Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2019
A Regional Conference of the Society for Industrial and Systems Engineering

Unmanned Ground Vehicle Deployment System

Audrey Hung and Samantha Price

Department of Systems Engineering
United States Military Academy, West Point, NY

Corresponding author: audrey.hung@westpoint.edu

Author Note: Audrey Hung is a senior at the United States Military Academy (USMA) pursuing a Bachelor of Science degree in engineering Management. Samantha Price is a senior at the United States Military Academy (USMA) pursuing a Bachelor of Science degree in Systems Engineering with Honors distinction. Much of the study is sponsored by United States Army Tank Automotive Research, Development and Engineering Center (TARDEC). The work was conducted in collaboration with Cadet Kristen Horn, Cadet Stephen Parrish, Cadet Andrew Young, Major Patrick Linford, and Dr. Vikram Mittal who provided mechanical engineering expertise and mentorship through the design and building phases.

Abstract: The United States Army has used various small Unmanned Ground Vehicles (UGVs) to conduct reconnaissance and disarm explosives for over two decades. These robots are remotely operated and are able to receive radio signals up to 800 meters away (*TALON Tracked Military Robot*). TARDEC has designed and built a robotic mule that can either be remotely controlled or tethered to an individual soldier to mimic movement (Lopez, 2018). This mule, named the Squad Multipurpose Equipment Transport (SMET), stores a UGV for transportation and keeps the devices in close proximity to an infantry squad. These two devices increase soldier survivability and effectiveness but have not been integrated with each other. A human element is still necessary to physically move the UGV from the SMET. To combat this problem, this project looks at integrating a robotic ramp into the system that can rapidly deploy from the SMET using a remote control. Named the Robot Deployment Device (RDD), the device allows for a relatively low incline so that the UGV can maneuver to and from the SMET. The RDD is the missing piece in robotic warfare and will further increase soldier survivability in combat scenarios.

Keywords: Unmanned Ground Vehicles, Robot, Soldier, SMET, TARDEC

1. Systems Description

The implementation of robotics in combat is not a novel idea. Over the past two decades, Unmanned Ground Vehicles (UGV) have played a critical role in the battlefield, especially for reconnaissance and disarming explosives. Two new robots are expected to expand the role of autonomous systems on the battlefield. The first is the Squad Multipurpose Equipment Transport (SMET), a robotic mule that can be remotely controlled or tethered to an individual soldier to mimic movement (Lopez, 2018). The SMET has the capacity to store a second, smaller UGV for transportation, allowing an infantry squad to access it during a mission. This second UGV can be used for reconnaissance or disarming explosives. These two devices increase soldier survivability by allowing them to increase their standoff from threats; however, they have not been integrated with each other. A soldier is still required to physically move the smaller UGV from the SMET. To combat this problem, this project looks at integrating a robotic ramp into the system that can rapidly deploy from the SMET using a remote control. Named the Robot Deployment Device (RDD), the device allows for a relatively low incline so that the UGV can maneuver to and from the SMET. The RDD is the missing piece in robotic warfare and will further increase soldier survivability in combat scenarios.

The optimal design of the RDD will aid in the deployment and redeployment of the UGV. The design has two parallel ramps that extend to make a ramp long enough so that the robot can climb the ramp under its own power. In comparison with other designs, the RDD will have the minimum number of parts needed to accomplish the mission, while still deploying the robot at a rapid rate. The lower the number of moving parts, the less the likelihood of mechanical failure. The reason why the two parallel ramp design was selected was because the other ramp designs were not long enough to create a shallow enough of an angle for the robot to climb. Creating the smallest climbing angle was the most important factor in the design process because the smaller the angle is, the easier it is for the UGV to redeploy back in to the housing compartment using its own power. For this project, both pieces of the ramp fit on the SMET and creates the ideal incline for the robot to climb. Both ramps can be deployed and retracted autonomously, allowing the soldier to maintain situational awareness with their environment and to be able to focus on other tasks. This will maintain the momentum of the warfighters in combat.

The key part of the system is interfacing. The overall scope of the project requires the RDD to integrate with the SMET and a smaller UGV. If the UGV cannot climb the ramp or if the device does not fit on the SMET, then the overall integration fails. The two-part design of the ramp also requires ramp one and ramp two to interface together within the housing unit on the SMET. The multi-faceted integration requires verification at every step and leaves minimal room for measurement error.

2. Problem Definition

One of the Army's initiative is to improve troop effectiveness (Colvin, 2018). The Army is currently looking into implementing the SMET into squad level operations (Colvin, 2018). The intent of the SMET is to decrease a Soldier's load while simultaneously being able to utilize the vehicle in a manner that could project power (Colvin, 2018). By integrating the SMET into formations, it would allow quicker and more reactive operations. If the Army can figure out an effective manner in which it can project power while minimizing a Soldier's presence, the SMET can become an extremely lethal tool to implement. One way that this can be done is if the SMET is able to deploy the UGV autonomously from it. Thus, the problem trying to be solved is how to design and prepare a working prototype of an autonomous Unmanned Ground Vehicle (UGV) system that can be affixed to military ground vehicles (SMET) and deploy/redeploy an UGV in fifteen seconds or less.

Stakeholder analysis provided the factors to be incorporated into the final design, as shown in Figure 1. The system must be maintainable, durable, compatible, efficient, and low-cost. Each of these top levels objectives are further decomposed into lower level objectives. The most critical of these lower-level objective is the deployment/redeployment time, which was provided directly from TARDEC.

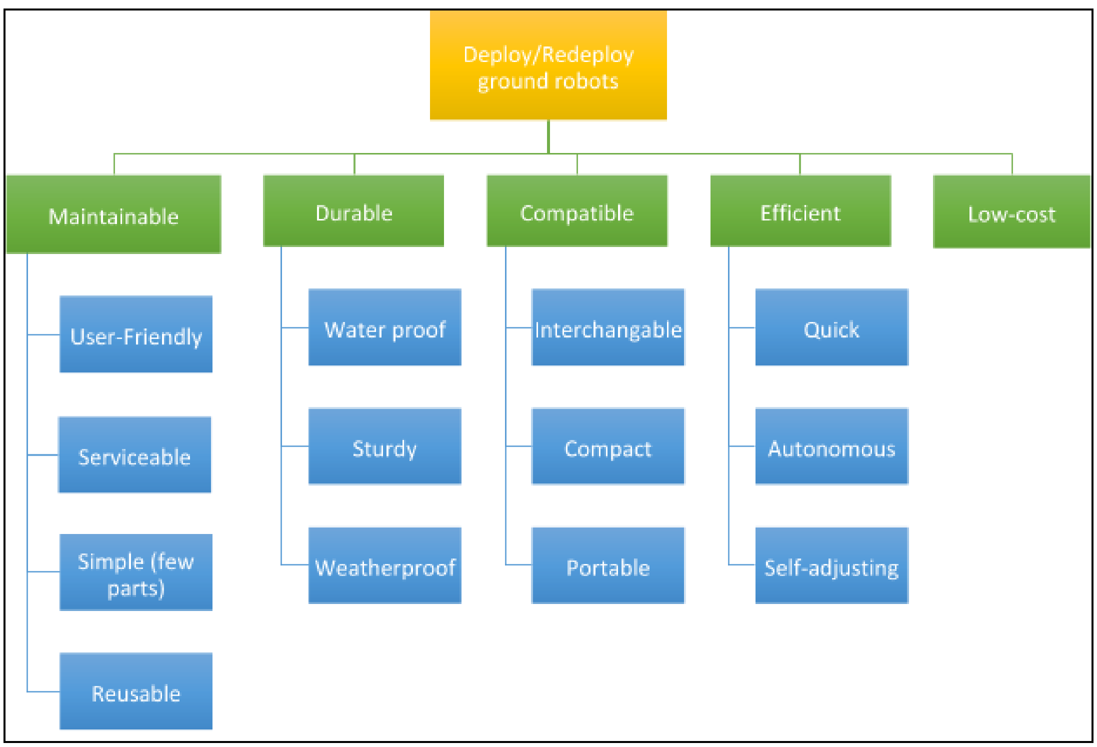

Figure 1. Objective Tree

3. Design Alternatives

Using the Objective Tree to determine system requirements, the study created an Alternative Generation Table to lay out all possible and feasible options for different components (See Table 1). These alternatives were generated based on availability, cost, and stakeholder preference.

Table 1. Design Alternative Table

Alternative Generation Table						
Device Type	**Device Size**	**Climbing Power**	**Frame Metal**	**Communication**	**Power Type**	**Number of Moving Joints**
Ramp	Small	Robot	Composite	Arduino	AC	2
Elevator	Medium	RDD	Aluminum	Raspberry Pi	DC	3
Folding Ramp/Box	Large		Titanium			4

The Design Alternative Table allowed for the creation of all possible combinations. When looking at the seven factors, there are a total of 648 combinations. The chart organized the features and functionalities in a way that allowed for various designs to be created that all met the design criterions. In order to narrow down the amount of combinations, the team met with the stakeholders once again, where it was decided that DC power would be the method in which the system would be powered by. The stakeholders then took a look over the possible combinations and narrowed the list down to the five alternatives shown in Table 2.

Table 2. Design Decisions Matrix

Small Robot Deployment Device Design Decisions							
Chariot	Ramp	Medium	Robot	Aluminum	Arduino	DC	3
The Devil	Elevator	Medium	RDS	Titanium	Raspberry Pi	DC	4
Hardly Qualified	Elevator	Medium	RDS	Aluminum	Arduino	DC	3
Mediocrity	Folding Ramp/ Box	Small	Robot	Aluminum	Raspberry Pi	DC	2
The Accordion	Folding Ramp/ Box	Large	Robot	Composite	Arduino	DC	4

ISBN: 97819384961-6-5

4. Final Design

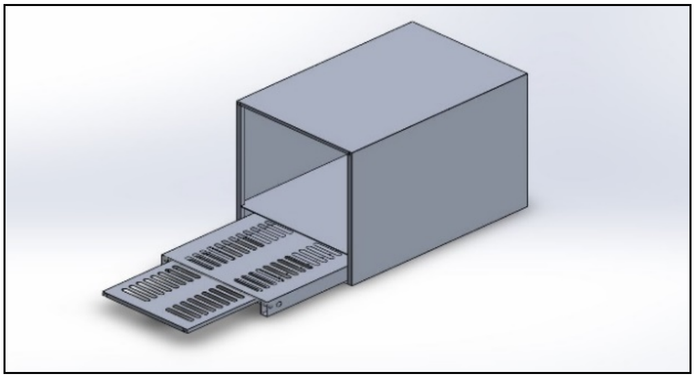

Figure 2. Conceptual Computer Design of the Chariot

After determining the initial five decisions for the device, it was necessary to weight the alternatives against one another. The stakeholder's ultimately made the final call that a folding ramp or box was not feasible and did not want to pursue those options; therefore, the team only had to compare the first three designs (See Table 3). The Weighted Decision Matrix allowed for a quantitative comparison between the alternatives to determine the highest overall rating, leading to the Chariot being the best design. It met the stakeholder's requirements the best and was similar to the original design TARDEC envisioned for SMET integration.

Table 3. Weight Decision Matrix

			Alternative 1: Chariot			Alternative 2: The Devil			Alternative 3: Hardly Qualified		
Design Criterion	Weight Factor	Units	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
# of Parts	0.133	Parts	10	1.00	0.133	13	0.70	0.0931	20	0.00	0
Deployment Time	0.534	sec.	30	1.00	0.534	90	0.40	0.2136	60	0.70	0.3738
Set Up Time	0.333	min.	5	1.00	0.333	5	1.00	0.333	5	1.00	0.333
				Total Rating	1		Total Rating	0.6397		Total Rating	0.7068

The Chariot is a two-part ramp driven by a chain and sprocket system that is attached to a motor. The first ramp is attached to the chain and sprocket drive system, which pushes the ramp out of the housing compartment. This chain and sprocket system is mounted on to the box frame. A second sprocket and chain system extends ramp one out of ramp two, creating a two-part ramp that can extend further than any other design while fitting on the dimensions of the SMET. The main advantage of the Chariot is the low climbing angle of around 30- 35 degrees. TARDEC's initial wooden prototype had a climbing angle of around 50 degrees, making it extremely difficult for the robot to climb on its own power. The smaller the climbing angle, the easier it is for the UGV to enter the housing unit. To account for the varying terrain that this system can be deployed in, there is a sensor attached to the motor to stop the extension of the second ramp as soon as it contacts the ground. The ramps and the box are made from aluminum because it has a high enough yield strength for our design and is lighter than steel. Aluminum decreases the overall weight of the system, making it easier for Soldier's to lift and transport.

ISBN: 97819384961-6-5

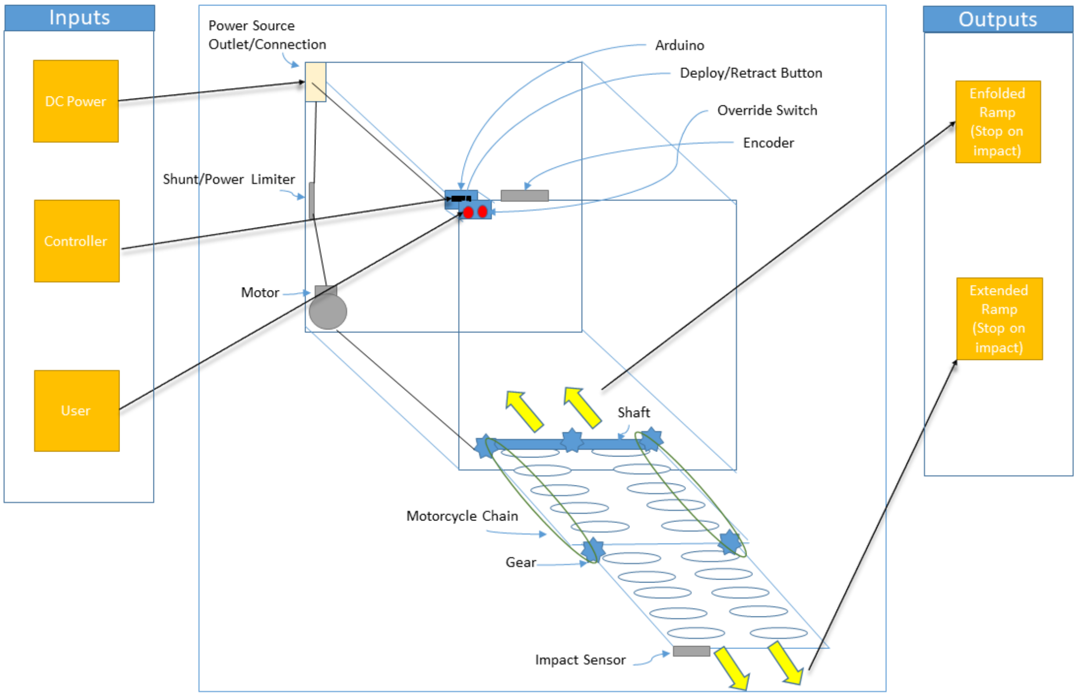

Figure 3. Product Architecture

However, the frame of the box is steel to reinforce the box itself and make the system more durable to the wears and tears of daily use.

The Product Architecture for the final design allows the team to look at all components and how they interact to get the final outputs (See Figure 3). In the initial phases of design, a user will press the Deploy/Retract button. This button is connected to the Arduino housed in a protective box. The Arduino draws its power from the power source, which comes from the SMET. A power limiter is connected between the power source and the motor to ensure that the motor will cut power if the ramp runs into a problem and does not burn out the motor. The motor will drive the motorcycle chains to deploy and retract the ramp. At the bottom of the ramp, there is an impact sensor that is connected to the motor and Arduino that tells the ramp to stop once the ramp hits the ground or another object. This graphical depiction ensures that the interfaces are interacting correctly and also allows the team to determine the best location for each of the components.

5. Implementation and Test Plan

In order to test the functionality of the ramp, the team is conducting tests on deployment, retraction, and all components. The main goal of the ramp deployment device is to safely deploy and retract the ramp to allow the robot to maneuver. With the main goal in mind, a test includes deploying and retracting the ramp numerous times and recording the time for each trial. With each of these tests, the group is also analyzing how well the limiter works in stopping the ramp on impact. The RDD is being tested in multiple environments: on a level surface, on a slope, and in the rain. By testing the functionality of the ramp and conducting these tests in different scenarios, the group can get a better idea of how well the device will perform overall as well as decide if the team has met the stakeholder requirements.

The systems that need to be tested are the Arduino, the motor, both ramps, and the power limiting sensors. Each subsystem is being tested five times at a minimum, looking at functionality, reliability, and durability. For the Arduino, the group is ensuring that it will properly interface between the controller and the motor so that the soldier can deploy the ramp when he/she presses the button on the controller. For the motor and ramp, the group is looking to see when the signal is given to the motor, if the motor will run, turn the shafts, and run the gear trains so that the ramp deploys. The sprockets and chains, as well as the rack and pinion, need to mesh well so that neither of the ramp sections gets stuck. The group is also getting the time it takes to deploy and retract the ramp to ensure it meets the design requirements and to see if improvements can be made. At completion of the building phase, a robot, like the TALON, will drive up the ramp to ensure the ramp holds the weight and that the robot can climb it. Lastly, the power limiting sensors are being tested to determine if they are functional. If the ramp hits an object before it is fully deployed, the sensor will read the spike in power being used and cut the circuit off, so the motor will stop and not burn out.

To run these tests, the group is creating a 32-inch high platform for the device to sit on. This simulates the device resting on the SMET. The device will then be placed with the opening facing the side, so that the ramps can deploy. A large, heavy object is also required to test the power limiter. The object will be placed near the device and then the ramp will be deployed. When it hits an object the limiter will shut off the motor. The team will also need a TALON or similar robot to drive up and down the ramp.

The first set of tests will be conducted indoors which will simulate an environment that protects the deice from environmental factors while maintaining STP conditions with minimal variation. Once tests are complete in this isolated environment, the device will be taken outside and tested again in variable conditions.

6. Conclusion

Currently the system is in the building phase with the team working on the integration of electrical components. TARDEC has asked the capstone group to complete the system by the end of April 2019 so that it can be displayed at a robotic mule demonstration in Fort Benning, Georgia. The device is a working prototype that will interface with the SMET, so that TARDEC can continue its research and create the best device for the U.S. Army.

Creating an autonomous deployment/ redeployment system for an UGV is an extremely critical task to complete because it can increase our troops combat effectiveness while simultaneously decreasing a Soldier's risk. The design of this study, the Chariot, is an extremely unique and durable design. The use of a two-ramp deployment system is able to accommodate the UGV's climbing angle, which is one of the most important components of the system. The smaller the climbing angle of the ramp is, the easier it is for the UGV to mount up. It is important to note that the system has included multiple factors of safety, making it extremely durable for day to day tasks.

If needed, future work that could be done to the prototype is to make it lighter by decreasing the factor of safety and looking for alternative materials. A type of alternative material that can be used is reinforced plastic, which would decrease the overall wait exponentially. By decreasing the weight of the system, it will make it easier for Soldiers to load on and off the SMET.

7. References

Colvin, G. R. (2018). Squad Multipurpose Equipment Transport "SMET 101".

Lopez, T. (2018, June 7). *New SMET will take the load off Infantry Soldiers.* Retrieved January 23, 2019, from U.S. Army: https://www.army.mil/article/206619/new_smet_will_take_the_load_off_infantry_soldiers

TALON Tracked Military Robot. Retrieved January 23, 2019, from Army Technology: https://www.army-technology.com/projects/talon-tracked-military-robot/