# 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 competition against schools from around the southeastern United States.

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 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 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 objects, transport them down the first lane, and into an unloading zone where the objects are offloaded. The first lane includes a hill that the robot must ascend, traverse, and descend while carrying the objects collected by the start position. After dropping off the objects collected at the start, the robot must make a left turn, collect more objects, and proceed down the second lane. The second lane includes a crater that the robot must cross using a zip line that is installed in the course. The robot must then drop off the second set of objects. To complete the course the robot must push a button that stops the timer for the run [1].

## III. Obstacles and Restrictions

This section will detail the restrictions and obstacles placed on the robot by the rules of the SECON competition rules. It will also detail the obstacles of the course as outlined in the SECON competition rules. It includes the shall and shall not statements of this project. All of these specifications can be found in the rules PDF ass cited in bibliography entry number one, sections 1.2, 1.3, and 1.4 respectively [1].

### 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. It must drive and navigate itself through the course. The only means of non-autonomous operation allowed in the rules is the starting of the robot, which may be a button or a switch that starts the robot. After this, the robot cannot be interacted with by any external force that is not a part of the course. This includes remote control, voice operation, or any other means of control.

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. This includes any arms or appendages that extend as long as they are contained within the cube as established. The rules also state a weight restriction of twenty-five (25) pounds, which the robot is not to exceed.

The robot shall have an emergency stop mechanism installed in case of malfunction or emergency.

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. Any unintentional interference from radar or LIDAR sensors is acceptable.

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 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) 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.

*3) Material Utilization and Removal Guidelines:* The team shall be responsible for any materials they or their robot introduce onto the course. This includes any parts that break apart from the main robot or any smaller units the robot splits into. 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 introduce any materials to the course that require sweeping or vacuuming to be removed from the course. The robot is allowed to deploy materials to the course for strategic maneuvers, such as laying down a bridge, in order to complete the course.

The robot shall not have any projectiles or turn any course objects or robot materials into projectiles. Items or materials may be dropped in a controlled manner by the robot.

### *B. Course Obstacles:*

The robot shall operate only within the confines of the course. These confines and the course itself are described in this section. The course exterior is a sheet of 3/8-inch-thick plywood that is a four (4) foot by eight (8) foot rectangle. The outer border of the course is 1-inch thick white-wood boards that are 4 inches tall and are assembled around the perimeter of the plywood base. The course includes a ramp with a height of 3.5 inches at an incline of 22.5 degrees. The robot shall climb this ramp to reach the landing area at the top. The ramp top landing is 16.5 inches long. The ramp to the zip line is 3.5 inches tall, with a top area of 14.5 inches. The zip line is 3/32 inches in diameter and leads to a landing area that is 13 inches long.

There are a number of zones and areas within the course as well as the areas described above. The thruster assembly area is an 18.6 inch by 22.875 inch rectangle in which the robot must assemble the thrusters for the rocket. The package pickup zone is the starting area and where a robot may collect packages to be delivered to the package delivery zone, which includes a large and small package placement area within. The fuel tank pickup zone is where robots may collect fuel tanks to be delivered to the launch pad. These tanks must be delivered in an upright position.

The course also includes a start light and a doomsday timer. The start light is a green light that signals the start of a run and the start of the doomsday timer. The robot shall recognize this light and start itself upon receiving the start signal from the light. The doomsday timer times each run and points are awarded based on completion time for the course.

A picture of the course is shown in Figure 1.

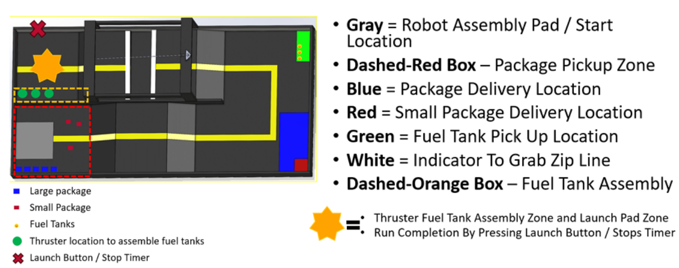


Fig. 1. Course Layout

### *C. Competitor/Instructor General Obstacles*

This section will list how the team will interact with each other, the other teams, and the judges before, during, and after the competition. The team shall show respect to all involved in the IEEE SECON hardware competition and will have respect for the tools and materials made available to them during this time. The team shall follow the spirit of fair play, and shall not cheat, steal, or sabotage other teams or their equipment. The team and the robot shall not shine light onto or into other playing fields at any time, and may not shine light into their own playing field unless the robot has its own self-illumination mechanism. The team shall adhere to the event schedule and be punctual to all competition functions. The robot shall undergo and pass a technical inspection that ensures the robot meets all specifications and safety requirements. The team shall follow the event's code of conduct, knowing that a violation of this code may result in expulsion from the competition. The team shall understand that the Judges' decisions are final and are not to be debated due to time constraints.

### D. *Time Constraint Obstacles:*

The team shall adhere to all timeline constraints as laid out in section six (6) of this proposal.

### E. *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) Movement:* The robot shall display movement in any direction for five (5) points. This movement will be autonomous and obvious.

*2) Start Recognition:* The robot shall start autonomously by recognizing the countdown timer's green light. Doing so will be awarded 5 points.

*3) Course Completion:* The robot shall complete the course. The competition is completed upon pushing the launch button. Pushing the launch button will stop the timer. No additional points can be accumulated after pushing the launch button, and the robot shall stop. Points are awarded based on the time the robot pushes the launch button as described below.

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

*4) Arriving at Thruster Zone:* The robot shall successfully arrive at the Thruster Fuel Assembly Zone. The successful arrival at the thruster fuel assembly zone is 20 points. A robot unit must be fully across the crater. A robot unit counts as an autonomous unit capable of self-movement. Dropping a part of the robot across the crater is not considered a robot unit.

*5) School Spirit Display:* The robot shall display team or school promotion in the thruster assembly zone. All teams are encouraged to display their logos, sponsors, and/or university. The display must be shown before pushing the launch button but after thruster assembly.

### B. *Secondary Objectives*

*1) The Package Assembly:* 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.

## V. 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 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

## VI. 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.

## VII. Broader Impacts

One of the benefits of an autonomously driving vehicle is that it can help reduce the tedious and overbearing tasks of humans in a factory setting. In industrial settings, an autonomous vehicle can optimize a load-carrying task such as quickly and efficiently transporting packages from one end of the factory to another. This also has the potential to reduce injuries to workers by doing most of the load-bearing transportation and could potentially increase productivity. Another benefit of autonomous vehicles is enhanced safety. They can operate in hazardous environments, such as search and rescue missions in disaster-stricken areas, or inspect dangerous infrastructure like nuclear facilities. Removing humans from dangerous situations reduces the risk to human life. While the initial investment in developing and deploying autonomous vehicles may be substantial, the long-term cost savings can be significant. These vehicles are able to operate 24/7 without breaks which can reduce labor costs. They also require minimal downtime for maintenance and repairs.

This project has the potential to help create a greater interest in autonomously driving vehicles for use in the future, which in turn can also create more jobs for those in the automotive engineering field. Projects such as the IEEE SECON competition have the ability to attract more students with interests in engineering fields.

This project poses a benefit to Tennessee Tech in a few ways as well. Businesses could see the project from Tennessee Tech University and invest in equipment or an autonomous vehicle program at Tennessee Tech. In turn, this could help their businesses by having more future engineers who are qualified to work on autonomous vehicles. Tennessee Tech could also utilize autonomous vehicles to give live virtual tours around campus to students who might be considering coming to Tennessee Tech.

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.

## VIII. Conclusion

This project will build on the success of those that 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.

## 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

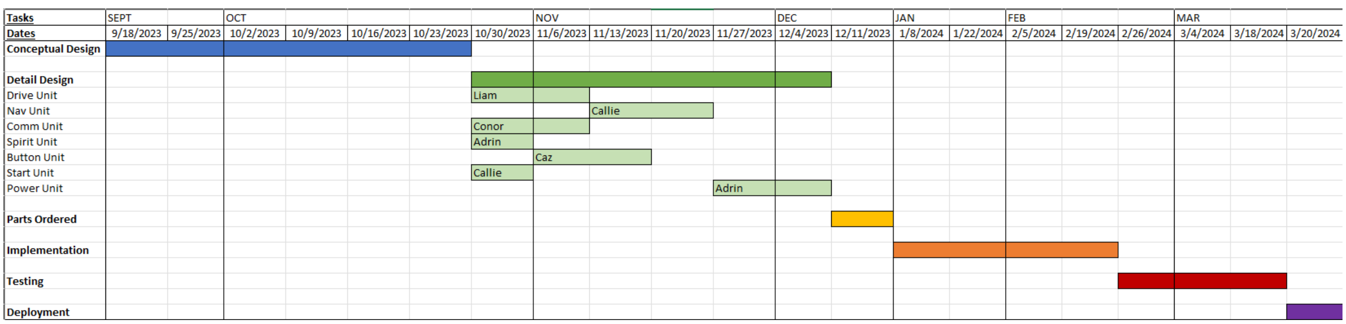


Fig. 3. Expected Timeline