Battle Effects Simulator Robot (BES Robot)

Sponsored by James Todd, PEO STRI

(https://www.peostri.army.mil/)

EEL 4914 | Senior Design I | Summer 2022 | Group 6

Jared Rymkos - Computer Engineering
Julia Kemper - Computer Engineering
Nicholas Nachowicz - Computer Engineering
Michael Rodriguez - Electrical Engineering

Table of Contents

1.Description of Project

1.1 Narrative

The US Army/ Department of Defense has expressed the need for a Modular Open System Architecture (MOSA) live fire robotic platform/system to support the training of US Army soldiers. The system is intended to be used on live fire training ranges to improve the overall training experience, increase training throughput and improve safety measures by removing the human element. The robotic system will automate the pyrotechnic handling and replacement by supporting the positioning of an existing US Army Battlefield Effects Simulator (BES) that will provide simulated hostile threat fire and hostile vehicle kill indications (as shown in figure 1A). These simulation fire and kill indications are achieved through the use of pyrotechnic cartridges that are activated by the BES (see figure 1B and 1C.) The robotic system design and control functions will align to the Robotic Operating System Military (ROS-M) framework and ecosystem using open source software to create the robotic framework.

Figure 1A – Example of hostile fire simulation

Figure 1B – Battlefield Effects Simulator (BES)

One of the primary benefits of developing a robotic system used for positioning the Battlefield Effects Simulator is to greatly increase safety during training. The robotic system will have multiple safety related attributes to include the ability traverse the live fire training range terrain without human assistance/entering down range zones, identify when it is in the correct location on the battlefield and verification that there are no moving elements within a certain vicinity of the robotic platform (i.e. location of the where the pyrotechnics will be fired). When the safety measures are completed, the robotic system logic must determine that the safety conditions have been met before it will allow the control system to send an activation signal to the BES to replicate improvised explosive device events, fire replication and other direct live fire. Initial RF protocols for control system wireless communication with the robot exist as a US Army standard, the interface specifications for control signals from the robotic platform to the BES will be developed by this senior design team. Due to this specification, the robotic system may need to act as a Dynamic Host Configuration Protocol network server that

Figure 1C – Pyrotechnics cartridge that is place inside Battlefield Effects Simulator provides a set of parameters to client devices. This will automatically allow the client to communicate on the network.

Along with the ability to support and control a BES, the robotic system will be autonomous with optimal path determination. The design will leverage GPS/GNSS to travel from point A to B smoothly and sensor fusion to detect and avoid any potential obstacles or collisions. This will include using continuous motor control and position tracking to prevent the robotic system from moving more than a specified amount off the correct path. The robotic system will have a sturdy body and wheels/tracks that will allow for it to move in and out of Stationary Armor Target coffin locations without any issues and interference. The robotic system must be power efficient to ensure the system will be able to support the training event and throughput objectives.

The objective of this project is to incorporate automation into a current manual process, effectively improving the safety of achieving training realism through the utilization of pyrotechnics for simulated hostile threat fire and hostile vehicle kill indications. The goal of this project is to improve the throughput of US Army training exercises and greatly improve safety measures by eliminating the human element.

2. Project Requirements Specifications and Constraints

2.1 Requirements

2.1.1 General

- The robot will follow the regulations given by PEO STRI.
- The robot will be ¼ the size of the product they wish to eventually create in the future.
    - The robot will hold 8 pyrotechnic rounds.
- The robot will drive autonomously to a specific destination that is given with an accuracy of 0.15m.
- The robot must be able to detect collisions to avoid existing equipment in or on the way to destinations.

2.1.2 Hardware

- Connected components inside the frame of the robot:
    - A custom PCB
    - Battery bank
    - Motors
    - GPS receiver
    - RF receiver
    - Receiver for accepting inputs from a person
    - AI processor

- A custom PCB will be attached to an ultrasonic sensor, GPS receiver, receiver to receive data on where to go, camera, infrared sensor, motors for the treads, external storage with AI development kit, and rechargeable battery bank.
- An ultrasonic sensor will be attached at the front and back of the robot so that it doesn't crash into anything while moving forward and backwards. Powered by a custom PCB.
- A GPS receiver will be powered by a custom PCB.
- There will be infrared sensors around the robot to investigate if any person is in the area and there will also be cameras giving the robot a 360° view that will also help in identifying people and if the robot is headed in the right direction without veering off course. These will be powered by the PCB.
- The robot will be utilizing 2 motors for the treads that it will use so that it can maneuver over rough terrain which will be controlled by the AI that is utilizing the PCB.
- A solar panel will be attached and help in recharging the battery bank.
- There will also be an RF receiver to enable wireless charging of the battery bank.

2.1.3 UI

- The robot will be turned on by a power button.
- The robot UI will tell how much battery life there is left on the machine.
- An application that will hold the UI to control the actual robot.
    - It will have different destinations that a user can select for the robot to go to.
    - The UI will display a fire button that will only be able to be pressed if the conditions around the robot are considered ok to fire in and the robot is stopped and in place.
    - The UI will also tell the battery levels on the application for when the robot is at the destinations selected.

2.1.4 Power

- Powered by a rechargeable battery
    - The rechargeable battery will be connected to solar cells that will be on the top portion of the robot that will help recharge it. There will also be an RF receiver that can be utilized to wirelessly charge the robot.
    - The rechargeable battery will have a battery life minimum of 10 hours.

2.2 Constraints

There are several constraints that this project will need to take into consideration. The two major constraints we are dealing with are time and money. Our team is on a strict schedule deadline for this project, and a budget, if at all one, is currently still being discussed. Environmental constraints will also impact this project due to the weather conditions the robot will need to function in. Our robot will also have to follow any constraints derived from our sponsor in the future.

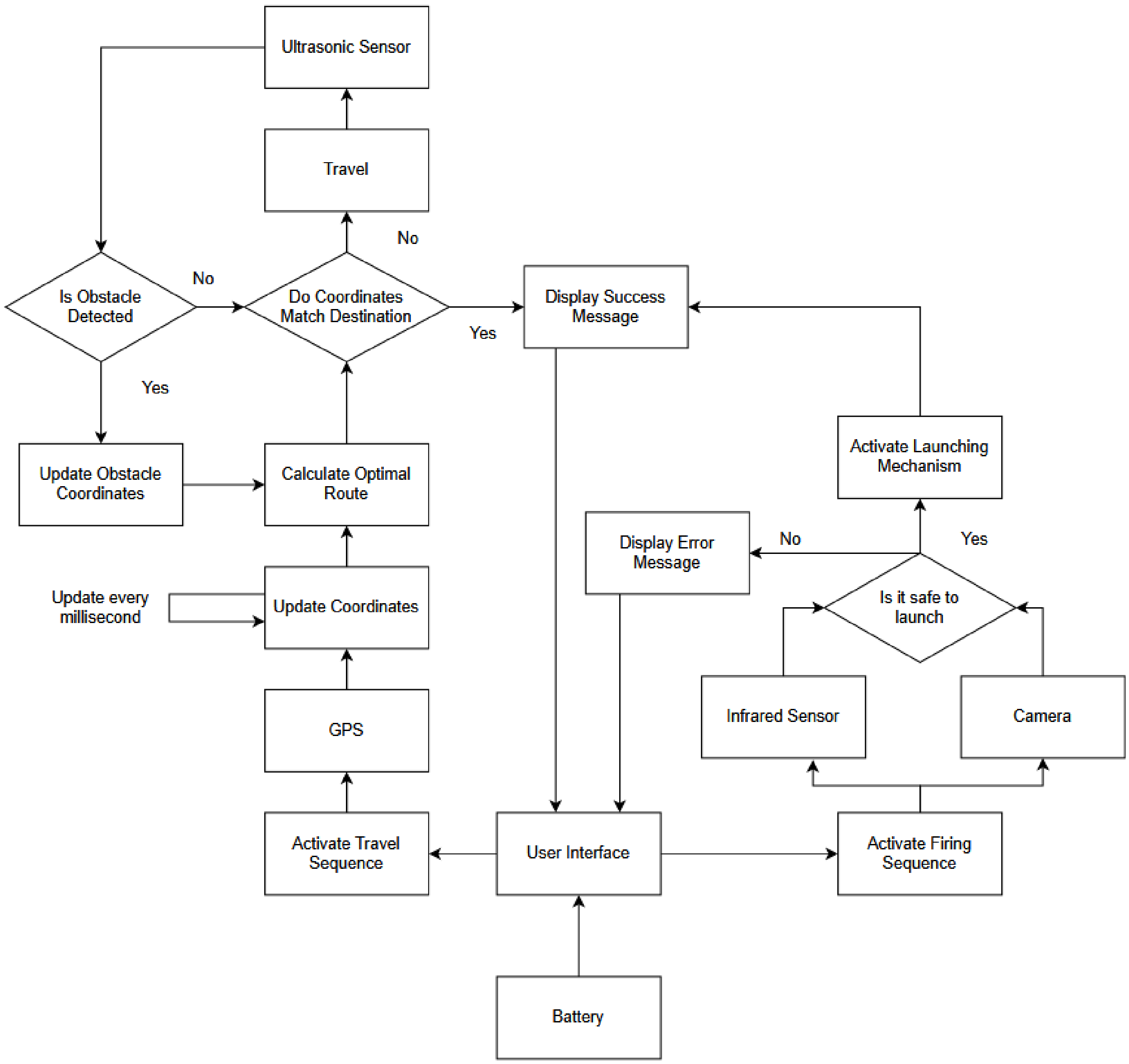
The Battle Effects Simulator Robot is sponsored by PEO STRI. We have been in communication with our sponsor about a budget for this project, if any at all. Our sponsor has not been able to disclose any information about a budget in the current state of our project. As for a rough estimate, we hope to keep the cost of the robot in the range of 300-750 US dollars. This is a rough estimate currently, and we will continue to update this amount when we have more information from our sponsor. To help with this constraint we will make sure to consider all options when looking at parts for our robot. We will make sure we choose parts that are both affordable and reliable. This is extremely important because this is a Modular Open System Approach (MOSA) robot. MOSA is a set of guidelines and requirements that results in affordable and efficient projects.

Time is another crucial constraint our team will deal with during the course of this project. Our team is tasked with building this robot in the span of two semesters. Our sponsor has expressed eventually turning this project into a multi-year project with our team building the initial, phase 1 prototype. Our sponsor has given us the goal of creating a robot that is a quarter of the size of the final product robot. This requirement will help in the constraint of time and money and will allow us to focus on continuously improving/perfecting the robot instead of creating a robot that is too large to encompass all of the sponsor's needs. Another factor that will affect our time constraint is how easily we can acquire parts. Electronics have been in a shortage for some time now and it's affecting the availability and delivery time of parts. We will be continuously researching and attempting to acquire parts during the course of Senior Design 1 semester in order to ensure delivery is timely and ensure parts are available.

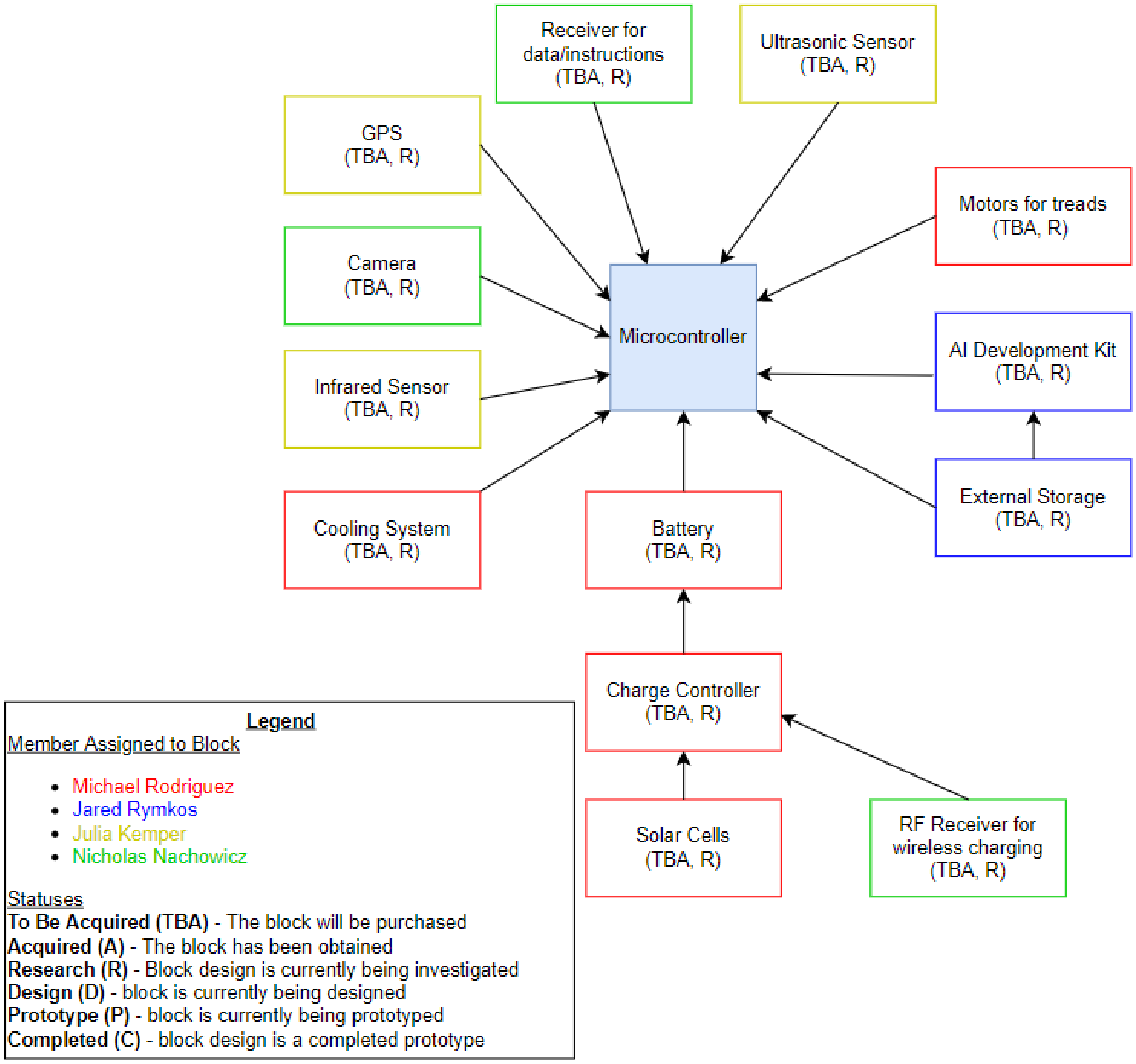
Our robot will experience rough weather conditions and high levels of heat due to the training ranges it will be operating on. We will have to take these factors into consideration when creating the design of our robot. Some large environmental constraints we will deal with are weather, temperature, and terrain. Our robot will need to function in the outdoor elements for most of its lifespan. When looking for parts, we need to consider the temperatures they can function properly in. The robot will be in the sun and experiencing extremely hot temperatures, potentially damaging the robot. We will be adding some features that will help with cooling the robot, but this will affect our cost constraint. The robot will also need to be able to withstand other drastic weather scenarios such as rain and fast winds. The terrain must also be considered when making this robot as it will not always be a flat surface. The robot must be able to make it from point A to point B accurately while traveling on gravel, into Stationary Armor Target coffins, and other non-ideal terrain. The last part of the environment that should be considered is the type of impacts that the robot may be taking. This robot will be holding dangerous pyrotechnics and needs to be able to withstand multiple launches every day. The hardware needs to be mounted well and protected or else the whole machine will be vulnerable to failures. It is expected that our sponsor or future senior design groups will reinforce the robot to withstand certain impact when necessary. Our team still plans to be considerate of where hardware should go to avoid damage regardless of reinforcement.

3. Project Block Diagrams

3.1 Software Block Diagram



3.2 Hardware Block Diagram



4. Project Budgeting and Financing

As of this time in the R&D process our project has not specified a budget for this project. We will be in talks with our supervisor to determine what our budget will be if they kindly allow. Below is our initial estimated costs for the project. This table is very vague and subject to change as we go further into the development process.

Item	Price (USD)	Quantity
Camera	$20.00 - $50.00	1+

Microcontroller	$1.00 - $7.00	1+
Infrared Sensor	$1.00 - $5.00	4+
Misc. Parts for PCB	$15.00 - $20.00	1+
Ultrasonic Sensor	$1.00 - $5.00	4+
GPS retriever	$3.00 - $6.00	1
Cooling System	Not determined	Not determined
Motors for Treads	$15.00 - $30.00	2
Motor Controller	$4.00 - $10.00	1
Solar Panel	$45.00 - $75.00	1+
Solar Charge Controller	$26.00 - $50.00	1
Power Switch	$1.00 - $2.00	1
Power Regulator	$1.00 - $2.00	1
Battery	Not determined	Not determined
Development Kit for AI	$60.00 - $100.00	1
External Storage	$10.00 - $25.00	1
RF receiver for wireless charging	$2.00 - $5.00	1+
Total	$205.00 - $392.00	—-

5. Project Milestones by Semester

5.1 Senior Design I

Description	**Dates**
Discuss Project Ideas	May 18 - May 28
Project Selection	May 28- May 31
Work on Divide and Conquer	June 1 - June 3
Divide and Conquer submission	June 3

Research on Project	June 3 - June 10
Communicate with Sponsor	June 6
Update project requirements/specification	June 10 - June 14
Update Divide and Conquer	June 14 - June 16
Divide and Conquer submission 2	June 17
Continue research on project design and implementation	June 17 - July 1
Documentation	June 24 - July 7
60-page Senior Design 1 Draft submission	July 8
Continue research/update draft	July 9 - July 21
Updated 100-page report submission	July 22
Finalize report/ make any necessary changes	July 23 - August 1
Final senior design 1 report submission	August 2
Begin Building Prototype Before Senior Design 2	TBA

5.2 Senior Design II

Description	**Dates**
Keep building prototype	August 22 - September 19
Communicate with Sponsor	TBA
Testing and Redesign	September 20 - October 17
Finalize Prototype	October 18 - November 15
Peer Presentation	TBA
Final Report Submission	TBA
Final Presentation	TBA