AOM ENGINEERING SOLUTIONS ERGONOCMICALLY DESIGNED TROOP BENCHES FOR INJURY REDUCTION DURING TRANSPORT IN ARMY TACTICAL TRUCKS

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ABSTRACT

Over the last several years all branches of the United States military have experienced an increased number of orthopedic and internal injuries to knees lower back, neck, and digestive system. Additionally the level of severity has also been increasing. Primary cause factors contributing to the overall increase in injuries to US military personnel include the increase in overall individual loads being carried by the individual soldier which at times can approach 150 pounds, higher operations tempo which results in greater exposure to higher levels of impact forces and for a greater duration. The greater impact forces are a result of the poor design of the current bench deployed on United States tactical vehicles, and the brutal nature of the third world transportation networks in Afghanistan and Iraq.

This paper documents the engineering approach utilized by AOM Engineering Solutions to achieve the following primary design objectives; improved ergonomic design for injury prevention, use of high strength/light weight materials for reduced weight and storage space requirements, innovative design that has resulted in off vehicle multi-functional design, and a design focus on reducing the overall logistic footprint.

The AOM Ergonomic Multifunction Troop Bench, (AOM EMTB), is fielded and has proven itself in the harsh tactical operating environment of Afghanistan since July 2007, with an additional 2,400 bench assemblies delivered in FY 2009. AOM Engineering Solutions is excited to continue to bring innovative products required to meet today changing tactical environments and improve the health, safety and welfare of today's military personnel.

INTRODUCTION

The nature of today's extreme environmental conditions in the tactical environment and the rapidly changing asymmetrical tactics being employed by enemy forces have challenged the United States military to rapidly adapt across a wide spectrum of requirements.

Due to the expeditionary nature of deployed US military forces, soldiers are often forced to operate in very austere operating conditions. This combined with increased wartime operating tempos, and third world infrastructure and transportation networks has resulted in increased wear and tear on both US military equipment and personnel. Extended lines of supply have also placed a premium on the use of high strength/light materials and multifunctional designs.

The one constant faced by today's Soldier and Marine is the individual equipment load, at times approaching 150 pounds. Combined with greater and longer duration impact forces experienced during transportation the end result has been a significant increase in injuries to the knee, lower back, neck, and digestive track of deployed US military personnel.

This paper will address how AOM Engineering Solutions developed the "AOM EMTB" which is an ergonomic troop bench designed to not only reduce the transportation induced injuries but also provide additional logistical and comfort benefits with the use of lighter weight composite materials. Primary design focus and intent of the AOM Engineering bench were the following design objectives:

- **Reduce Injuries.** Improve overall ergonomic design of AOM bench with primary design goal to reduce overall impact forces transmitted and experience by the individual soldier.
- **Use of High Strength/Light Weight Materials.** Through use of light weight high strength materials, and innovative and creative design, AOM was able to achieve significant reductions in overall weight and storage requirements. Weight and size reductions allow the tactical commander to increase tactical loads for fuel, water, ammo, and food.
- **Multi-Functional Design.** Creative design elements also enabled AOM to offer the Commander a multi-functional bench. AOM bench can be installed back to back offering increased tactical observation and security capabilities during convoy movements in a tactical environment. Additionally the AOM bench can be deployed off the vehicle to provide a standalone seating capability. The AOM bench can also be utilized as a litter and sleeping platform when necessary. This design capability offers the soldier a value added multi-functional tool when compared to the current single function bench.
- **Reduced Logistic Footprint.** The AOM bench design also reduces overall logistic requirements. Most bench maintenance can be performed with the common multi-tool carried by most soldiers, and the AOM design significantly reduces

required part numbers to be carried in the logistics system.

DESIGN CRITERIA

Initial Design Discussion and Direct Soldier Input

Scope of Work. The first action by AOM Engineering personnel was to develop a clearly defined scope of work. This allowed AOM to develop the engineering goals and objectives which resulted in significant overall design improvement. Our primary objectives were to reduce to reduce and prevent soldier injury, use high strength composite materials, create a multi-purpose bench, and reduce the logistic footprint.

Direct Soldier Input. In 2004, USSOCOM sponsored an event at Fort Campbell **[1]**, that was attended by AOM Engineering Solutions personnel, to review vehicle related joint operational requirement documents (JORDS) in which part of the discussion included safety related items that can improve soldier comfort and reduce neck, back, knee, and internal injuries. The sponsor of this event indicated to the audience that these were the most common non-combat related injuries that the soldiers are experiencing today.

Contributing factors to the increase in frequency and severity of injuries to US military personnel were the increase in weight carried by individual Soldiers and Marines, greater impact forces experienced during transport, and the overall poor ergonomic design of the currently deployed troop bench. The primary design focus and intent identified above were a direct result of the discussion and information gained during the 2004 USSOCOM event.

Ergonomic Data. AOM Engineering Solutions used the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) dated September 2008 **[2]** as the bench mark for the ergonomic design. Thou this data was created for office chairs, engineers at AOM welcomed the challenge to incorporate these characteristics in the bench design. The benchmark data can be found in **Table 1** and will be discussed in detail later in this paper.

MODELING AND SIMULATION QUALIFICATION

AOM Engineering Solutions designed the AOM EMTB using Solidworks Premium 2009 **[3]**. AOM created the design of the AOM EMTB and then tested it using finite element analysis (FEA) simulations. While designing the AOM troop bench, engineers were tasked with design ease of manufacturing, which included interchangeable and fewer part numbers. The reader will see that AOM Engineering Solutions met their objectives in reducing non-combat related injuries and producing an ergonomic, multi-function troop seating product.

Design, Engineering & Finite Element Analysis (FEA)

- **Design.** The overall design process was inclusive of information and concerns as expressed by Fort Campbell personnel, review of truck cargo bed design, competitive

analysis of current bench, and establishment of ergonomic design objectives to best match USACHPPM.

- **Engineering.** A primary design objective was to develop a troop bench with greatly reduced storage requirements. The achievement of this design objective allowed the AOM EMTB to be stored outside of the primary cargo area. This increased useable storage space by 13%. This allowed the customer to transport two additional troops and add a fully operational weapons station. The drawing found in **Figs. 1 & 2** illustrates the fully collapsible capability and nature of the AOM EMTB. Additionally, **Fig. 3** shows the space requirement occupied by the current bench.

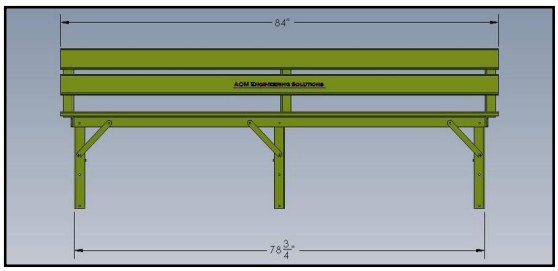


Fig. 1 – AOM EMTB in Fully Open Position

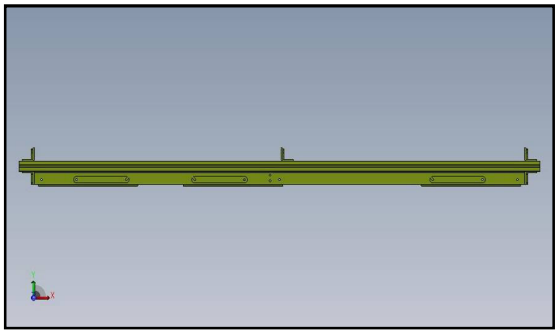


Fig. 2 – AOM EMTB in Fully Closed Position requires 4.66 ft.³

Fig. 3 – Current Troop Bench in Storage Configuration Requires 7.0 ft.³ with AOM EMTB in Storage Configuration 4.66 ft.³

	Current (in.)	AOM EMTB (in.)
Length	84”	84”
Width	4”	6”
Height	36”	16”
Volume (Ft.³)	7.0	4.66

The AOM EMTB offers a 33% savings in storage space.

- **Finite Element Analysis (FEA).** SolidWorks Premier was used to run finite element analysis (FEA) was on all individual components and the leg assembly. The illustration shown in **Figs. 4** shows the results of a simulation when loads were applied in a clockwise twist stress analysis of the of the AOM EMTB leg assembly. The results found that the leg assembly was not at risk.

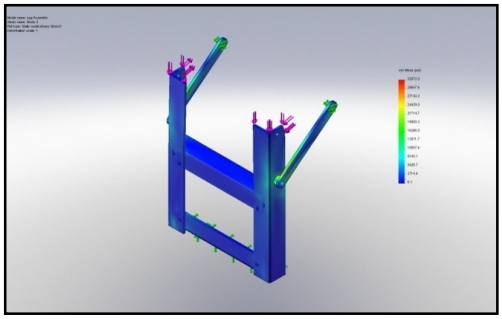


Fig. 4 – AOM EMTB Leg Assembly – Clockwise twist FEA Analysis

The results of the counter clockwise twist stress FEA analysis conducted on the AOM EMTB leg assembly is found in **Fig. 5**. As with the clockwise analysis, no apparent design concerns exists.

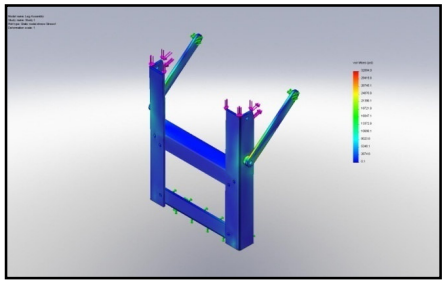


Fig. 5 – AOM EMTB Leg Assembly – Counter -clockwise twist FEA Analysis

In addition to twist related FEA simulations, AOM engineers tested the AOM EMTB using high side load stresses of 1,000 lbs. As can be seen in **Fig. 6**, the AOM EMTB leg assembly performed well.

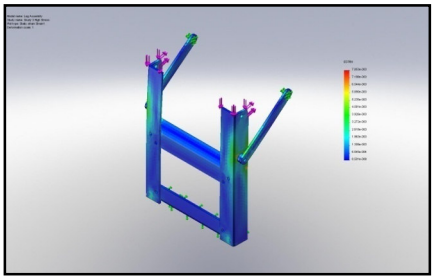


Fig. 6 – AOM EMTB Leg Assembly - High Stress, 1,000 lbs. Side Load Stress Analysis FEA

To date, all FEA analysis of the patent pending AOM EMTB has been favorable. AOM engineers are currently working on other patent pending design improvements to further improve the durability and the multifunction use of the AOM EMTB so that it can be used to further assist the war fighter in reducing orthopedic and digestive track injuries.

Design Achievements

Injury Prevention and Reduction. The primary engineering objective was to design an optimal ergonomically correct bench within current packing constraints that would offer increased injury prevention and reduction. The base line requirements utilized by AOM Engineering were the stated requirements and recommendations as contained in the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) dated September 2008 for ergonomic chairs. Direct soldier input received at the USOCOM event was also factored into the overall design. With the USACHPPM information found in **Table 1**, located at the end of the paper, the design focus of AOM Engineering included the following:

- **Seat Height.** As recommended by USACHPPM, seat height parameters should be within 15-22” (38-56cm) in height. The 18” (46 cm) height of the AOM EMTB, shown in **Fig. 7**, is at optimal nominal height and provides an additional 20% increase in height than the current bench. This height

places the hips above the knees of the soldier which assists in distributing road impact loads through the legs and not directly through the lower back

Fig. 7 – Optimal 18" Seat Height on the AOM EMTB

- **Seat Pan Depth**. As recommended by USACHPPM, seat pan depth should be no greater than 16.9" (43cm). With your back against the backrest, the front edge of the seat pan should not touch the crease of the knee. If the seat pan depth is to short, the bench will not provide adequate under thigh support. If too long, the seat will contact the back of the knee and cause discomfort. The seat pan depth of the current bench is 14" (35 cm) which provides inadequate under thigh coverage when the soldier is seated with his/her gear. The seat pan depth of the AOM EMTB is 16" (40.5 cm) as shown in **Fig. 8**. This provides an additional 15% under thigh coverage when compared to the current bench. This additional surface area coupled with position of the hips above the knees distributes impact forces over more under thigh area. The result is less impact forces to the lower back.

Fig. 8 – Optimal 16" Seat Pad Depth on the AOM EMTB

- **Backrest Recline Angle**. As recommended by USACHPPM, the minimum backrest recline angle is 15° within the range of 90° and 120° and should lock into place. The current bench has a 0° or 90° vertical backrest which compromises the soldiers seating posture. Their gear prevents them for being able to sit with their back against the backrest and they are forced to sit on the edge of the seat creating a situation of compromised seat pad depth resulting in a decrease in under thigh support. This leads to increased orthopedic injury due to impact forces being absorbed over a smaller surface area of the body. When not wearing the gear, the backrest interferes with the back of the helmet forcing their chin into their chest leading to vertebra damage and muscle strain. The AOM EMTB

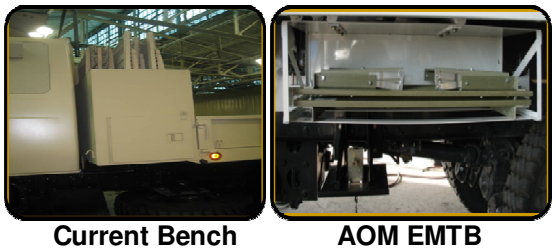
backrest recline angle is 12.5° as shown in **Fig. 9**. This angle still enables the soldier to sit back with their gear without helmet interference. Additionally, the angle provides several extra inches to accommodate the gear so seat pad depth is not compromised increasing necessary under thigh coverage.

Fig. 9 – Improved 12.5° Backrest Recline Angle AOM EMTB

Though AOM was not able in all cases to meet USACHPPM requirements due to cargo area packaging constraints, it clearly is a major improvement over the current bench.

Use of High Strength/Light Weight Materials. The use of high strength/light weight materials in the AOM EMTB offers the following engineering advantages:

- **Overall reduction in storage space requirements.** Current bench requires significantly greater storage space. As seen in **Fig. 10**, the patent pending AOM EMTB design utilizes vehicle dead space for storage. This provides and additional 13% of cargo bed space. In the stored position, the AOM EMTB requires only 4.66 ft.^{3}. This is 33% less than the 7.0 ft.^{3} of the current troop bench.



Current Bench (7.0 ft.^{3}) **AOM EMTB (4.66 ft.^{3})**

Fig. 10 - Comparison of Storage Requirements Between the Current Troop Bench (left) and the AOM EMTB (right)

- **Greater resistance and NBC contamination.** Utilization of composite materials offers greater resistance to NBC (Nuclear Biological Chemical) when compared to current benches constructed of wood, composites, and steel. Both of the factors are major benefits of the AOM EMTB composite construction.
- **Lighter Weight.** Use of composite materials offers greater strength at reduced weight when compared to the conventional materials used to construct the current bench. The Use of composites in the AOM EMTB has achieved a 4.5% weight reduction when compared to the current bench. This weight reduction has been achieved with no compromise in structural integrity. Reduced weight allows the commander to carry greater mission critical items such as fuel, water, and ammo.
- **Materials Specification.** Other than some structural fixtures, the entire AOM EMTB is made from

pulltruded fiberglass. The material complies with MIL PFR 62419 [4]. This performance specification for composite materials for military vehicles enables composite and commercial plastics to replace troop bench slats, seat racks, stakes, and planks.

Pulltruded fiberglass offers some distinct advantages over the current multi-material design. Other than it's resistance to chemicals, it is structurally sound. It also provides some desirable elastic characteristics that allow the material to flex in the seat assembly. This flexing is excellent in absorbing road impact

Multi-Functional Design. The AOM Engineering bench was designed offer a number of built in multi-functional design advantages. The multi-functional capabilities offer the individual soldier and tactical commander an increased number of capabilities at no additional cost, or associated penalties in terms of weight or space requirements.

- **Outward Facing Seating Option.** Outward seating option allows the commander the option of back to back tactical outward facing seating as shown in **Fig 11**.

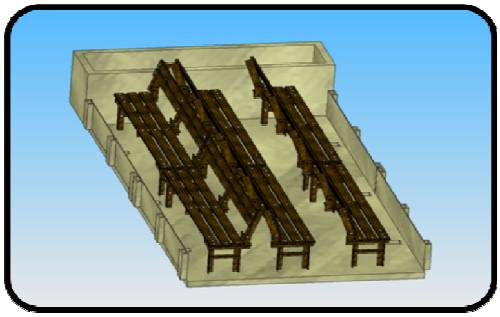


Fig. 11 – AOM EMTB Outward Facing Configuration

The need for increased security during tactical convoy operations has lead to a number of field expedient solutions for outward seating. **Fig. 12** shows United States Marines sitting on a standard issue cot to achieve an outward seating configuration. While achieving the necessary improved security, this places United States military personnel at greater risk of injury due to the limited structural integrity of the cot when compared to the AOM EMTB outward facing option.

Fig. 12 – US Marines Sitting on Standard Issue COTS to Achieve Outward Seating Configuration

The Outward seating option offers significantly improved tactical observation and security capabilities during convoy operations when compared with the inward seating configuration of the current bench found in **Fig. 13.**

Fig. 13 – Current Bench (Inward Facing)

- **Off Vehicle Command Post Seating Option.** The AOM bench offers a standalone seating option which allows the AOM EMTB to be deployed off vehicle for utilization for "command post" and briefing area seating as shown in **Fig. 14**. This capability is not available with the current bench.

Fig. 14 – AOM EMTB Capable of Off Vehicle Command Post Seating

- **Off Vehicle Sleeping Platform.** With the standalone capability the AOM EMTB can also be utilized as an off vehicle sleeping platform, offering the individual soldier a greater level of comfort in a field environment as shown in **Fig. 15**. This capability is not available with the current bench.

Fig. 15 – AOM EMTB Capable of Off Vehicle Sleeping Platform

- **Litter Capability.** When collapsed to its lowest level, the AOM bench can be utilized, if necessary as a field expedient litter. Both the seat and backrest assemblies, can be used as litters. **Fig. 16** shows the seat assembly separated from the backrest assembly. In this configuration, this assembly can easily be used as a litter. This capability is not available with the current bench.

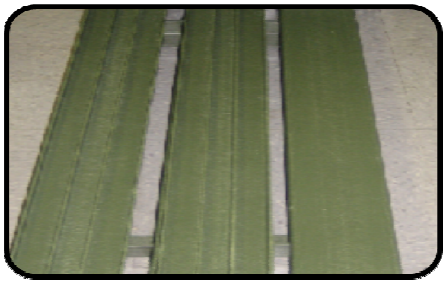


Fig. 16 – AOM EMTB Capable of Being Used as Off Vehicle Litters

Reduced Logistics Footprint. The AOM design focus and intent was to reduce overall logistic footprint and requirements. This was achieved through the following design applications:

- **Soldier Friendly Maintenance.** AOM EMTB is simple and easy to maintain. Most bench maintenance can be performed with the common multi-tool carried by most soldiers. The multi-use tool found in **Fig. 17** can be used to repair the AOM EMTB. AOM engineers purposely used hex bolts instead of carriage bolts at the request of the soldier due the problem with carriage bolts tendency to strip. This simplifies overall field maintenance.

Fig. 17 –Gerber Multitask Tool. Can be Used to Repair the AOM EMTB in the Field

- **Reduced Part Numbers.** Simple design has greatly reduced required part numbers reducing overall logistics footprint as shown in **Fig. 18**.

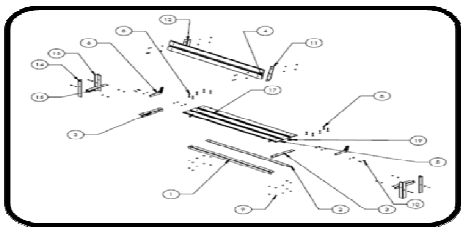


Fig. 18 – AOM EMTB Simple Design Requires Few Parts.

Many of the components are interchangeable.

CONCLUSION

Rapid Deployment of Prototype

Evidence of AOM Engineering Solutions achieving it's over design goals and objectives of the AOM EMTB have been the successful deployment and utilization by United States military personnel in Afghanistan since July 2007.

Commercialization

Based on its' demonstrated performance in a combat environment, an additional order of 2,400 AOM troop benches **[5]** was received in the fourth quarter of 2008 and 2,400 AOM EMTB bench systems were produced and delivered to the customer in the first quarter of FY 2009.

Shown below in **Fig. 19** is a deployed on a Navistar Troop carrying truck with the AOM EMTB benches. Note how the benches are stored under the bed of the truck.

Fig. 19 – Fielded Navistar Defense Troop Carrying Truck Equipped with the AOM EMTB Troop Bench

The space savings in the bed of the truck enabled the truck provider to add-on to the cab of the truck so that and additional 2 soldiers can be transported

and the vehicle was equipped with a weapon.

REFERENCE

[1] Nov. 2004, USSOCOM JL ATV meeting at Fort Campbell.
[2] USACHPPM Ergonomics Program Fact Sheet, "It's a fact… You should know what to look for in an ergonomic chair, Sept. 2008
[3] SolidWorks 2009 – Premier with SolidWorks Simulation
[4] US Army Tank-automotive and Armaments Command, "Performance Specification composite Materials for military Vehicles, MIL-PRF-62419A, 22 Jan. 1996
[5] Navistar Defense, Order for 2,400 AOM EMTB Troop Benches, Oct. 2008

Table 1: US Army Center for Health Promotion and Preventive Medicine (USACHPPM) dated September 2008

Criterion	USACHPPM	Current Bench	AOM EMTB	AOM Benefit
Seat Height	15" – 23"	15"	18" (20% Improvement)	18" height accommodates greater population of deployed troops when compared to current bench
Seat Pad Depth (under thigh coverage)	16.9"	14"	16" (15% Improvement)	Additional under thigh surface support area distributes impact forces over a greater area
Backrest Recline Angle	15° (min.)	90°/0°	12.5° (1,250% Improvement)	AOM bench is significantly closer to USACHPPM recommendations