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Student-Driven Design of a Lift System for EOD Equipment Handling

Dr. Yousef Sardahi, Marshall University

Dr. Yousef Sardahi, an Associate Professor at Marshall University's Mechanical and Industrial Engineering Department, completed his Ph.D. at the University of California, Merced, in 2016. His research primarily focuses on control system design and multi-objective optimization.

Asad Salem

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Erin Webb[1], Josie Farris[2], Yousef Sardahi*[3], Asad Salem[4], Sudipta Chowdhury[5], and Brian Gazaway[6]

[1-5]Department of Mechanical and Industrial Engineering, Marshall University, Huntington, WV 25705,
webb424@marshall.edu,farris33@marshall.edu
sardahi@marshall.edu, asad.salem@marshall.edu,
chowdhurys@marshall.edu
[5]CMI2 - Civil-Military Innovation Institute,Morgantown, WV 26505, *bgazaway@cmi2.org*

Abstract
This paper presents a student-led research project, supervised by faculty and sponsored by the Civil-Military Innovation Institute (CMI2), focused on reducing the physical burden on Explosive Ordnance Disposal (EOD) personnel when loading and unloading heavy equipment, such as MRTS-II and CRS-H robots, from Oshkosh M-ATV vehicles. The students designed an improved lift system to enhance operational efficiency and reduce injury risks, emphasizing ease of use, independence from external power sources, and adaptability to varied terrains. Through hands-on experiences like CAD modeling, laser scanning, and iterative design refinement based on detailed feedback from EOD soldiers, the students gained practical insights into problem-solving and design iteration. Soldier input, gathered through surveys and field observations, was instrumental in balancing functionality with practical constraints. The project highlights the educational value of real-world feedback and iterative design, with future work focusing on scaling and testing the system for broader military applications.

Keywords: Student-Led Research, Lift System Design, Hands-On Learning, Real-World Problem Solving.

Introduction

Soldiers are often required to carry very heavy loads, often exceeding 45 kg. The physiological and biomechanical responses to carrying such a load, however, are situation-specific, but the same musculoskeletal injury pattern is always apparent. On the other hand, these types of injury have operational consequences for military activities in general[1].

*Corresponding author: sardahi@marshall.edu

These have been supported by biomechanical studies showing that carrying heavy loads significantly increases knee joint contact forces, ground reaction forces, and leg stiffness—especially in high-intensity tasks such as a run-to-stop maneuver. Such increased forces and modified biomechanics increase the chances of injury, especially with heavier loads[2]. Carrying heavy loads also modifies gait patterns, increasing trunk, hip, and knee flexion and hip and knee extension moments. These gait mechanical changes can promote musculoskeletal problems in the form of muscle strains and joint pains[3,4].

The effects of heavy load carriage on physical performance are enormous. For instance, soldiers undergoing heavy military training show declines in lower-body power output, maximal lifting strength, and body mass. Often, these declines are combined with hormonal changes, including decreased levels of testosterone and insulin-like growth factor-I (IGF-I) and an enhanced cortisol level impairing physical performance even more[5]. Prolonged military operations involving underfeeding and sleep deprivation aggravate this condition by a decline in physical and occupational performance even more[6].

These are risks that can be mitigated by appropriate conditioning and reconditioning programs. Such should be designed to encompass sessions of load carriage in conjunction with resistance and aerobic training, for which the speed of march and the terrain must be varied in order to maintain the load carriage intensity. Progressive resistance training in addition to aerobic training has indeed been shown to lead to significant improvement in load carriage performance based on the results of systematic reviews, hence a need for a balanced training program[7].

The application of robotic arms has gained significance for military operations due to the potential contribution they could make in terms of efficiency, safety, and operational improvement.

Military robots can facilitate vast logistics improvements with heavy load transportation and placement using robotic arms. Evidence is also seen in the development of lightweight transport robots like the μ-SMET, which enables military field operations by guaranteeing dependability in last-mile delivery to soldiers on field operations with supplies like food and medication that are essential for their survival[8]. These robots can carry quite substantial payloads, while their design allows compactness and versatility for operation on various terrains and in multiple scenarios.

The main advantages of using robotic arms in military vehicles are related to enhancing safety for soldiers. It is important to notice that these automata reduce the physical work of a soldier by transporting heavy equipment and supplies to him, freeing his time for mission-critical tasks. This is evident in the design of robotic mules that can carry soldiers or their equipment. These systems are capable of negotiating challenging terrains and can be controlled by GPS or an emitter with a sensor carried by a soldier to ensure that soldiers are not exposed to unnecessary risks[9]. Other areas where robotics add to the overall effectiveness of operations include robotic arms in military vehicles. Agility and quick response are now the watchwords in current military strategy, and robotic systems form an essential component for achieving these objectives. Indeed, acquisition plans for the US military strongly embrace efforts to develop robotic systems that are fully autonomous or semi-autonomous/cooperative to conduct reconnaissance missions, breaching missions, and other highly essential tasks[10]. Integrating robotic arms with such systems would further bolster the military's capabilities along various operational spectrums, including urban warfare, tasks conducted in remote fields, or other combat theaters.

The following paper presents a student-driven research project, sponsored by CMI2, for the design of an improved lift system to reduce the physical burden on EOD personnel when handling equipment in Oshkosh M-ATV vehicles. During this process, students gained practical experience in CAD modeling and design iteration, as well as feedback from EOD soldiers to increase the operation's effectiveness and safety.

Student-Driven Research: A Pathway to STEM Skills and Careers

Student-driven research projects in contemporary education, particularly in science, technology, engineering, and mathematics, form major building blocks. Projects help to build a much-closer understanding of their subject matter while being equipped with the basic set of skills quite necessary for their future careers.

Student-centered research projects contribute to both conceptual and practical skill development. One systematic review of IRPs within high school science settings concluded that IRPs are positively associated with improved learning concerning scientific concepts, motivating high school students to study science, and the development of practical skills[11]. Within these many projects, real science is often concerned with problem-based and project-based learning; their enactment thus provides the students not only with practical experience but also with in-depth insight into the principles of science.

Undergraduate research programs are particularly effective in enhancing critical thinking and communication skills. Students learn to think independently while carrying out research, to critically analyze data, and to present results. In that way, students develop skills which are of great value during professional life[12]. Those projects which are carried out in cooperation with external partners, such as universities and employers enhance the communication and teamwork abilities of students even more[11].

Such research-based education has a greater impact on the career desires and aspirations of the students. It is assessed that many students in the future will pursue a career in their field of study when they are working on research projects. For instance, when students PjBL courses during the initial years of college, it has a positive effect on student's perception about the skill that dealt with STEM and their career aspirations too in STEM[13]. Finally, students who have the experience of doing research show a greater likelihood of pursuing careers in academics and research-oriented areas[14]. Another important skill developed in the process is leadership and project management through student-driven research projects. Projects that involve students from different cohorts working together, under the supervision of faculty staff, provide opportunities for students to take over leadership roles and handle long-term projects[15]. For career development, this is quite essential since such a concept prepares students to project manage and take on leadership challenges at work[16].

In particular, these research projects have been very helpful for usually underrepresented groups of students in general science. Students from these groups feel much more positive about science and are most likely to pursue a scientific career as a result of their engagement with the research projects[11]. This only underlines that the possibilities for research should be provided to all types of students, regardless of their background.

Problem Statement

The EOD unit of the US Army plays an essential role in the detection, neutralization, and disposal of explosive threats in hazardous environments. While much attention is given to the technical and operational aspects of handling such explosive devices, one of the biggest challenges—but often ignored—faced by EOD personnel in doing their job involves physical strains that arise from tending to and transporting heavy equipment. Specialized robots, weighing 160 lbs. and 440 lbs., are among the critical tools used by EOD units, such as the MTRS-II (see Figure 1) and CRS-H (see Figure 2), respectively. The robots often undergo on and offloading from the Oshkosh M-ATV vehicle (see Figure 3) for operations in combat zones with extreme and hazardous conditions. These heavy robots have to be lifted manually by soldiers onto up to 58-inch-high platforms, repeating loading and unloading in missions.

Figure 1: MTRS II Robot

Figure 2: CRS-H Robot

Such heavy equipment, repeatedly lifted manually in combat and field environments, is not only a health hazard but also an efficiency limitation for EOD missions. Current methods of deploying the MTRS-II robot require the efforts of several soldiers, reducing personnel availability for critical security tasks during high-stakes operations. Moreover, such prolonged physical exertion will reduce the stamina and long-term health of the soldiers, especially in the psychologically stressful conditions of military missions.

Therefore, the development of a technologically assisted one-person lift system for MTRS-II and CRS-H robots is key to reducing physical burdens that lead to injuries among soldiers while improving efficiency during EOD operations. It is important to note that, with this capability, other soldiers would be freed to maintain security as one soldier was able to deploy the MTRS-II in a quick manner and minimize the exposure of soldiers to hazardous environments. In this way, the mission could be executed faster. Further, it would expand the operation issue of the M-ATVs by enhancing flexibility and readiness in diverse combat operations. It will provide an effective,

Figure 3: Oshkosh M-ATV vehicle

durable, and easy-to-operate solution for the field by integrating advanced engineering design with subject-matter expert input to improve the safety and performance of EOD personnel.

Design Process

The design of the single-operator lift system is based on several key criteria: 1) the nature and weight of the robot being lifted; 2) limitations of the M-ATV; 3) ease of use; 4) independence from external power sources; and 5) adaptability to a variety of operational environments and conditions. These factors guide the development of a system that is efficient, versatile, and practical for military applications.

Nature of Robot

The design process centered on addressing the challenge of efficiently loading the MTRS II (160 lbs.) and CRS-H (440 lbs.) robots into the M-ATV while meeting the requirement of supporting a minimum load capacity of 440 lbs. This necessitated constructing the lifting mechanism from robust materials like steel to handle the substantial weight. The robots' dimensions—33" x 22.8" x 19.5" for the MTRS II and 44.5" x 30" x 51.5" for the CRS-H—further shaped the design to ensure safe handling without damaging any exposed components. Another critical factor was incorporating the robots' ability to ascend a 90-degree incline over a 3-foot distance, integrating this mobility feature into the lifting mechanism to enhance functionality.

Limitations of the M-ATV

The available attachment points for any lift mechanism are limited because of the various components mounted on the back of the M-ATV as shown in Figure 4. The design process is further constrained by the M-ATV's existing responsibilities (see Figure 5), such as towing trailers, storing essential equipment, and the allocation of its pneumatic and electric power to other systems.

Figure 4: Back of M-ATV (attachment points)

Figure 5: M-ATV with all equipment that gets stored in the back

Ease of Use

Given the urgency of EOD missions, the mechanism must be fast and easy to deploy. In time-critical situations, the lift system must be swiftly set up and stored to avoid exposing soldiers to unnecessary risk.

Independence of External Power Sources

As mentioned earlier, all power sources from the M-ATV are already dedicated to other equipment. The idea of adding an extra power source for the lift mechanism was considered during the design process but was ultimately rejected due to the system's need to operate reliably in highly critical situations. To minimize the risk of failure, the decision was made to eliminate power sources and opt for a fully mechanical system instead.

Adaptability to Diverse Circumstances

EOD missions frequently take place across varied terrains, requiring the lift mechanism to function effectively in different conditions, such as on inclines, in extreme temperatures, in confined spaces, or even while in motion. Additionally, soldiers emphasized the need for the lift system to handle a variety of loads, beyond just the previously mentioned robots.

Design Phase Methodology and Execution

At the beginning of the design process, the team developed several preliminary concepts and ideas to address as many of the outlined constraints as possible. The initial approach to creating a new lift mechanism typically involved, starting with a sketch. Figure 6 presents a sketch of Lift Mechanism #1 (Sliding Plates), which is one of the lift mechanisms that was developed.

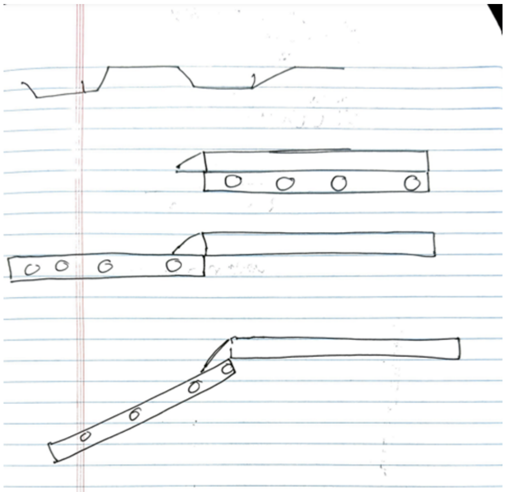

Figure 6: Illustrative Concept Sketch of Lift Mechanism # 1 Sliding Plates

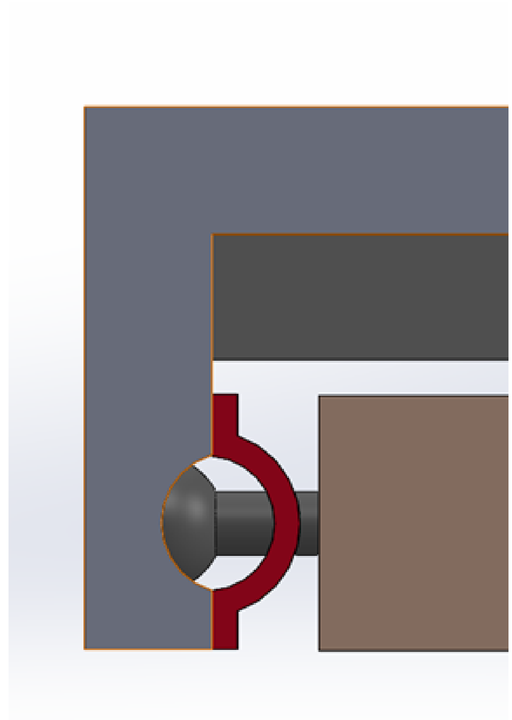

Figure 7: Example of CAD Model – Lift Mech. 1 Sliding Plates Ball Bearing

The team began by transforming their initial sketch into a CAD model using SolidWorks (Figure 7), creating a scaled, three-dimensional representation. This model was then further developed into an animated simulation, enabling the team to visualize how the system's components interact and move. After confirming the system's functionality, they used Creality K1 Max 3D printers to produce small-scale prototypes that demonstrated the mechanism's motion in a physical setting. The final step involved integrating the designs into a real model of the M-ATV. Using the Creaform HandiScan Black, they 3D scanned the back of the M-ATV (Figure 8), converting the mesh data into a functional CAD model that was incorporated into the animations, creating a cohesive and fully operational model.

Figure 8: Research Assistants Erin Webb and Josie Farris 3D Scanning the M-ATV

Lift Mechanism Designs

The team came up with many design ideas, models, and different versions of each design. However, they narrowed the options down to seven final mechanisms, based on how practical they were and feedback from EOD soldiers. Below is a description of these models.

Sliding Plates Lift Mechanism

The Sliding Plates design, depicted in Figure 9, allows the mechanism to fit seamlessly into the M-ATV bed, making it compact and easy to store. It also does not rely on any power source. However, this design would only work for the MTRS-II and CRS-H drivable robots, as they would have to drive up the ramp into the truck. Another limitation is that it depends upon mostly flat ground to deploy correctly.

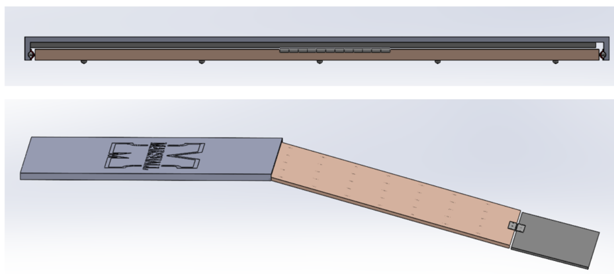

Figure 9: Sliding Plates Lift Mechanism Front and Side View

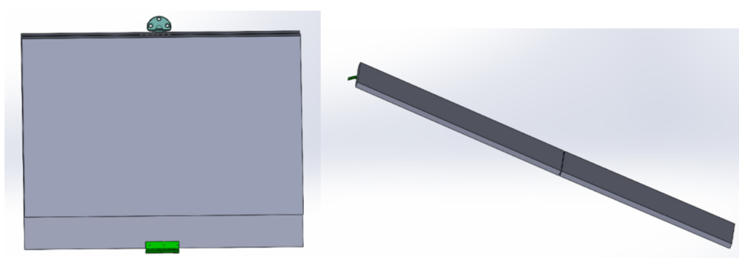

Figure 10: Sliding Plates Lift Mechanism Front and Side View

Folding Plates Lift Mechanism

As shown in Figure 10, this design serves as a door as well as a ramp, compacts easy storage as it would be in the place of a tailgate on the M-ATV, does not rely on any power source, and leaves all space within the M-ATV free for other equipment. Its limitations include depending upon mostly flat ground to deploy correctly, the weight of the ramp may be considerable depending on the material, and it would only work for the MTRS-II and CRS-H drivable robots.

Rotational Chain Crane Hoist – Top Mount

The freedoms of this design, as evident by Figure 11, include rotating 360 degrees to allow for diverse loading angles, lifting a variety of loads, not depending on a power source, and not taking up any space within the M-ATV. The limitations include relying on an operator to use the hand chain crane, and the maximum capacity being a half-ton.

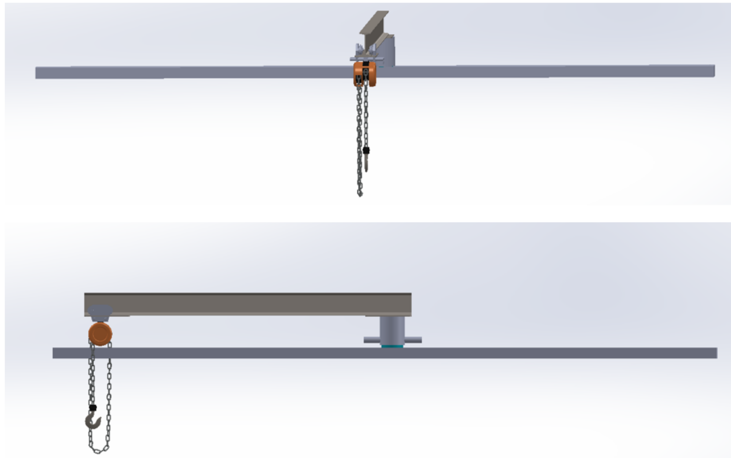

Figure 11: Rotational Chain Crane Hoist Lift Mechanism front and rotated view

Figure 12: Electric Hoist Lift Mechanism side view

Electric or Manual Hoist – Side Mount

This system is designed to be mounted on the outer frame at the rear of the M-ATV using two brackets as shown in Figure 12. These brackets allow up to 180 degrees of rotation, providing versatility in loading angles. The system can be installed on either the left or right side of the rear of the M-ATV and, when not in use, securely latched to the horizontal upper beam of the vehicle's frame for storage during transit. This rotational capability is particularly beneficial when handling loads in confined spaces or on uneven surfaces, ensuring that the cargo can be approached from the most practical angle. Equipped with a lifting arm modeled as an I-beam, the crane arm offers stability and strength to handle various types of loads, including the MTRS-II and CRS-H. A battery-powered winch enables the operator to effortlessly lift and lower these loads, while the hoist ring and attachment hook provide a secure connection for lifting. In cases where reliance on battery power is undesirable, the hoist ring can be adapted for a manual chain crane, allowing an operator to manually control the lifting and lowering process. This manual option provides flexibility in environments where power sources may be limited or where manual control is preferred. The system is designed to manage loads up to 500 lbs., ensuring it can handle a wide variety of cargo types.

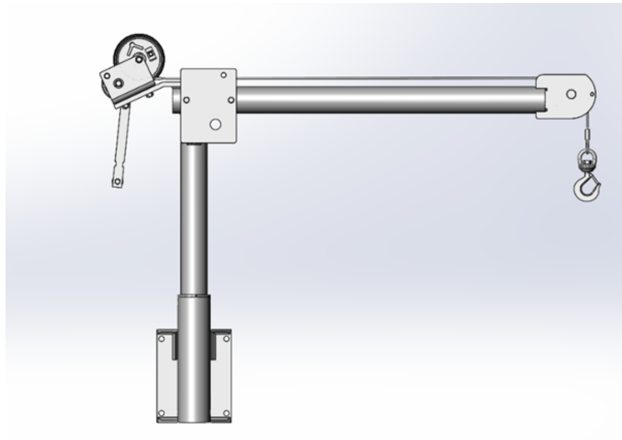

Figure 13: Hand Winch Crane Lift Mechanism side view

Hand Winch Crane

This mechanism (see Figure 13) is stored on the side of the M-ATV leaving the inside of the vehicle open for other equipment, it rotates 180 degrees for versatile loading angles, can lift a variety of loads, and is completely manual. The downsides of the design are that it requires an operator to crank the hand winch and has a maximum half-ton capacity.

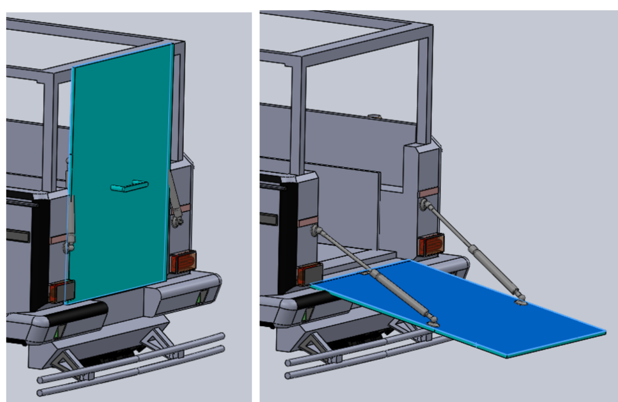

Figure 14: Dashes/Shocks Fold Gate in standard and deployed positions

Dashes/Shocks Fold Gate

The Dashes/Shocks Fold Gate, shown in Figure 14, is a completely non-powered system; it utilizes dashes to aid in lifting the weight of the ramp. It also serves as a door to the back of the M-ATV when folded up which also means it does not take up any space within the vehicle. However, it only works for the MTRS-II and CRS-H drivable robots and would depend on a relatively flat loading ground

Dashes/Shocks Lift Gate

The Dashes/Shocks Lift Gate mechanism, illustrated by Figure 15, is located at the rear of the vehicle and provides 2,100 square inches of surface area for efficient cargo loading and unloading. It has a hinge mechanism that allows the platform to fold up to a 90° angle, serving as a secure

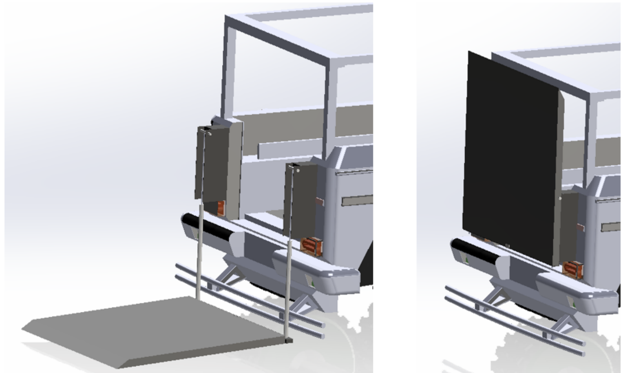

Figure 15: Dashes/Shocks Lift Gate in deployed and stowed positions

rear door during transit. In this position, the platform keeps the cargo safely contained while the vehicle is moving. The platform is designed to handle heavy loads of up to 500 lbs. and can be adapted to various operational needs. The platform's movement is controlled by force-adjusting dampers, which provide different levels of resistance depending on the direction of movement. These dampers are engineered to require more force when lowering the platform and less force when raising it, ensuring that the platform moves only when the force exceeds the weight of the cargo. This reduces the risk of damage to valuable equipment such as the MTRS-II and CRS-H. Additionally, the dampers make it easier to lift heavy cargo, improving the overall efficiency of the system. The mounting brackets securely attach both the dampers and the platform to the M-ATV's frame, protecting these components from environmental factors and ensuring long-term durability and reliable performance.

Survey and Feedback

A brief survey was conducted evaluating the seven lifting systems for the MTRS-II and CRS-H robot deployment from the M-ATV. The survey was administered to EOD Soldiers and Design Experts within the military using Google Forms. The team was able to collect a total of 76 responses, with most respondents holding the rank of Staff Sergeant, Sergeant, or Captain and most identified their role within the EOD as EOD Officer or Team Leader.

The survey questions are as follows:

1. How many years have you been serving in the military?
2. What is your typical role within the EOD unit?
3. Considering the Overall integration with the M-ATV system, how well does the Foldable Ramp Gate fit in terms of spatial compatibility, structural integrity, and operational harmony?
4. Considering how it fits with the M-ATV system, how does the Sliding Ramp measure up in terms of fitting into the available space and working smoothly with other operations?
5. Taking into account its integration with the entire M-ATV system, how does the Dash-Based Fold Gate perform in occupying the design and seamlessly operating alongside other processes?

6. Reflecting on its compatibility with the M-ATV system as a whole, how well does the Dash-Based Lift System align with the available space and smoothly interact with other functions?
7. Assessing its alignment with the M-ATV system, how does the Electric or Manuel Hoist Operation function cohesively with other processes?
8. About its integration with the M-ATV system, how does the Hand Winch Crane- Side Mount perform in terms of spatial compatibility and maintain coherence with other system components?
9. In evaluating its integration with the M-ATV system, how does the Rotational Chain Crane perform in terms of spatial compatibility and function in unison with other operations?

Figure 16: Dr.Yousef Sardahi and Research Assistants Erin Webb and Josie Farris working with the M-ATV Trailer

In addition to survey data, the team collected direct feedback from soldiers during site visits. Early in the project, the team went to Camp Dawson, WV, where they saw soldiers manually lifting robots or using rachet straps to load them into the M-ATV, both of which were physically demanding. Soldiers highlighted the need for a versatile, power-free system. Later, the team visited Fort Carson, CO, twice, where similar loading methods were observed, and soldiers stressed the importance of a compact lift system due to limited vehicle space. The team also examined and scanned the trailer (see Figure 16) attached to the M-ATV to ensure the lift mechanism wouldn't interfere, scanning the trailer for compatibility.

Results and Evaluation

Survey Responses Regarding the Folding Plates Gate Design

30.3% of respondents said the mechanism does not fit well within the M-ATV, while 27.6% said it does fit well with some advantages introduced. Soldiers liked the enhanced security measures introduced by the potential integration of an enclosed system and dual functionality as a door to prevent gear from falling out of the vehicle. It was noted that the system includes a manual operation to avoid power failures. Soldiers disliked the impractical ramp length needed to avoid steep inclines and the fact that soldiers needed to exit the vehicle for operation, leaving them exposed to outside threats. They expressed concerns about resolution/maintenance time for ramp-related problems and compatibility issues with current EOD equipment setups.

Survey Responses Regarding the Sliding Ramp Design
32.9% of respondents said the design does not fit well within the M-ATV, while 27.6% said it does fit well and introduces some advantages to the system. 10.5% had neutral feelings about the mechanism. Soldiers appreciated the simple design due to being potentially lighter and enhancing maneuverability as well as reducing the strain on personnel during deployment. They noted relatively easy maintenance requirements and optimized storage aspects. Soldiers expressed concern that on an incline the ramp may not be long enough to reach the ground and feared the ramp may be prone to jamming. They disliked that the operator would have to exit the vehicle to operate the mechanism.

Survey Responses Regarding Dash-Based Folding Plates Gate Design
28.9% of respondents stated that the mechanism fits well and provides additional advantages to the system, 21.1% said it fits well with some minor issues, and 21.1% said it does not fit well at all. The soldiers saw benefits such as increasing tailgate functionality and adding additional gear storage capacity. It was pointed out that the additional point of support minimizes concerns regarding weight distribution and that operators can remain in the vehicle reducing risk, while also allowing for single-person operation. Respondents were concerned that the ramp length may be insufficient depending on incline and load angle and that the system could not work with the trailer attached to the M-ATV. They disliked the amount of space required to deploy the ramp and had fears of high maintenance requirements.

Survey Responses Regarding Dash Based Lift System
28.9% of respondents said the design fits well with some advantages while 28.9% also said the design does not fit well. 22.4% said the design fits with some minor issues. Respondents liked that the system could offer better loading and unloading capabilities, especially for heavy items like munitions and robot platforms. They liked the fact that it could make it easier to access equipment stored in the M-ATV and that it could potentially provide additional external storage space. Soldiers fear high maintenance requirements for the mechanism and the complexity of the design. They also expressed concerns regarding installation, especially the lack of available space under the M-ATV.

Survey Responses Regarding Electric or Manual Houst System Design
32.9% stated that the design does not fit well within the system, 21.1% said it does fit well and provides additional advantages, and 19.7% had neutral feelings about the mechanism. The advantages that were pointed out include the simplicity of the design reducing the risk of failure, the versatility of the design that could allow it to serve as a bomb lift, and the powered and nonpowered options that offer flexibility in usage. The disadvantages include the risk of accidents due to the weight of the robot, slow functionality potentially prolonging loading and unloading, risk of mechanical failure, and requirement for extensive training to not damage the robots in the loading process.

Survey Responses Regarding Hand Winch Crane System Design
40.8% said the design does not fit well, 21.1% were neutral, and 13.2% said it fits well with some advantages. Respondents liked that the system facilitates easy movement of heavier items into the back of the vehicle, requires minimal modification to the M-ATV, and does not require any maintenance reducing costs. They disliked the time it would take to operate, potentially causing delays in loading and unloading, the risk due to the weight of the robot being suspended in air, and that training would be required to not damage the robots during loading.

Survey Responses Regarding Rotational Crane System Design
38.2% said the mechanism does not fit well, 26.3% were neutral, and 14.5% said it fits well with minor issues. The advantages include superior reliability and functionality compared to traditional ramp systems, a side-mounted system that offers improved space utilization and greater load-bearing capacity, and its capability to easily move heavier items into the back of the M-ATV. The respondents disliked the risk posed by the robots being suspended in the air, the difficulty in maneuvering the equipment due to hoist location, and that it would require training to reduce the risk of damaging the robot during loading.

Survey Summary
38.2% said the mechanism does not fit well, 26.3% were neutral, and 14.5% said it fits well with minor issues. The advantages include superior reliability and functionality compared to traditional ramp systems, a side-mounted system that offers improved space utilization and greater load-bearing capacity, and its capability to easily move heavier items into the back of the M-ATV. The respondents disliked the risk posed by the robots being suspended in the air, the difficulty in maneuvering the equipment due to hoist location, and that it would require training to reduce the risk of damaging the robot during loading.

Challenges and Lessons Learned
During the design process and fieldwork, the team had to address several challenges, including material strength and weight, the integration of the trailer with the M-ATV, and technical issues with equipment used in the field.

Material Strength and Weight
The first foreseen challenge that the team encountered was the strength of whatever material the mechanism would be made from. The material would need to be strong and reliable without being too heavy – due to many of the designs relying on an operator to deploy. To combat this the team designed dash-based lift mechanisms so that the system remained independent from a power source but offered some type of lifting aid of the system itself. The dash-based designs provided support to the operator when deploying the system since it is likely that any mechanism would need to be made from at minimum 1” thick stainless steel or aluminum, adding significant weight to the design.

Addition of the Trailer to the M-ATV
During a field visit, the team discovered the use of the trailer attachment to the M-ATV which posed significant challenges to many of the design concepts already developed. To accommodate the trailer the team needed more information, such as minimum space between the vehicle and the trailer at a variety of positions including at an angle and on an incline. To adapt to this new

challenge the team sought out this data by using 3D scan data of the trailer and the M-ATV to simulate the rotation angles between the two. With this information, designs could be modified to fit within the minimum space allowed when the trailer was attached to the M-ATV.

Technical Difficulties with Equipment in the Field

Acquiring this scan data of the trailer proved to be its challenge, testing the team's ability to solve problems on the spot. Because of the variation in environmental factors and the size of the objects being scanned new difficulties arose such as the Scanner's inability to see the scan targets based on where it was calibrated (sun vs shade) and trouble finding a reference point because the M-ATV and trailer are so large. To solve this the Team learned to increase/decrease the shutter on the scanner to adapt to being in more or less light than when calibrated, to constantly go back to an area previously scanned to create a reference, and to change scan angles to give it more visibility.

Lessons Learned from Fieldwork

While working on sight the team learned some lessons regarding the user's needs. It was observed that every inch of space in the M-ATV is utilized and because of this, the soldiers would like an extension to set the robots on to optimize space within the vehicle and to save time when pulling the robot out. The team learned that most soldiers on sight favored a crane option because of its manual components and adaptability with the trailer – which is always a consideration. Any extension would need to be of the correct dimensions to avoid the trailer at any angle or elevation. Any crane system would need to be quickly deployed and stored efficiently while being operatable from the vehicle and the ground.

Student Reflections and Learning Outcomes

The student-led project focusing on the design of a lift system for EOD equipment handling provided a hands-on learning experience, allowing students to enhance both their technical and practical skills. Through their work, they gained expertise in design software, prototyping, scanning technology, and engineering problem-solving, while also strengthening their ability to collaborate, communicate, and manage projects effectively. The reflections below highlight key takeaways from the project and how it contributed to their professional growth.

Development of Technical Skills

One of the most valuable aspects of this project was the opportunity to gain hands-on experience in technical areas. Students worked extensively with SolidWorks to convert initial design ideas into detailed 3D models, considering factors such as the M-ATV's size and the weight of the robots. This process helped them understand how to design scalable components that could be tested and adjusted as needed. In addition to design work, students used 3D printing to create small-scale prototypes, allowing them to physically test their concepts and refine key mechanisms to ensure they operate smoothly. They also used laser scanning tools to map out the dimensions of the M-ATV and its trailer, ensuring that their lift system would fit properly with existing equipment. By incorporating real-world data into their work, they gained a better understanding of how to merge new designs with pre-existing structures.

Strengthening Problem-Solving and Critical Thinking

The project introduced students to several engineering challenges that required creative problem-solving. One of the biggest hurdles was selecting materials that were lightweight yet strong enough to support up to 440 lbs. They carefully evaluated materials like stainless steel and aluminum, ultimately designing a dash-based lift mechanism that reduced the physical effort required from operators. Another obstacle emerged during field visits, where they realized that the M-ATV was often used with a trailer. This required adjustments to their design to ensure compatibility. Using 3D scan data, we plan to refine our approach and create a system that works seamlessly with the existing setup.

Teamwork and Effective Communication
Collaboration played a key role in the project's success. The two students divided responsibilities between them . This experience helped them understand how to efficiently delegate tasks and work as a team to achieve a shared goal. They also gathered direct feedback from EOD soldiers, conducting surveys and discussions to refine their design. The feedback highlighted the need for a compact, easy-to-operate system, which led to further improvements. Through this interaction, students learned how to incorporate user input into product development, ensuring that their design met the needs of the end-users.

Real-World Application and Career Growth
This project allowed students to see how engineering principles are applied in real-world settings, reinforcing what they had learned in their coursework. By working on a military-grade lift system, they applied concepts from mechanical design, material science, and structural analysis, gaining a deeper understanding of how these elements come together in practical applications. The experience also boosted their confidence and encouraged them to consider careers in mechanical engineering and product development. Additionally, the project's success underscored the importance of diversity in engineering, as it was led by female students, serving as an example of how women can take on leading roles in technical fields.

Conclusion

The Robot Lift System was designed to meet key user needs and operational constraints, focusing on creating a lift mechanism capable of handling various loads into the M-ATV. Strength, weight, ease of use, and adaptability were primary considerations.

After initial concepts were formed, the team developed detailed CAD models in SolidWorks, allowing them to visualize components in 3D and ensure compatibility and structural integrity. Functional animations followed to simulate the mechanism's movement and behavior in the field. Small-scale prototypes were then created using 3D printing, enabling the team to test the system and make quick modifications based on performance.

Surveys and feedback from EOD soldiers were critical in refining the final design and addressing concerns about storage, compatibility, and ease of deployment. Insights from site visits helped emphasize the need for a compact, easy-to-use solution.

Future work could involve scaling the system for broader military use, enhancing its impact across different operations. Further testing in diverse environments and with larger user samples is essential to validate performance and identify any additional improvements. Collaboration with military personnel in ongoing field testing will ensure continuous refinement, making the system more effective and accepted by users.

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