roll up into a 6” by 18” cylinder and weighs 13.5 lbs. however, discussions with the manufacturer have led them to design a light weight system that can bring the weight down to 9 lbs with a plastic that could handle 2-3 operations before needing replacement. They also have designed one that has plastic similar to the SKEDCO that weighs in at 10.7 lbs. Their lightweigh “harness in a bag” weighs only 5 lbs and is sold separately. This can be used to hoist the patient where they do not have to be dragged.

Figure 12: Travois rescue system

The second is called the Travolis system designed by Mr. Dirk Cahaan, a retired Combat Controller and built by TravoisRescue Systems. This system packs down into the 6” by 24” cylinder that is used for the base wheel. No information was availble on the weight of the system. New versions have made the wheel cylinder watertight so it aids in floatation. Travois is a device that allows a single rescuer to extract a casualty from a battlefield, burning building, mountainous area, or any emergency situation. This can be done alone over varying terrain, floated across water, or up and down stairs while minimizing effort and at times accomplished hands free to carry a weapon, radio, fire hose, rescue equipment, etc.

3.4. Usability test methods

To determine the effectiveness of any of these new designs they would need to be tested in an operationally relavant environment. Most of the relavant factors that are important to a stretcher (e.g. ease of setup, securing patient, ease of use, portability, etc) all affect time to complete the mission. Therefore we would use this as the dependant varialble in determining the effectiveness of the new concepts. The GA-SPO agreed to use these new concepts during a training session of operational PJs. We would set up an instrumented 95% percentile male manekin to measure accellerations and stress on the patient. Each PJ would take turns rescuing this manekin using the same obstacles (water, rocky terrain, swamp) over a 500 meter distance using the various stretchers including the baseline Talon II and the Skedco. The PJs would be equiped with a health meter to measure their heart rate and speed of travel. This way we will be able to analyze each step in the “rescue” as well as the overall time to complete the mission. The various devices (Travois rescue, RiteRescue, protoype, Skedco, and Talon II) will be presented in random order for each participant so that the effect of fatigue or learning will not be a factor in the analysis. The items not associated with speed (bouancy and durabilty) will be assessed separately. Since not all aspects can be accounted for we also plan to get subjective responses from the PJs during the test to determine if there are any other parameters that should be considered for an operational unit.

4. Results

4.1. Inflatable Deflection Tests

All weights were placed in the center of the 36 Inch span. The results of the deflection test are detailed in Table 3 and shown graphically in Figure 13.

Table 3: Measurement of inflatable deflection under load

Test Bench Configuration	Inflatable Test Article	Inflation (PSI)	Weight (lbs)	Maximum Deflection (mm)
36" span	Ribbed polyurethane	8	0	0.0
36" span	Ribbed polyurethane	8	45	14.0
36" span	Ribbed polyurethane	8	65	21.0
36" span	Ribbed polyurethane	8	95	32.0
36" span	Ribbed polyurethane	8	115	39.0
36" span	Ribbed polyurethane	8	125	44.0
36" span	Ribbed polyurethane	6.8	45	22.0
36" span	Ribbed polyurethane	6.8	65	27.0
36" span	Ribbed polyurethane	6.8	95	37.0
36" span	Ribbed polyurethane	4.6	0	0.0
36" span	Ribbed polyurethane	4.2	45	19.0
36" span	Ribbed polyurethane	4.2	65	27.0
36" span	Ribbed polyurethane	4.2	95	80.0
36" span	Ribbed polyurethane	3.95	45	27.0
36" span	Ribbed polyurethane	3.95	65	41.0
36" span	Ribbed polyurethane	3.95	75	76.0
36" span	Dropstitch Polyurethane	9.9	0	0.0
36" span	Dropstitch Polyurethane	9.9	45	17.5
36" span	Dropstitch Polyurethane	9.9	65	22.2
36" span	Dropstitch Polyurethane	9.9	95	34.9
36" span	Dropstitch Polyurethane	9	45	19.0
36" span	Dropstitch Polyurethane	9	65	27.0
36" span	Dropstitch Polyurethane	9	95	39.7
36" span	Dropstitch Polyurethane	8	45	19.0

36" span	Dropstitch Polyurethane	8	65	29.7
36" span	Dropstitch Polyurethane	8	95	46.0
36" span	Dropstitch Polyurethane	6.8	45	22.2
36" span	Dropstitch Polyurethane	6.8	65	30.1
36" span	Dropstitch Polyurethane	6.8	95	55.5
36" span	Dropstitch Polyurethane	6	45	25.4
36" span	Dropstitch Polyurethane	6	65	36.5
36" span	Dropstitch Polyurethane	6	95	80.9

The inflated ribbed bladder deflected less under load. When inflated to low pressures, the bladders would reach a clear buckling point where the response to increased load was less linear and more pronounced. However, when the ribbed design was inflated beyone 6.8 PSI and the dropstitch was inflated beyond 8 PSI, no buckling was encountered using weights less than 95 lbs, but the

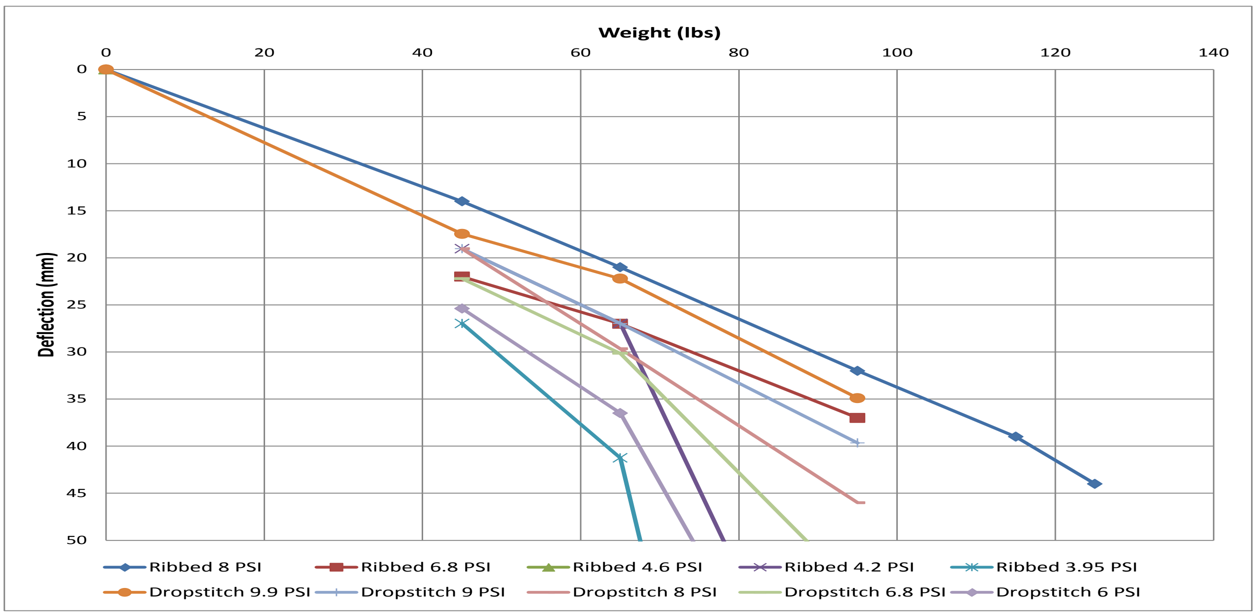

Figure 13: Deflection of inflatable test articles under load

ribbed design demonstrated less deflection per lb. than the dropstitch design.

4.2. Prototype usability testing

The usability testing was transferred to the USAF School of Aerospace Medicine (SAM) section of the 711th Human Performance Wing for the usability testing. As a result the field usability testing will be documented in a separate report authored by USAF SAM.

5. Conclusions

The original concept of building an inflatable stretcher was feasible and the testing concluded that enough pressure could be put into the system to support a 200 lb patient with his battle dress. However when seeing the PJs in operation and the damage that was done to the SKEDCO it was concluded that the inflatable Polyurethene systems would not hold up to that kind of wear and the idea was abandoned. However the process of looking for a replacement and separating the hoisting function from the transport function led to the design of the quick connect harnessing system. The transport system was explored and several desins have been completed.   While we were developing these concepts we found the two commercial systems. The RiteRescue folks were contacted since their “harness in a bag” was very similar to what we were trying to build and they have a manufacturing capability. In order to be of use to the AF it has to be built by someone. They were willing to make modifications to their system and that has reduced the weight of the bag to 5 lbs. With their plastic slide system (approx 6 lbs) this system can reduce the weight to the PJs by 6 lbs when compared to the SKEDCO weight of 17 lbs. It also reduces the volume footprint from 8”x30” cylinder for the SKEDCO to a 6”x18” cylinder for the RiteRescue light. This system can also securly fasten a patient in for hoisting in less than 10 seconds as compared to multiple minutes for the current systems. Since the system uses adjustable straps this system has demonstrat that even a small child (less than 35 lbs) can be rapidly secured for hoisting. This is important since the PJs often have to rescue civilian children caught in the crossfire of hostilities or natural disasters.

This project has successfully demonstrated that new concepts can be brought to bear to help the AF PJs in doing their jobs easier and faster. The operation usabilityof these new concepts has been transferred to the USAF School of Aerospace Medicine for collection of objective and subjective data on how these systems will compare to the current operation systems (Talon II and SKEDCO). The critical parameter for the PJs is how fast they can get the patient to safety where they can be treated. A stretcher has to be light, compact, operational, durable and fast to remove patient off the battlefield to assist in this mission. Operational evaluation will be critical in determining which of these designs will best meet these requirements in all operational situations.

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AFRL	Air Force Research Laboratory
DoD	Department of Defense
IDEA lab	Innovate, Develop, Explore, Apply Lab
OSTP	Office of Science and Technology Policy
PIA	Partnership Intermediary Agreement
R&D	Research and Development
SBIR	Small Business Innovative Research
WBI	Wright Brothers Institute
GA-SPO	Guardian Angel System Program Office (GA-SPO)