




## 2021 BEST Robotics Competition Rules

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## Section 1 General Rules

### 1.1 Overview

This is a student-oriented contest. The students will gain the most if they do the work. Mentors and coaches are to provide guidance only and not to make parts, detail design, nor force their will on the students.

The rules governing the BEST competition consist of the following:

1. Section 1 BEST General Rules
2. Section 2.1 Returnable Kit List
3. Section 2.2 Consumable Kit List
4. Section 3 Game Specific Rules (may supersede Generic Rules)
5. On-line Question and Answer (Q&A) system

Most questions about the game can be answered by first **READING THE RULES THOROUGHLY**. All questions concerning these rules (during the 6-week design and construction phase, not during the competition) must be submitted to the Game Committee in writing through the web-based interface at **<https://www.bestrobotics.org>**. All questions and answers will be distributed to all teams via the web. Responses to the posted questions on the web site are an extension of the rules. In the event of contradiction between the rules and the Q&A responses, the Q&A responses supersede the rules.

### 1.2 Safety

Safety may not and will not be compromised.

1. Safety is a priority.
2. The referees will disqualify any machine that appears to be a safety hazard.
3. Batteries, chargers, and other components of the BEST Control System Kit may not be tampered with or altered in any way.
4. Except for a power drill/driver and a soldering iron/gun (electrically powered only), no power tools (including battery operated) will be allowed in the pit area during any BEST activity. Common hand tools will be allowed. The power drill/driver may be used for drilling and/or hardware insertion/removal, but not for grinding, sawing, routing, etc. The allowed power tools can be operated only in the pit area or in the hub designated workstation area.
5. All individuals working on the machine in the pit area must wear safety gear appropriate to the activity (e.g., safety glasses should be used when soldering or drilling).
6. Any illegal tools may be confiscated for the day.

## 1.3 Robot Design Constraints

### 1.3.1 Material Constraints

Each team receives two kits: a Returnable Kit and a Consumable Kit. Each machine must be constructed using only the materials that appear on the returnable and consumable kit lists (provided in Section 2). Exceptions to this rule are described in [Section 1.3.2.1](#).

The Returnable Kit List and Consumable Kit List are the official references for parts; therefore, they define the type and quantity of parts that can legally be used on the machine. The team is responsible for confirming that items in the received kits are consistent with the items on the lists and include no excess parts. Excess parts may not be used.

### 1.3.2 Construction Requirements

1. All robot construction is to occur after the hub Game Kickoff event has been held. There should be no part construction prior to the Game Kickoff event nor reuse of parts from previous competitions. Robot parts may be permanently marked (via scribing, drilling holes, etc.) by BEST personnel to prevent reuse.
2. There are no restrictions on the tools or machines that are used to create parts; however, there is still the expectation that students will be taught how to use these tools/machines and that they will be the ones using and operating them in the fabrication of the parts.
3. The VEX Cortex microcontroller and battery must be secured to the robot. The Cortex microcontroller must be mounted to your robot through the holes provided on its base (suggest using #8 machine screws to avoid damaging the Cortex).

#### 1.3.2.1 Returnable Kit

1. All Returnable Kit items, including boxes and packing, **must be returned** at the conclusion of the contest in the same condition as received except as noted in item 2 below.
2. Returnable Kit equipment cannot be modified in any way, with the following exceptions:
  - a. The belt stock supplied in the returnable kit may be modified as needed (e.g., cut, holes punched, etc.); however, the belt that is provided as loop may not be modified.
  - b. Servo horns may be modified as desired.
  - c. BEST IR Sensor Kit may be assembled.
3. The Returnable Kit List specifies certain items that may not be attached to the machine (e.g., the battery chargers).

4. The motors and servos may not be opened for any reason. For example, it is illegal to change the gearing or to re-wind the armature of any motors.
5. The pulleys, bearings, and shoulder screw included in the return kit may not be modified. You may not use any glue or adhesive tape on these items.
6. Tape/adhesive/glue may not be applied to any returnable item unless specifically allowed (see [Section 1.3.2.3](#)). The adhesive portion of the supplied Velcro™ brand hook and loop fastener may not be attached to the battery or to any other returnable item.
7. Paint may not be applied to any Returnable Kit item.
8. The VEXnet Joystick, servos, VEX Cortex microcontroller, VEXnet Keys, batteries, and battery chargers may not be tampered with, modified, or adjusted in any way. The only exception is that the VEX Cortex microcontroller may be programmed as desired.
9. Teams may not put labels or rubber bands on the VEXnet Joystick, nor make internal, reversible modifications to the joysticks.
10. Wires may be soldered to the motor power lugs.
11. Only the motor controllers or the servo power adapter cables may be plugged directly into the VEX Cortex microcontroller motor ports. Motor ports 1 and 10 cannot be used (do not plug the screw terminal motor interface cables into these ports). Only the screw terminal sensor interface cables or the cables from the BEST IR Sensor Kit may be plugged directly into the VEX Cortex microcontroller digital/analog input/output ports. No other connection methods to the Cortex may be used. Soldering to the Cortex microcontroller or to any of the interfacing cables is not allowed.
12. The BEST-supplied 7.2 Volt NiMH 3000maH batteries are the only allowed source of electrical power for the functional components of your entire machine.
13. The 7.2 Volt batteries may **only** be connected to the VEX Cortex microcontroller through the supplied mating connectors. Do not attempt to connect the 7.2 Volt batteries to any other Cortex input other than the battery connector. Do not attempt to connect the 7.2 Volt batteries to any item/circuit other than the Cortex microcontroller.
14. Only one 7.2 Volt battery may be used on the machine during a match. Even if unconnected, the other battery may not be on the machine.
15. On Game Day, replacement batteries will only be provided upon proof of battery failure (e.g., a bad connection) on an exchange basis (you must turn in the faulty battery).
16. You must play all your Game Day matches using the 7.2 Volt batteries supplied by BEST. Team-owned batteries (that power the robot) and team-owned battery chargers for the 7.2V batteries

are not allowed on the field or in the pit area on Game Day; however, team-owned batteries are allowed during other BEST activities.

17. You may use the provided AAA rechargeable batteries or team provided batteries in the VEX Joystick.

### 1.3.2.2 Consumable Kit

1. Consumable Kit parts may be modified as desired within the constraints of these rules.
2. Limited numbers of replacement parts may be available from your local hub, upon a justified request. Otherwise, lost or damaged kit material may only be replaced with identical components. Replacement parts purchased by the team must have the same:
  - a. material as the kit part;
  - b. treatment or grade as the kit part; and;
  - c. dimensions as the kit part.

e.g. a 1x4 may **not** be replaced with a 2x4 of the same total volume.
3. The Consumable Kit list identifies optional items that may be provided by the team and used on the machine.
4. Team supplied pennies may not be altered.
5. The only Consumable Kit items that may be used to conduct electricity are the provided wire, the snap-plug terminals or the (optional) quick-disconnect terminals (and also soldering material at the wiring connections). The only exception is that any of the Consumable Kit provided/allowed metallic materials may be used as part of a sensor circuit.
6. No package materials may be used (materials that come with kit items to protect or store them before use). Examples: The plastic film that covers the adhesive portion on the hook and loop strip; cardboard roll at the center of a tape roll.

### 1.3.2.3 Additional Materials, Constraints and Exceptions

1. Lubricants may be used for lubrication only. A machine may not intentionally contaminate the playing field or an opponent's machine with lubricant.
2. Paint, finish, and/or decals may be used on the robot as described. They cannot be applied to any of the returnable items. Paint or finish cannot be used to change the mechanical properties of what it is applied to. The optical properties (color and reflectivity) of the paint/finish/decals may be used in a functional manner on the robot.

3. Other non-functional decorations are only permitted if they do not aid the machine in performing the game tasks. If you can remove it or cover it up (and you may be asked to) and your machine behaves the same, it is probably non-functional. Lights can be added to the machine, but no strobe lights are allowed.
4. Video capture devices (like a GoPro or a phone) are allowed on the robot subject to the rules for decorations and with the additional rules listed below:
  - a. display screen cannot exceed 6" diagonal
  - b. display must be turned off or covered up
  - c. non-BEST kit mounting brackets/hardware are considered to be a part of the device
  - d. recommend that device be protected from possible contact with field or other robots (BEST not responsible for any damage that occurs to the device during game play)
  - e. device cannot be transmitting a signal (no streaming)
  - f. BEST officials may ask for the device to be removed at any time for any reason
5. Non-functional decorations may use a separate power source (e.g., 9V battery).
6. The use of markers/paint/printouts may be used to provide visual information that does not aid the team in performing the game tasks. Examples of what is allowed would be things such as labeling machine parts with a marker, placing a copy of the Cortex port use schematic on the machine, and so on.
7. You may solder electrical wire connections using your own solder except where electrical connectors are provided. Where connectors have been provided (i.e., on the VEX Cortex microcontroller, servo power adapter cables, servo extension wires, batteries and other returnable items), they must be used without soldering to the connector. Solder may be applied to connectors included in the Consumable Kit (e.g., bullet connectors or quick-disconnect connectors).
8. No welding, brazing or structural soldering is allowed.
9. Metal, rubber, and plastic items may be heated and reformed, but may not be melted and re-cast.
10. Materials may not be changed chemically. The exceptions are that strings and the outer sheath of the shock cord may be singed to prevent loose ends and that kit allowed resin and hardener may be mixed to result in epoxy.
11. Residue-free "painters" tape (supplied in the Consumable Kit) may be used on any Returnable Kit items except the Joystick.

12. Thread locker may be used on Consumable Kit fasteners.

### 1.3.2.4 Team Custom Parts

Two Team Custom Parts (TCP) are allowed.

1. Each part can be made from any uniform (homogeneous) team supplied material.
2. Each part must be able to fit, unconstrained, into a 2" x 4" x 4" cuboid.
3. Each part must be a single continuous piece of material (when in its operational state).
4. The basic raw stock form of the chosen material must be used for the part. The starting raw stock must be rectangular or cylindrical material if the final part retains any of the original raw stock shape. Material starting shape is irrelevant for parts that are in a liquid state in the forming process or if the final part is completely carved/machined from a solid block of the material.
5. No other kit parts may be embedded in a TCP.
6. No hazardous materials are allowed (rule 1.2 item 2 still applies).
7. No welding is allowed (rule 1.3.2.3 item 8 still applies).
8. Melting is allowed (rule 1.3.2.3 item 9 is waived).
9. Chemical change is allowed (rule 1.3.2.3 item 10 is waived).

### 1.3.3 Size

1. At the start of each match, the machine must fit, **unconstrained**, within a cubic space that is 24 inches on a side (machine can be powered on during this check). The machine must remain within the maximum size limit, unconstrained, until the beginning of the match.
2. Once the match begins, the machine may unfold and change size through its own power.
3. There is no size requirement at the end of the match (i.e., the machine does not have to return to its initial configuration).

### 1.3.4 Weight

1. The weight of the machine may not exceed 24 pounds, including the battery and all parts and devices of your machine (e.g., detachable pieces, optional equipment, tethered parts, decorative items, etc.).

### 1.3.5 Energy Sources

1. The energy used by the machine must come solely from:
  - a. electrical energy derived from the single onboard battery pack;
  - b. storage achieved by the deformation of the springs provided in the kit or springs created per the [Team Custom Part rules](#);
  - c. a change in the altitude of the center of gravity of any part of the machine; and/or;
  - d. stretched items (inner tube/rubber bands/shock cord/TCP) are allowed provided that the part is attached to the machine so that it will not fly off if broken

### 1.3.6 Compliance

1. All machines will be inspected for compliance with the regulations before the competition. Machines must meet these regulations to qualify for the competition. The winning machines may be inspected again following the competition. Failure to comply with the regulations will result in disqualification.
2. No substitute machines are allowed. Machines may be modified between matches but must still meet all the regulations after the modifications are made. The compliance official must approve all modifications prior to the team's next match of competition.
3. Random re-checks of machines will be performed throughout the day at the discretion of the referees. Any machine found to be non-compliant will not be allowed to continue the competition until brought into compliance and may be disqualified from prior matches.
4. The machines may not leave the competition site between the time they are checked for compliance and the start of the competition without approval from the competition officials.
5. Teams that place high enough to advance to a regional/national championship are allowed to make repairs and/or functional improvements to their machine. Machines will be rechecked for compliance prior to the regional/national championship competition.
6. A machine may have multiple configurations, like different arms that can be swapped out. Each configuration must meet size and weight requirements independently and be approved through a compliance check. The sum total of all parts and materials from all of the configurations cannot exceed the quantities defined by the Returnable and Consumable Kit Lists.

### 1.3.7 General

1. Machines must be designed to operate by reacting only against the surfaces of the playing field (including the PVC pipes, ramps, etc.), the opponents' machines, and the air. Machines are allowed to clamp to anything in the field except another machine.

2. During a match, the machine may only be controlled through normal operation of the VEXnet system. Touching the robot (except as allowed by the [Game Specific Rules](#)) will result in penalty or disqualification as described in [section 1.4.3](#).
3. No external devices may be connected to the joystick during match play unless specifically provided by BEST competition personnel (things such as an auxiliary power supply or a channel shifting dongle).
4. Machines must prominently display their team number.
5. Powered tandem devices are permitted and may use an umbilical to connect the two devices. This umbilical is considered part of the machine and is subject to the same constraints as the rest of the machine.
6. All projectiles must have a frontal area greater than 10 square inches. A projectile is anything launched through the air, whether free flying or tethered. Parts that detach or fall from a machine and remain on the playing surface are not considered projectiles.
7. Gaining traction or gripping game pieces through the use of adhesives, or by abrading or breaking the surface of the field is not allowed. The friction tape (either side) from the Consumable Kit is not considered an adhesive and is allowed (actually intended) for gripping.
8. Spiked wheels are allowed only if the portion of the spike in contact with the field has at least one dimension greater than ¼ inch.
9. Strategies aimed only at destruction, damage (e.g., stabbing, cutting, etc.), over-turning, or entanglement of an opponent's machine are not in the spirit of the competition and are not allowed. Turning over an opponent's machine may or may not result in a penalty depending on the opinion of the referees. Review section 1.4.3 for a description of penalties for overly aggressive actions.
10. Machines may deploy detachable components on the field. A component is considered "detached" if it has no kit parts connecting it, directly or indirectly, to the set of kit parts that includes the battery. Such components may be used to capture, contain, manipulate game pieces, and/or block another machine. Such components may not be launched at, deliberately attached to, or otherwise deliberately used to entangle another machine. Incidental contact between any machine and such detachable components after deployment will not result in a penalty for any team. Detached components will not count as "part of the machine" unless otherwise stated.
11. Following the competition, all items provided in the Returnable Kit must be returned to the hub (local BEST organization). The rest of the machine may be retained by its respective school.

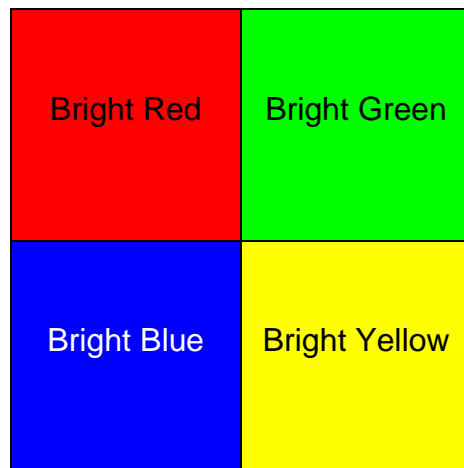
## 1.4 Head-to-Head Competition Rules

### 1.4.1 General

1. Referees have ultimate authority during the competition. No protests will be allowed.
2. On Game Day there will be individuals identified as Team Advocates to answer questions about the game or rules. Do not approach referees, scorekeepers, or other officials with questions.
3. A referee, at their discretion, may untangle machines that become entangled with part of the field, or each other, for more than 10 seconds or that may appear to be damaging the field because of the entanglement. A machine that is high-centered on an element of the field or on a game piece is not considered entangled. A machine that has tipped over is not considered entangled. A referee may ask the driver to quit attempting to free their machine if the field is at risk of being damaged.

### 1.4.2 Field Colors

Specific team locations on the field (e.g., driver/spotter locations, robot starting area, allowed team maneuvering areas, team scoring areas, etc.) are designated through the following four-color scheme.



### 1.4.3 Drivers and Spotters

1. During a match, only one student member of each team is allowed in the team driver's area and one student member is allowed in the team spotter's area. Adult coaches and teachers are not allowed in either of the areas during matches. Students are not allowed to stand on platforms of their own construction (or each other) to get a better view. A hub may, on a case-by-case basis, make unique provisions for special needs drivers/spotters as deemed appropriate.

- Only one person per match is allowed to drive the machine (i.e., operate the VEXnet Joystick). Prior to the competition, each team must submit a driver list to the organizers. The minimum number of student team members on the driver list is shown in the following table:

Student team members <b>present</b> at competition	<b>Minimum</b> number of students on driver list
2-4	2
5-6	3
7-8	4
9 or more	5

*Please note that the previous table reflects the minimum number of drivers required; BEST encourages participation by as many team members as possible. Also note that the number of student team members present at the competition is used to determine the minimum number of drivers on the list.*

- The first person on the driver list is the driver for the first match; the second person on the list is the driver for the second match, etc. This rotation will continue for successive matches until the list is exhausted, at which time the rotation will start again at the top of the list. Rotation in successive phases of the competition (e.g., seeding, semi-finals, and finals) will begin where the previous phase rotation left off. If the organizers eliminate a match for any reason, the driver rotation will continue in accordance with the driver list with the driver scheduled for the eliminated match (or matches) being the first driver for the following match.
- The spotter may be any student from the team.
- Spotters and drivers are not allowed to handle the game pieces prior to a match.
- During a match, spotters and drivers may not communicate with anyone through the use of any electronic devices or other signaling technique that involves a signaling aid that is not part of the human body (e.g., signs, sticks, marked gloves, etc. are not allowed).

#### 1.4.4 Penalties

- A 20-second suspension may be assessed for a variety of infractions that are detailed below and in Section 3 Game Specific Rules of this document. This penalty requires the driver to surrender their VEXnet Joystick to a referee for a period of 20 seconds. The referee will return the joystick

to the driver upon expiration of the penalty and the machine may continue the match. Penalty decisions of the referees will be final.

2. If a driver touches their own machine before any part of it has left the starting area, a 20-second penalty will be assessed after contact ceases. Machine contact within the starting area is allowed only for the purpose of debugging a defective machine (e.g., turning on the on/off switch). If a spotter or driver otherwise touches their own or another team's machine, the machine of the individual doing the touching will be disqualified.
3. Spotters and drivers are not allowed to enter the field during a match. If a spotter or driver enters the field during a match, their machine will be disqualified.
4. If a spotter or driver leaves the designated spotter or driver area, a 20-second penalty will be assessed as described in item 1 of this section.
5. Machines that touch the ground outside the field boundary will be assessed a 20-second penalty as described in item 1 of this section. Machines that completely leave the field will be stopped for the duration of the match.
6. Damaging any portion of the field or game pieces may result in disqualification. Intentionally moving or tipping over static portions of the field is considered damaging the field and will result in disqualification.
7. Referees may instruct the driver of an aggressive machine to cease an action if the referee feels that another machine or the field may be damaged by that action. Referees will disqualify a team from a match if a major breach of the rules occurs.
8. Disqualification is on a match basis, except for non-complaint machines as noted in Section 1.3.6. Any team that is disqualified will receive zero points for that match.

### **1.4.5 Match Protocol**

1. There will be at least five referees during each match. The Head Referee will act as timekeeper and the other four referees will monitor each of the teams.
2. Each match will be three minutes long and will be played with four teams, if possible. The scoring software will assign teams to a match and will determine the team's quadrant/color for each match.
3. Teams will be notified of their field and position assignment at least two minutes before the match. Teams must be in the staging area at the end of the preceding match.
4. Prior to the beginning of the match, teams must wait at the designated staging area until the beginning of the setup period. Once signaled, teams have the duration of the setup period to place their robot into a valid starting position.

5. As a guide, a maximum setup time of 30 seconds will be allowed once the team arrives at the field. If a team has not successfully placed their robot by the end of the setup period, the head referee has discretion to allow the team to continue to place their robot and assess a [20-second penalty](#) to be applied at the beginning of the match or whenever the team is ready to begin play.
6. At the start of each match, the machine must be placed at the designated starting area. The spotter or driver may enter the field prior to the start of the match to place the machine in its starting location and prepare it for the match. Temporary alignment marks on the field are not permitted. Additional team members may be allowed to assist in setting up the machine but must leave the field area prior to the start of the match.
7. The machine, driver and spotter must be in the designated location(s) at the start of the match to score any points during the match. The driver and spotter must remain in the designated areas during the match.
8. A maximum of 30 seconds will be allowed at the end of each match for removal of the machines. Additional team members may be allowed to assist in removing the machine.
9. At the end of the match, the driver and spotter must remain in the designated areas until referees have completed scoring of the match and indicated that robots may be removed.
10. Following the match, the referee will review the scored items with the driver; the driver will sign the scorecard indicating agreement.

### 1.4.6 Competition Protocol

There will be four phases to the head-to-head competition:

- a seeding phase,
- a wildcard phase,
- a semi-final phase, and
- a finals phase.

This protocol will be the same for both hub contests and championships.

Section 3 Game Specific Rules define any tiebreakers for determining which team advances from one phase to another in the event of a tie. If no tiebreaker is identified, the default method will be 1) Engineering Notebook scores, 2) head-to-head match results, 3) Coin toss, in that order.

#### 1.4.6.1 Seeding Phase

The Seeding Phase will consist of a round robin competition among all participating teams. Each team will participate in up to eight matches against randomly selected opponents. Fewer than eight matches per team may be played when time limitations exist, but no fewer than five matches. All teams will participate in the same number of matches. Match scheduling will

attempt to ensure that each team plays on each quadrant of the field and that back-to-back matches are limited.

The team ranking during this phase will be based on the average of the points scored during the seeding matches excluding the teams' lowest match score. Consult Section 3 Game Specific Rules for any variation to this ranking method.

For competitions with 32 or fewer teams, the top 7 teams from the seeding phase will automatically advance to the semi-finals phase. The final team to advance into the semi-finals phase will be selected from the remaining teams during the "Wildcard Phase".

For competitions with greater than 32 teams, the top 14 teams from the seeding phase will automatically advance to the semi-finals phase. The final two teams to advance into the semi-finals phase will be selected from the remaining teams during the "Wildcard Phase".

#### **1.4.6.2 Wildcard Phase**

For competitions with 32 or fewer teams, the wildcard phase will consist of a single match between the four (4) teams with the highest BEST Engineering Notebook scores, who have not automatically advanced to the semi-final phase. The team achieving the highest score during the wildcard phase will advance to the semi-finals.

For competitions with greater than 32 teams, the wildcard phase will consist of two matches between the eight (8) teams with the highest BEST Engineering Notebook scores who have not automatically advanced to the semi-final phase. This phase will consist of 2 matches of 4 teams (as all matches are limited to 4 teams), which may be played in parallel. The two (2) teams achieving the highest scores during the wildcard phase will advance to the semi-finals.

The wildcard phase will be conducted according to the rules for the seeding phase. Each wildcard team will play in only one match during this phase.

#### **1.4.6.3 Semi-Finals Phase**

During the semi-finals phase, each team will participate in three (3) matches based on the rotation shown in Table 1 or 2. The team ranking at the end of the semi-finals will be based on the total points each team accumulated during their three matches. No scores will be dropped and the scores from all previous phases will be disregarded. Game play will be the same as previously described for the seeding phase. Only the top four (4) ranked teams from the semi-finals phase will advance to the finals, regardless of the number of teams competing in the semi-finals.

**Table 1. Field Position Assignments for 8-team Semi-Finals**

Semi-Final Match	Field Position Assignment			
	Yellow	Blue	Red	Green
1	Seed 4	Seed 6	Seed 3	Seed 2
2	Seed 7	Seed 1	Seed 5	Seed 8
3	Seed 3	Seed 7	Seed 8	Seed 4
4	Seed 6	Seed 5	Seed 2	Seed 1
5	Seed 5	Seed 3	Seed 6	Seed 7
6	Seed 8	Seed 2	Seed 1	Seed 4

**Table 2. Field Position Assignments for 16-team Semi-Finals**

Semi-Final Match	Field Position Assignment			
	Yellow	Blue	Red	Green
1	Seed 4	Seed 13	Seed 1	Seed 16
2	Seed 5	Seed 10	Seed 3	Seed 15
3	Seed 6	Seed 9	Seed 8	Seed 11
4	Seed 16	Seed 4	Seed 2	Seed 14
5	Seed 8	Seed 5	Seed 6	Seed 12
6	Seed 7	Seed 11	Seed 9	Seed 10
7	Seed 3	Seed 14	Seed 13	Seed 2
8	Seed 10	Seed 12	Seed 5	Seed 1
9	Seed 15	Seed 6	Seed 16	Seed 7
10	Seed 14	Seed 8	Seed 11	Seed 13
11	Seed 1	Seed 7	Seed 4	Seed 3
12	Seed 2	Seed 15	Seed 12	Seed 9

### 1.4.6.4 Finals Phase

The four (4) top ranked teams will participate in three (3) matches during the finals phase. Field assignments per match will rotate as shown in Table 3. The final team ranking will be based on the total points accumulated by the team during these 3 finals matches. No scores will be dropped and the scores from all previous phases will be disregarded. Game play is the same as previously described for the seeding phase. The winner is the team with the most points accumulated during the three final matches.

**Table 3. Field Position Assignments for Finals**

Final Production Match	Field Position Assignment			
	Yellow	Blue	Red	Green
1	Semi-Final 1	Semi-Final 2	Semi-Final 3	Semi-Final 4
2	Semi-Final 4	Semi-Final 3	Semi-Final 2	Semi-Final 1
3	Semi-Final 3	Semi-Final 1	Semi-Final 4	Semi-Final 2

## 1.5 Other Rules

1. Student eligibility is left to each individual school.
2. All contestants on the gym floor must wear shoes appropriate to the gym floor surface as determined by the sponsoring BEST organization.
3. Each team will be provided with their own workspace in the pit area in which they may place a table with a surface area no greater than 2400 square inches if a table is not provided by the hub. Each team will have access to one electrical plug for battery charging. The exact specifications and location may vary from hub to hub.
4. Each team may bring a toolbox with basic hand-tools subject to the safety constraints listed in [Section 1.2](#) . If a part is broken during competition and the team cannot repair it with tools or material they have, consult the sponsoring BEST organization. They will make their best effort to help the team replace the part, given local shop and/or spare material availability.
5. At least one practice day will be available preceding Game Day. Consult the sponsoring BEST organization for times and locations. Tables and electricity will be available on a shared basis and teams must provide their own tools. The same safety rules apply to practice days as they do during the competition

## Section 2 Official Kit Contents

The official BEST Kit Lists are shown on the following pages. Refer to section 1.3.1 for details regarding Kit constraints and usage. Each machine must be constructed using only the materials (quantity, type and grade) that are on the returnable and consumable kit lists. The ONLY exceptions are described in Section 1.3.2.3.

## 2.1 Returnable Kit

### 2021 BEST Returnable Kit List

	Qty	Item Description	Required/ Optional	Source	Part Number
<b>BEST Control System Kit (VEX 270-1605)</b>	1	Cortex Microcontroller	Req'd <sup>3</sup>	VEX Robotics	278-2194
	1	VEXnet Joystick	Req'd	VEX Robotics	276-2192
	2	VEXnet Key 2.0	Req'd	VEX Robotics	276-3245
	4	Motor Controller 7.2V 4A	Req'd	VEX Robotics	276-2193
	2	Large Motor	Req'd	VEX Robotics	276-1611
	2	Small Motor	Req'd	VEX Robotics	276-1610
	2	7.2 V 3000 mAh NiMH battery – modified w/ PowerPoles	Req'd <sup>1</sup>	VEX Robotics/Other	276-1491
	2	Charger Adapter (for Cortex and Battery Charger)	Req'd <sup>2,3</sup>	None - Hub Assy Req'd	n/a
	8	Screw Terminal Sensor Interface Cable 3-wire	Req'd <sup>4</sup>	VEX Robotics	276-3071
	4	Screw Terminal Motor Interface Cable (red and black wires)	Req'd	VEX Robotics	276-1608
	4	Servo Power Adapter Cable	Req'd	VEX Robotics	276-2195
	1	Smart Battery Charger & power cord	Req'd <sup>2,3</sup>	VEX Robotics/Other	276-2519, 276- 2520
	1	8-bay AAA Smart Battery Charger & power cord	Req'd <sup>2</sup>	VEX Robotics/Other	276-1622
	6	AAA NiMH Rechargeable Batteries (installed in Joystick)	Req'd	VEX Robotics/Other	276-1696
	1	USB A-A Cable	Req'd <sup>2</sup>	VEX Robotics/Other	276-1403

	Qty	Item Description	Required/ Optional	Source	Part Number
<b>BEST Servo Kit (VEX 270-1682)</b>	4	Futaba 3003/3004 or HiTec HS-422/HS-425BB Servos	Req'd	various	
	4	servo horn screw	Req'd	various	
	5	Servo horn (radius not to exceed 1")	Req'd	various	
	2	24" servo extension cable (600 mm also allowed)	Req'd	various	
	2	40" servo extension wire (36" or 1000 mm also allowed)	Req'd	various	
	16	rubber grommet	Opt <sup>5</sup>	various	
	16	brass spacer	Opt <sup>5</sup>	various	
	16	servo mounting screw	Opt <sup>5</sup>	various	
<b>BEST Motion Components Kit (VEX 270-4395)</b>	1	1/4" bore, 24 tooth, (small) drive pulley	Req'd	VEX Robotics	270-4395
	1	1/4" bore, idler (dia. to match 24 tooth pulley)	Req'd	VEX Robotics	
	1	1/4" bore 120 tooth, (large) drive pulley	Req'd	VEX Robotics	
	1	170 tooth, 3 mm pitch, 9 mm wide HTD loop belt	Req'd	VEX Robotics/ Other	
	1	3 mm pitch, 9 mm wide HTD strip belt, 3 ft long	Req'd	VEX Robotics/ Other	
	1	1/4" dia. shoulder screw w/ #10-32 thread	Req'd	VEX Robotics/ Other	
	1	76mm roller blade wheel (78A to 82A) w/ bearings and 6mm spacer	Req'd	VEX Robotics/ Other	
	1	6mm roller blade wheel axle (any style)	Req'd	VEX Robotics/ Other	
	4	R4AZZ Ball Bearing (0.25 ID x 0.75 OD x 0.28 wide)	Req'd	VEX Robotics/ Other	

	Qty	Item Description	Required/ Optional	Source	Part Number
<b>Hub Provided</b>	1	spare (replacement) servo horn screw	Req'd	various	
	2	BEST IR Sensor Kit (1 assembled)	Req'd	BEST Robotics	
	3	6" servo extension cable (150mm, 8" or 200mm also allowed)	Req'd	various	
	3	24" servo extension cable (600 mm also allowed)*	Req'd	various	
	1	18" (or less) USB extension cable (between Cortex and VEXnet key)	Opt <sup>5</sup>	various	
	1	VEX Programming Hardware Kit	Opt <sup>2,5</sup>	VEX Robotics	276-2186
	2	Metal wheel hubs (1.5" max dia, 0.5" max thk, 0.250" bore, with set screw)	Req'd	VEX Robotics/ Other	270-6430
	2	window alarm sensor	Req'd	McMaster-Carr	8039A12
	2	1/4" shaft coupler, with set screws	Req'd	ServoCity	625104
	any	containers, bags, boxes	Req'd <sup>2</sup>	Hub Supplied	

Notes: <sup>1</sup> Only one battery can be used on the robot at any given time.

<sup>2</sup> These items cannot be used on the robot.

<sup>3</sup> Cortex and battery charger may be converted (by the Hub only) to PowerPole connectors, eliminating the need for the adapters.

<sup>5</sup> Teams may use these Returnable Kit optional items even if they are not supplied by their Hub.

\* Any shroud protecting the male pins must be removed (so it can be plugged into Cortex).

## 2.2 Consumables Kit

### 2021 BEST Consumable Kit List (provided by the hub)

Type	Qty	Item Description
igus® Donated Parts	1 meter	Energy Chain, P/N E2-15-20-028-0, w/ 2 each mount brackets (P/N E2.150.20.1 & .2)
	2 ea	DryLin® N Linear Guide system, P/N NK01-27-2-450
	6 ea	igubal® Flange Mount Spherical Bearing, 1/4", P/N EFOI-04
	6 ea	igubal® Pillow Block Mount Spherical Bearing, 1/4", P/N KSTI-04
	6 ea	iglide® G300 Flanged Bushing, 1/4", P/N GFI-0405-06
	6 ea	igubal® 1/4" Rod End Bearing, 1/4"-28 Thread, P/N EBRI-04
	2 ea	DryLin® S, 1/4" diameter, hard anodized Aluminum Shaft, P/N AWI-04, 18 inch length
Plastic and Metal Stock	1 ea	1/4" thick polypropylene sheet, 12" x 24"
	1 ea	1/8" thick PVC Type 1 sheet 12" x 24"
	1 ea	0.5" thick x 2" wide 6061-T6 aluminum flat, 12" long
	1 ea	0.063" thick 5052-H32 aluminum sheet, 12" x 12"
	2 ea	0.25" diameter AISI 1018 steel round, 24" long
	4 ea	piano wire, 0.063" diameter, 12" long
Wood Stock	1 ea	5/16" to 3/8" thick 2' x 4' plywood, any grade
	1 ea	3/16" to 1/4" thick 2' x 4' plywood, any grade
	2 ea	1" x 4" (nominal) #2 whitewood, 2 ft long
	1 ea	1/4" dia. oak dowel, 3 ft long
Pipes and Fittings	2 ea	3/4" schedule 40 PVC pipe, 5 ft long
	1 ea	1" schedule 40 PVC pipe, 5 ft long
	10 ea	3/4" PVC 90 degree elbow (slip)

	10 ea	3/4" PVC tee (slip)
	1 ea	PVC cement, 4 oz or 8 oz
<b>Hardware</b>	4 ea	2.5" x 5/8" steel ZN, corner angle bracket
	4 ea	2" x 3/8" steel ZN, flat angle bracket
	2 ea	2.5"H x 1.75"W x 0.055" narrow hinge w/removable pin
	2 ea	1.5"H x 1-3/8"W x 0.05" narrow hinge w/nonremovable pin & 4 screws
	1 ea	3/4" metal pipe hanger tape, 28 gauge, 10 ft long
<b>Electrical</b>	12 ft	18 gauge stranded copper wire, red insulation, single conductor
	12 ft	18 gauge stranded copper wire, black insulation, single conductor
	12 ft	CAT3 24 gauge, 4 twisted pairs of conductor wire
	16 ea	snap-plug terminals (bullet connectors), insulated, male (optional*)
	16 ea	snap-plug terminals (socket for bullet connectors), insulated, female (optional*)
	20 ea	quick-disconnect terminal, insulated, female, ~1/8" wide (optional*)
	10 ea	quick-disconnect terminal, insulated, female, ~3/16" wide (optional*)
	4 ea	sub-mini snap action switch, SPDT, 0.1 A, Omron P/N SS-01GL13PT
	2 ea	rotary potentiometer, linear, 10K ohm, 300°, panel mount, 6mm (approx.) shaft
	2 ft	heat shrink tubing, 1/4" OD expanded, 2:1 ratio, polyolefin
	10 ea	11" long x 0.18" wide nylon cable tie
	20 ea	4" long x 0.1" wide nylon cable tie
<b>Tapes and Adhesives</b>	1 ea	vinyl electrical tape, 3/4" wide, 60 ft
	1 ea	friction tape, 3/4" wide, 60 ft
	1 ea	all purpose duct tape, 2" (or 1.88") wide, 50 to 60 yd, (color optional)
	1 ea	painters tape, 1" (or 0.94") wide, 30 to 60 yd.

	1 ea	carpenters wood glue, 4 oz
	1 ea	5 minute epoxy, 0.85 oz
Threaded Fasteners	1 ea	1/4"-20 threaded rod, 3 ft long, steel
	25 ea	1/4"-20 hex nut, steel
	25 ea	1/4" SAE flat washer, steel
	25 ea	1/4" medium split lock washer, steel
	6 ea	1/4-28 x 1" screw, nylon (mates with igus rod end)
	6 ea	#10-32 x 1" socket head screw, high strength (150 KSI min) steel**
	25 ea	#10-32 x 1-1/2" machine screws, steel, round/pan head, phillips **
	25 ea	#10-32 machine screw nuts, steel
	25 ea	#10 flat washer, steel
	100 ea	#8-32 x 1-1/4" machine screw, steel, round/pan head, phillips **
	100 ea	#8-32 machine screw nuts, steel
	25 ea	#8 medium split lock washer, steel (optional*)
	100 ea	#8 flat washer, steel
	25 ea	#4-40 x 1" machine screws, round/pan head, steel **
	25 ea	#4-40 machine screw nuts, steel
	10 ea	#2-56 x 1" machine screws, round/pan head, phillips, stainless **
	10 ea	#2-56 machine screw nuts, steel
	10 ea	#2 flat washer, steel
	100 ea	#8 x 1" sheet metal screw, steel, hex head
	100 ea	#6 x 1" wood screws, steel, flat head
	25 ea	#4 x 3/4" wood screw, steel, slotted drive, round head

<b>Miscellaneous</b>	5 ft	3/4" nylon sticky back hook and loop fastener
	1 ea	#18 twisted nylon or polypropylene seine twine, 225 to 250 ft long (color optional)
	4 ft	1/4" polypropylene covered shock cord (color optional)
	1 ea	bicycle inner tube (26" x 1.375" to 2.25" max)
	25 ea	#10 Rubber Band (1/16" wide x 1-1/4" long)
	25 ea	#32 Rubber Band (1/8" wide x 3" long)
	100 ea	1 1/4" long paper clips, 0.033 dia wire (No. 1 Regular)
	1 ea	VEX motor mounting kit ( 4 mounts + screws)

**Approved Optional Items (provided by the team) <sup>1</sup>**

Qty	Item Description
10 ea	wooden spring type clothes pins
2400 sq in	corrugated cardboard, 1/4" maximum thickness
2 ea	empty food/beverage PETE container with screw on cap/lid (2 liter max.) <sup>2</sup>
3 ea	wire coat hangers with or without plastic coating, 1/8" dia. max.
3 ea	solid core golf balls
1 ea	5 minute epoxy, 0.85 oz
3 ea	~10oz empty metal soup can with lid removed
24 lb	pennies (cannot be altered; bank wrappers allowed)
1 ea	8 oz. PVC primer
36 ea	craft "Popsicle" sticks (maximum dimensions; 4.75" long, 0.44" wide, 0.10" thick)
1 ea	metal paint grid for 5 gallon bucket
4 ea	CD or DVD disk (standard size: 120mm diameter x 1.2 mm thick)
25 ea	deck or drywall screws; 2-1/2" maximum length
25 ea	wire management clips/ties/wraps (can only be used on wiring)
1	3/4" or 1" rigid foam board insulation, 1' x 4'
2 ea	Team Custom Part <sup>3</sup>

**Notes:**

\* Teams may use these optional items even if they are not supplied by the hub.

\*\* Teams may substitute shorter screws of the same type and grade.

<sup>1</sup> These items can be used *in addition* to the items that are supplied by the hub.

<sup>2</sup> PET or PETE (polyethylene terephthalate) is identified by a number 1 recycling symbol.

<sup>3</sup> See *Team Custom Part Guide* for further explanation and examples.

## 2.3 Design and Programming Software Tools

BEST Robotics provides various design tools and programming software at no cost to participating BEST teams. This currently includes:

- Sketching software – 2D sketching
- Computer-Aided Design (CAD) software – 2D & 3D Solid Modeling
- Computer-Aided Manufacturing (CAM) software – 2-axis and 3-axis tooling
- Software Development (programming) and Simulation Environments
- Mathematics, Computational and Research software
- 3D Printer Driver software
- Technical Documentation Tools

Software access instructions are provided on your BEST National Registry Team Workflow page and should remain confidential. There may be specific system requirements, internet access requirements, account creation requirements or other stipulations for team/team member use of the software. Unless otherwise indicated, all software and software licenses should only be used by BEST participants for the purpose of competing in the BEST program.

## Section 3 Game Specific Rules



### 3.1 Introduction

There are 3 levels of competition supported by the *Demo Daze* game.

*Table 3.1. BEST Robotics Competition Options*

Competition	# Teams Competing	Field Configuration
Classic Multi-team Competition	Multiple teams up to 4	Physical Field, 4 Quadrants
Classroom Competition	Single team	Physical Field, Single Quadrant
Online Competition	Single team	Virtual Field, Single Quadrant

The field is designed to support all 3 of these possible configurations. Rules throughout this section apply to all physical field configurations. The virtual field configuration is described in Section 3.9 .

In the multi-team competition, multiple teams compete in head-to-head matches at the same time. In the single team competitions (classroom, online), the team competes in individual time trials against the clock. For the purposes of these game rules, a single match is equivalent to a single time trial.

## 3.2 Game Premise

Construction and Demolition (C&D) materials consist of the debris generated during the construction, renovation and demolition of buildings, roads, and bridges. How we manage these C&D materials makes up a significant part of the engineering effort on any construction or demolition site. Additional concerns such as site safety and preserving parts of an existing environment lead us to seek the next BEST innovation using robotics. BEST Robotics is experimenting with how robotics can be used to perform the complex and safety critical tasks on construction and demolition sites. Robots that can accomplish tasks such as demolition, waste removal and recycling, and site safety installations will improve efficiency and safety at these sites. The ability to complete the work while avoiding unnecessary damage or disturbance to areas that are not targeted for demolition and to work autonomously in the highly unsafe areas will provide the most valuable improvements in the world of construction.

## 3.3 Overview and Objectives

Teams are tasked with performing the operations at a demolition site including planning and executing a building demolition, construction security and safety measures at the site, clearing the site of trash and recapturing reusable and recyclable construction and demolition (C&D) materials resulting from the demolition activity.

Demolition will be accomplished through robotic equipment either running autonomously or through control by an operator (driver), who must remain outside the boundaries of the site for safety reasons. A construction worker (spotter) is available to support loading the robotic equipment with some items used in the construction of safety measures at the site.

The crews have done some early preparation on the site for the upcoming demolition.

- Fencing has been brought to the site but is not installed.
- Security light poles have been brought to the site but not yet installed. Installation sites for the lighting have already been prepared.
- The site grounds may be littered with other trash resulting from the site preparation activity.
- Some valuable construction equipment was left on the site grounds and needs to be secured.

A large haul flat-bed trailer has been brought to the site for collecting reusable/recyclable C&D materials during the building demolition activity.

## 3.4 Game Field

Each team plays on a section of field, which is approximately 10 ft on each side, with outer boundaries defined using 1-inch wide tape. (Detailed dimensions and specifications for the field are provided separately in the field drawing package.) The robot starting area is in one corner of the field, closest to the spotter. The driver and spotter must remain in their designated areas adjacent to the robot starting area throughout the game.

The single-team field (also called a quadrant) is shown in Figure 3.1 and is the configuration used for single team time trials during a *Classroom Competition*.

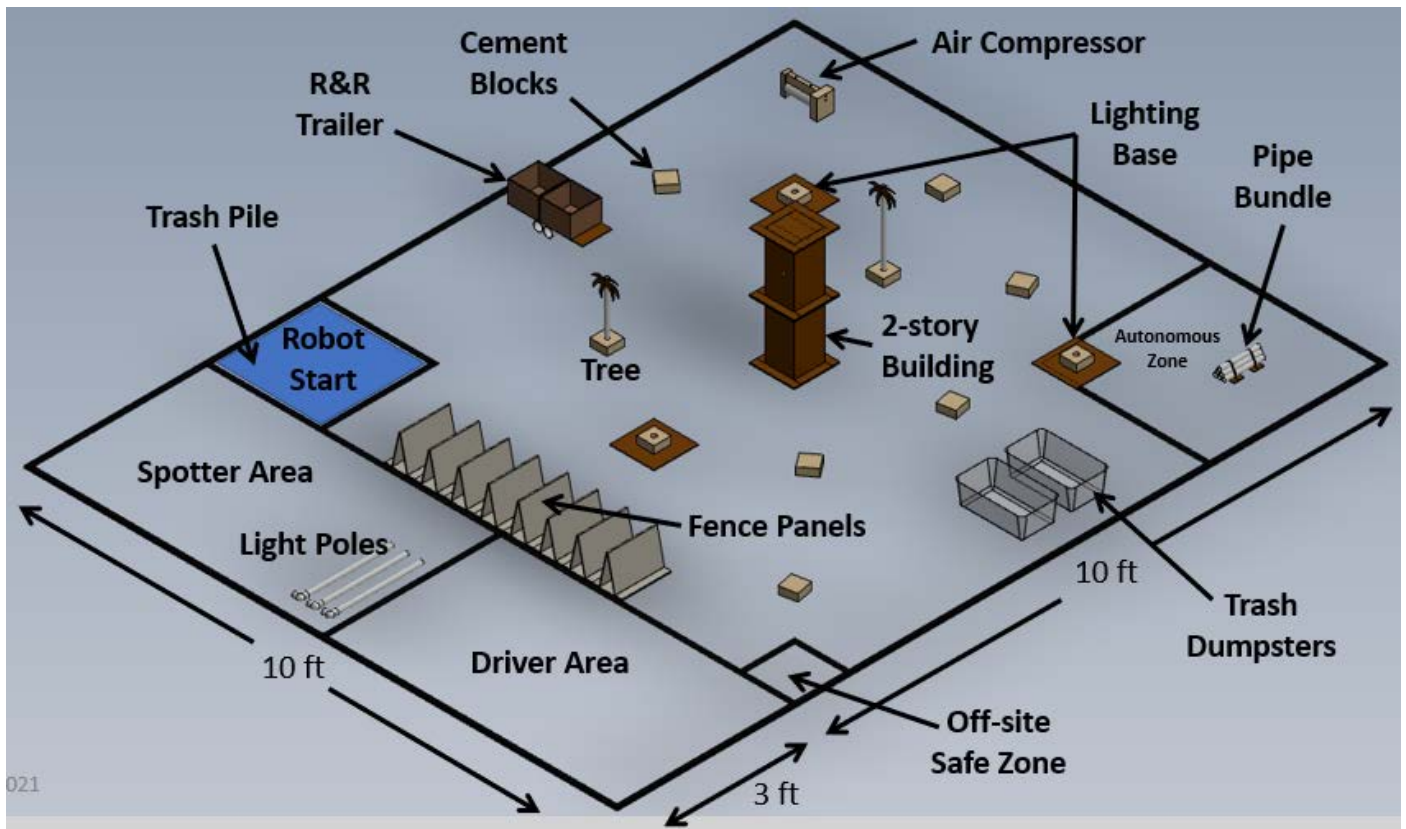
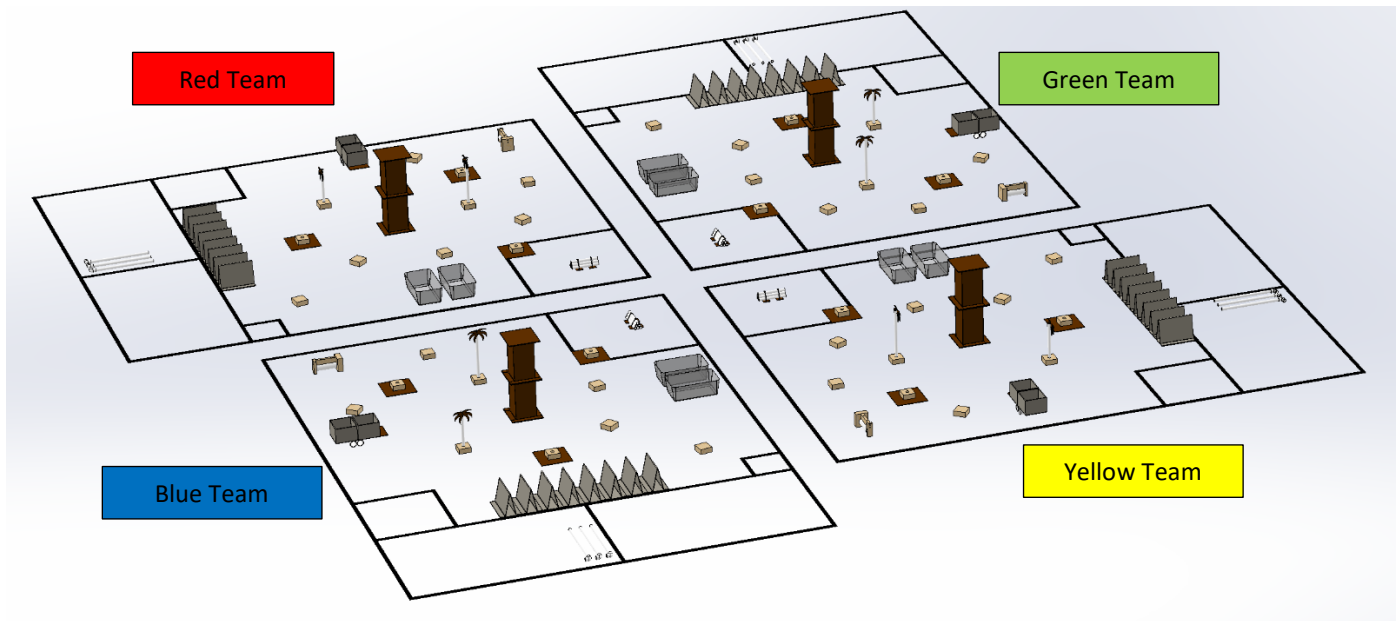


Figure 3.1 Single Quadrant Game Field for Single Team Competition

The floor surface of the single-team field used in the Classroom Competition can be any hard surface (concrete, tile, wood, laminate) or low-pile indoor/outdoor carpeting.

The virtual field used in the *Online Competition* is similar in layout to the single-team field.

A multi-team (Classic) competition field has 4 color-coded quadrants, separated by a neutral zone as shown in Figure 3.2. Game pieces are assigned to a single quadrant and each robot operates within its own quadrant.



*Figure 3.2 Full Playing Field for Multi-Team Competitions*

The floor surface of the multi-team field used in the Classic Competition will be low-pile indoor/outdoor carpeting.

In either the single-team or multi-team field configurations, the robot and game pieces may not completely leave their quadrant. The robot may not enter the driver or spotter areas or other team quadrants.

### 3.4.1 Robot Starting Area

The Robot Starting Area exists within the field boundaries at the corner of the quadrant closest to the spotter area. A team's Robot Starting Area is designated by colored tape (for multi-team competitions) and measures 24" x 24" from the outside edge of the tape line. The robot may freely enter and exit the Robot Starting Area.

Once demolition begins, the Robot Starting Area doubles as a Trash Pile where items that are considered trash can be placed instead of in the trash dumpsters.

### 3.4.2 Driver and Spotter Areas

Each competing team has one driver and one spotter at the field. The driver and spotter areas are designated by colored tape and each measures 60 ½" x 36". The Spotter Area is adjacent to the Robot Starting Area along one edge of the field. The Driver Area is located adjacent and to the right of the Spotter Area, when viewed from outside of the playing field.

### 3.4.3 Off-site Safe Zone

A dedicated Off-site Safe Zone exists within the field boundary, at the field quadrant corner adjacent to the Driver Area. The square Off-site Safe Zone is designated by tape and measures 12" x 12" from the outside edge of the tape line. The robot may freely enter and exit the Off-site Safe Zone.

### 3.4.4 Autonomous Zone

An Autonomous Zone exists in one corner of the site and is designated by tape lines surrounding a pipe bundle. The autonomous zone is a very dangerous part of the site and caution must be used to retrieve items from this area. The area measures approximately 36" L x 36" W to the outer edge of the tape. The pipe bundle in this area is to be recovered and salvaged as reusable materials. Robots may retrieve the pipe bundle under operator control or autonomously (the much safer and recommended method for retrieval). If retrieving the pipe bundle autonomously, the robot must operate autonomously while any part of the robot is [inside](#) the autonomous zone.

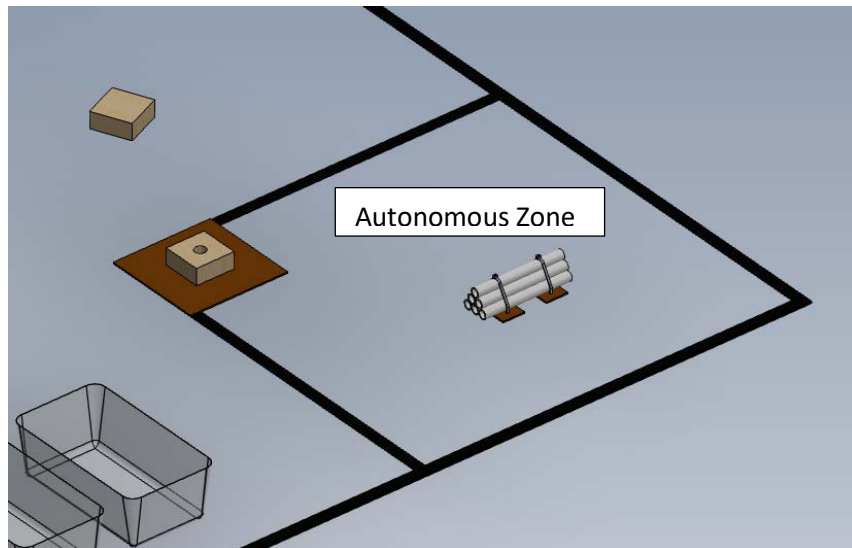


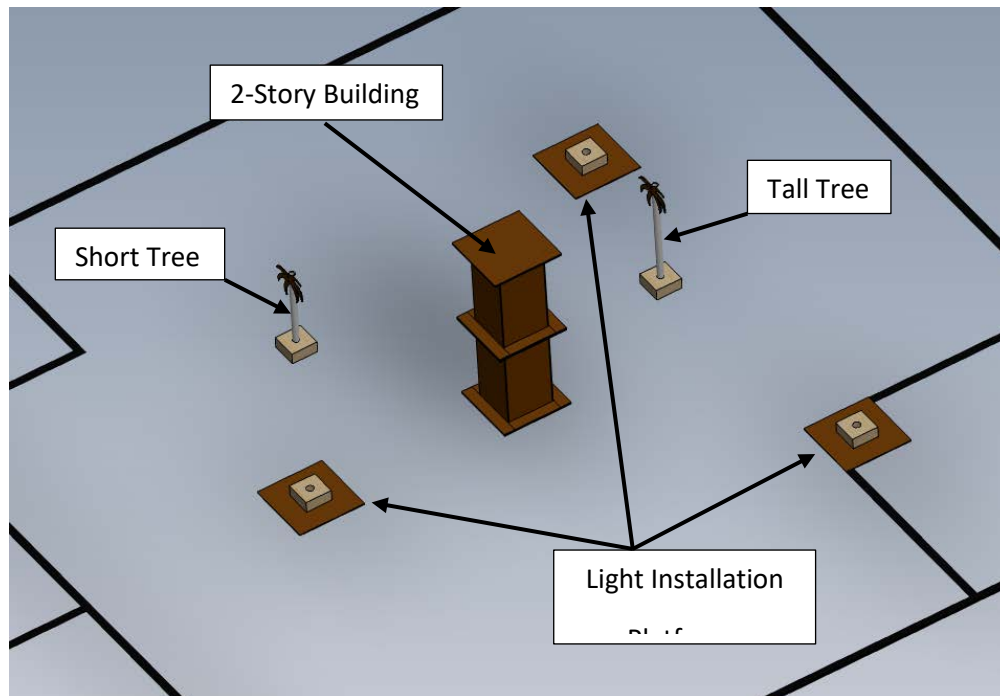
Figure 3.3 Autonomous Zone

### 3.4.5 Two-Story Building

A two-story building exists at the center of the demolition site as shown in Figure 3.4. The building is scheduled to be demolished and removed from this site.

The building is a two-story structure consisting of a first-floor, second-floor, roof, and four walls on each floor. There are additional floor joists (supports) attached and internal to the structure. The building dimensions are nominally 6" W x 6" L x 24" H. Each floor is ~12" in height. The floors of the building extend out ~1.5" from the building walls.

Inside the building are various materials such as insulation, copper wiring, water pipes, scrap tile, and scrap metal. Some of the materials are considered trash and others are reusable/recyclable. Refer to section 3.5.2 for details of the building contents.



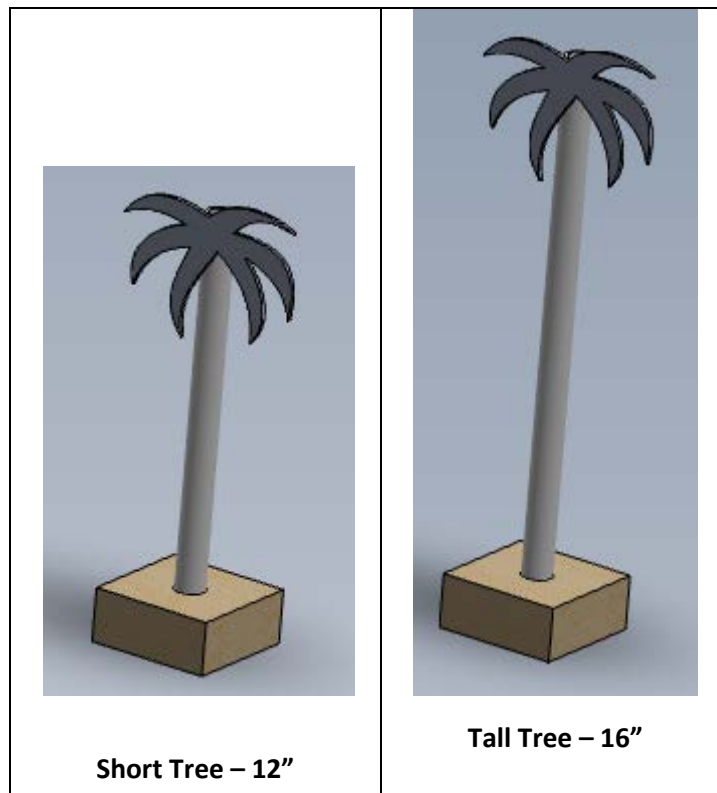
*Figure 3.4 Building, Trees, and Light Fixtures*

### 3.4.6 Trees

The construction site has two existing trees that must remain undisturbed throughout the demolition. The trees are stationary in the locations shown in Figure 3.4 and may not be moved or knocked down during demolition activities. If a tree is moved or falls, it may not be returned into its original position. (See [penalties for disturbing a tree](#))

The two trees are of differing heights. The short tree is 12" tall with a base of 3.5" x 3.5". The tall tree is 16" tall with a base of 3.5" x 3.5".

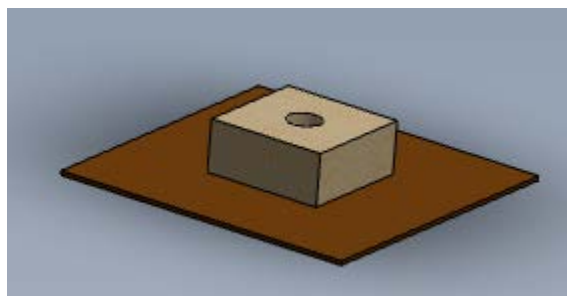
Each tree covers a 1" x 1" square tape pattern, designating its starting location and used in determining any disturbance of the tree that would invoke a penalty. Each tree is centered on the 1" square tape pattern at the beginning of the match. Rotation of the tree within the base is not considered to be a disturbance.



*Figure 3.5 On-Site Trees*

### 3.4.7 Lighting Platforms

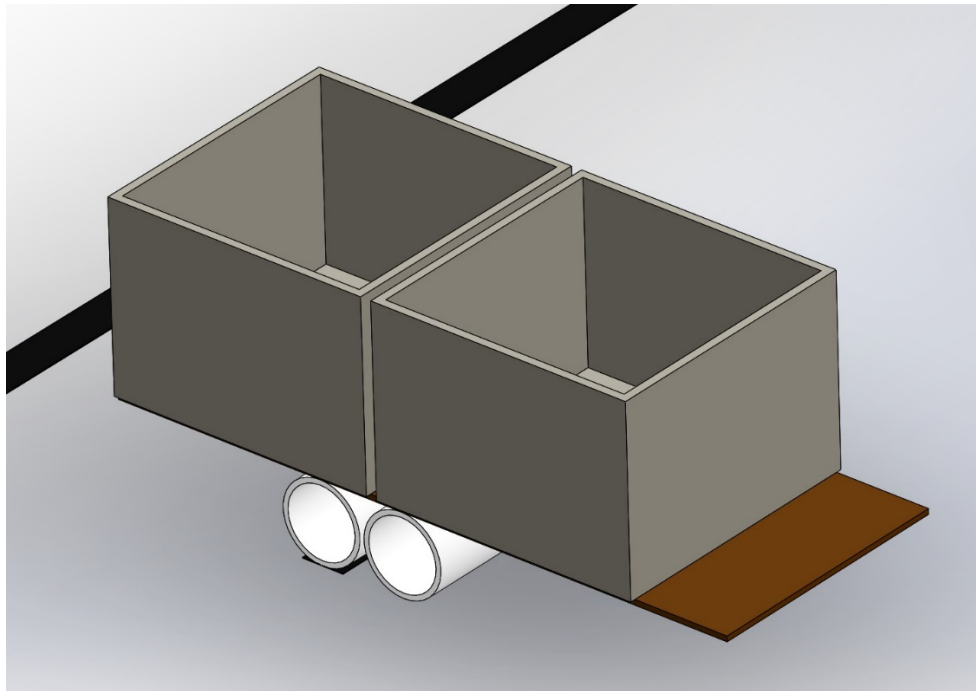
Security light poles have been delivered to the site and are awaiting installation. Three installation platforms have already been prepared for the lighting at fixed locations on the field as shown in Figure 3.4. The receptacle for the light pole is a 7/8" diameter hole drilled into a 3.5" x 3.5" x 1.5" block that is centered on a 9" x 9" base. Figure 3.6 depicts a single installation platform. Each light installation platform covers a 9" x 9" square tape pattern, designating its starting location and used in determining any [disturbance](#) of the platform.



*Figure 3.6 Lighting Installation Platform*

### 3.4.8 Flat Bed Trailer

A large flat-bed trailer has been brought to the site for collecting reusable and recyclable materials as the demolition progresses. The trailer is 15" L x 6" W x ~2" H, with a two-axle wheel-base. Two removable containers exist on the trailer. Each container is nominally 6" W x 6" L x 4" H and is used to store the Reusable and Recyclable (R&R) materials from the demolished building for transport from the site.



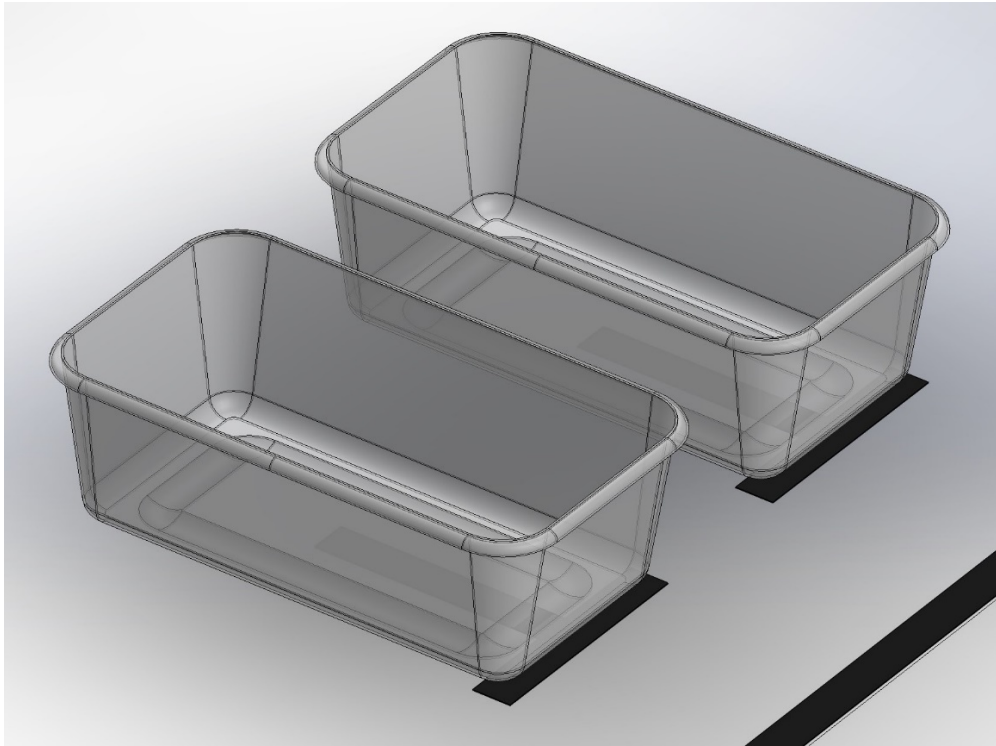
*Figure 3.7 Flat Bed Trailer with Reuse & Recycle Containers*

There is a 6" long tape line under the wheel closest to the field border used for initial placement. The trailer may not be moved such that the entire tape line is exposed from a top view. This is considered [disturbed](#).

Robots load the trailer with reusable and recyclable materials (placed into the R&R containers) for later transport. The trailer must be balanced before it can be hauled safely from the site. Only the R&R containers and [pipe bundle](#) may be loaded on the trailer.

### 3.4.9 Trash Dumpsters

Two trash dumpsters are available on the site as shown in Figure 3.8. Each dumpster measures approximately 13" L x 7" W x 4.5" H. They are located side-by-side and are spaced approximately 2" apart. The dumpsters are used for collecting [TRASH items](#) such as demolished building walls, floors, roof, cement blocks, etc.



*Figure 3.8 Trash Dumpsters*

There is a 6" T-shaped tape line beneath each dumpster used for initial placement. Dumpsters may not be moved such that the entire 6" T-shaped tape line is exposed. Such a movement is considered [disturbed](#).

### 3.5 Game Pieces

There are three types of materials at the construction site as shown in Table 3.2.

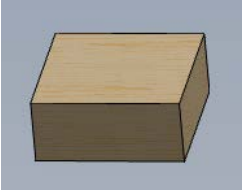


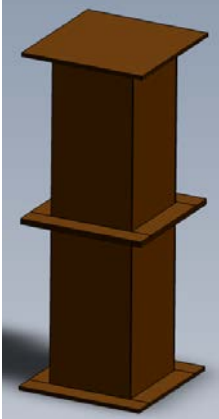
- 1) Trash
- 2) Reusable material(s)
- 3) Recyclable material(s)

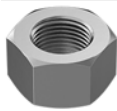

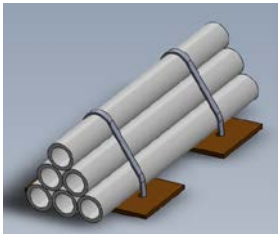

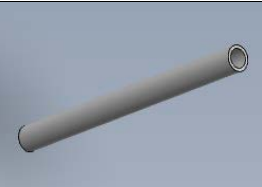
Materials exist both inside the two-story building and external to the building, strewn about the construction site.

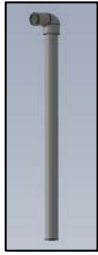
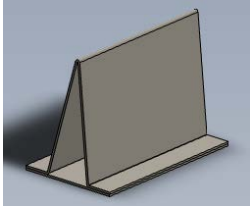
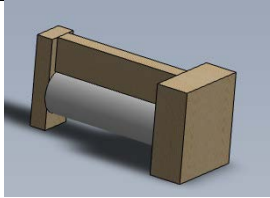
The site preparation crew has already delivered security and safety items to the site for use by the demolition team.

The site preparation crew inadvertently left their valuable air compressor on-site.

Table 3.2 Game Pieces and Starting Locations

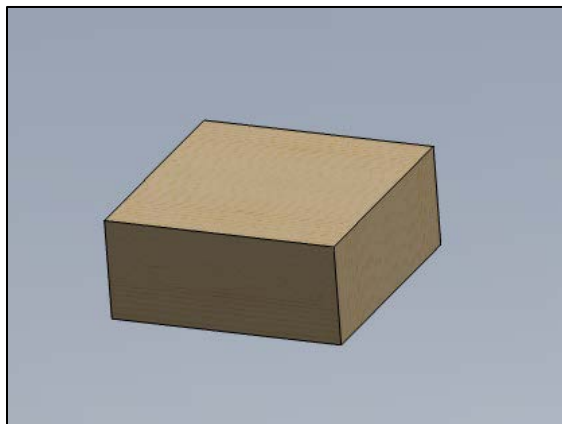
Material	Qty (per quad)	Starting Location	Photo
<b>TRASH</b>			
Cement block 3.5" x 3.5" x 1.5" Wood Block	6	Site Grounds	
Building Insulation, Cotton balls (1" size)	6	Inside Building	
Scrap Container, Solo Cup 16oz  Note: the scrap containers are worthless and have no impact to the final score. They are only present to simplify transport of other materials.	2	Inside Building	
Building walls/floors/roof, various sizes, Masonite & 1x4	11 8 walls 2 floors 1 roof	Inside Building	

<b>RE-USABLE</b>			
Scrap Metal, 3/8" Nuts 0.24 oz each	25	Inside Building, Inside Scrap Container	
Scrap Tile, 4-part mesh tile, 2" hexagonal, 6.25" L x 4" W 4.13 oz each	3	Inside Building, Inside Scrap Container	
Pipe bundle, Six 1/2" x 8" pvc pipes, Arranged in triangle bundle 11.40 oz	1	Site Grounds	
<b>RECYCLABLE</b>			
Copper Wire Segments, 6" Romex, 14-2, straight 0.85 oz each	6	Inside Building, 3 on each level	
Water Pipe, 1/2" PVC pipe x 4", straight 0.85 oz each	8	Inside Building, 4 on each level	

SECURITY AND SAFETY EQUIPMENT			
Light Poles, ½" PVC, ~18" Long	3	Spotter Area	
Fence Panels, Cardboard 6" W x 10" L x 7" H.	8	Site Grounds	
VALUABLE CONSTRUCTION EQUIPMENT			
Air Compressor, Wood & PVC, ~ 3.5" W x 8.25" L x 4" H	1	Site Grounds	

### 3.5.1 Cement Blocks

There are 6 cement blocks left strewn about the site during the initial site prep work. Cement blocks measure 3.5" W x 3.5" L x 1.5" H. The cement blocks are considered trash and should be cleared from the site and disposed of in the Trash Pile or the Trash Dumpster(s).

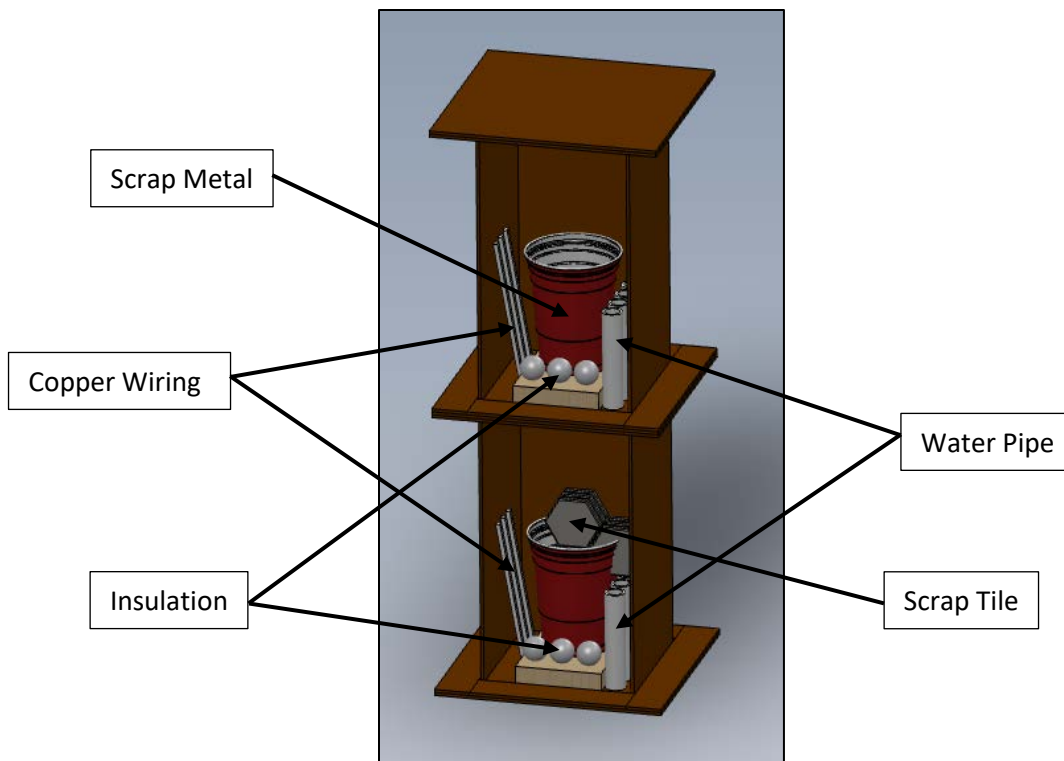


*Figure 3.9 Cement Block*

### 3.5.2 Building & Building Materials (inside building)

The building frame itself (the floors, walls, and roof) is considered trash after demolishing the building and should be disposed of accordingly in the Trash Dumpster(s) or the Trash Pile.

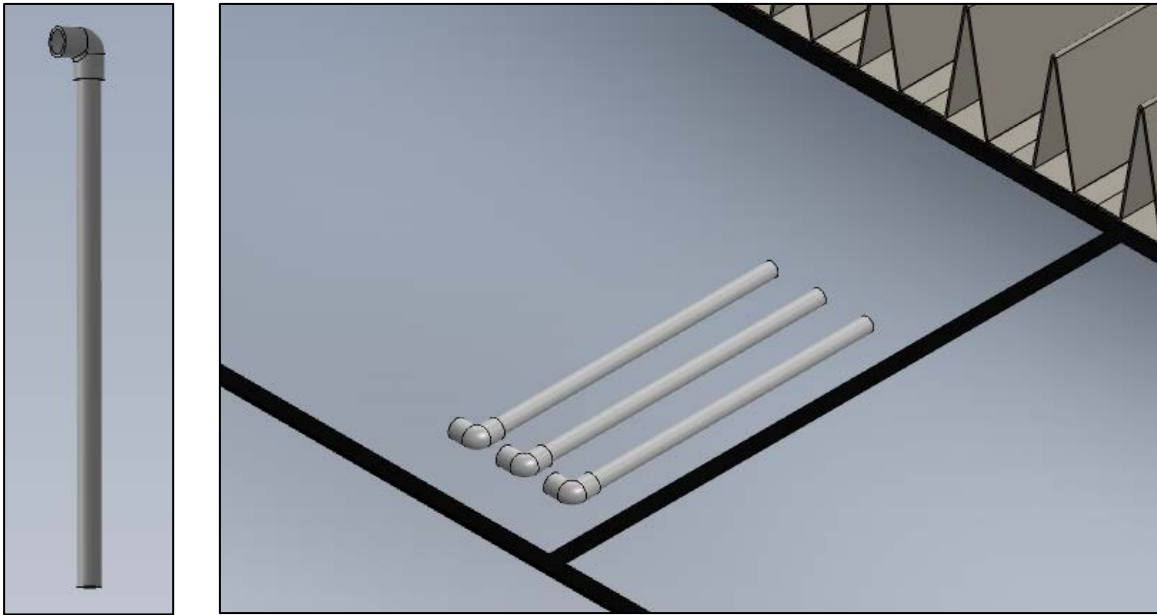
Inside the building, there are multiple materials that become exposed as the building is demolished. Some of these materials are trash and others are reusable/recyclable. This includes building insulation, water pipe, copper wiring, scrap tile and scrap metal. Figure 3.10 shows the contents of the building before demolition occurs. The prep crew has already placed the tile and metal into scrap containers inside the building.



*Figure 3.10 Building Contents Before Demolition*

### 3.5.3 Light Poles

Security light poles have been delivered to the site and are awaiting installation. Three installation platforms have already been prepared for the lighting. The poles must be vertically installed at the installation platforms. The light poles are  $\frac{1}{2}$ " PVC pipe, approximately 18" in tall and begin the match in the spotter's box. They must be loaded onto the robot or into the Robot Start Area while the robot is in the Robot Start Area before they can enter the field.



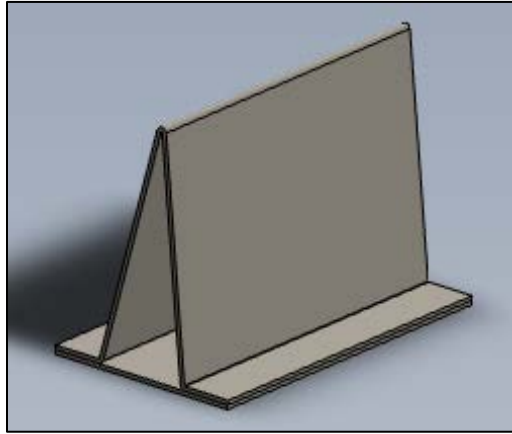
*Figure 3.11 Light Poles*

### 3.5.4 Fence Panels

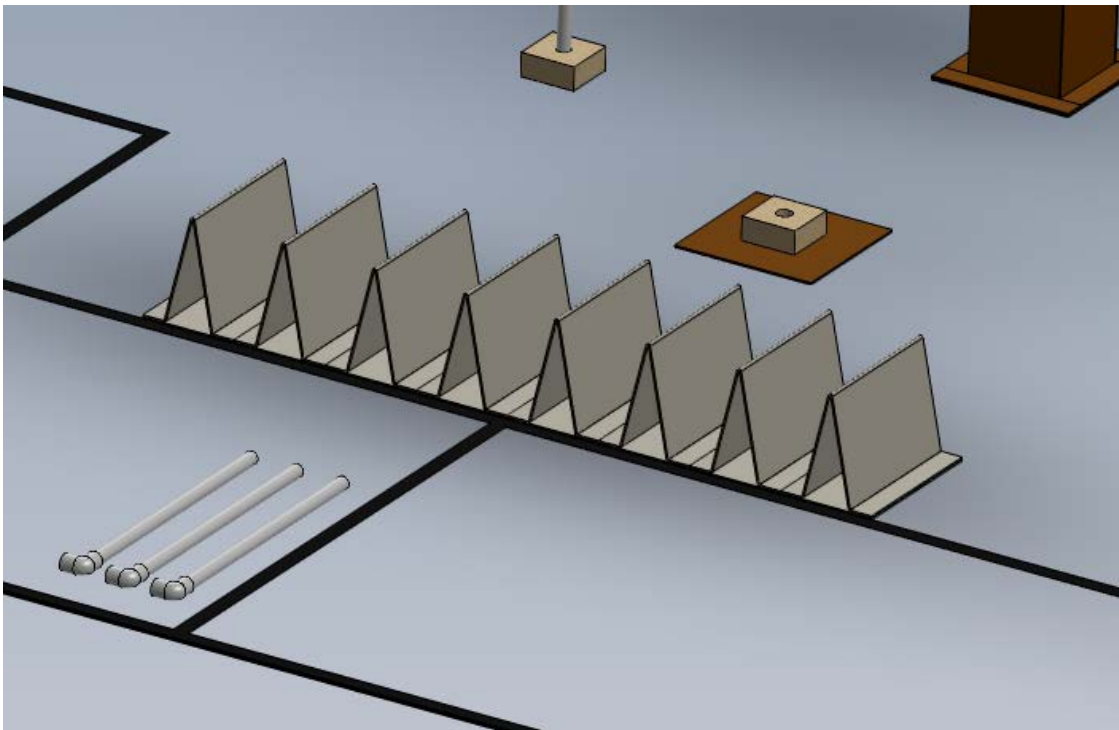
The preparation crew has delivered eight fence panels to the site. The fencing is used to secure the site or specific valuable contents left overnight at the site. The fence panels are grouped along one edge of the site nearest the driver and spotter. The panels are used to construct fencing in one of two locations:

- Installed end-to-end along the (straight) edge of the site farthest from the driver box. Attached sections are not required to be contiguous; partial fencing is acceptable.
- Installed end-to-end in any closed polygon shape surrounding the trailer. The closed polygon may consist of any number of fence panels greater than one and include the closest edge of the field.

Each fence panel has a triangular shape and measures 6" W x 10" L x 7" H. Fence panels are "connected" by butting the short ends against each other within the allowed spacing and angle tolerances. See section 3.7.3 for detailed rules and tolerances.



*Figure 3.12 A Single Fence Panel*

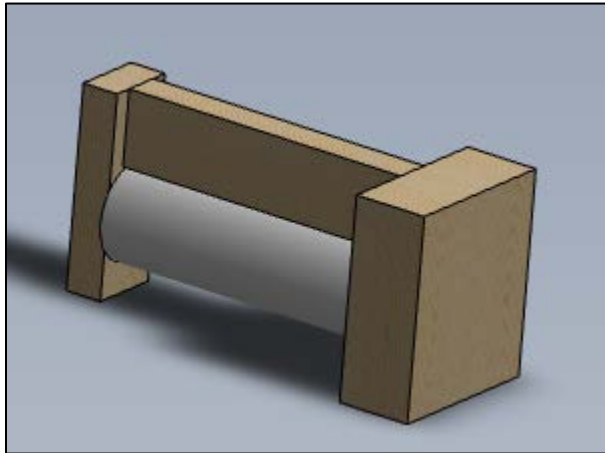


*Figure 3.13 Fence Panels Starting Location*

### 3.5.5 Air Compressor

An air compressor was left on site by the preparation crew. This valuable piece of equipment needs to be retrieved/removed from the site to a safe area or secured at job completion. The air compressor measures approximately 3.5" W x 8.25" L x 4" H.

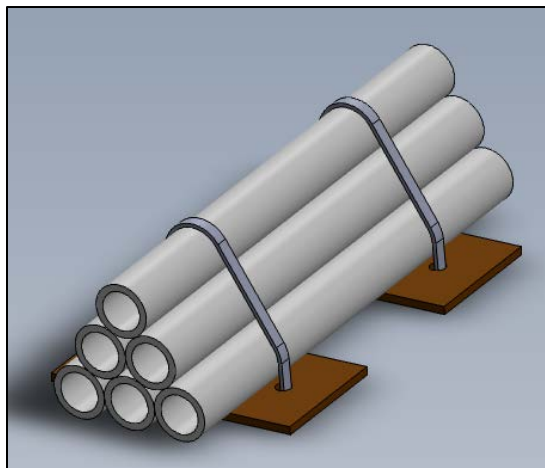
The air compressor may be moved to the Off-site Safe Zone, secured inside the closed-polygon fencing, or lifted off the floor by the robot before the end of the match.



*Figure 3.14 Air Compressor*

### 3.5.6 Pipe Bundle

The pipe bundle consists of six  $\frac{1}{2}$ " PVC pipes, 8" in length, bundled in a triangle formation and strapped to two small pallets (masonite boards). The pipe bundle is considered reusable material.



*Figure 3.15 Pipe Bundle*

## 3.6 Interaction Rules

### 3.6.1 Interaction with Other Robots, the Field and Game Pieces

- The robot must remain fully [inside](#) the Robot Starting Area and in the 24" x 24" x 24" starting configuration until the match begins.
- The robot may not leave the field during the match. At least one drive wheel of the robot must remain inside the outer tape edge defining the field (quadrant) border.

- c. During a **multi-team competition**, the robot's wheels may not enter another team's quadrant.
- d. The robot's wheel(s) may not enter the driver or spotter areas.
- e. Any violation of rules 3.6.1 (a-d) will result in a [20-second penalty](#).
- f. Game pieces that contact the floor outside the field boundaries are considered out of play and may not be returned to the field. The Robot Starting Area, Autonomous Zone and Off-Site Safe Zone are all areas inside the field boundaries.

### 3.6.2 Driver and Spotter Rules

The following rules apply to the driver and spotter. All rules are cumulative and must all be satisfied.

- a. The spotter may touch the field or robot inside the Robot Starting Area during interactions with the robot (loading of light poles).
- b. Light poles are the only game piece that may be inside the Spotter's Area.
- c. Other than debugging a non-functioning machine, the spotter may not manipulate the robot in any way after the match starts. This includes any manipulation of the robot other than installing the light poles.

Any violation of the following rules (d through f) will result in a **disqualification** for the current match.

- d. The driver may not touch any part of the field, any game piece, or the robot during the match.
- e. A team's light poles must stay within the Spotter's Area during the match until they are placed on the robot or into the Robot Starting Area.
- f. Throwing or tossing of game pieces is not allowed.

Any violation of the following rules (g through m) will result in a [20 second penalty](#) during the current match.

- g. The driver must keep his/her feet within the Driver's Area during the match.
- h. The spotter must keep his/her feet within the Spotter's Area during the match.
- i. The spotter may only interact with the robot when any part of the robot is [inside](#) the Robot Starting Area.
- j. The spotter may not be touching the robot or any part of the field when the driver is touching the joystick.
- k. The driver must maintain "hands off" the controller while the spotter is loading game pieces onto the robot.
- l. The joystick must be placed on a "hands free" surface (chair, desk, box, other) or on the floor before the spotter touches the robot and remain there during periods of interaction with the robot. "Hands free" means no touching the joystick during this time.
- m. After the match starts, the spotter may place any number of light poles onto the robot or inside the Robot Starting Area when any part of the robot is inside the Robot Starting Area (note rules j, k). The robot is considered inside the starting area when any part of the robot has broken the plane of the starting area.

### 3.7 Game Play

The primary objectives are to

- **Demolish and remove the building from the site**
  - Demolish the building and remove it from the site
- **Install safety/security measures at the site**
  - Install fencing for security.

- Install lighting for safety.
- **Separate and recover recyclable and reusable materials**
  - Place the reusable items inside the R&R containers
  - Place the recyclable items inside the R&R containers
  - Prepare the flat-bed trailer for transport by balancing the load
- **Remove trash from the site**
  - Place all trash in the trash pile or trash dumpster(s).
- **Recover/secure the air compressor**

### 3.7.1 General Rules

- a. The robot may use any technique desired to demolish the building and expose its components and the materials inside.
- b. The metal and tile Scrap Containers (Solo cups) are not worth any points; they are only available to simplify transport of materials. These containers are considered part of the game field. Non-intentional damage may occur through consequences of demolishing the building (e.g., building falls on the containers). Damage due to specific robot manipulations (such as crushing the container with the robot claw/gripper) will result in a penalty and possible disqualification from the match.
- c. Trees that are knocked down or **Disturbed** (per section 3.8.3.1 ) during the match will result in a [penalty](#).
- d. Trailer, dumpsters or light installation platforms that are [Disturbed](#) will result in a [nullified score](#) for the disturbed item (refer to section 3.8.4 ).

### 3.7.2 Collect/Remove Trash from the Site

- a. Table 3.2 identifies the materials that are considered *Trash*. Points are awarded for *Trash* that is inside the Trash Pile boundary or fully supported by one or more Trash Dumpster(s), including stacked materials, at the end of the match.
- b. Recyclable and Reusable materials may also be scored by placing them **Inside** the Trash Pile boundary or Dumpster(s) as indicated in Table 3.3.
- c. Game pieces must be fully [inside](#) the outer edge of the tape line defining the Trash Pile, for those pieces to be awarded points.
- d. Dumpster(s) must remain upright, with the entire bottom face touching the floor, for game pieces supported by the dumpster(s) to be awarded points.

### 3.7.3 Construct Security Fencing

- a. Fencing may be constructed in one of two locations, or both locations, as shown in the Figure 3.16 example:
  - i. *Straight Barrier*: Constructed end-to-end anywhere along the 10' (straight) edge of the site farthest from the driver box (Field Edge A). Attached panels are not required to be contiguous; partial fencing is acceptable.
  - ii. *Closed Polygon Barrier*: Constructed end-to-end in any closed polygon shape surrounding the trailer. The closed polygon must consist of more than one fence panel and include the closest edge of the field.

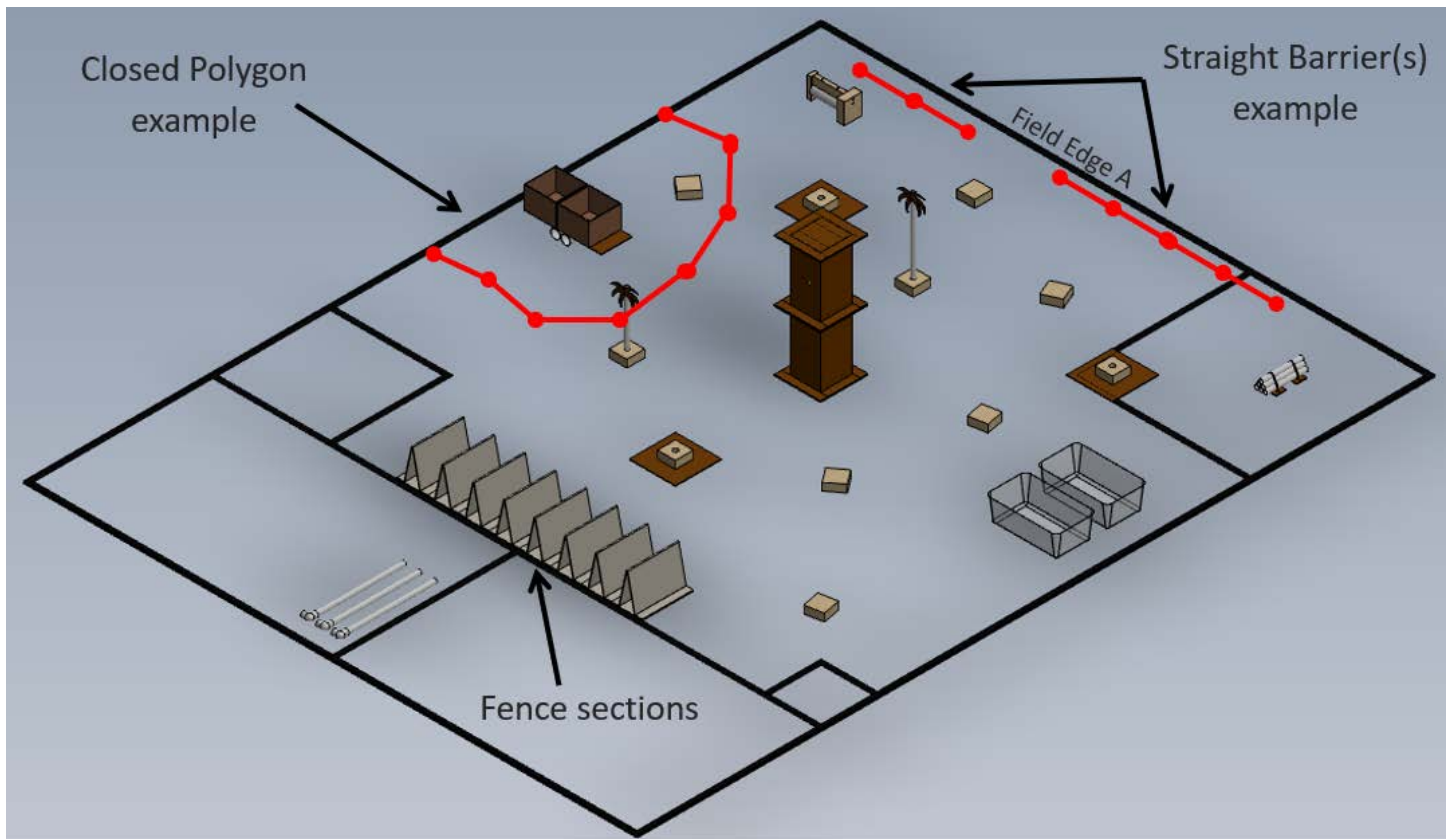


Figure 3.16 Fence Construction Options

- b. Two fence panels are considered “connected” if they meet the following spacing, angle and orientation requirements.
  - i. **Spacing:** No greater than 1.5” (2x4 width) space between the two closest points on the base short edges of two fence panels. (*Evaluation note:* the connection is valid if you cannot slide the smallest width of a 2x4 [use a cement block game piece] through the opening)
  - ii. **Angle:** Short edges of two fence panels must be within 90deg of each other. See Figure 3.17 for examples.
  - iii. **Orientation:** Fence panels must be upright (base is in full contact with the ground but may overlap another fence base).
- c. Points are awarded for each valid connection between two fence panels. Two fence panels are required for a valid connection (see rule 3.7.3 b).
- d. For the *Straight Barrier* fencing, the distance (gap) between the closest point of a fence panel and the outer edge of the tape defining the Field Edge A (see Figure 3.16) must be no greater than 10”. If the distance is greater than 10”, the fence panel and its connections are invalid. (*Evaluation note:* Use the long edge of another fence panel to measure the distance).
- e. For the *Closed Polygon Barrier* fencing, the distance (gap) between the closest point of an end fence panel and the outer edge of the field boundary must be no greater than 1.5”. If the distance is greater than 1.5”, the fence

panel and its connections are invalid. (*Evaluation note:* the fence panel is valid if you CANNOT slide the smallest width of a 2x4 [cement block game piece] through the gap).

- f. Bonus points are awarded for a closed polygon fence shape surrounding the Flat-bed Trailer.

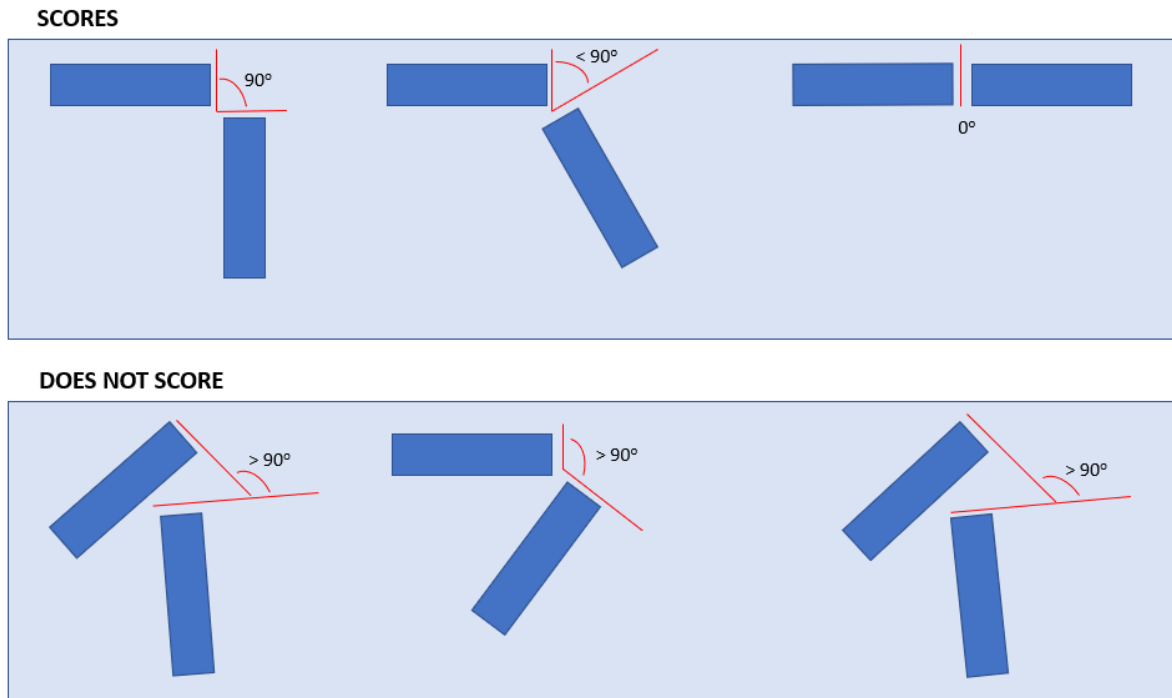


Figure 3.17 Fence Panel Connections, Angle Requirement

### 3.7.4 Install Safety Light Poles

- a. Only the robot may cause the light poles to enter the field beyond the Robot Starting Area.
- b. Light poles may be manipulated by the robot in any fashion to complete installation (carried, pushed, set on floor, rolled, picked up, rotated, etc.).
- c. The spotter may load as many light poles onto the robot as desired. See 3.6.2 for loading constraints.
- d. Points are awarded for each light pole installed into a light installation platform at the end of the match.
- e. Points will be nullified for each light installation platform that is disturbed from its original starting location.
- f. A disturbed light installation platform may not be returned to its starting location and will no longer be awarded points for an installed light pole.

### 3.7.5 Collecting Reusable and Recyclable Materials

- a. Table 3.2 identifies the reusable and recyclable materials to be collected.
- b. Reusable and recyclable materials may be placed in the R&R containers, dumpsters or trash pile.

- c. Only ONE type of material may be stored in a single R&R container. Multiple types of material stored in a single R&R container will nullify any score for the R&R container contents.
- d. The bottom face of the R&R container must be touching the field floor or the bed of the trailer for any contents to score.
- e. The pipe bundle may NOT be stored in an R&R container.
- f. Points are awarded for Reusable and Recyclable materials that are fully supported by one of the R&R containers, including stacked materials, and rules (a)-(e) are satisfied at the end of the match.
- g. Points are awarded for Reusable and Recyclable materials that are [inside](#) the Trash Pile boundary at the end of the match.
- h. Points are awarded for Reusable and recyclable materials that are supported by one or more dumpsters at the end of the match.

### 3.7.6 Loading the Trailer

- a. R&R Containers may be removed from the trailer.
- b. The trailer load may only consist of R&R container(s) and/or pipe bundle. No other items can be placed directly on the trailer.
- c. The R&R containers and/or pipe bundle may not be stacked on top of each other on the trailer.
- d. The bottom face of the R&R container must be touching the bed of the trailer.
- e. No additional points are awarded for R&R containers fully supported by the trailer, except when the Trailer Balancing Bonus conditions are met (see 3.8.2 ).
- f. Points are awarded if the pipe bundle is fully supported by the trailer at the end of the match and both pallets (masonite) of the pipe bundle are completely in contact with the surface of the trailer bed. The pallets may not hang over any edge of the trailer.

### 3.7.7 Balancing the Trailer

- a. A bonus multiplier is applied to the trailer load if the trailer is balanced at the end of the match.
- b. The points awarded for the trailer load will be doubled if the trailer balancing conditions are met. (See 3.8.2 )
- c. R&R containers (containing eligible game pieces) and the pipe bundle are both eligible for the Trailer Balancing Bonus.
- d. Materials may not be placed under the trailer to aid in stabilizing or balancing the trailer at any point during the match. Such action is considered [disturbing](#) the trailer.

### 3.7.8 Recover/Secure the Air Compressor

- a. Points are awarded if the air compressor is in ONE and ONLY ONE of following states at the end of the match.
  - a. Lifted
  - b. Safe
  - c. Secured
- b. *Lifted*: Points are awarded if the air compressor is in the robot grasp (see rule 3.8 c.), is not touching the floor and is at least 1.5" above the surface of the floor.
- c. *Safe*: Points are awarded if the air compressor is [inside](#) the safe zone and is touching the floor.
- d. *Secured*: Points are awarded if the air compressor is inside the closed-polygon fencing (see Figure 3.16) and is touching the floor.

### 3.7.9 Autonomous Retrieval of the Pipe Bundle

In the autonomous retrieval task, the robot must retrieve the pipe bundle from the Autonomous Zone under its own control. The pipe bundle is considered retrieved only when the pipe bundle and robot are completely outside of the Autonomous Zone. Autonomous retrieval is scored independent of loading the pipe bundle on the trailer for transport.

#### Task Description

- a. Robots shall retrieve the pipe bundle from its original starting position in the Autonomous Zone.
- b. Robots must retrieve the pipe bundle autonomously (i.e., with no driver control).
- c. Each attempt must begin with the robot completely outside of the Autonomous Zone.
- d. The team may attempt the autonomous retrieval as many times as desired until successful subject to rule 3.7.9 e).
- e). An attempt concludes when the driver touches the joystick or the end of match (time=0:00) is reached.
- e. If the pipe bundle is moved from its original starting location on an unsuccessful attempt (see rule 3.7.9 o), no additional attempts may be performed.

#### Procedure

- f. The autonomous retrieval can be attempted at any time during the match. The driver must notify the referee of the attempt before initiating any autonomous retrieval.
- g. An autonomous setup period will begin when the robot is outside the Autonomous Zone and the driver is no longer touching the joystick. The joystick must be placed on a “hands-free” surface (chair, desk, box, other) or on the floor.
- h. The driver will initiate the autonomous retrieval period by pressing any combination of buttons on the joystick without lifting it from the hands-free surface.
- i. The autonomous retrieval period ends when the driver touches the joystick or the end of match (time=0:00) is reached.
- j. If the driver picks up the joystick or touches it prior to the pipe bundle and robot exiting the Autonomous Zone, the retrieval attempt ends. The driver may resume manual control of the robot.
- k. Once an autonomous retrieval period has begun, the driver may not move the pipe bundle under manual robot control until AFTER the referee evaluation is complete (see rule 3.7.9 m).
- l. The retrieved pipe bundle is not required to be placed on the trailer to receive Autonomous Retrieval points.

#### Evaluation

- m. At the end of the autonomous retrieval period, the referee will evaluate the attempt and score the autonomous pipe bundle retrieval as successful or unsuccessful (by a thumbs up or thumbs down).
- n. An Autonomous retrieval attempt is scored as “successful” when
  - the driver touches the joystick on the hands-free platform, and
  - the pipe bundle and robot reside completely outside the Autonomous Zone.
- o. An Autonomous Pipe Bundle retrieval attempt is unsuccessful if the driver touches the joystick and the pipe bundle and Robot are not both outside of the Autonomous Zone.
- p. If the autonomous retrieval is successful, points will be awarded for the retrieval.

### 3.8 Scoring

- a. All points, except for the Autonomous Pipe Bundle Retrieval, are determined at the end of the match.
- b. Game pieces are scored based on their final location at the end of the match.
- c. Any game piece that the robot or spotter is touching at the end of the match does not score except for the Air Compressor.
- d. Penalties are assessed by referees in real-time during the match.

#### 3.8.1 Scoring Summary

Table 3.3 - Table 3.5 summarize the points awarded for each game piece in a scoring position at the end of the match. Table 3.6 summarizes the points awarded for successful completion of the autonomous retrieval task.

As indicated in the tables, some game pieces are also eligible for additional bonuses. Notice that the pipe bundle is eligible for two bonuses.

Table 3.3. Scoring Summary (Trash, Reusable Materials, Recyclable Materials)

Game Piece	End of Match Location (Points Each)				Max # Possible Per Team	Max Possible Points Per Team <sup>3</sup>
	Trash Pile	Dumpster	R&R Container	Trailer		
<b>Trash</b>						
Cement Block	2	5			6	30
Insulation	3	10			6	60
Building Wall	7	15			8	120
Building Floor/Roof	15	30			3	90
<b>Reusable Materials<sup>1</sup></b>						
Scrap Metal	1	2	4		25	100
Scrap Tile	5	10	40		3	120
Pipe Bundle <sup>2</sup>		50		100	1	100

<b>Recyclable Materials<sup>1</sup></b>						
Copper Wire	4	7	20		6	120
Water Pipe	3	4	13		8	104

<sup>1</sup>Eligible for Trailer Balancing Bonus

<sup>2</sup>Eligible for Autonomous Retrieval Bonus

<sup>3</sup>Not including possible bonuses

*Table 3.4 Scoring Summary for Safety & Security*

<b>Game Piece</b>	<b>Points Per Connection<sup>4</sup></b>	<b>Points Per Installation</b>	<b>Max # Possible Per Team</b>	<b>Max Possible Pts Per Team</b>
Fence Panel Connection <sup>5</sup>	10		7	70
Installed Light Pole		75	3	225

<sup>4</sup>Points awarded for each connection between two fence panels (3.7.3 c)

<sup>5</sup>Eligible for Closed Polygon Fencing Bonus

*Table 3.5 Scoring Summary for Air Compressor*

<b>Game Piece</b>	<b>Safe</b>	<b>Lifted</b>	<b>Secured</b>	<b>Max # Possible Per Team</b>	<b>Max Possible Pts Per Team</b>
Air Compressor State	20	40	60	1	60

*Table 3.6 Scoring Summary for Autonomous Retrieval Task*

<b>Task Completed</b>	<b>Points for a Successful Retrieval</b>	<b>Max # Possible Per Team</b>	<b>Max Possible Pts Per Team</b>
Pipe Bundle Autonomous Retrieval	120	1	120

### 3.8.2 Bonuses

- a. A Trailer Balancing bonus is awarded for eligible game pieces supported by the trailer when the Flat Bed Trailer load is balanced at the end of the match. The trailer bed must not be touching the floor and both wheels must be touching the floor.
- b. The Trailer Balancing Bonus will double the points received for eligible game pieces in scoring position on the trailer (i.e., pipe bundle or items within R&R containers).
- c. An Autonomous Retrieval Bonus is awarded when the Pipe Bundle has been retrieved autonomously (see 3.7.9 ) and it is successfully loaded onto the trailer (see 3.7.6 ).
- d. The Autonomous Retrieval Bonus will double the points received for successfully loading the pipe bundle on the trailer, independent of Trailer Balancing.
- e. The Closed Polygon Fencing Bonus is awarded when a valid closed polygon barrier surrounding the trailer is constructed (see section 3.7.3 ).
- f. The Closed Polygon Fencing Bonus will double the points received for each fence panel connection in a valid closed polygon barrier surrounding the trailer (see section 3.7.3 ).

### 3.8.3 Penalties

#### 3.8.3.1 Disturbing Trees

- a. A tree falling, knocking a tree over, or moving the tree such that the 1" square tape pattern underneath its base is fully exposed, will result in a [20-second penalty](#) being assessed for each occurrence.
- b. When a tree falls or is disturbed, it is considered uprooted and may not be moved back into its original starting position.
- c. Only one [20-second penalty](#) will be assessed per tree that is disturbed. A maximum of 40 sec of penalty can therefore be assessed in one match if both trees are disturbed.

### 3.8.4 Score Nullifications

#### 3.8.4.1 Disturbing Light Installation Platforms

- a. If a light installation platform is moved such that the 9" x 9" square tape pattern covered by the platform becomes fully exposed, the platform is considered disturbed and will not be awarded points for a light pole installed into it.
- b. Once disturbed, the platform is no longer a scoring opportunity for the duration of the match.
- c. A disturbed light installation platform may not be moved back into a valid scoring position.

#### 3.8.4.2 Disturbing the Trailer

- a. If the trailer is moved such that the tape line underneath becomes fully exposed when viewed from a top-view, the trailer is considered disturbed.

- b. Once disturbed, the trailer is no longer a scoring opportunity for the duration of the match.
- c. A disturbed trailer may not be moved back into a valid scoring position.
- d. Material placed under the trailer is also considered to be disturbing the trailer.

### 3.8.4.3 Disturbing a Dumpster

- a. If a dumpster is moved such that the tape line underneath becomes fully exposed, the dumpster is considered disturbed.
- e. Once disturbed, a dumpster is no longer a scoring opportunity for the duration of the match.
- f. A disturbed dumpster may not be moved back into a valid scoring position.

### 3.8.5 Scoring Definitions

**Disturbed** – moved beyond the allowed amount.

**Resting** – touching such that the entire weight of the object is supported by what it rests on.

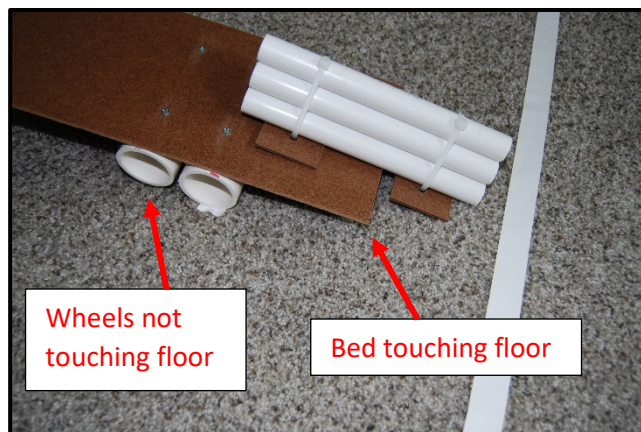
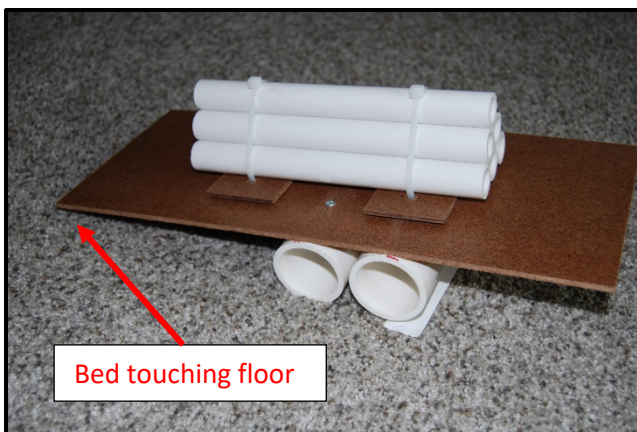
**Inside, In, Within** – within the imaginary infinite vertical planes defined by the innermost sides of a container/area or the outer edge of a tape line defining the boundaries of an area or grid space.

### 3.8.6 Example Scoring

#### 3.8.6.1 Trailer Balancing Bonus

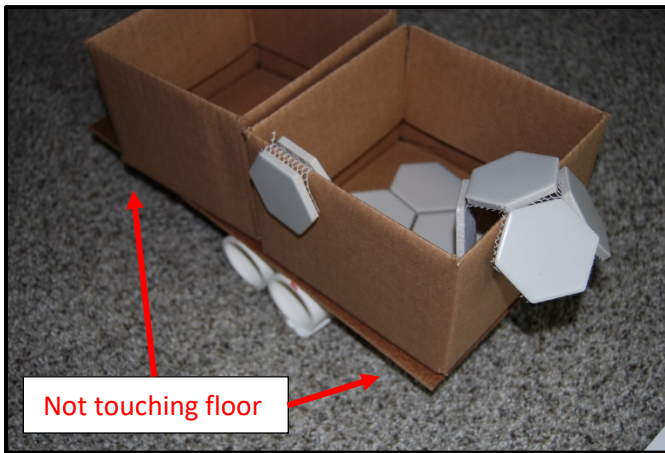
These examples **DO NOT** score the Trailer Balancing Bonus because either

- a) both wheels are NOT touching the floor, or
- b) the trailer bed IS touching the floor:



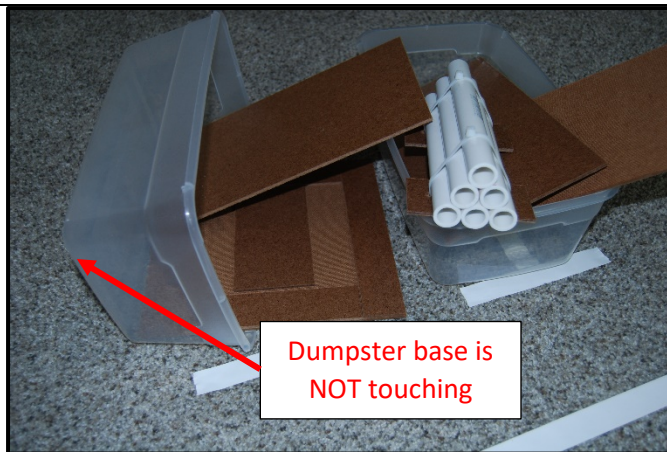
These examples **DO** score the Trailer Balancing Bonus because

- a) Both wheels **ARE** touching the floor.
- b) The bed of the trailer **IS NOT** touching the floor.
- c) The trailer has not been disturbed.

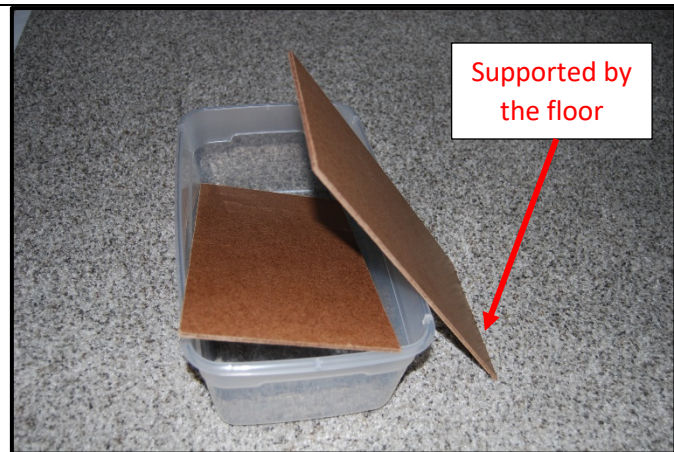


### 3.8.6.2 Supported By

The items in the left bin **DO NOT** score because the base of the dumpster is **NOT** touching the floor.

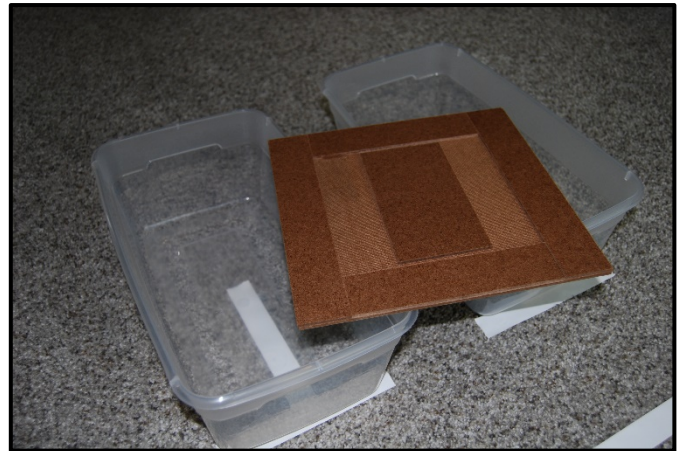


**One** item **DOES NOT** score because it is supported by the floor.



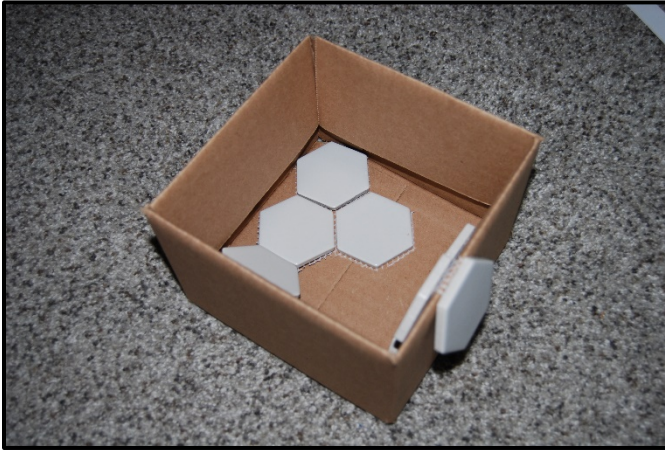
All items in the following examples **DO** score because

- a) The item(s) are fully supported by one or more dumpsters, or by stacked material which is fully supported by the dumpster(s).
- b) The dumpster where the item is stored is NOT disturbed.



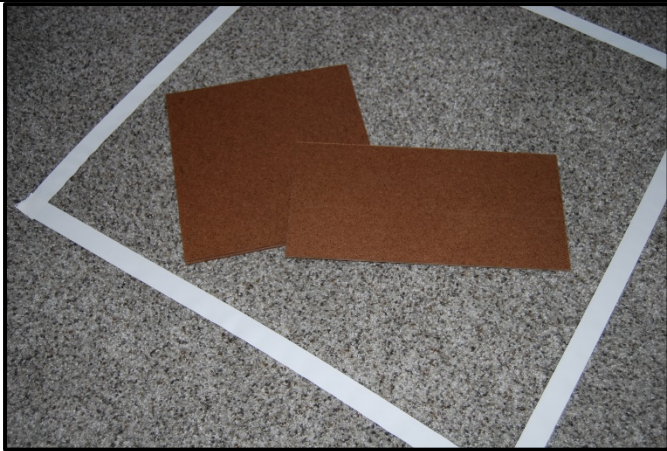
All items in the following examples **DO** score because

- The items are fully supported by the R&R container or a scrap container within the R&R container.

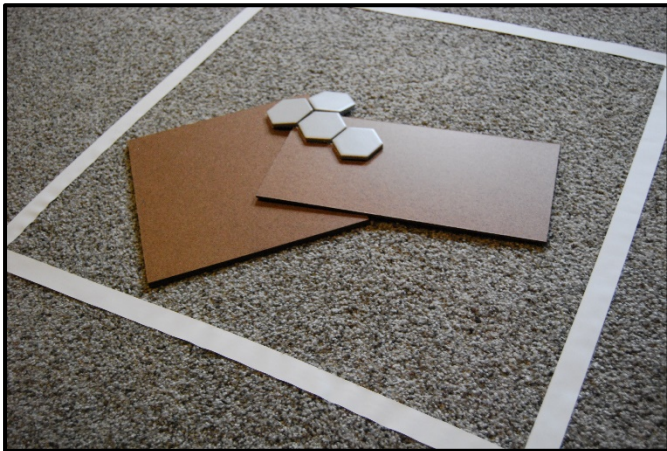
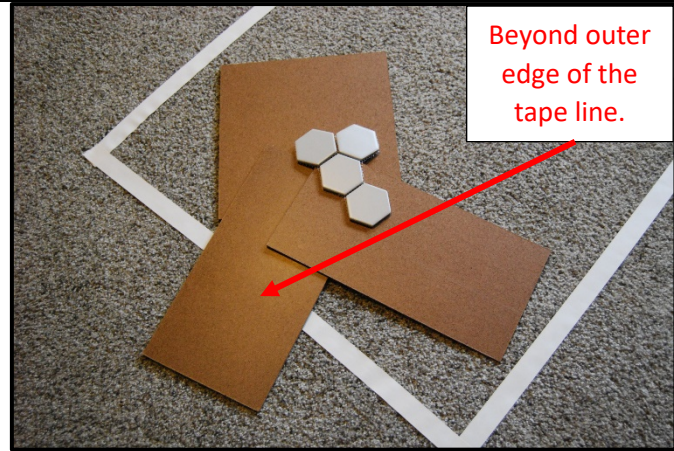


### 3.8.6.3 Inside

These items **DO** score because they are all inside the outer edge of the tape boundary defining the trash pile.

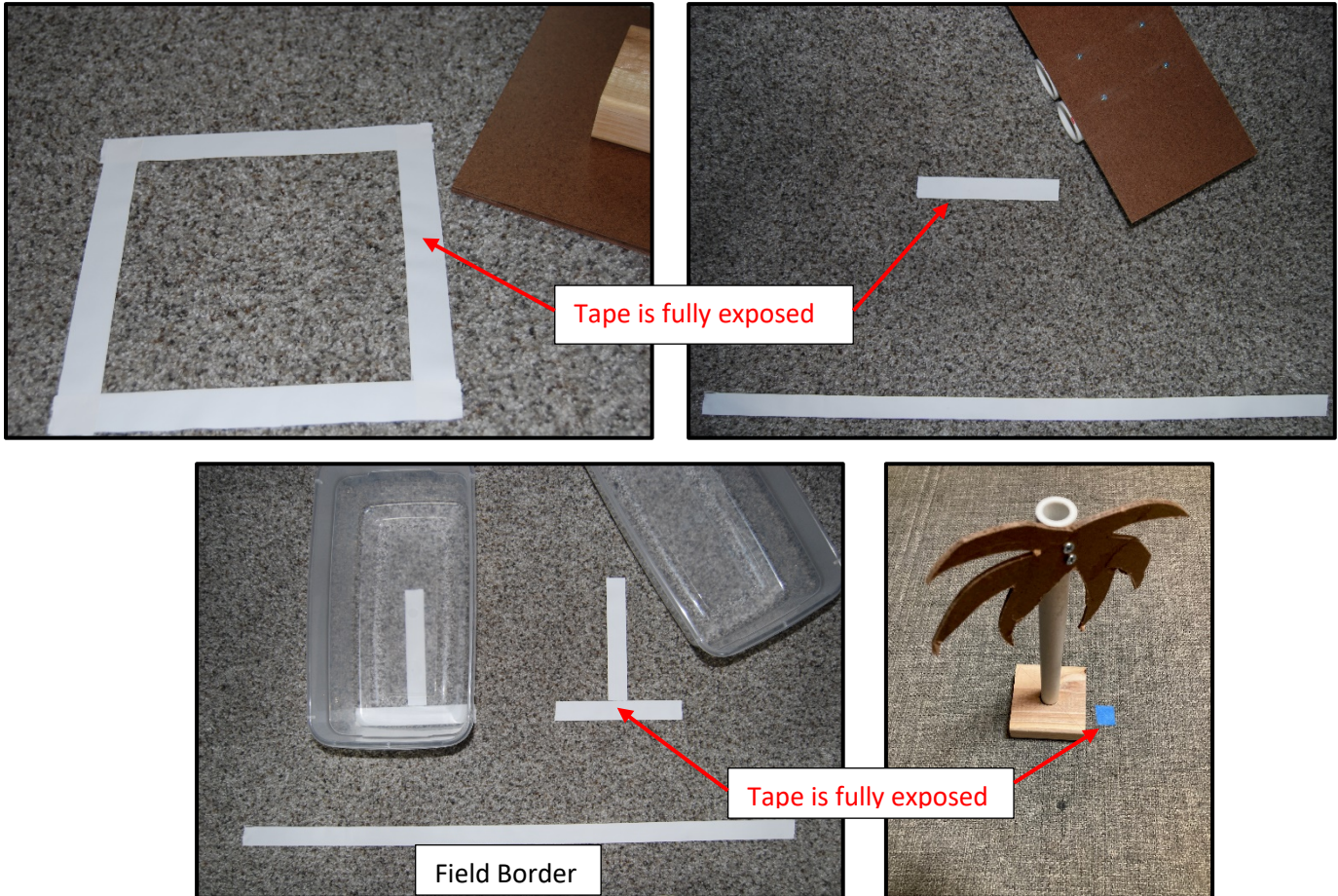


**One** of these items **DOES NOT SCORE** because it is not fully inside the outer edge of the tape boundary defining the trash pile.

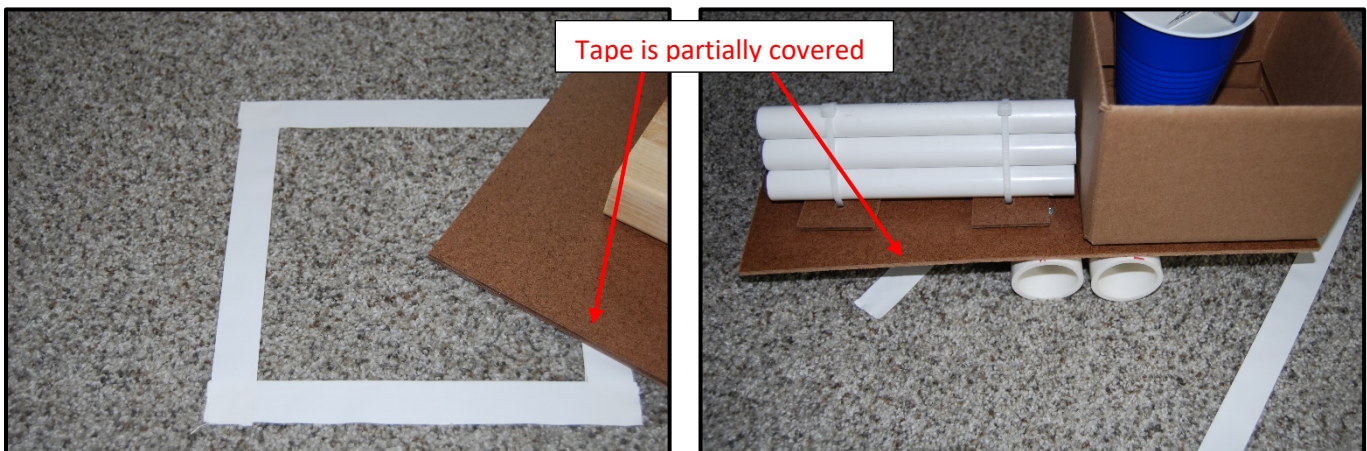


### 3.8.6.4 Disturbed

These items are considered **DISTURBED** because the tape lines are fully exposed:



These items are considered **NOT DISTURBED** because the tape lines are not fully exposed:



### 3.9 Autonomous Programming Challenge Virtual Game Play

The Autonomous Programming Challenge will be offered as an independent challenge for the BEST Classic and BEST Classroom competition formats. This challenge will be used for the robot performance time trials in the BEST Online competition format; driver-controlled robot performance will not be included in the BEST Online competition format.

This challenge will use a virtual field and robot within the Mathworks MATLAB/Simulink environment. The virtual field will represent a single field quadrant very similar to the field described throughout this section. The virtual robot is provided within this environment; teams only need to program the robot to accomplish the game tasks. Game play will be like that described throughout Section 3 but with some changes (unique objectives, additional sensors, alternate challenges). A complete description of the virtual field, virtual robot and challenge rules are provided in the ***Autonomous Programming Challenge Rules*** document.

## Section 4 Awards and Judging

### 4.1 Head-to-Head Competition / Robot Performance Judging

The head-to-head competition / robot performance results for a team are dependent on the following criteria:

- The Student Participation Survey must be completed by all students on the team roster prior to competing in any head-to-head, classroom or virtual competition. Refer to the BEST National Registry Team Workflow for due dates. Completion of the survey will be verified at the Robot Compliance Check.
- An Engineering Notebook must be submitted by the participating team prior to competing.
- All team members (students, teachers, mentors) must individually register in the BEST National Registry prior to competing on Game Day.
- A participating team must be compliant with the General Rules (constraints, etc.) and successfully pass the Robot Compliance Check prior to competing

Any team that does not meet these criteria may be eliminated from consideration of awards and/or advancement.

The Final head-to-head competition ranking is determined through robot performance using the Game Specific scoring rubric defined in Section 3 .

- For BEST Classic Competition, this will consist of the head-to-head competition results (all phases executed)
- For BEST Classroom Competition, this will consist of results from the Robot Performance Time Trials.
- For BEST Online Competition, this will consist of results from the Robot Performance (Autonomous Programming) Time Trials. There will be no Driver-Controlled Robot Performance Time Trials.

### 4.2 The BEST Award

The BEST Award is presented to the team that best embodies the concept of *Boosting Engineering, Science, and Technology*. This concept recognizes that inclusiveness, diversity of participation, exposure to and use of the engineering process, sportsmanship, teamwork, creativity, positive attitude and enthusiasm, and school and community involvement play significant roles in a team's competitive experience and contribute to student success in the competition beyond winning an award.

In accordance with the BEST philosophy, **materials submitted by teams must be the work of students.** The involvement of student peers in auxiliary roles to support a school's official BEST team – i.e., journalists, photographers, artists, musicians – is encouraged.

Space constraints at each regional championship site will determine the number of teams that can compete for the BEST Award at the championship (check with the specific guidelines published by each regional championship). For a team to be eligible to compete for the BEST Award at any of the regional championships, the team: (1) must have placed in the top 3 teams in the BEST Award judging at their local hub competition, and (2) must agree to compete in all five of the BEST Award component categories at the regional championship.

### 4.2.1 Judging Evaluation and Criteria

Evaluation of competitors will be based on the criteria outlined here. An evaluation score of 100 possible points will be composed of the following components:

Component I - Engineering Notebook (required for ALL teams)

Component II - Marketing Presentation (required for BEST Award consideration)

Component III – Team Exhibit and Interviews (required for BEST Award consideration)

~~Component IV – Spirit and Sportsmanship (required for BEST Award consideration)~~

Component V - Robot Performance (required for BEST Award consideration)

Judged Components	Point Value
Engineering Notebook	30 points
Marketing Presentation	25 points
Team Exhibit and Interviews	20 points
<del>Spirit and Sportsmanship</del>	<del>10 points</del>
Robot Performance	15 points

*Total 90 points*

Refer to Section 5 for details on each of the Judged Components.

Refer to the **2021 Awards and Judging – Hub Logistics** document for the specific judging scenario at your local hub. Championship events will always judge all components; teams that advance to a championship as eligible to compete for the BEST Award must compete in all four components.

### 4.2.2 Judging Procedure

- A distinguished team of judges from private and public sectors with technical and non-technical expertise will evaluate teams. Judges will serve on a rotation schedule.
- As each team completes a component, it will be assigned a component score that is the average of individual scores of the judges reviewing it.
- The organizing hub/championship may choose to drop the lowest judges' score for any judged component at their discretion.
- Teams should know in advance that scores among many teams frequently differ by only fractions of a point.

### 4.2.3 Judging Results

- Each team will be provided with a copy of its score sheets within 3 days following their local competition.
- Teams advancing to a championship can use judges' comments to make improvements as they wish subject to the schedule restrictions of the championship (e.g., Engineering notebook due dates).

### 4.2.4 BEST Award Recognition

The teams ranked first, second, and third in the BEST Award judging will receive trophies superior to the teams finishing first through third in the Head-to-Head robot competition.

## 4.3 Simulink Design Award

The "BEST Simulink Design Award" sponsored by MathWorks is an award open to all teams participating in the competition. The award is presented to one team in each of the 3 BEST championship regions (South's, Texas, and Denver) that best applies the Simulink in the programming of their robot based on the judging criteria below and their robot's performance in the competition. Any team using MathWorks MATLAB/Simulink to design their software (i.e., robot program) is eligible.

### 4.3.1 Applying for the Award

To apply for the award, teams are required to submit their best Simulink model and a short video describing their program design using Simulink. The entries must be submitted before 11 PM (local time) two weeks before their respective regional championship. See the **2021 Awards and Judging – Hub Logistics** document and the BEST Robotics website for more information on deadlines.

Information that teams need to provide when submitting their entry:

- Name of School
- BEST Hub (know which hub you belong to)
- Team Contact
- Team Contact Email Address (**important:** all entries are tied to the email address)
- # Students on the Team
- Simulink Model File (.slx file)
- Link to YouTube Video (3 minutes maximum)
- Brief Description (256 chars) of how the team used Simulink to program their robot

A PASSCODE may be required to submit your entry. The PASSCODE will be the same as the current year's Game File Password. Contact your Hub or refer to your Team Workflow page on the BEST National Registry to get the PASSCODE.

### 4.3.2 Simulink Design Award Guidelines

- Only one entry per team is allowed.
- All teams can participate for the award within their region. There will 1 winner per region.
- Every entry should include the following items:
  - 1 Simulink model file (\*.slx)
  - 1 video link (use YouTube only)
- The Robot program must be created using Simulink. Submissions of programs designed using other software will not be accepted. The submitted Simulink file should not be a pre-built example model or the default program. It should be your own program or a modification of the existing examples or default program.
- The video should be no more than 3 minutes in length and include at least a 1.5 minute overview about the program design (e.g. a screencast of the Simulink model with voice over).
- Multiple submissions may be made by a team prior to the submission deadline always using the same email address during submission. Only the last submitted entry will be scored.
- Final submissions for this award must be uploaded at [http://www.bestinc.org/simulink\\_award/form.php](http://www.bestinc.org/simulink_award/form.php) before the stated deadlines.

### 4.3.3 Simulink Design Award Evaluation

The award will be given to one team from each region and be based on the judging criteria and robot performance in the competition. The following criteria will be used for judging each entry using a maximum 100pt scale. The Simulink model is worth up to 70 points and the video is worth up to 30 points.

<b>Simulink Model</b>		<b>Possible Points</b>
Creativity	Innovative, creative and original work	10
Functionality	Error-free and designed to achieve the game tasks	10
Software Design Practices	Best practices like commenting, block naming, etc.	15
Difficulty and Mastery	Level of Simulink knowledge demonstrated in executing the tasks	20
Readability	Clean, organized and easy to comprehend	15
	<b>TOTAL</b>	<b>70</b>
<b>(YouTube) Video</b>		<b>Possible Points</b>
Creativity	Interesting, innovative, and informative	5
Quality of the video	Video making process and technical execution	10
Concept	Engaging, coherent and appropriate	10
Clarity	Message is clear and well-communicated	4
Adherence to Guidelines	Video length and content on Simulink usage	1
	<b>TOTAL</b>	<b>30</b>
	<b>Total Possible Points</b>	<b>100</b>

#### 4.3.4 Simulink Design Award Recognition

The winning teams will be awarded the following:

- Cash award
- Trophy with inscription 'BEST Simulink Design Award – by MathWorks', and
- a MathWorks hat for each team member

The winning teams from each region will be recognized on the BEST website ([www.bestrobotics.org](http://www.bestrobotics.org)) and their regional championship website.

#### 4.4 Robot Critical Design Review

The intent of the Robot Critical Design Review (CDR) is for students to explain their design in detail, including design features/functionality, the requirements and strategies that influenced certain design features, the methods and results of each design discipline, and design risk assessment. Judges ask questions, provide feedback on areas to improve, proposed alternative solutions to investigate, etc., to ensure the team's success.

### 4.4.1 Robot CDR Guidelines

The CDR is a multi-disciplined technical review, conducted at both system-level and component-level, to ensure that an initial product baseline is established and that all customer requirements have been addressed to satisfaction.

- Each team will present a Critical Design Review (CDR) of their robot design to a panel of judges.
- The format and content of the review is determined by the team.
- The goal of the CDR is to ensure that the final design will meet the application requirements. The application requirements consist of the rules for robot construction and the game play objectives.
- The CDR consists of explaining the details of the design and game strategy and presenting how it will satisfy the objectives.
- Judges are expected to ask questions during the review that will require detailed knowledge about specific functionality or components of the robot and every design discipline involved. Students presenting the CDR should be capable of answering with specific details. Judges may ask questions at any time during the review.
- Judges will use the CDR to provide feedback to teams on their design, including requirements that were overlooked, additional analysis that may be beneficial, and generally how to improve their design.
- The review will take no more than 25 minutes. Judges will have 5 minutes for conferencing following the review, if needed, to complete the evaluation.
- At least 3 students will actively participate as presenters in the CDR.
- The CDR will review results from the following design disciplines:
  - Systems, Mechanical, Electrical, Software, Test, Human Factors, Risk Assessment
- The CDR will provide a detailed review of:
  - Requirements
  - Functionality Overview
  - Design Specifications (Component and System)
  - Risk and Lessons Learned

### 4.4.2 Robot CDR Evaluation

The Robot Critical Design Review will be judged as an independent award. Its score will not influence the BEST Award Score. Robot CDRs will be evaluated considering the following:

- **Requirements**
  - Did the team present requirements (and strategies) that influenced their design specifications?
  - Did the team present both stated and derived requirements?

- Did the team present how the requirements influenced their design?
- **Functionality**
  - Did the team describe the functionality of the robot in detail? Including how each of the robot's tasks will be performed.
  - Did the team present block diagrams of major robot components?
  - Did the team discuss any prototyping or modeling that was performed (either successful or unsuccessful)?
- **Research**
  - Did the team present any research performed regarding technical solutions (e.g., drive mechanisms, lift mechanisms, etc.)?
- **Design Specifications (component and system)**
  - Did the team present component and system-level specifications? (e.g., capabilities and technical specs)
    - e.g., weight, dimensions, speed, lift, structural integrity, power, processing, accuracy, etc.
  - Did the team use diagrams, tables, graphs, equations, calculations, simulations, and/or explanations to show "how" they arrived at specifications?
- **Multi-discipline review**
  - Were multiple design disciplines represented in the review? Systems, mechanical, electrical, software, test, human factors, etc.
- **Risk Assessment**
  - Did the team review known risks in their design, including alternate or back-up plans if the mission objectives are not able to be accomplished?
- **Innovation**
  - Were innovative design elements or processes used?
- **Lessons Learned**
  - Did the team share lessons learned?

## 4.5 Skills Challenges

Skills challenges will be offered at select hubs. Various awards will be provided for teams that finish in the top of a skills challenge category. The complete rules, instructions, and evaluation criteria are covered in separate rules documents for each of the skills challenges.

The following skills challenges are required to be offered for the BEST Online competition. They may optionally be offered for the BEST Classic competition and BEST Classroom competition. Check your hub's **2021 Awards and Judging – Hub Logistics** document to see which skills challenges are offered.

- Autonomous Programming Skills
- ~~BEST Mania IQ Challenge~~
- BEST Minecraft Challenge

The following skills challenges may be offered at the hub's discretion for any competition format. Because these skills challenges are optional, the rules, instructions, and evaluation criteria for each of the challenges are provided in separate rules documents.

- Robot Modeling Challenge
- Engineering Drawings Challenge
- Website Design Challenge
- Video Design Challenge

## 4.6 Additional Awards

Refer to Section 7 for details on additional awards provided at the Hub and Championship levels.

## Section 5 BEST Award Components

### 5.1 Engineering Notebook (30 Points)

- The Engineering Notebook will be worth 30 points towards the BEST Award.

#### 5.1.1 Notebook Requirements

- ALL participating teams are required to submit an Engineering Notebook at both the local competition and the regional championship following the requirements stated herein. All notebooks will be evaluated on a 30-point scale.
- For competitions having 32 or fewer total teams, the notebook scores of all teams will be used to determine which 4 teams earn a chance to participate in the single “wildcard” match. The winning wildcard team will be one of eight total teams that advance to the semifinals phase.
- For competitions having greater than 32 total teams, the notebook scores of all teams will be used to determine which 8 teams earn a chance to participate in one of the two “wildcard” matches. The two winning wildcard teams will be two of sixteen total teams that advance to the semifinals phase.
- The purpose of the notebook is to document the process the team used to design, build, and test their robot.
- The notebook must be delivered in electronic format (PDF only).
- Please see the **2021 Awards and Judging – Hub Logistics** document for information on when and how the notebook is to be submitted.
- The notebook must meet the following specifications:
  - The title page must identify the school, team name, teacher contact, and team number
  - 35 typed **single-sided** pages or less (note that the title page and Table of Contents page(s) will not be counted as part of the 35 pages)
  - The document should be formatted as standard, 8 ½” x 11” paper, double-spaced, 1” margins, and Times New Roman (preferred) or similar business-style font no smaller than 12 pt. Single-spacing is acceptable in tables and outlines.
  - Teams may include a supplemental appendix of no more than 40 total pages of information. The appendix may include support documentation such as drawings, photos, organization charts, minutes of team meetings, test results, etc. *This material should directly support the process described in the primary document and NOT reflect activities related to community or promotional efforts, spirit development, or team building.*

#### 5.1.2 Notebook Evaluation

- The notebook will be judged on the documentation of the team’s:
  - ***Implementation of the Engineering Design Process***
    - Evidence that the engineering process was effectively used.

- **Research Paper**
  - Correlation between the current year's game theme and how related technological practices or scientific research is being used at a company/industry/research lab in the team's state or region; Any information related to the game theme, such as history, famous inventor(s), or major milestones; Analysis of the game theme/problem and the related technology's impact on the human experience, our needs, adaptations, and progress with solutions throughout history; Creativity in linking the game theme to appropriately related science/technology content; Proper use of grammar and composition throughout the paper; citations of sources used to gather information for the paper
  - The research paper must be a minimum of 2 pages and maximum of 5 pages (of the allotted 35 pages), including citations.
- **Brainstorming Approaches**
  - How well organized and productive was the brainstorming approach used? How well was the brainstorming approach documented?
- **Analytical Evaluation of Design Alternatives**
  - Use of analytical and mathematical skills in deciding upon and implementing design alternatives
- **Offensive and Defensive Evaluation**
  - Analysis of the gaming strategies and design elements used to achieve specific team goals
- **Software Development Process**
  - Evidence that a software development process was effectively used including
    - Project scope/requirements/specification ("what" the robot should do without stating how)
    - Design ("how" the software will achieve the scope/requirement/specification)
    - Implementation (tools, methods and techniques used in your programming)
    - Test/Verification (methods used to verify correct operation of the robot program)
    - Deployment (source code management, release, download frequency, etc.)
  - Evidence that software design methods/techniques were explored and utilized.
- **Safety**
  - Evidence that safety training took place and safe practices were followed to prevent students' misuse of tools and other devices/equipment that may result in personal injury or damage to property
- **Support Documentation**
  - Team organization, team minutes, test results, CAD/other drawings, photos, etc. that support the main document
- **Overall Quality and Completeness of Notebook**
  - Organization, appearance, adherence to specifications, quality of content

## 5.2 Marketing Presentation (25 Points)

- The Marketing Presentation will be worth 25 points towards the BEST Award.

### 5.2.1 Purpose and Context

- The purpose of the Marketing Presentation is for students to learn how to address the needs of a potential client, share product and brand information and navigate the business environment.
- The Team's Role: To create a company that designs and manufactures robots (the product).
- The Judge's Role: To serve as the client who is looking to purchase a robot(s) to solve a problem(s).
- The Problem: Refer to the Game Specific Rules and research the real-world relevance of the game premise in today's industry.

The context for the presentation is as follows:

Your team is a business pitching your latest invention/product to a group of decision makers at BEST Inc. headquarters in response to a Request For Proposal (RFP). Your goal is to inform, persuade, and build trust between your company and your potential client.

Your company's brand promise will establish a shared understanding of the client's problem and how your product delivers the solution. The only details about the engineering team and the manufacturing process that need to be included are those that highlight the unique characteristics or how the characteristics differentiate your product from a competitor. Storytelling should be an important tool to add personality to your brand and create a stronger connection with your client.

BEST Inc. is very involved in community outreach. Share how your team, as a potential vendor embraces the same social responsibility.

To close the meeting, propose a formalized offer for the client.

### 5.2.2 Marketing Presentation Guidelines

- A minimum of 4 and maximum of 8 students may participate in the room for the presentation. Each student present must have an active role in the presentation.
- Participating teams will sign up for a presentation time to occur at a time designated by the local hub or championship.
- Only students may participate in the presentation/discussion, including setting-up and dismantling the presentations. Teachers, parents, mentors, and other loving adults are not permitted to watch the presentation.
- The only printed or other materials that teams may give to the judges are a brochure and business cards. No gifts for the judges please.
- Robots and models may be used during the presentation for demonstration purposes.
- Teams should represent diversity in grades, gender, race, ethnicity, and abilities. Teams are encouraged to share and demonstrate how their efforts are inclusive.

- Videotaping/photographing the presentation by students will be allowed; however, the person(s) handling recording devices will be counted in the maximum students allowed and therefore s/he will need to contribute to the presentation beyond capturing footage or images.
- The presentation format is the prerogative of the team.
- The team must provide any equipment it wishes to use or check with the local hub or championship for information about what equipment can be provided. See the **2021 Awards and Judging – Hub Logistics** for details of equipment provided at your hub/championship event.

### 5.2.3 Marketing Presentation Logistics

- There will be a check-in station in the general area of the presentation rooms where teams should check in prior to their time slot.
- The presentation/meeting will last for no more than twenty-five (25) minutes including any setup/breakdown. Teams are expected to begin with formal presentation.
- The meeting may become conversational with judges beginning to ask questions after ten (10) minutes of uninterrupted presentation by the team. The team may instigate a conversational format at any time, if desired. This is to encourage a business meeting atmosphere.
- Teams should use the judges' questions as cues and adapt their conversation. Be prepared to go off script and have a dialog exchange with the judges.
- At least five (5) minutes will be scheduled between presentation sessions to allow breaks for judges, rotations, and additional time to confer without the team present.
- The local hub or championship will provide event-specific information (times, locations, etc.). Refer to the **2021 Awards and Judging – Hub Logistics** document for these additional details.

### 5.2.4 Marketing Presentation Evaluation

Presentations will be evaluated with consideration of:

- **Company Overview**
  - The team introduced themselves and explained their roles within the company.
  - The team expressed a mission statement for their company stating the company's purpose for being, encapsulating culture, values, and ethics.
  - The team created a consistent brand and brand promise – the value or experience customers can expect to receive every time they interact with the company.
  - The team created a strong visual identity based on the brand and mission statement.
  - The team defined their public image through their publicity, social responsibility, and community awareness activities.
  - The team explained their budgets and expenses, including any funding sources (sponsors or in-kind contributors, fundraising events, etc.).
  - The team included their company sustainability and 1-year company outlook including employee development, recruitment, and training.
- **Product Features**
  - The team clearly defined the problem and the customer priorities.

- The team explained their product's features and how the product's benefits solve the client's problem.
- The team clearly defined how the product is unique, desirable and produces a benefit(s) to the client.
- The team identified factors that differentiate their brand and product from the competition.
- The team used visual aids to effectively enhance the presentation.
- **Business Offer**
  - The team explained the product's acquisition cost and manufacturing cost.
  - The team proposed their delivery and aftermarket support including warranty and training for the client's workforce to operate and/or maintain the product.
  - The team proposed a formal offer to the client (judges).
- **Business Professionalism**
  - The team met the 4-8 participant guidelines and was dressed professionally, or theme based.
  - The presentation was understandable, well organized, and prepared.
  - The team was conversational and engaged in discussion.
  - The team included testimonials to support research or success stories.
  - The presentation was creative and interesting.

### 5.3 Team Exhibit and Judges Interview (20 Points)

- The Team Exhibit and Judges Interview will be worth 20 points towards the BEST Award.
- The purpose of the Team Exhibit is for students to display a visual story of the team's outcomes and impact. It is designed within the annual game theme and depicts the team's work in three realms: Robot/Product Features, Marketing/Branding, and Community Outreach/Advocacy.
- The purpose of the Interview is to
  - strengthen students' communication skills- (as listeners and speakers),
  - validate their knowledge and understanding of the work done by the entire team, and
  - spotlight unique design features, activities, or learnings.

#### 5.3.1 Team Exhibit and Interview Guidelines

- Hubs hosting Classroom and Online competitions will implement Virtual Team Exhibits, while hubs hosting a Classic competition may choose to implement Physical or Virtual Team Exhibits. Refer to the **2021 Awards and Judging – Hub Logistics** document for details on which format your hub will implement.
- Championships may choose to implement Physical Team Exhibits or Virtual Team Exhibits, or both; the championship Team Exhibit format will be communicated following your hub kickoff.

##### 5.3.1.1 Virtual Team Exhibits

- Virtual Team Exhibits will be implemented using a dedicated WordPress website for the team.
- The Virtual Team Exhibit must use the system provided through the BEST National Registry Team Workflow page.

- Only those themes and widgets available through the virtual exhibit template can be use.
- Native html coding is allowed.
- Primary exhibit content should be placed on the front page.
- Pages other than the HOME page are allowed for additional content. The virtual exhibit should not exceed 3 additional pages.

### 5.3.1.2 Physical Team Exhibits

- Refer to the **2021 Awards and Judging – Hub Logistics** document for standard table size at your local hub competition and availability. At championships, each team may be provided with a standard six-foot long table (approximately 29 inches wide) upon request. Skirting for the table will not be provided.
- An 8' X 8' X 8' exhibit space will be allocated per team at your local hub and the championships. All exhibit content must remain within the defined exhibit area.
- All exhibits must display the national BEST Robotics logo in plain view
- Teams are encouraged to use recycled, upcycled and repurposed items and to avoid using expensive store-bought display boards and structures. Consideration is given to creative and hand-made exhibit props.
- Each team should bring one extension cord and one power strip for any electrical needs. Refer to the **2021 Awards and Judging – Hub Logistics** document for possible electricity and electrical limitations at your local hub competition.
- Any audio-visual equipment and extra extension cords will be the responsibility of the team.
- Each team is responsible for the security of its own material.
- Each team is responsible for breakdown of its team materials and clean-up of its exhibit area following the awards ceremony on Game Day.
- All material should be clearly marked with the appropriate identification and contact information.
- Refer to the **2021 Awards and Judging – Hub Logistics** document concerning when and where team exhibits can be set up at your hub or championship competition.
- Candy and other food and drink items are not permitted at exhibits as complimentary handouts. Refer to the **2021 Awards and Judging – Hub Logistics** document concerning specific rules for your hub or championship competition.

### 5.3.1.3 Student Interviews

- During the scheduled interview time, at least one student representative from the team must be present who is able to respond to informal questions asked about the exhibit. In addition, student representatives should be aware that judges may ask questions concerning robot design and construction. These questions will be part of the interview evaluation of the team.
- Teams should expect to be evaluated by two to four different judges during a single interview period.

- In addition to the scheduled interviews at a Classic competition, the judges may also interview team members in the pit area and in the seating area at any time.

### 5.3.2 Exhibit and Interview Evaluation

- **Exhibits** (10 points) will be evaluated on:
  - Social Responsibility
    - The team used visuals within the exhibit to effectively share outreach information, methods, audience and outcomes.
    - The team used testimonials and/or storytelling effectively to communicate impact in their school and community.
    - The exhibit reflects the diversity of the team (company) and their school and community (target audiences).
    - Team, Hub and national BEST sponsors are clearly displayed.
    - Hub and national BEST Robotics logos and/or branding are visible.
  - Product and Brand
    - The exhibit tells a story based on visual impression and brand promise is evident.
    - The team showcased information of their product (robot) in an informative manner.
    - The team embraced technology and used it in a meaningful and relevant way within their exhibit.
    - The exhibit is cohesive, engaging, interactive and creative.
  - Exhibit Design/Manufacturing and Adherence to Specifications
    - The exhibit effectively balances the use of print, models, multi-media, graphics and other technology.
    - The team adhered to all specifications set forth by the Hub/Championship
- **Student Interviews** (10 points) will be evaluated on:
  - Company Elevator Speech
    - Clearly defines what benefits the product (robot) delivers.
    - Explains outreach and social responsibility.
    - Conveys the company's brand through tone and language.
  - Testimonials and sharing the Brand
    - Students communicated the brand personality.
    - Students explained how their product (robot) provides brand advantage.
    - The team used testimonials to communicate impact in their school and community.
    - Outreach efforts and outcomes were shared.
  - Game Theme and Learning Experience
    - Students clearly articulated an understanding of the game theme/problem.
    - The students showed evidence they were the primary designers and builders of their product (robot), exhibit and all materials.
    - Students clearly articulated lessons learned through the BEST experience.

- Students communicated the impact of the BEST Robotics program on his/her path toward STEM or career choice.

## 5.4 Spirit and Sportsmanship (10 Points)

The Spirit and Sportsmanship component will not be judged in 2021 competitions. There will be zero points awarded for this component for all teams.

## 5.5 Robot Performance (15 Points)

- The *Robot Performance* component will determine the final 15% of possible BEST Award points.
- Robot Performance points will be awarded based on the total game points earned throughout the seeding phase of the head-to-head competition (for BEST Classic competitions), or during the robot performance time trials (for BEST Classroom or BEST Online competitions), according to the following scale:
 

• Team finishes in top 20% of all teams competing at hub	15 Points
• Team finishes in top 40% of all teams competing at hub	12 Points
• Team finishes in top 60% of all teams competing at hub	9 Points
• Team finishes in top 80% of all teams competing at hub	6 Points
• Team finishes in top 100% of all teams competing at hub	3 Points
• Team is unable to score any points during the competition	0 Points
- Up to 15 Robot Performance points will be possible

## 5.6 BEST Robotics Brand Usage Guidelines for Teams

Although BEST Robotics does not require teams to design websites or tee shirts or maintain a certain level of presence on social media, students are encouraged to explore options and we support their creativity. BEST Robotics also wants to ensure that our brand is presented in a clear and consistent manner across our footprint. Therefore, we ask students to follow these guidelines:

- Include the BEST Robotics national logo on all digital and printed materials.
- Team websites should include
  - On the homepage - the national logo and a link to national website
  - Storytelling from students (video or quote with pictures)
  - Testimonials from community leader (video or quote with pictures)
- Tee shirts should include the national logo, set apart from other sponsors or positioned above all other sponsors
- All social media posts during or about your team's outreach activities should include the hashtag: #BESTRobotics and tag @BESTRobotics.

## Section 6 Advancement to Championship

The total number of teams a hub will be allowed to send to a championship is determined by the championship. Traditionally this number is related to the number of teams competing at the hub, the total number of teams in the region, and the maximum number of teams that the championship venue can accommodate.

If a championship is offered, the advancing teams will be selected using the following priority order:

1. BEST Award 1<sup>st</sup> Place
2. Game Head-to-Head/Time Trials 1<sup>st</sup> Place
3. BEST Award 2<sup>nd</sup> Place
4. Game Head-to-Head/Time Trials 2<sup>nd</sup> Place
5. BEST Award 3<sup>rd</sup> Place
6. Game Head-to-Head/Time Trials 3<sup>rd</sup> Place
7. BEST Award 4<sup>th</sup> Place
8. Game Head-to-Head/Time Trials 4<sup>th</sup> Place
9. BEST Award 5<sup>th</sup> Place
10. BEST Award 6<sup>th</sup> Place
11. BEST Award 7<sup>th</sup> Place
12. etc.....

The list above is intended to illustrate the qualification order, not necessarily the exact number of teams advancing from each hub. In 2021, hubs will have the option of foregoing any playoff phases (wildcard, semifinals, finals) and ranking Game head-to-head place based on seeding phase or dedicated time trials alone.

### Exception to the qualification order:

A hub has the option to advance a Game winner OR a BEST Award winner at their discretion IF the hub is limited in the number of advancing teams that can participate in the BEST Award at the championship, and IF a BEST winner also places as a Game winner.

For example, if a championship allows four advancing teams per hub, BUT only two advancing teams can participate in the BEST Award, AND a Game winner is also a BEST Award winner at the hub level, a hub could be forced to advance a 3<sup>rd</sup> place BEST Award team that cannot compete in the BEST Award at the Regional level. In such a case, the hub can opt to send the 3<sup>rd</sup> place Game winner instead of the 3<sup>rd</sup> place BEST Award winner.

## Section 7 Standard Required Awards

### 7.1 Hub-Level Awards

The following summarizes all hub level awards that will be given. Awards distributed may be dependent upon the competition; see the Competition Specific Awards section for details on which awards will be given at each BEST hub competition. Optional awards are given at the hub's discretion.

#### **BEST Award**

Awarded to the team that best embodies the concept of ***Boosting Engineering, Science and Technology***. Winning the BEST Award is considered the highest achievement any team in the competition can accomplish. First, second, and third place finishes will be awarded.

#### **Head-to-Head Competition Award or Robot Performance Award**

Awarded to the teams whose machines finish first, second, and third in the head-to-head robotics competition or Robot Performance Time Trials. A fourth place "finalist" may also be awarded.

#### **Most Robust Machine**

Awarded to the team whose machine requires the least maintenance during and between matches and is generally the sturdiest machine in the competition.

#### **Founders Award for Creative Design**

Awarded to the team that makes best use of the engineering process in consideration of offensive and defensive capabilities in machine design. Awarded in recognition of BEST founders Steve Marum and Ted Mahler.

#### **BEST Critical Design Review Award**

Awarded to the team presenting the best overall Robot Critical Design Review to the judges that includes technical discussion of robot design features/functionality, requirements and strategies that influenced feature design, and the methods and results of each design discipline (mechanical, electrical, software, test, human factors, logistics, etc.).

#### **Skills Challenges Awards**

Awards are offered for multiple Skills Challenges categories. Awarded to the team with the highest cumulative score in the skill category as determined by the rubric or scoring method for that skill. The skills categories awards are:

- Autonomous Programming Skills Award (1<sup>st</sup> place, minimum)

- ~~BEST Mania IQ Challenge (1<sup>st</sup> place)~~
- Minecraft Challenge (1<sup>st</sup> place)
- BEST Robot Modeling Award
- BEST Engineering Drawings Award
- BEST Website Design Award
- BEST Video Design Award
- BEST Engineering Notebook Award (at Hub's discretion)
- BEST Marketing Presentation Award (at Hub's discretion)
- BEST Team Exhibit Award (at Hub's discretion)

## 7.1.2 Competition Specific Awards

### 7.1.2.1 Classic Competition

The following awards will be given at all BEST Classic Competitions, when multiple teams compete in a head-to-head fashion:

- Required awards:
  - BEST Award (1<sup>st</sup> – 3<sup>rd</sup> place)
  - Head-to-Head Competition Award (1<sup>st</sup>-4<sup>th</sup> place)
  - Founder's Award for Creative Design
  - Most Robust Design Award
- Optional awards (at hub discretion):
  - BEST Critical Design Review Award
  - Any Skills Challenge Awards

### 7.1.2.2 Classroom Competition

The following awards will be given for all BEST Classroom Competitions:

- Required awards:
  - BEST Award (1<sup>st</sup> – 3<sup>rd</sup> place)
  - Robot Performance (1<sup>st</sup> – 3<sup>rd</sup> place)
  - Founder's Award for Creative Design
- Optional awards (at hub discretion):
  - BEST Critical Design Review Award
  - Any Skills Challenge Awards

### 7.1.2.3 Online Competition

The following awards will be given for all BEST Online Competitions:

- Required awards:
  - BEST Award (1<sup>st</sup> – 3<sup>rd</sup> place)

- Autonomous Programming / Robot Performance (1<sup>st</sup> – 3<sup>rd</sup> place)
- BEST Critical Design Review Award
- Founder's Award for Creative Design
- ~~BEST Mania IQ Challenge (1<sup>st</sup> place)~~
- BEST Minecraft Challenge (1<sup>st</sup> place)
- Optional awards (at hub discretion):
  - BEST Robot Modeling Award
  - BEST Engineering Drawings Award
  - BEST Website Design Award
  - BEST Video Design Award
  - BEST Engineering Notebook Award
  - BEST Marketing Presentation Award
  - BEST Team Exhibit Award

## 7.2 Regional Championship Awards

The following awards will be given at all BEST regional championships:

### **BEST Award**

Awarded to the team that best embodies the concept of ***Boosting Engineering, Science and Technology***. Winning the BEST Award is considered the highest achievement any team in the competition can accomplish. First, second, and third place finishes will be awarded.

### **Head-to-Head Robotics Competition Award or Robot Performance Award**

Awarded to the teams whose machines finish first, second, and third in the head-to-head robotics competition or Robot Performance Time Trials. A fourth place "finalist" award may also be awarded.

### **Founders Award for Creative Design**

Awarded to the team that makes best use of the engineering process in consideration of offensive and defensive capabilities in machine design; awarded in recognition of BEST founders Steve Marum and Ted Mahler.

### **Most Robust Design**

Awarded to the team whose machine requires the least maintenance during and between matches and is generally the sturdiest machine in the competition.

## **BEST Simulink Design Award**

Awarded to one team in each of the 3 BEST regions (Denver, South's, Texas) that best applies MATLAB/Simulink based on the specified judging criteria and their robot's performance in the competition.

## **7.3 National Level Awards**

The following awards will be provided at the national level, considering all participating teams:

- Autonomous Programming Challenge National Champion
- ~~BESTMania IQ Challenge National Champion~~
- BEST Minecraft Challenge National Champion