Spring 2024 ME EN 3230 Competition:

Overview

This semester's Mechatronics Competition will be a challenge inspired by the video game **The Legend of Zelda: Tears of the Kingdom**. In the video game, the character *Link* can use his newly acquired powers to *fuse* together various mechatronic devices from the lost *Zonai* civilization. The goal is for your Robot *Link* to successfully *fuse* together different *Zonai* vehicles (cars, hovercraft, etc) within a 5 minute time limit. Various *Zonai* devices (wheels, fans, batteries) represented by different colored blocks can be obtained from a pair of *Zonai* Dispensers, and can be *fused* in various combinations on a provided chassis (using embedded magnets). Each team of students will design a robot that utilizes various sensors and actuators to navigate the playing field and construct their *Zonai* vehicles autonomously. A CAD model of the playing field is shown in Figure 1. You will see the physical playing field when you come to lab.

There will be Project Milestones (PM) assignments associated with designing, constructing, and programming a robot to complete the objectives. Completing all the PM assignments does not guarantee you will complete all the objectives, but the progression of the PMs is designed to keep teams on schedule and ensure you have the tools to design a successful robot.

Rules

Rules are subject to change and clarification but should be finalized by Week 3 of lab. You will be notified of any changes made by Canvas. Be sure your canvas notification settings are set to immediately notify you of any announcements. Each team is responsible for knowing the rules. TAs can provide clarification, but students must refer to this document (and any official Canvas updates/clarifications) for the final ruling.

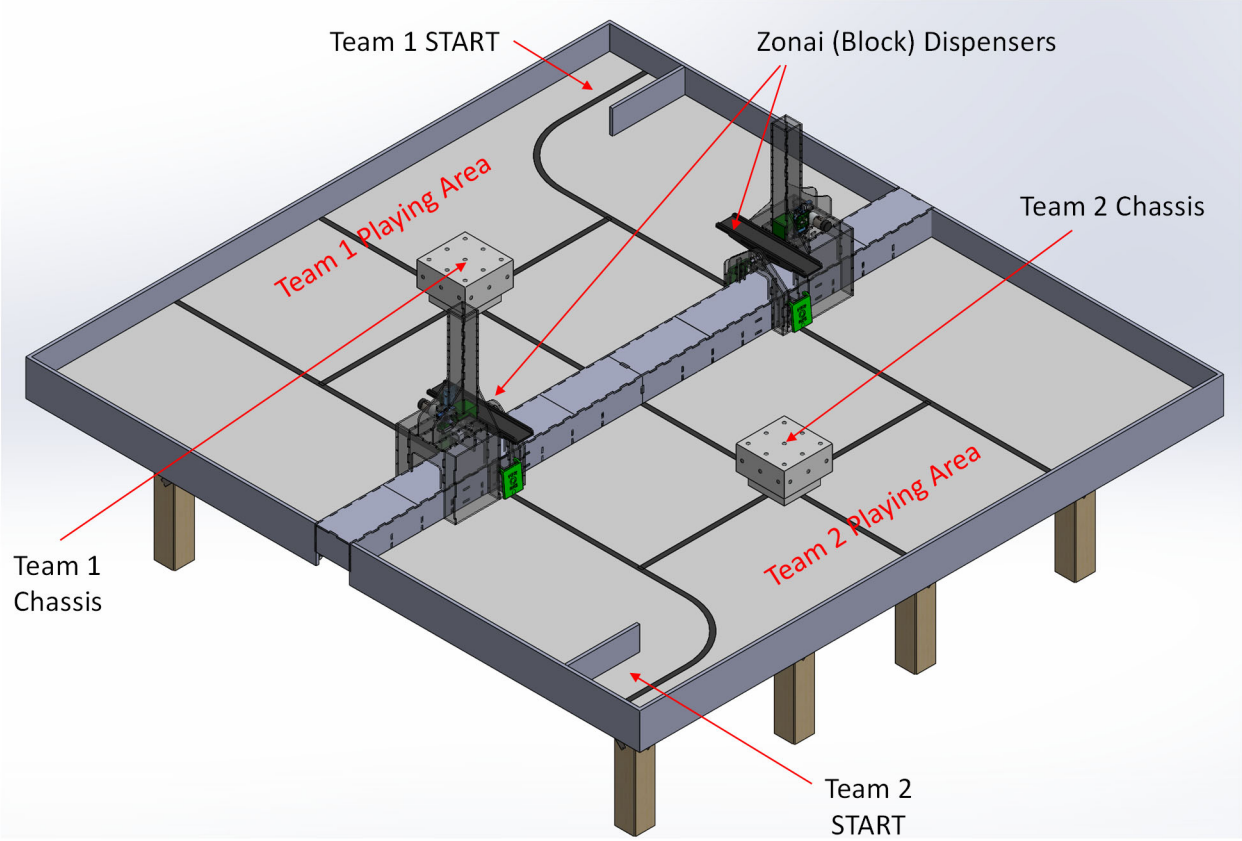

Figure 1. Competition Playing Field

1. Teams

In each lab section, you will form teams of 4 students. Your team will be formed based on the skill survey finished in Week 1 (PM 0). Each team will design and manufacture a robotic solution to complete the competition objectives. A robotic solution includes the Robot and a wireless controller/transmitter.

2. Game Play

2.1. Two teams will compete simultaneously, one team on each side of the playing field. *Zonai* devices (colored blocks) can be obtained from either of two *Zonai* dispensers in the center of the field. There will be 3 different colored blocks in play (representing wheels, fans, and batteries). Either team can obtain blocks from either dispenser. Each team has a stationary chassis in the center of their playing area, to which they can *fuse* (magnetically attach) the various *Zonai* devices at specific locations. Before the match starts, one *Zonai* device will already be *fused* to the chassis in a randomly determined location.

2.2. Each team's robot will begin in their respective START area. Prior to the START signal, the teams will have 30 seconds to send a wireless command to their robot telling it which blocks to *fuse* to which locations on their chassis. After the START signal is given, the teams must send a wireless START command to activate their robot. The robots will then have 5 minutes to collect blocks and *fuse* them to their chassis. Once the robot starts moving, the robot must operate fully autonomously with no further instructions.

2.3. Terminology:

2.3.1. For a *Zonai device to be successfully fused*, it must be magnetically attached to one of the designed locations on the chassis and be supported by nothing other than the chassis.

2.3.2. A *Zonai vehicle is considered complete* if each of the *Zonai* devices required to form that vehicle are *successfully fused*.

2.4. At any time within the 5 minute match (typically if a team's robot malfunctions or gets lost) the team may choose to manually reset their robot to the start area and continue game play.

2.4.1. At reset, the robot must be picked up and placed within the start area. Before the robot starts moving again, the teams may send another wireless command telling the robot what blocks remain to be *fused* to the chassis. The team must then send another wireless START command to reactivate the robot and resume game play.

2.4.2. Teams may reset their robot as many times as they like during the 5 minute match.

2.4.3. If the robot is carrying any blocks when the reset is initiated, the blocks will be removed from the field. Any blocks dropped on the field floor will also be cleared from the field during reset.

2.4.4. Touching the robot/field by hand, or sending any commands (typing on your computer during attempt) to the robot will trigger a mandatory reset.

3. Scoring

3.1. Matches are scored according to the following rules:

3.1.1. Each *Zonai device successfully fused* = 1 pt

3.1.2. A *Zonai vehicle completed is awarded the following bonus points:*

Zonai Vehicle	**Required Zonai Devices**	**Bonus**
Motorcycle	Two wheels[1] on opposite sides of chassis	3 pts
Car	Four wheels[1] on four corners of chassis	6 pts
Tank	Six wheels[1] (three each on two opposite sides)	9 pts
Hoverbike	Two fans[2] on opposite sides of chassis	3 pts
Quadcopter	Four fans[2] on four sides or four corners of chassis	6 pts
Hovercycle	Motorcycle + Hoverbike	6 pts
Hovercar	Car + Quadcopter	12 pts
Hovertank	Tank + Quadcopter	15 pts
----------	Each battery[3] on a completed vehicle	1 pts

[1] Wheels can only be placed on the sides of the chassis

[2] Fans can be placed on sides or top of chassis

[3] Batteries can be placed in any location of the chassis

3.1.3. For example, if a team builds a hovercar with two batteries, they get 10 pts for fusing 10 *Zonai* devices (4 fans + 4 wheels + 2 batteries), plus a bonus of 14 points (12 pts for hovercar + 2 pts for batteries), for a grand total of 24 points. Note that any extra wheels or fans that are attached but do not upgrade the vehicle are only worth 1 pt each (no bonuses).

3.1.4. All scoring will take place at the end of the match based on which blocks are *successfully fused* to the chassis at the end of the 5 minutes. If a team is done before

the 5 minutes are up, they may choose to manually remove their robot from the playing field. If both teams do this, then the match will be declared complete and scored.

3.1.5. If two teams have the same score at the end of the match, then tie-breakers will apply in the following order:

3.1.5.1. The team with fewer resets will win the tie.

3.1.5.2. The team who completed their vehicle faster will win the tie.

4. Competition Course

Figures 2 and 3 show a dimensioned layout of the competition playing field.

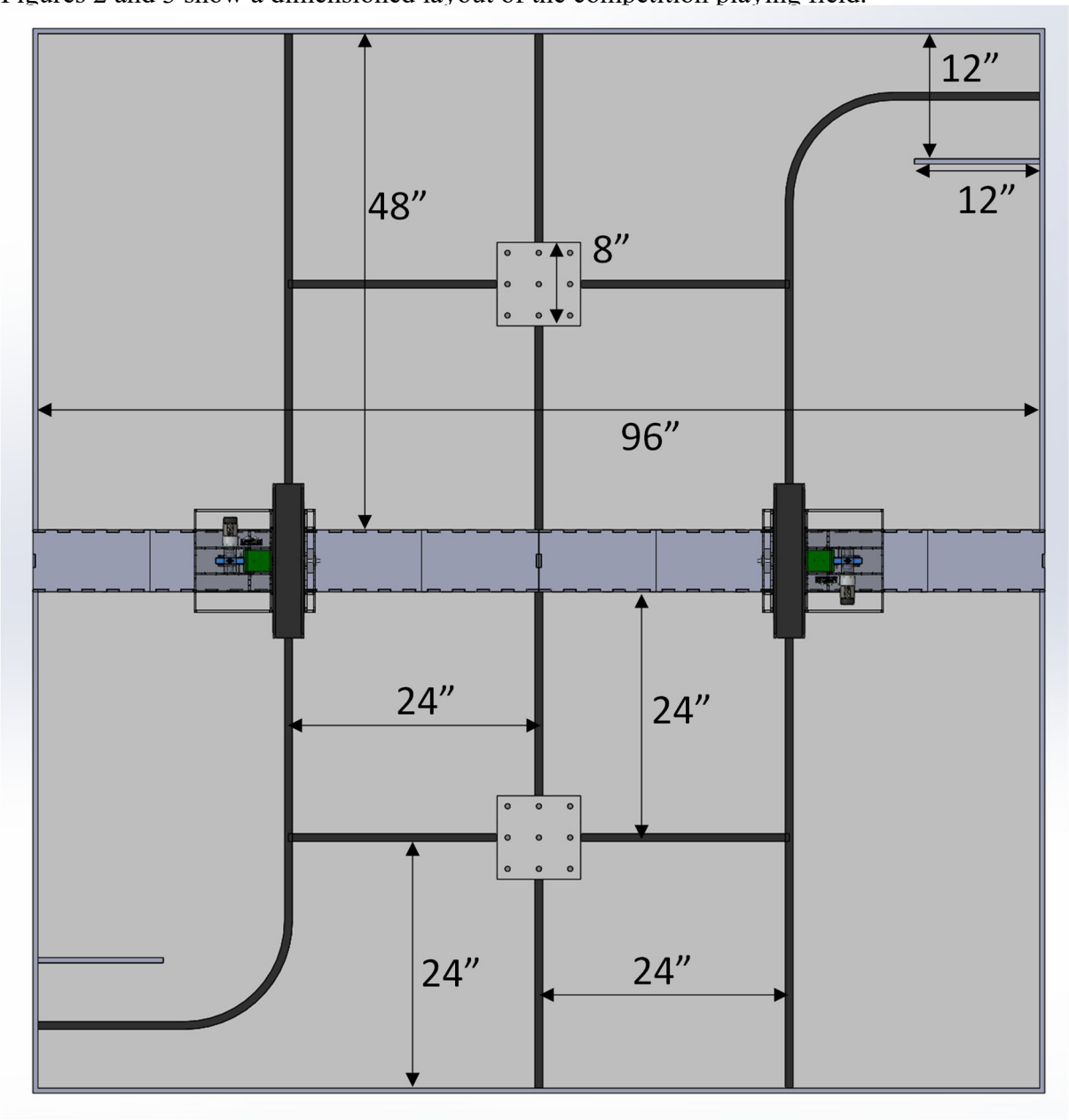

Figure 2. Playing Field Dimensions (Top View)

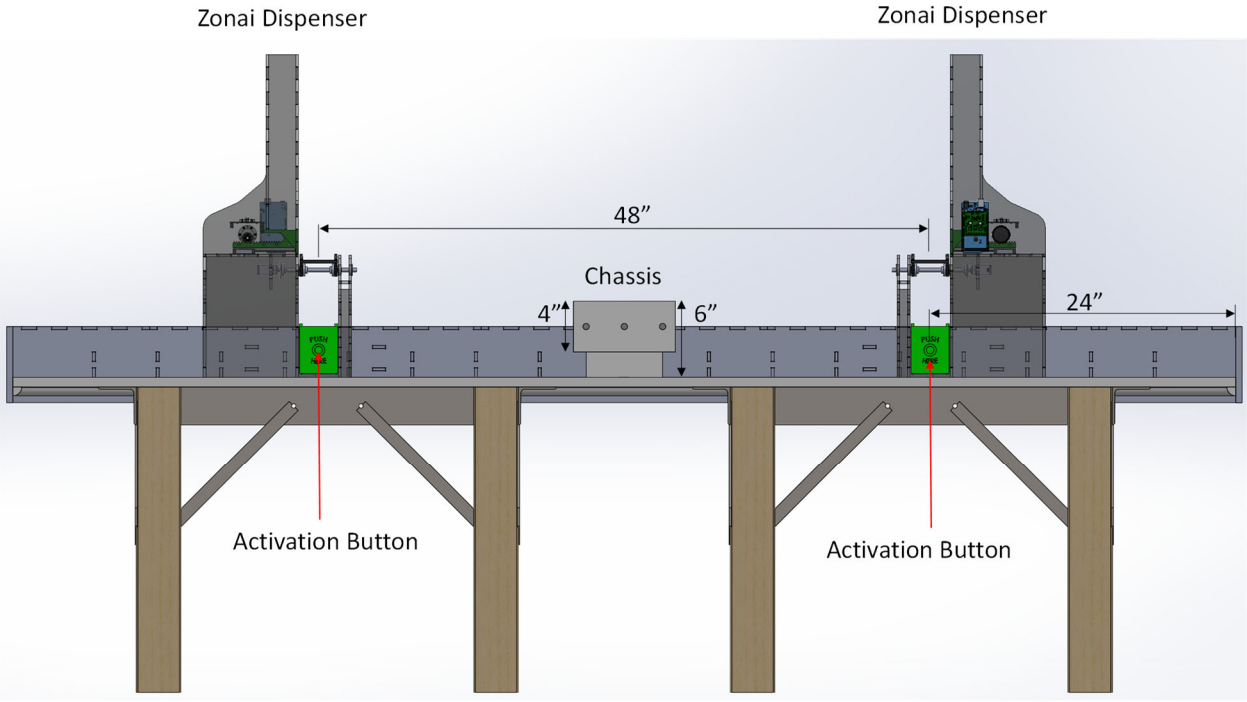

Figure 3. Playing Field Dimensions (Front View)

NOTE: all dimensions are approximate. You should plan to measure the actual field as constructed for actual dimensions. Tolerances of dimensions and the field setup are ±1/8 in. Dimensions will vary throughout the semester as the field is used and moved for competition day. TAs will do their best to keep the dimensions the same, but students should design a robot that can handle the variations robustly.

4.1. START area

- Each start area is a 12”x12” square area enclosed by walls on three sides. The robots must fit completely within the start area at the beginning of the match, and may not extend or move beyond the start area prior to the START signal.
- A curved black line extends from each start area to the nearest *Zonai dispenser*. Successful robots will use line-following sensors to autonomously navigate this line.

4.2. Zonai Dispensers

- There are two *Zonai* Dispensers in the middle of the field that can be accessed by either team’s robot. Black lines on the floor of the playing field will help teams navigate to the dispensers. Successful robots will use line-following sensors to navigate to the dispensers and proximity sensors to detect when they reach a dispenser. Each dispenser will dispense one *Zonai* device (colored block) at a time onto its platform. The platform is controlled by a servo motor that can be activated by the large buttons underneath the dispenser. If a robot hits the button beneath their side of the dispenser, the dispenser platform will tilt towards that robot’s side of the playing field and the block will slide down their side of the platform. The tilting of the *Zonai*

dispensers is modeled in Figure 4, with important height dimensions labelled. The blocks will be queued in a random order in the dispenser.

- In order to receive a block, the dispenser must be activated by pushing the large button underneath. If two robots approach the same dispenser from opposite sides, whichever robot hits their button first will receive the next block. The dispenser cannot be activated again until it returns to its horizontal position. The first robot to depress the button AFTER (and not before) the dispenser returns to its horizontal position will receive the next block. IMPORTANT: This means that if your robot is keeping the button pressed while the platform is still tilted, it will have to release the button and depress it again after the platform returns to horizontal in order to activate the dispenser. There will be a small magnet at each end of the platform so that robots can sense when the platform is horizontal. Successful robots will use magnetic sensors to detect the state of the platform so they know when to hit the button. Successful robots will have a mechanism to receive one or more cubes from the dispenser before navigating to their chassis. Other than hitting the activation button, robots MAY NOT mechanically interfere with the automated operation of the dispensers. Any such interference will trigger a mandatory reset to the START area,

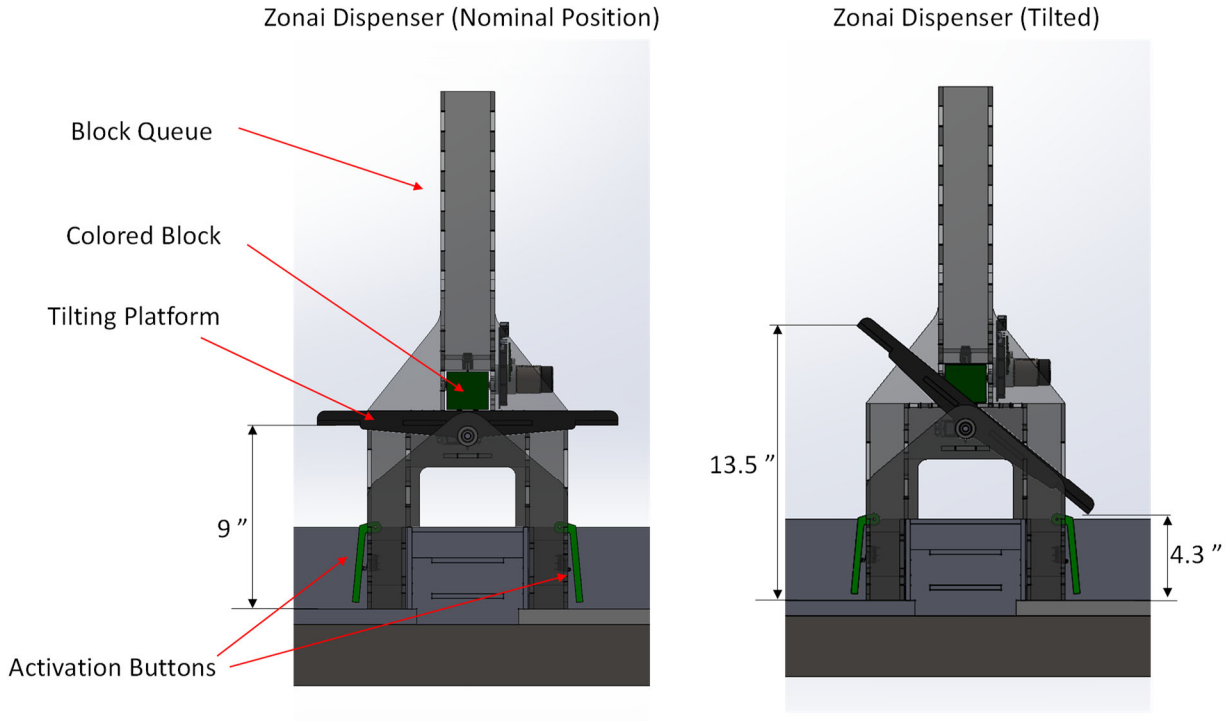

Figure 4. Zonai Dispensers

- The *Zonai* Devices (colored blocks) will consist of 2” wood cubes with 0.02” thick steel plates on the faces weighing approximately 150 grams each. The steel plating will allow the devices to be *fused* (magnetically attached) to the magnets embedded in the chassis. There will be three different *Zonai* Devices:

RED = *Zonai* Wheel	BLUE = *Zonai* Fan	YELLOW = *Zonai* Battery
		

The cubes will have the same color on all 6 faces. Successful teams will use a color sensor to detect the identity of the cubes. Robots are free to discard unwanted blocks anywhere on their side of the playing field.

4.3. Chassis

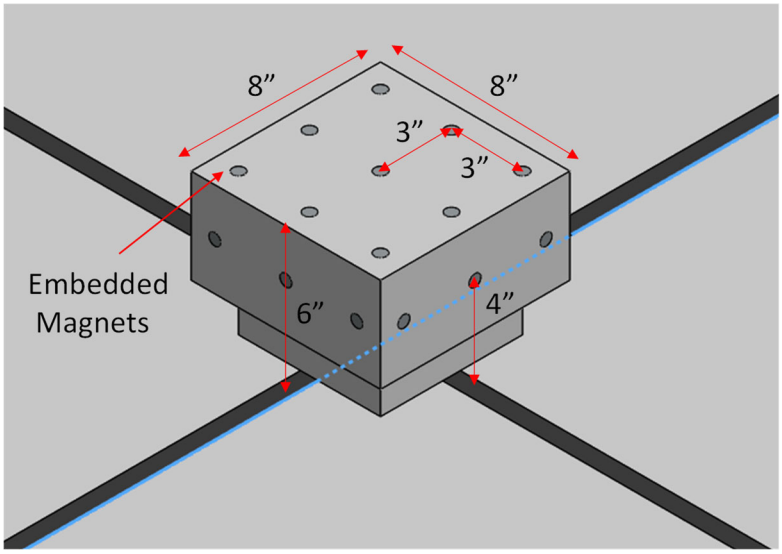

Figure 5. Chassis Dimensions

- Each team has one stationary chassis in the center of their 4’x8’ playing area, with dimensions shown in Fig. 5. Each chassis has an 8”x8” square face on top which sits 6” above the floor of the playing field, with a 3x3 grid of magnets (spaced 3” apart on center). Each side of the chassis has a 4”x8” face with a 1x3 grid of magnets (spaced 3” apart, and 4” above the floor of the playing field). The middle spot on the top of the chassis will be occupied by *Link* and his control stick. Thus a total of 8 blocks can be magnetically attached on the top, and 3 blocks on each side. Successful robots will have mechanisms to position their colored blocks and attach them to the desired spots on the top and sides of the chassis to construct *Zonai* vehicles.
- There will be straight black lines on the floor of the playing field leading to the center of each side of the chassis. Successful robots will use line-following sensors and proximity sensors to navigate to the various sides of the chassis.
- Successful teams will program their robot based on a *State Transition Diagram* in order to keep track of its progress on the playing field.

5. Robot Construction

Each team is tasked with designing and manufacturing a robotic solution (robot and control) to the competition. Each solution must be an original design created by each team, although teams are encouraged to review highlight videos from prior semesters to gain insight about what does and does not work. Prior to competition, robots will be inspected. **Robots not complying with the rules will not be allowed to compete and will suffer the consequences of not competing.**

5.1. Robot size:

- 5.1.1. The robot must start completely within the starting region 12 in. x 12 in.
- 5.1.2. The robot can change its size once it leaves the starting configuration.
- 5.1.3. The robot must remain as one mechanically connected machine and may not leave parts on the field or have parts that separate themselves entirely from the robot.

5.2. Robot weight

- 5.2.1. There is no weight restriction on the robot.

5.3. Micro-controllers and programming

- 5.3.1. Your solution must use one Arduino Mega (on robot) and one Arduino Uno (remote control). Teams may have their Uno connected to a PC via USB cable during the competition.
- 5.3.2. At competition your robot must have a single Arduino program to complete the course. Wireless communication will be used to tell the robot which ingredients to deliver to which table and when to start moving.
- 5.3.3. Code cannot be uploaded during the competition.

5.4. Power source

- 5.4.1. One 9.6 V rechargeable NiMH battery will be the only power source allowed on the robot.
- 5.4.2. No other electrical power sources may be used on the robot.

5.5. Wireless communication and autonomy:

- 5.5.1. X-bee radios will be used for communication to the robot, one on the Mega and one on the Uno.
- 5.5.2. To begin each match, teams will be instructed to place their robot in the starting area, and reset their robot Arduino. Teams then have 30 seconds to send a wireless command to the robot, telling it which colored blocks to fuse to which locations on their chassis. Upon being given a START signal, the teams must then send a wireless START command to activate the robot. Other than sending the order information and START command, the team is not allowed to communicate any information to the robot. The timing for the event begins when the START signal is given. Any debugging, touching, or contact with the controller/robot after START command is transmitted and the robot starts moving will count as a failure/reset.
- 5.5.3. The goal is for the robot to complete the match autonomously, but teams can send wireless STOP commands when a robot malfunctions, in which case teams will be allowed to reset their robot to the START area. During reset, teams may wirelessly

resend information to their robot about which blocks remain to be fused to which locations on the chassis before sending a wireless RESTART command. Otherwise, the same rules from 5.5.2 apply.

5.5.4. Teams must use the same code throughout the match. Teams can upload code prior to starting the match, but cannot re-upload or upload different code after beginning the match.

5.5.5. No other communication from the operators to the robot may be used (i.e. sound, light, proximity, etc.).

5.6. Manipulators

5.6.1. Teams are encouraged to develop manipulators to accomplish tasks in the match.

5.6.2. No commercial manipulators or kits can be used. Designs can be inspired by prior work, but your design must be original; no copies or reproductions allowed.

5.6.3. Adhesives and magnets are not allowed for gripping or attaching to the course.

5.7. Sensors

5.7.1. Successful teams use color sensors, rangefinders, reflectance arrays, Hall effect sensors, and motor encoders on their robot. Technically, there are no explicit sensor requirements for the competition, however teams **will be required** to demonstrate the following in PM assignments:

5.7.1.1. Differentiating colors using a color sensor

5.7.1.2. Wall-following or Wall-approaching using rangefinders

5.7.1.3. Line-following using reflectance arrays

5.7.1.4. Localizing a magnet using a Hall effect sensor

5.7.1.5. Wheel odometry using encoders already incorporated in the motors.

5.8. Wiring

5.8.1. Teams are required to connect an on/off switch and a 10A fuse in line with the battery to the robot.

5.8.2. No solderless breadboards are allowed at competition.

5.8.3. All electrical components must be secured. Any loose components are likely to short out and start a fire.

5.8.4. Proper insulation must prevent inadvertent grounding inside the robot.

5.8.5. Teams are encouraged to organize (label, color code, route) wiring for purposes of troubleshooting and repair (not subject to inspection).

Hint: Do not drill, file, or trim wires near any electrical components. One chip will short out a controller and cost you!

5.9. Manufacturing

5.9.1. All rough edges and sharp points must be safely smoothed, filled, or covered.

5.9.2. Semi-permanent fasteners must be applied, tape and Velcro are not acceptable for structural fastening; they are only acceptable for wire routing purposes. Glues and epoxies should be used sparingly. No adhesive residue may be left on the course by the robot.

5.9.3. Teams are required to have a team name or number displayed on their robot for competition.

5.9.4. Teams are encouraged to apply finishing touches to improve the appearance of their robots (not subject to inspection).

5.10. Budget

5.10.1. Each team's robot may consist of a total of $650 worth of parts and materials. $550 of that may be requisitioned from parts and materials stocked in the lab and will be charged to the team's lab account (funded by lab fees). The remaining $100 may be purchased from external sources (e.g. internet, hardware store) using out-of-pocket money (non-reimbursable).

5.10.2. Mechanical parts requisitioned from the lab may be returned if they are in good condition and the team's lab account will be credited. Parts with electronics (sensors, servomotors, Arduinos, etc.) may not be returned unless they are in their original sealed package. 37mm gearmotors may be returned/exchanged, contingent on them passing a diagnostic test.

5.10.3. Teams may overspend their lab account to requisition replacement parts (as long as the total value of parts remaining on the robot is $550 or less), but teams will be required to reimburse the department at the end of the semester for the amount exceeding $550, or else a Hold will be placed on their grades.

5.10.4. You will be given a list of available parts and prices for items stocked in the lab.

5.10.5. Team's budgets will only be graded based on what final parts are on the robot. Teams will be required to keep a log of their requisitions/purchases on their own, and on Design Day, teams will be required to present a cost accounting worksheet (CAW) itemizing the quantity and price of all parts and materials on their robot.

5.10.5.1. The CAW **WILL NOT** need to keep track of fasteners, wiring, tape, adhesives, etc. These are considered free to use on the project.

5.10.5.2. This CAW **WILL** account for all raw material, actuators, mechanical parts, and electronics (chips, shields, sensors, etc.). If you are unsure about what must be accounted for, ask your TA.

5.10.5.3. Materials and parts should be separated into those requisitioned in-lab and those purchased out-of-pocket.

5.10.5.4. Any "donated" parts will count towards the "out-of-pocket" budget and must be accounted for with a fair market value estimate.

5.10.5.5. The CAW must follow the provided template format.