IEEE SECON 2024 Hardware Competition Robot

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I. Introduction

The purpose of this project is to build an autonomous robot to be sent to the IEEE Southeast Convention, herein referred to as SECON, to compete in the student hardware competition. This robot will be used to represent Tennessee Technological University in a competition against schools from around the southeastern United States. During the competition the robot will navigate the course, demonstrate school spirit, and finally push a button to complete the run. This robot will function to attain as many points as possible while minimizing risk to ensure a consistent score on each run and completion before the competition's start date. The strategy defined takes into account the difficulty of the competition's tasks as well as the abbreviated timeline of the team, to produce a realistic and attainable product. The robot will perform specifically chosen tasks consistently, although it will not attempt all possible tasks to minimize risk during both development and deployment.

The team is comprised of members of the Electrical and Computer Engineering Department and the Mechanical Engineering Department of Tennessee Technological University, herein referred to as the team. The team is tasked with creating a robot that can complete tasks autonomously without any human input after the robot has been started. The competition is scored by the awarding of points for completing specified tasks, and this proposal addresses how the robot will achieve these goals and the strategy for reliably gaining as many points as possible.

The objective of this project is to improve the development of engineering skills that the team has gained in their time at Tennessee Tech. The skills include, but are not limited to, systems engineering, project management, project design, and project execution using a practical engineering project. This project also serves as an opportunity to promote the College of Engineering here at Tennessee Tech to other schools and employers in the area.

This proposal will start with a background of previous projects and will detail the course the robot is required to complete. Then it will describe the restrictions and obstacles placed on the robot and its tasks. Following that, this proposal will describe the scope of the project, define the shall statements, and outline the strategy for the collection of points in the competition.

II. Background

This section will detail the background of this project. This will include discussing previous robots built for IEEE competitions by Tennessee Tech and looking at how those robots were built. It will also look at the relevant literature supplied by the IEEE SECON competition guidelines.

There have been two robots built by Tennessee Tech in the last two years that have been to the SECON competition. These robots won eighth and fourth place respectively, and were built by members of the capstone program. The robot from the 2022 competition was built by an all electrical and computer engineering team, while the 2023 robot was built by a collaboration of electrical and mechanical engineers. This seems to indicate that the inclusion of mechanical engineers will boost the chances of the robot's success in the competition. Thus, this project will be built by a collaboration of both EE and ME students. Both robots were made to run autonomously and to the specifications provided by the IEEE SECON competition for those years. There are several systems used in those robots, such as autonomous driving systems, that this project will take inspiration from. The power systems used by these robots are simplistic and easy to replicate and will inspire the power systems of this robot. The power systems historically consisted of a battery that supplied 12 volts to the robot at currents up to 2 amps. This will be sufficient to meet the requirements of the robot proposed in this paper. The driving system, while similar at a high level, will be significantly different as both previous TTU robots used wheels, while this year's competition has blocks placed on the course that could potentially interrupt movement if wheels are used. However, finding another movement system, such as treads, is also easy to replicate, as many children's toys and radio-controlled vehicles use similar alternative movement systems. As for navigation of the course, many educational programmable robots use some form of line tracking or other navigation tactics. Thus it is feasible to propose that our robot will be able to navigate the course by sensing the painted lines in some capacity to direct its movement. The team spirit and button-pushing tasks are somewhat unique to this year's competition, therefore, solutions are not as well established as other systems. However, this gives the team the flexibility to come up with an innovative, yet simple solution that produces consistent results. Knowledge of these previous competition robots, small-scale vehicles, and other programmable robotic units proves that the concept of building this year's hardware competition robot to navigate the course, demonstrate team spirit, and push the stop button is feasible and attainable.

The rules for the competition are laid out by the IEEE Conference team. They include a course layout, a description of all tasks to be performed, and any constraints placed on the robots. These constraints will be discussed in more detail in the next section of this paper. The design of the course to be run by the robots is as follows. There is a track that is four feet wide and eight feet long, split into two lanes. The first lane begins at the starting zone where the robot has to collect a number of boxes, transport them down the first lane, and into an unloading zone where the boxes are offloaded. The first lane includes a hill that the robot must ascend, traverse, and descend while carrying the boxes collected at the start position. After dropping off the boxes collected at the start, the robot must make a left turn, collect fuel tanks, and proceed down the second lane. The second lane includes a crater that the robot must cross, a zip line is included across the crater for the team to use if needed. The robot must then drop off the fuel tanks, by placing them on their specific bases. Extra points are offered if the robot displays some dynamic demonstration of team or school spirit at this point. To complete the course the robot must then push a button that stops the timer for the run [1]. The objectives that this robot will strive to achieve are box collection and delivery, crater navigation, team spirit display, course completion, and pressing of the stop button. The fuel tank collection has been omitted from our strategy, as it has been deemed too risky and complicated to confidently design and perform in the timeline the team has committed to. This decision still allows for a majority of the points to be collected as consistently as possible.

III. Obstacles and Restrictions

This section will detail the restrictions and obstacles placed on the robot by the rules of the SECON competition. This section will also discuss any obstacles and restrictions placed upon the robot by stakeholders and standards as well. It includes the shall and shall not statements of this project.

A. Robot Obstacles

This section details the restrictions placed on the robot itself.

1) Robot Specifications: The robot shall operate autonomously, meaning it cannot have any outside operation or control mechanisms. Thus, the robot shall be powered with a battery so that it is free to move and not restricted by cord length. The robot also shall have a navigation system built in, that will detect the lines painted on the course and follow them, turning at appropriate corners and performing other appropriate actions as needed without user input.

The rules state a size restriction on the robot, therefore it shall fit in a one (1) foot cube at the start of the competition. After a run is started on the course the robot may expand to fill a larger area as long as it remains within the bounds of the course. The rules also state a weight restriction of twenty-five (25) pounds, which the robot is not to exceed. The robot shall use materials that are an appropriate weight for its function and limit excessive weight where possible while maintaining the weighting that is necessary for traversing the course. The robot also shall have any extra appendages properly folded or otherwise stored away to fit within the cubic foot requirement, and will only deploy these appendages once the start sensor system has acknowledged the beginning of the run.

The robot shall have an emergency stop mechanism installed in case of malfunction or emergency. This stop mechanism shall cut off the power to any system that results in the movement of the robot, however, it shall not turn off the navigation system or other main controller to limit boot times.

The robot shall not be composed of or make use of hazardous materials. This includes but is not limited to, explosives, toxic materials, corrosives, or flammable liquids or gasses.

The robot shall not intentionally interfere with other robots or teams in any way.. The robot shall not use any system that would potentially interfere with other teams' operations, this includes shining bright lights or sending out signals that could be intercepted by other teams.

The robot shall be confined to the course. It shall not leave the course area at any time during a run. The course may not be altered in any way to ensure that this restriction is met. The robot shall be properly constructed in a way that it cannot leave the course, while also preventing damage to the walls, the button, the crater, and the boxes that it interacts with.

The robot shall not pose a threat to any human or the course in any way. This includes not physically harming anything it comes into contact with.

The robot shall have clearly labeled start and stop switches. These switches will be easily accessible during the robot's operation.

The robot shall be decorated with Tennessee Tech colors and display the Tennessee Tech logo on the chassis.

2) Stakeholder Restraints: The robot shall not pose a threat to human life. This is a basic requirement for any autonomous system developed at Tennessee Tech.

The robot shall use some motion system other than wheels to navigate the course. This will allow for it to navigate over obstacles such as objects on the course that would otherwise jam or inhibit other means of movement such as the omni-wheels used on previous robots developed at TTU.

The robot and the team shall demonstrate appropriate school spirit so that TTU as an entity is properly represented and supported.

3) Multi-Robot Use and Collaboration: The robot shall not include any flying parts or UAVs if the robot splits into multiple units. The robot is allowed to split into multiple units but must start in one unit within the starting area of one (1) foot cube as described in the previous subsection.

The robot shall be of a unique design and construction and will be a collaboration of the mental and physical efforts of all team members on this project.

The robot shall not use any detachable parts or secondary robots in its operation. It shall be a single unit that operates as a whole unit for the duration of the run through the course. The operation of the robot is defined as the robot actively moving throughout the course. Some parts may be detachable or swap-able outside of the robot's operation.

4) Material Utilization and Removal Guidelines: All materials introduced to the course shall be easily removable after each run. The team shall spend no more than five (5) minutes removing materials from the course after the completion of any run. The robot shall not break into any smaller pieces nor shall it bring anything into the course other than pieces specifically attached to its chassis.

The robot shall not have any projectiles or turn any course objects or robot materials into projectiles.

B. Course Obstacles:

The robot shall navigate the course using a coded system to traverse the course following the yellow line across the center of the course.

Before starting the course the robot shall engage the box collection system to grab the boxes at the start of the course.

The robot then shall ascend and descend the hill that exists at the beginning of the course, the robot shall also be transporting the boxes at this point.

Before turning the corner, the robot shall deliver the boxes to the appropriate zone by disengaging the box collection system. The robot then shall specifically navigate the crater by driving down into it and then driving up out of the crater. The walls of the crater are different heights, and this will allow the robot to drop into the crater unharmed and then drive out the other side. This negates the need for a robotic arm to attach to the zip line in order to cross the crater.

At this point, the robot shall have arrived in the fuel tank assembly zone and shall deploy the team spirit system. Finally, the robot shall depress the stop button which will then end the timer for the robot's run.

A picture of the course is shown in Figure 1.

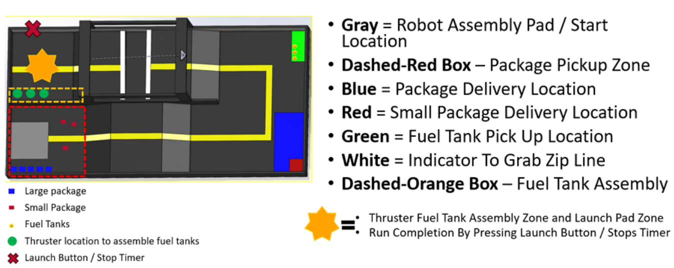

Fig. 1. Course Layout

C. Time Constraint Obstacles:

The team shall adhere to all timeline constraints as laid out in section six (6) of this proposal. These time constraints are incredibly important as the team has an abbreviated timeline compared to other capstone teams, and other SECON hardware competition teams in the past. The robot must be designed, implemented, appropriately tested, and ready to deploy by March 20th, 2024. Adherence to the timeline outlined in section six is critical as any delay could push the project's completion past the deployment date.

D. Budget Constraint Obstacles:

The robot shall not exceed the budget given to the project by the customer, the Electrical and Computer Engineering Department at Tennessee Technological University, as proposed in section five B of this proposal.

IV. Measures of Success

There are a total of 120 points awarded in each run of the course. This section details how the team plans to receive the most points consistently with primary objectives, and then any extra points with secondary objectives after the primary objectives are successfully completed. The goal of this project is to minimize risk by reducing complexity in order to achieve repeatable results.

A. Primary Objectives

1) Start Recognition: The robot will start autonomously by recognizing the countdown timer's green light. This shall be achieved by using a sensor to detect the green light. At the home course, the robot will be tested and success will be determined upon the robot starting 90 percent of the time the green light is activated. A manual backup system shall also be implemented in case of failure of the sensor.

2) Course Completion: The robot must complete the course by using line detection to determine where the yellow line is along the center of the course. It must average a minimum speed or 0.111 feet per second. The competition is completed upon pushing the launch button. Thus, the robot will push the stop button using some spring-loaded contact that will properly depress the button 95 percent of the time during testing. For course navigation, the robot also will be balanced properly in order to climb the hill and have enough power to ascend quickly up the hill. The robot must climb the hill 95 percent of the time during testing.

3) Arriving at Thruster Zone and Crossing the Crater: For the robot to successfully arrive at the Thruster Fuel Assembly Zone, it must be fully across the crater. A robot unit counts as an autonomous unit capable of self-movement. Dropping just a part of the robot across the crater is not considered a robot unit. The robot shall cross the crater by slowly driving down into and then up out of the crater. This will be accomplished by having a sloped front of the tank treads that move the robot, as well as having the entire unit properly weighted. This will allow for it to climb up out of the crater. The robot must successfully cross the crater 95 percent of the time during testing.

4) School Spirit Display: The robot can display team or school promotion in the thruster assembly zone. The school spirit display must successfully be displayed at least 50 percent of the time that the robot reaches the thruster assembly zone during testing.

B. *Secondary Objectives*

1) The Package Assembly: If all of the primary objectives have been accomplished where the robot can consistently complete all primary objectives across multiple operations, the team shall focus on the secondary objective of moving the large boxes to their specific zone of the course. If this is the case, the following shall statements will be adhered to.

-The robot shall collect the large boxes at the beginning of the course using a beam or immobilized arm to sweep the objects along behind the robot and deposit them in the drop-off zone. This shall successfully occur 80 percent of the time during testing.

V. Point Strategy

A. *Primary Objectives Points*

Five points are awarded for movement in any direction. This is the most basic of the primary objectives that are awarded points.

Autonomously recognizing the start of the timer is awarded another five points.

Completing the course is awarded points based on the time in which the course is completed for a maximum of 30 points. Points are awarded based on the schema that 5 points will be deducted for each additional 15 seconds. Thus, 1 minute 45 seconds (1:45) or less = 30 points, 1:46 2:00 = 25 points, 2:01 2:15 = 20 points, 2:16 2:30 = 15 points, 2:36 2:45 = 10 points, 2:46 3:00 = 5 points, above 3:00 = 0

Successfully arriving at the thruster assembly zone is awarded 20 points.

Successfully displaying team spirit in a dynamic way is awarded 10 points.

B. *Secondary Objective Points*

Each package (small or large) placed in the package delivery zone (blue area) will be 2 points. An additional 1 point is awarded for a large package being placed in the blue zone. An additional 3 points are awarded for small packages being placed in the red zone. These colored zones can be seen in Figure 1 in the previous section. Points are not awarded unless packages are fully within their designated zones, even if only slightly misplaced. This makes for a total possible points of 30 points, 5 large boxes at 3 points possible per box, and 3 small boxes at 5 possible points per box.

VI. Project Resources

The design, planning, implementation, and testing of the SECON robot require time, materials, tools, and personnel with specific sets of skills. The time is outlined in section VI. Tools will be provided by the Tennessee Technical University Electrical Engineering Capstone Lab and the members participating in this project. The personnel includes:

- Callie Battenfield
  - C++ Programming
  - Microcomputers
- Caz Bilbrey
  - Excel Programming
  - 3-D Printing
- Liam Counasse
  - Auto-CAD
  - Assembly Programming
- Adrin Jackson
  - Hardware Applications
  - Power Analysis
- Conor Orr
  - Python Programming
  - KiCAD PCB Assembly

A. *Design Methodology*

The team follows a design methodology that is parallel to the Measures of Success as discussed in section 4 of this proposal. The team will select priority tasks and subsystems to delegate to individual team members or a group of members. These tasks focus on the primary functions of the robot such as motor function, steering, autonomous driving, and sensory inputs. These priority tasks focus on designing, building, and debugging the robot with the capability to complete the primary objectives and then developing the robot to complete all secondary objectives if there is enough time and money left to lend to the successful implementation.

B. *Budget*

The proposed budget for this project is outlined below. It contains an estimate of the minimum and maximum parts required, as well as the minimum and maximum costs of each part. This is in no way an exhaustive parts list and does not reflect the parts the team may need in order to complete this project. The budget the team is proposing can be seen in Figure 2 below.

SECON 2024 Budget

ITEM	QUANTITY		UNIT COST		SUBTOTAL	
	MIN	MAX	MIN	MAX	MIN	MAX
MOTOR SYSTEM						
BRUSHLESS MOTOR	2	6	$5.00	$25.00	$30.00	$150.00
SERVO MOTOR	1	3	$10.00	$20.00	$20.00	$60.00
POWER SYSTEM						
SWITCH	3	4	$1.00	$5.00	$3.00	$20.00
TOGGLE	1	2	$1.00	$5.00	$3.00	$10.00
WIRE	N/A	N/A	$20.00	$40.00	$25.00	$40.00
FUSE	1	10	$1.00	$5.00		
CHASSIS						
PLEXIGLASS (LEXAN)	1 SQR FT	4 SQR FT	$10.00	$20.00	$10.00	$80.00
PLA FILAMENT	2	4	$25.00	$75.00	$50.00	$300.00
MISC	N/A	N/A	N/A	N/A	$20.00	$60.00
CONTROLLERS						
MICROCONTROLLER	1	2	$20.00	$40.00	$20.00	$80.00
RASBERRY PI	1	1	$40.00	$60.00	$40.00	$60.00
MOTOR CONTROLLER	2	3	$20.00	$40.00	$40.00	$120.00
POWER CONTROLLER	1	2	$10.00	$50.00	$10.00	$100.00
MISCELLANIOUS						
RGB SENSORS	2	3	$2.00	$20.00	$4.00	$60.00
ROBOT ENCLOSURE CONSTRUCTION MATERIALS	N/A	N/A	N/A	N/A	$50.00	$100.00
Misc Components	N/A	N/A	N/A	N/A	$20.00	$60.00
		RANGE OF SUBTOTAL			$345.00	$1,300.00
		MARGIN OF ERROR = 50%				
		ADJUSTED SUBTOTAL			$517.50	$1,950.00

Fig. 2. Proposed Budget

VII. Project Timeline

- Project Proposal - September 17th, 2023
- Conceptual Design and Planning - October 29th, 2023
- Detail Design Complete - December 8, 2023
- 100% Parts Ordered - December 8, 2023
- Winter Break - December 9th, 2023 - January 11th, 2023
- Implementation Complete - February 25, 2024
- Testing - February 25, 2023 - March 19, 2024
- Spring Break - March 11, 2024 - March 15, 2024
- Competition - March 20, 2024
- Close Out - March 24, 2024 - April 20, 2024

This timeline has been formulated to provide appropriate time for tasks as well as provide as much extra time as possible as a buffer. Breaks in the school year have been built into the project timeline during natural pauses in the project, such as after parts ordering and at the end of the testing phase. However, time during these breaks can be used for additional work if deemed necessary. A detailed timeline can be seen in Figure 3 in the appendix.

VIII. Broader Impacts

The most substantial impact of this project is the consumption of financial and material resources for a robot that is only useful in the single instance of the SECON competition for the year 2024. Afterward, the robot is displayed in a case for a few years and is then eventually deconstructed. The robot could potentially cost northwards of two thousand dollars at the high end of the budget as proposed in this paper, and the materials, while salvageable, will most likely be used only the one time. This impacts the ECE department at Tennessee Tech and the future of TTU at the SECON competition, for if the robot fails to perform well in the competition the project may not be renewed for the following year due to the costs. The environmental impacts, while minor, are still impacting this project as sensitive electronics like a micro-controller or Arduino chips use resources that are non-renewable. Thus, this project generates a significant amount of waste, and ways to limit this should be considered. One way to reduce waste is to be sure the expensive components are easily removable after the competition so future capstone groups can have access to those parts without having to order new ones. Another is to use recyclable filament in all 3D printings for the robot in order to make the chassis and other parts recyclable when the display period is over. A third way to reduce waste is to ensure the team is salvaging other components from storage from the IEEE office and past capstone project leftovers, such as electronic components like resistors and integrated circuit chips.

This project poses a benefit to Tennessee Tech as well. The university will get more visibility from students at other universities and prospective students if the robot performs well at the competition. Having a robot that the university can show off to future and prospective students during tours or events like the spring showcase will help bolster the reputation of the ECE department here at TTU.

Although autonomous robots have the potential to make lives easier, there are some issues involved with them as well. One example is they are limited in how they adapt to their environment. This is because most of the time these autonomous vehicles are designed to carry out a specific task, and some natural causes may occur that the robot was not specifically programmed for and can cause an error and have the possibility to be hazardous. Another issue is that if these autonomous robots are connected to a network they could be hacked through injection and compromise safety.

IX. Conclusion

This project will build on the success of those who have come before it and will work to complete both the primary and secondary objectives as outlined in section 4. The primary objectives will be completed with a high level of consistency before the secondary objectives are attempted, as per the strategy to attain the most possible points in the limited time frame of this project. The robot will adhere to all shall and shall not statements as outlined in this paper, and most importantly will not cause harm to any human life. The proposed budget of 2000 dollars, while subject to change, is the baseline needed for this project and should cover all costs associated with the completion of this project. The project will be completed before the SECON competition in March of 2024 as per the timeline outlined in section 6. The recognition that the success of this project will bring to Tennessee Technological University could have a major impact on the engineering college here, as described in section 7. The goal of this project is a feasible one and will be a successful venture as a project for this capstone team With the proposed strategy, budget, and resources, the challenges of the difficulty of the competition tasks, abbreviated timeline, and broader impacts can be navigated well and in a productive manner.

References

[1] R. Voicu, "Ieee southeastcon 2024 student harware competition rules," accessed 9-6-2023. [Online]. Available: https://ieeesoutheastcon.org/wp-content/uploads/sites/497/SEC24-HW-Competition_V5.6-1.pdf

APPENDIX

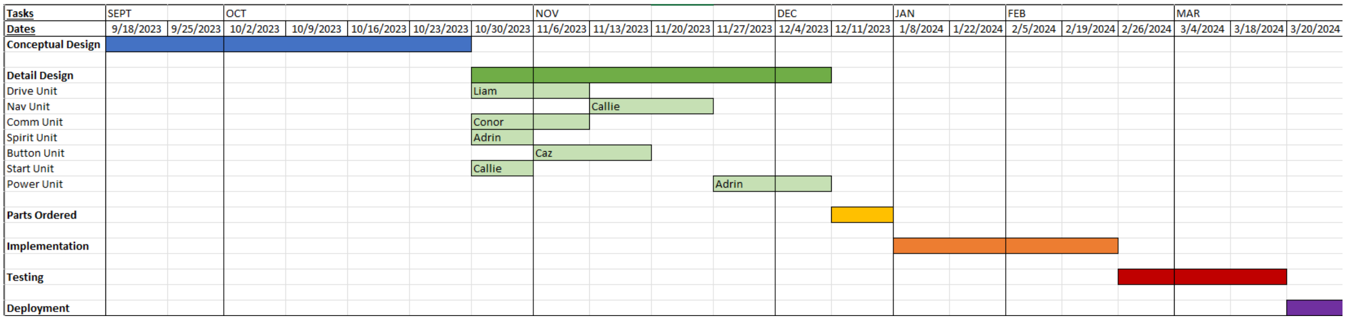

Fig. 3. Expected Timeline