Conceptual Design Phase 1

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I. Introduction

A. Problem Definition

The Southeast Conference (SECON) is held annually by IEEE in different places around the southeast United States. In 2024 the conference will be held in Atlanta, Georgia on the week of March 20th. As part of the conference, there are several competitions that students from many different universities are allowed to compete in. One of these competitions is the Student Hardware competition where students build autonomous robots to complete specified tasks that change from year to year. This year the competition is themed around a rocket launch where humanity's fate is determined by the successful launch of the rocket to resupply an orbital defense network. The robot must autonomously navigate a U-shaped course within a 3-minute time limit. There are several tasks contained within the course, including climbing a hill, crossing a crater, and moving rocket parts to the launch pad.

There are several constraints placed on the robot by the competition rules. The first and most important constraint is that the robot must operate autonomously, meaning it can have no operation commands sent externally to the robot. To meet this constraint the robot shall be capable of making decisions based on the course conditions. The second constraint is that the robot must fit within a one cubic foot area at the start of each competition run, and it shall not weigh more than 25 pounds, however, after the start of each run the robot may expand to any size that fits within the course bounds. The team has also specified that the robot shall stay as one whole unit throughout the run, and not split into multiple parts. Finally, the robot shall not cause any harm to the course or harm to any bystanders. [1].

II. Background

A. Conceptual Design

The design process began by identifying key competition rules and point-gaining tasks. The scoring schema played heavily into the first design phase of this project. This was broken down into how achievable certain points were, and whether or not it was feasible to aim for those point categories. This lead to a design that ignores the riskier tasks and aims for quick course completion over anything else. The team has elected to ignore the specific placement of the boxes and instead has opted to put them in the larger, less specific drop-off area. The team has also decided to ignore the thruster assembly section as the movement and assembling of the thruster pieces would be extremely risky and time-consuming both during the competition and during design. Instead of focusing on these areas, the team shall: focus on areas of the robot's construction that are integral to being as competitive as possible, minimize risk, and prioritize consistent results.

The robot design is split up into seven main sections. The chassis and drive train systems will support the robot's movement. The power supply system will deliver power to all the robot's functions. The main controller will act as the brain of the robot, directing signals from other systems. The team spirit display will show team spirit at the designated times to earn bonus points in the competition. The button press system will be the system to stop the timer to complete the run of the course. The box sweeping mechanism will collect and deposit the large boxes into the overall drop zone. Finally, the start recognition system will start the robot on each course run. These systems will be outlined in further detail later in this design phase paper.

III. Ethics and Standard Considerations

A. Ethical Considerations

The team commits to transparency during this project. This transparency is to the members of the team, the instructor/advisor, and the customer. This robot must be designed with the intention to do no harm to any person/persons and/or physical property. The robot will not infringe upon the intellectual property of others through its design or programming. This team will commit to ethical practices and interactions internally and externally. This includes reporting progress honestly, not infringing upon the ideas of others without permission to use those ideas, and the team will not infringe on copyright or trademark laws. The other main ethical constraint in building this robot is the use of recyclable materials. The robot shall be designed in such a way that 35 percent of its parts are recycled. This is to improve the environmental and financial cost of constructing a robot with a single, unique purpose. The other way to cut down these costs is that the large electrical components shall be designed to be easily removable, so that they may be harvested and repurposed in future projects undertaken at TTU.

B. Standard Consideration

The standards of this project fall under the jurisdiction of the CPSC, the Consumer Product Safety Commission, a

United States government commission. The team commits to following the standards. The robot will be accessible to the students participating in the project, the customer, the instructor/advisor, and potentially others after the completion of the project. This level of accessibility requires that the robot meet the electrical and mechanical standards. The Electrical safety standards are as follows: live electrical components shall be enclosed. Motors, transformers, and similar components must be secured. The robot must be GFCI, Ground Fault Circuit Interrupter, protected, The mechanical safety standards are as follows: no pressure over 5 psi, moving components with the capability to harm must be enclosed, and parts that have the potential to become projectiles must be secured [2]. The robot must also adhere to standard ISO 10218 which covers the safety practices for the construction of non-industrial robots. This states that all powered moving parts shall be covered by stationary or mobile guards. It also states that no part of the robot shall move faster than 1 inch per second except for the drive systems, which are limited to 1 foot per second. The robot must also have an emergency shutoff that leaves all mobile components in the de-energized position. This standard also states that a robot must not have any single fallible piece that leads to the failure of a safety function, requiring backups for all safety functions [3].

IV. Overall Design

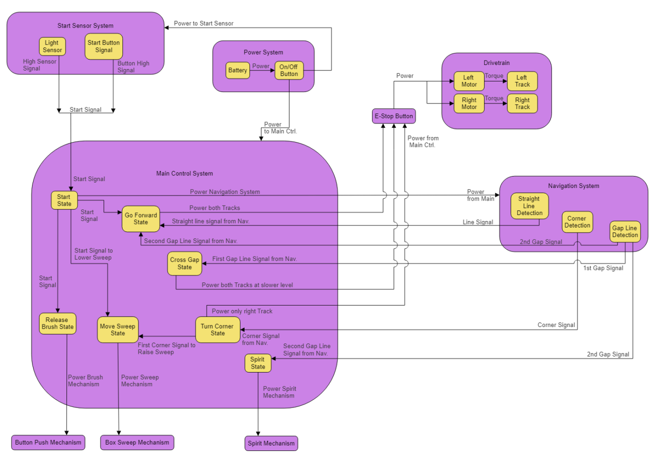

Fig. 1. Full Block Diagram

The overall design of the robot is depicted in Figure 1. It consists of a chassis and drive train, a power supply, a main controller, a start recognition system, and a navigation system. The power supply feeds into the start recognition system and the main controller. The start recognition system feeds into the main controller. All the other systems are fed by the main controller, and the navigation system feeds back into the main controller. The details of these connections will be outlined in the following sections of this paper.

V. Chassis and Drive Train

The chassis of the robot will be designed and implemented by the Mechanical Engineers of the team and will be discussed in more detail in their reports. The drive train as shown in Figure 2 will consist of two motors that each drive a track on the robot. These tracks will be the propulsion system of the robot. The drive train will receive input from the main controller to determine if the robot should turn or go straight, and at what speeds the motors should operate. However, as per ISO 10218, the power to the drive train must be wired through the emergency stop, this is to allow the motion of the robot to be ceased at any point by depriving the drive train of the power for the motors [3]. This is also a requirement of the Hardware Competition rules [1]. If the emergency stop is not engaged power will be provided from the main controller at varying levels, depending on signals from the main controller, to either one motor and track or to both motors and tracks at the same time. This will allow precise control during all points of the navigation of the course.

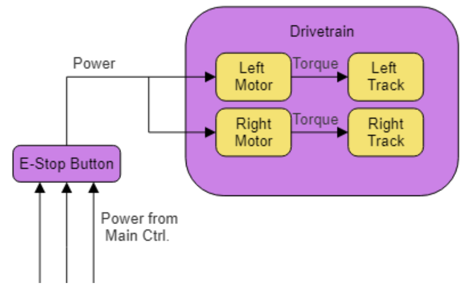

Fig. 2. Drivetrain Block Diagram

VI. Power Supply

The power system will consist of a battery that provides power to the entirety of the electrical systems in the robot. The battery will be able to supply the robot with power at full load for at least an hour of operation. This is to cut down on the charging time and the amount of batteries the team will need to purchase to power the robot through multiple consecutive runs through the course. The battery type will be determined in the detailed design. The battery will feed power directly to an on-off switch that will then send power to the rest of the robot. This is so that the battery can be left in the robot while not in use and not be draining power from the battery. From this switch, power will be sent to the start recognition system and the main controller for the robot, as depicted above in Figure 3. The main controller will then send power to the rest of the robot's systems, as detailed in the main controller section of this paper.

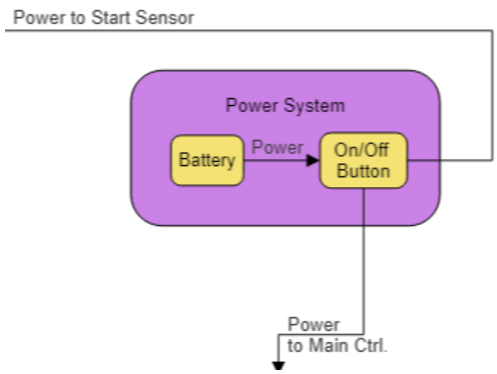

Fig. 3. Power Block Diagram

VII. Main Controller

The main controller of the robot, as depicted in Figure 4, will receive and distribute signals to and from every other system in the robot. The main controller will receive the start signal from the start sensor subsystem as detailed in that section of this paper and that signal will engage the start state inside the main controller. The start state sends power to the navigation system and it sends signals to the go forward state, the move sweep state, and the release brush state. Powering the navigation system allows for the main controller to receive input from the navigation system to multiple different states within the main controller.

The go-forward state sends a signal to the drive train to move the robot forward by driving both tracks. This is triggered for the first time to move the robot off of the starting pad to where the navigation system can detect the yellow line. It is then triggered when the navigation system detects a straight line and is turned off when the navigation system does not until it receives the signal from the navigation system that the robot has crossed the crater. It will then be active until the robot is shut down.

The release brush state upon receiving power from the start state will send power to the brush mechanism, which is the button presser system. This will release the button-pressing mechanism for it to be able to push the stop button at the end of the run.

The move sweep state will send power to the sweep mechanism to lower and raise the arm that will sweep some of the boxes into the deposit section of the course. The signal to lower the arm will be sent upon receiving power from the start state, and the signal to raise the arm will be sent when the signal from the turn corner state is received to deposit the boxes in the appropriate area.

The turn corner state receives a signal from the navigation system that a corner has been detected and then sends a signal to the drive train to make the turn. The first time it receives the signal from the navigation system to turn the corner it will send a signal to the move sweep state to raise the arm of the sweep mechanism.

The cross-gap state will receive a signal from the navigation system that will tell it when to start the cross-gap state when it reaches the white line perpendicular to the yellow line. This will initiate an analog signal that controls the motor speed to slowly approach the decline in the gap and continue to move until the robot reaches the end of the course.

After the robot reaches the second line across the gap, the signal from the line reading sensors will detect the second line and send power to the team spirit mechanism which will be a unique representation of Tennessee Tech University. At this point, the main controller is no longer needed and will simply allow the robot to move across the board to press the button, once pressed the run will end and the robot will be shut down by the team via the emergency stop or the on-off switch on the power supply.

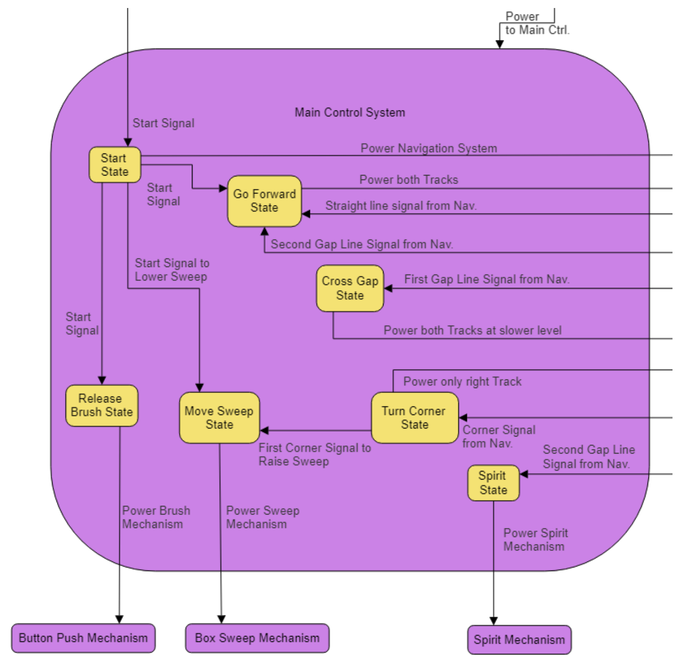

Fig. 4. Main Control Block Diagram

VIII. Start Recognition

The start recognition system is the initial trigger for the autonomous operation of the robot. It receives power from the power supply upon turning on the robot with the on-off switch. It sends a signal to the main controller on one of two conditions. The first is when it senses the green start light that signals the start of the run, and this sends a signal to the start state of the main controller. The second is a push button that sends the same signal to the start state of the main controller, but this is only to be used if the light sensor does not start the operation of the robot.

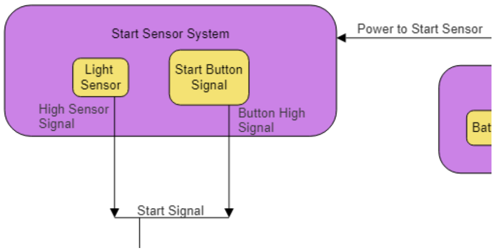

Fig. 5. Start Sensor Block Diagram

IX. Navigation System

The Navigation System serves as the central control hub, responsible for directing the robot as it traverses its predefined course as shown in Figure 6. Its operation begins with the reception of the start state signal from the micro-controller, signifying the system's readiness. Once initiated, the Navigation System tracks a distinctive yellow line across the course and sends a signal to the micro-controller. When the robot reaches a turn in the yellow line, it communicates with the micro-controller, directing the robot to execute the turn. The navigation system is continuously monitoring the line sensor to ensure precise completion of the maneuver. After the turn, the robot straightens itself for the next curve. At the first gap line, the Navigation System sends a signal to the cross-gap state of the micro-controller. Upon detecting the second gap line, the line sensor relays data, prompting the Navigation System to send signals back to the micro-controller: one for regular forward motion and the other to activate the 'Spirit State.' The robot continues its journey until it has navigated the entire course, receives a shutdown command, or runs out of line to read, ensuring precision and efficiency in its navigation tasks. This robust design framework lays the foundation for the successful execution of the robot's course traversal.

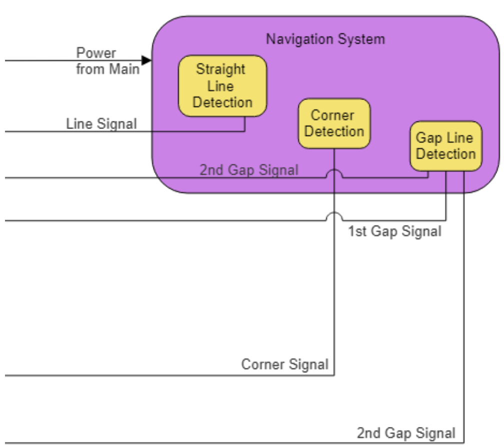

Fig. 6. Navigation Block Diagram

X. Analysis

For our drive train, we will be using DC motors. In order to validate the operation of our motors we can take the specifications and parameters of our selected motor and model the motors in LTSpice. Then once modeled we can give a range of different values for the load and the input voltage that will show the response of the motor to different input conditions.

We will also use stepper motors as our actuators for some of our control systems such as for our sweeper arm that will collect some of the boxes. In order to simulate this we can create an equivalent analog circuit in LTSpice or Matlab and test different duty cycles on the stepper motor. This is because it requires different pulse width modulations to change the direction and angle of the arm attached to the stepper motor. For the arm/sweeper that is attached to the stepper motor, we can determine the length by analyzing the SECON obstacle documentation and basing our arm/sweeper length from the center of the course where our robot will be placed, to the right side of the wall.

Our power system for the whole robot can be modeled in LTSpice by modeling our systems and sub-systems as a load and doing a transient analysis of how much power our system draws over a certain period of time at maximum capacity. Modeling our system at maximum capacity or full load gives us an idea of what type of amp hour and voltage our battery needs to be to support the full system.

XI. Appendix

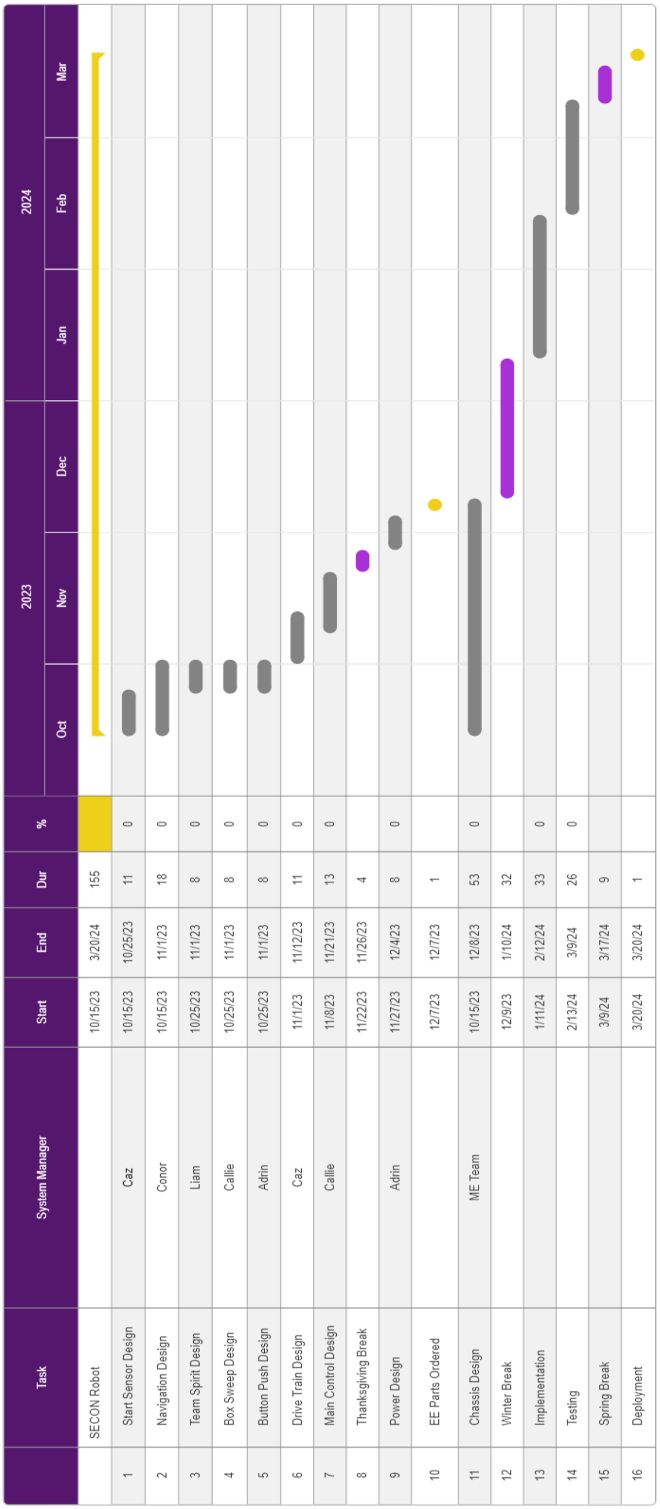

Fig. 7. Design Timeline

References

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[2] CPSC, "The dangers of electric toys," accessed 10-3-2023. [Online]. Available: https://www.bing.com/ck/a?!&&p=06377dcc098b2afeJmltdHM9MTY5NjI5MTIwMCZpZ3VpZD0wNDU5NzNiNi1iNDI3L ptn=3&hsh=3&fclid=045973b6-b427-6a0d-04e4-61d7b50b6b3b&psq=cpsc+sfatey+alert+the+dangers+of+electric+toys&u=a1aHR0cHM6Ly93d3cuY3BzYy5nb3YvczNmcy1wdWJsaWMvMjg3LnBkZg&ntb=1

[3] ISO, "Iso 10218," accessed 10-3-2023. [Online]. Available: https://cdn.standards.iteh.ai/samples/51330/c008a0a974584a5098400991b63eaae9/ISO-10218-1-2011.pdf