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Decatur Heritage Christian Academy

Eagles Robotics Innovative Systems (E.R.I.S.)

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# Executive Summary

The overarching goal of E.R.I.S. robotics is to improve work efficiency on the demolition field. To do this, we have created a two-drive system robot that is also capable of autonomous movement, and we have decided to name it the Demolition Roomba, or the “Doomba.” By having semi-frequent meetings each Tuesday and Thursday for weeks, we developed ideas for our robot’s primary functions. Our strategy is plain and simple: we are going after the highest point values first. Our robot includes three separate claspers for reinstating light poles, an arm with friction tape to pick up bundles of pvc pipes, and a scoop to move concrete blocks, an air compressor, and most importantly, a condemned tower.

 Our team focuses on two different aspects, both the engineering and marketing sides of the BEST competition. The engineering team focuses on the building, testing, and programming of the robot, and the marketing team focuses on the Marketing Presentation, the Engineering Notebook, t-shirt and robot design, and booth design. Our team is spread across these two areas, which constantly pass ideas back and forth, and we also include diverse students ranging from grades 7-12, male and female, and even a foreign exchange student.

Figure 1: DOOM-BA

Our goal is to advance to the next step of the competition at Auburn; we want to obtain a ranking that schools as small as ours do not normally reach. Our goal is to be the underdogs that conquer the competition.

# Research Paper

The world today is full of crowded streets and expanding businesses. Because of the need for space, many old buildings and structures are torn down to be replaced. The two major reasons leading to demolition of buildings are if it is condemned or a homeowner wants to redevelop it. Commonly in these old buildings there are a lot of hidden dangers for the workers assigned to bring them down. The old southeastern towns of the United States can be especially harmful, because of fragile architecture and hidden or covered up tunnels and basements. The focus of the BEST Robotics game this year is to teach and find innovative solutions to these demolition based problems and prioritize safety for these crews. The most common causes of these demolition accidents are structure failures, hazardous liquids and gases, and electricity paired with potential for fire and water. The priority of E.R.I.S. Robotics is to create a robot that faces these tasks and prevents them; solving them both efficiently and consistently.

To begin with, a leading danger of the crew’s work environment and prohibitor of their progress is previous or unknown architectural damage or failure. Architecture is not always reliable in the long run because the designer cannot know what might strike the building, whether it be storms or just material normal “wear and tear.” Even renowned British architect Norman Foster states, “As an architect, you design for the present, with an awareness of the past for a future which is essentially unknown” [1]. Designers try to use past experiences to influence the shape of their structure, however, what will eventually happen is impossible to predict. This creates dangers for demolition workers that hurt their progress, and slows down work time significantly because of consistent safety meetings that have to be held an upwards of 10-20 times per day.

To combat this, the first place the workers of Johnson, Bates, and Legg Construction would look is to find the original builder to see the weak points in structure. Unfortunately, the majority of the time there is no way to retrieve the original building plans. This leaves them with the process of examination which, at least for their company, has led to no fatalities so far. A system of documentation in a place like city hall or a local courthouse could easily solve this problem by devising a small department for keeping building records. Also, the coming presence and expansion of self automation in robots could allow for the workers to not only stay out of harm's way, but additionally, it would allow for quicker inspections because of the removed risk and safety factors.

Another potential form of severe damage in buildings is hazardous liquids and gases. The main form of this waste being found in old buildings is from hydraulic elevator fluid. This petroleum based solution has been predominant in elevators for over 60 years [2]. After years, the acid builds up under the elevator, leaving gallons of waste, and it has to slowly be drained, which is very time consuming. This also leaves a large window of time where the oil mist could be inhaled, which can cause damage to airways and lungs [3], and a worker who is exposed to it by touch experiences weakness in hands while any accidental ingestion of it can cause death [4]. With more common medical dangers, such as asbestos and mercury, the demolition site quickly becomes a very dangerous field of work.The technology to combat these problems was made possible by the HAZMAT (hazardous materials) suit. Modern civilian hazmat suits took development in 1940 [5]. This protective gear, created originally to defend U.S. soldiers in World War II, allows for safe excavation of this waste. Demolition crews also take time to make sure that every homeless person taking refuge there is out before they begin to tear it down. They have to take concern about other people being present and being exposed to these chemicals and fumes, and their job includes the guaranteed protection to move everyone out. Finally, the demolition crews also use any form of machinery whenever it is possible. They focus on putting the risk factor on the machine, rather than allowing more sources of damage to workers. Human lives are not replenishable, but machinery can be replaced.



Figure 2: Removal of Hazardous Waste

Furthermore, demolition is delayed and hurt by potential for electrical problems, water damage, and future fires. The very first thing a demolition company does is to make sure that both the power and water are shut off completely, as told by Johnson, Bates, and Legg Construction. The property owner and the city both check to ensure that it is turned off, and ensure it in the form of a Demolition Certificate [6]. Even though this is certified by the city and the owner to be true, the demolition company still has to be safe and check for certain problems. For example, previous water leakage could cause walls or floors to be unsturdy and collapse. Also, a blown fuse, exposed wires, or waterlogged outlets or power boxes can lead to electrocution, and/or a potential to start a fire.

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Figure 3: Example Demolition Request Permit

Through careful inspection, many of these can be avoided, but sometimes it is impossible to see. This is why, going towards the future, using robots as scapegoats to take the falls is a breakthrough idea. Not only do they have the potential to save lives, but they also are expendable and could be built to work more efficiently than humans. Humans already rely on safety in using machinery to do tasks that would harm them physically, so controlling a robot, using what they have already been taught to do, would allow the job to be done safely. The challenge comes in designing a robot that could work more efficiently than normal, and that is what is being proved further into this Engineering Notebook.

To summarize, demolition is overall a risky form of industry. Over time, buildings wear down, hazardous material begins to take form, and electrical and water damages uncontrollably come and go. Technology has advanced to a degree to protect humans in their job, with both the HAZMAT suit and heavy machinery, but the dangers are still prominent. A replacement for humans would preserve the value of life, and going into the future, an efficient robot can ensure that. The speed at which demolition is completed and the environment for the workers can both be improved with the coming age of robots.

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# Implementation of the Engineering Design Process

In deciding our development program, we used an engineering design process which is shown below in Figure 3. The steps we followed in their specific order are to ask, imagine, plan, create, experiment, and improve. To highlight our use of the Engineering Design Process, we describe our approach for the 2 major stages of our robot development: 1) Initial Design, 2) Development of Autonomous Mode.

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Figure 4: ERIS Robotics Engineering Design Process

## Initial Design

The first step to our engineering process is to ask. We ask what needs to be done to start formulating a basic idea based on both goals and restrictions. The need of our robot is to target the largest point values on our optimal route which are the autonomous retrieval of the pipe bundle and placing the light poles. Our justification is further described in the analytical evaluation section.

Our second step is to imagine. This involves taking in opinions on how to solve a certain problem. By looking into the proportions of the playfield and the functions our robot would need, we viewed what functions it would need to perform an autonomous retrieval of pipes, load that pipe bundle onto the trailer, and place light poles in the bases. This set of our team’s ideas are further discussed in the brainstorming section.

Our third action is to plan. We did this by brainstorming how to put the ideas to use. We decided to use a scoop to easily and autonomously pick up the pipe bundle (we would also use it if we had extra time to move more debris, including the tower). Additionally, we used our long pole system to pick up the pipe bundle and balance it on the trailer. We also used claws to grip the light poles, and along with the spotter, could easily drop the lights into place with a single press of a button.

Our fourth initiative is to create. We are establishing the design for physical use. To create the robot we used a combination of a pvc frame with wood layer on top, cut out to have our scoop built into the robot, and we used our motors for two rear wheels that solely drive the robot (a two wheeled system) and for our long pole arm, that will pick up the pvc bundle.

Our fifth procedure is to experiment. We used trial and error of design to reach a certain standard. Our practice led to three main challenges. First, we lost traction in our wheels when we moved on top of the tape. Second, we were losing time moving counterclockwise around the field because our maneuverability was hindered since our light pole holder was on the opposite side of the robot than the bases. Finally, the light poles kept sliding out of the claws because they were not compressing around the pipes tight enough.

Our sixth and final step is to improve. We work on redesigning to reach a new achievement of function. To fix these problems, we redesigned our robot to fix: 1) our robot’s traction by putting grips around the wheels, 2) our route by going clockwise to allow for easier set up of the light poles, and 3) we made our claws compress tighter to hold the poles.

## Autonomous Mode

Our initial design was focused on developing movement and the physical functions of the robot. Our next question was, how do we develop autonomous functionality? Our initial design decision was to use the square cutout to surround the pipe bundle while in autonomous mode, however, our team had to develop a strategy for lining up and exiting from the autonomous zone.

Our team imagined multiple ways that our autonomous mode could be implemented, which included various button combinations on the controller and the idea of holding down a single button to activate autonomous mode. After playtesting, our team also realized that having the robot enter the autonomous zone, collect the pipe bundle, and then turn left was the preferred method.

Our software team planned and created the autonomous functionality using RobotC. The driver would line up the robot, then hold down the right trigger for 3 seconds (while announcing to the judge they are going autonomous), which activates the autonomous mode.

Once the autonomous function was created, we had to experiment with the length of the robot’s first forward movement, degree of the left turn, and it’s final straight movement. We used stopwatches to identify how long each phase should roughly take and then furthered experimentation by changing the code values until the best solution was found.

We continued improving the autonomous function and found that we needed to go forward for 2.5 seconds, turn left for 1.4 seconds, and then continue going forward for 2.5 seconds.

# Brainstorming Approaches

Our first priority that drove the basis of the robot’s design is improving the safety of the demolition crew. By finding out how to fix these many construction/demolition site challenges in under three minutes, we can allow for some extent of real life reform to occur to increase safety overall for workers. We began our brainstorming meeting by looking at the playfield and analyzing our requirements, including: putting up light poles, clearing and sorting debris, knocking down and cleaning up the resulting mess of a tower, setting up fences, and autonomously lifting a pvc pipe bundle and balancing it on a trailer.

Originally, our plan involved a tube-like claw that would compress around the tower and carry it to the debris zone. However, because of height limits and the general unsteadiness of the tower, it made the goal of lifting it unrealistic.

Additionally, we considered having a retractable claw that would pick up pieces of debris and move the light posts one at a time, but it would waste too much time to pick up each piece individually. We ended up abandoning these strategies, and the form of our robot started becoming clear.

Our solution ended up putting the focus of the design of the robot to work by using our spotter and the ground of the playing field to its advantage. For example, we are planning to have our spotter load the light poles into the robot's three “claws,” so they will be carried at a certain height, just above the base of the light pole, to be easily dropped into place.

Additionally, we are taking advantage of using the general ground by sliding both the tower and the debris with the robot, so we will not have to make use of a scoop that can easily get caught and/or fracture.

Furthermore, we inserted an autonomous command for the robot to move toward the pipe bundle and push it into a carved out gap, which has been made wide enough to have some marginal error and still work efficiently, and turn right 90 degrees to move out of the autonomous zone.

We then will reposition the robot and use an extendable dowel with friction tape to pick up the pvc bundle, as to limit any chance of dropping the pipe bundle before reaching the trailer. In our team meeting, we also discussed the importance of balancing the pipe bundle on the back of the trailer instead of the front because of the weight distribution made possible by the placement of the trailer wheels.

Our biggest and most heavily focused on agenda, however, was to make the robot easy for everyone to drive, no matter how much previous experience they may have had. To do this, we focused on limiting the number of buttons needed for commands, and even created two separate driving functions for people to decide which set of commands they found easier to use.

# Analytical Evaluation of Design Alternatives

## Analytical Evaluation of Scoring Opportunities

Using the group’s brainstormed ideas, we began analytically evaluating the feasibility and scoring opportunities that each design would give. First, our engineering team looked at the feasibility of each design.

|  |  |
| --- | --- |
| Design | Feasible? |
| Large Claw | Yes |
| Vertical Tube | Yes |
| Long Pole | Yes |
| Pushing Cutout | Yes |
| Light Pole – Removable | No |
| Light Pole – Claw | Yes |
| Autonomous | Yes |

The only design eliminated during this process was the removable light pole, which was unable to let go of the light pole once the light pole was put into the base. The other designs were feasible, so we began putting focus on which designs offered the highest amount of possible points.

|  |  |  |
| --- | --- | --- |
| Design | Possible Scoring Opportunities | Total Scoring Possibility |
| Large Claw | Moving all debris to dumpster/trash pile |  |
| Vertical Tube | Moving top half of tower to trash pile |  |
| Long Pole | Picking up pipe bundle and fence posts |  |
| Pushing Cutout | Pushing tower and cement blocks to trash pile, pushing air compressor to safe zone, pushing pipe bundle out of unsafe zone. |  |
| Light Pole – Claw | Dropping 3 light poles into bases |  |
| Autonomous | Autonomously retrieving pipe bundle |  |

After identifying each different potential route and outcome, we came up with our solution to achieve the most points. Based on these standards and our scoring analysis, we decided on using 4 parts: the long pole, pushing cutout, light pole – claw, and autonomous mode. This design would ultimately remain to end up as our final robot as well.

Lastly, we also considered the driving conditions, and since there are many obstacles scattered throughout the field, including trees and the lamp bases, we decided to use smaller wheels on our robot. This would not slow us down, but it would allow us to have more precise movements with every touch of the joystick. Our goal is to focus on speed and consistency, and our ideas constantly develop towards that goal, reaching better heights with each new implementation and addition.

## Analytical Evaluation of Robot Design

In addition to our scoring opportunities, we analytically evaluated various aspects of our robot design. For example, our team believed that we may have additional time at the end of the round to attempt to push the entire tower towards the trash pile using our pushing cutout scraper, and when practice runs began to end in just 2:30, we began to put those 30 extra seconds to use. To ensure this idea to push the tower was feasible, we designed the pushing cutout mechanism to rest ½” off the ground because the Masonite has a 1” thick base plate. Next, we developed our pole mechanism to be exactly the height of the pipe bundle when fully extended down. This will allow for easier grabbing of the pipe bundle for our drivers. We also cut the pvc light pole clamp to use two halves that were each 5.75 inches long to allow for a smaller drop from the mechanism into the base, but also a radius of 0.25 inches, giving a compressed grip to ensure consistency.

# Strategy Evaluations

## Offensive Evaluation

The first goal of the team is to send the robot to get 520 points by autonomously moving to pick up the pipe bundle and lay them on the trailer for the balancing bonus. We will do this by running wooden dowels, and by allowing the arm to kick back up to a certain height after being pushed all the way down, a tremendous amount of time is saved in not having to line up the dowel with the top pvc pipe (upwards of 30 seconds). The second task of the team is the hardest to accomplish. It is putting in the light poles for 225 points. We will have our spotter load the poles, and they will also assist the driver in lining up the robot to make sure the installment goes smoothly. The light poles are a challenge to set up, but our team is willing to spend that time for 75 points, even considering the difficulty. Additionally, this task is done simultaneously along with the other tasks as we move along the field, which makes it easy for us to progressively gain points.

Next, we will move the air compressor into the safety zone using our carved out scoop/scraper for \_\_\_ points. Lastly, we will pick up all the tower debris by pushing it with our robot, and move everything we can into the dumpster without sorting for an estimated 300 points.

## Offensive Route

Our main priorities were to set up the light poles, use autonomous motion to move the pipe bundle and load it onto the trailer, and move the air compressor to it’s designated safe zone. To do this, we originally followed a counterclockwise path around the course, however, we decided the opposite was faster because it allowed the robot to easily be aligned with the lamp bases..

The final route our team decided was first setting up the nearest light pole to the starting box. Then we would begin clockwise around the field to load the second light pole, and pick up the nearby air compressor. We then push the air compressor into the safe zone. Next we place the final light pole, and line up the robot for it’s autonomous retrieval of the pipe bundle. We then pick up and load the pipe bundle on the trailer.

Because of the differentiating skill levels of our drivers, our planned main route takes between 2:30-3:00 minutes for each driver. As a bonus, if a driver completes the intended mission with extra time remaining, they will have an opportunity to push the tower into the robot starting box.

## Defensive Evaluation

This year, the BEST Robotics game keeps the robot’s playfields separate, so the Defensive Evaluation in terms of competition has been reduced significantly. However, for our robot’s safety and consistency, we implemented certain tactics to keep the function steady. We used smaller wheels to have more precise commands, and cover less distance in a single left joystick press so as to not lose any time. We also carved the robot to be narrower to avoid knocking out poles or getting caught on trees, so that we would not disturb the set play field or tasks we had already completed and lose points. Furthermore, we will maintain speed by allowing the robot to knock over trees as long as they still remain in contact with their tape outline, so that they will still be counted as undisturbed. Additionally, we added a server adapter to keep the 4-pronged claws lifted high enough above the carpet, so the wire prongs will not get caught on the loose strands of the carpet and stall the robot.

We are also using pennies as counterweights to keep the whole back end of the robot dragging on the ground. This way, we can pick up a bigger amount of materials and the robot will not fall forward. Finally, we are using a two-drive system that also uses autonomous motion, and we are going to be able to give our team a few weeks of practice driving this fairly simple system before competition day.

Additionally, our driving practice focused on making sure that we did not move the trees or light poles too far out of place because of the time penalty, but we still slightly pushed them to create better pathways for our robot. We also decided to completely avoid setting up the fence posts because of greater danger of a penalty by it being moved into the driver or spotter’s box. Lastly, we decided to move the tower along the ground instead of knocking it over, so this way, we do not have to worry about knocking over the tree between the tower and the starting box.

# Software Development Process

Our software development process was recommended by our mentor who is a full-time software developer. He recommended that we add an informative header, comments throughout our code, and a changelog to note when major updates to the code have been made. To further discuss our software development process, we show each step of the program and which parts developed at certain times.

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Figure 5: Software Design Changelog

Version 0 (10/15/2021): Our software team added basic directional movement of the frame after we finished the first prototype of the robot. This included movement forwards and backwards using the left analog stick and the extension of the dowel mechanism with the right analog stick.

Version 1 (10/18/2021): Our software team added functionality to open, drop, and close the light pole mechanism. The open state releases the light pole and allows for the robot to drive away. The drop state slightly opens the light pole mechanism allowing for fine movement when the robot is near the light pole base. The close mechanism holds the light pole in place when moving around the game field. The light pole mechanism starts in the closed state, then with a button press enters the drop state, then the same button press will enter the open state. Our team programmed a unique button for each of the 3 claw mechanisms (one for each light pole) that circulate between the motions.

Version 2 (10/22/2021): Our engineering team made a modification to the light pole mechanism to add more friction tape, which required tuning the open, drop, and close states in the code to account for the smaller radius of the hole in the claspers. This version updated the open, drop, and close states to work better with the updated version of the light pole mechanism on the robot.

Version 3 (10/25/2021): Our software team added autonomous mode. To do this, the robot moves forward for 2.5 seconds, then turns left for 1.4 seconds, and then continues forward for 2.5 seconds. To debug the exact times required for each stage, we used stopwatches and multiple code deployments to ensure it was just right. To activate autonomous mode, the right trigger is held down for 3 seconds, because we found there was sometimes a delay with Vexnet leading to the autonomous mode not being correctly started if we made the hold down duration shorter than 3 seconds.

Version 4 (10/28/2021): A common issue for some of our drivers was the lack of precise robot movement, especially when picking up the pipe bundle. To help with this, our software team implemented a “fine-tuning” mode for the robot which would allow the robot to move at ¼ speed by holding down the left trigger.

# Safety

One thing our team prioritizes is safety. We had each member of our team and their parents sign the BEST safety form, and it ensures the limitations each student has on which tools they could or could not use. We additionally had a safety meeting stressing that some tools can be very dangerous. The value taught in the safety meeting was that it is not worth it to be reckless. We focused on maintaining health above messing up a part of the robot. In the design process of the robot, caution was also used in the form of protective equipment while forging the materials into the individual pieces of the robot, and we had mentor supervision throughout the whole building process of the robot.

Figure \_\_: Safety sheet

# Support Documentation

## Appendix A Team Organization

## Appendix B Meeting Minutes

-September 18, Saturday 10:00-11:30

Kickoff and Begin Planning at Calhoun.

-September 21, Tuesday 3:00-4:00

Go Over Team Divisions and Registrations at DHCA.

-September 23, Thursday 3:15-4:45

First Brainstorming Session for Robot at Mullican Aerospace.

-October 4, Monday 4:15-6:00

First Prototype and Beginning Code at Mullican Aerospace.

-October 14, Thursday 3:15-4:45

Meet with Johnson, Bates, and Legg to learn Background of Demolition at Mullican Aerospace.

-October 19, Tuesday 3:15-6:00

Build our Practice Field at Central Baptist.

-October 26, Tuesday 4:30-7:45

First Driving Practice at Central Baptist.

-October 28, Thursday 4:30-7:00

Driving Practice and Begin Planning Marketing Presentation at Central Baptist.

-October 29, Friday 4:00-6:30

Driving Practice and First Draft of the Notebook Due at Central Baptist.

-October 30, Saturday 11:00-12:00

Official Practice Field at Calhoun.

-November 2, Tuesday 4:00-6:30

Driving Practice, Booth Construction, and Marketing Presentation Practice at Central Baptist.

-November 4, Thursday 4:00-6:30

Driving Practice, Booth Construction, Second Draft of the Engineering Notebook Due and Marketing Presentation Practice at Central Baptist.

## Appendix C CAD Drawings

## Appendix D Extra Photos

## Appendix E Code and Algorithms