2020 IEEE Robotics Competition

Game Manual Revision B

3/72020

Introduction

Overview

This section describes the motivation for and overview of the 2020 IEEE R5 robotics competition.

Theme

Pollution of various forms is an ever-present problem in our modern world. For the last 50 years, considerable attention has been focused on larger institutional sources of pollution, and while there is more to do, significant progress has been made. Many individuals have also learned to make better personal choices, yet the basic problem of litter remains pervasive worldwide. There are still large numbers of people that feel entitled to simply drop or toss waste items they are through with wherever they are. This is particularly evident walking along the roadside, or looking in or underneath the stands after a sporting event. In much of IEEE region 5, high winds and open country allow outdoor litter to be dispersed from its source into other settings. It commonly finds its way into streams and lakes, where it causes additional environmental problems. It also commonly appears on the grounds of people that have personally made efforts to avoid creating litter, insulting them and adding to their burdens.

There are three different approaches required to address this problem. It is important to educate those who do not already know better about the consequences of their behavior. It is also important to create a form of accountability for those that continue polluting behavior. Finally, it is important to responsibly clean up the mess before it creates greater problems. This year's game has elements representing each of these areas. But unlike many former games, we are not merely cleaning up some symbolic representation of trash; we will actually be picking up and properly disposing of four extremely common articles of actual litter. With a modest amount of additional work, we expect a successful robot from this year's competition could actually be used to help clean up areas that have been badly littered, such as grounds after a sporting event.

The Contest

Competitors will be tasked to pick up items of litter on a 12ft X 12ft standard VEX robotics field. This size field, although larger than has been used for the IEEE R5 robotics competition in the past, was selected to better scale the robots and the game to the sizes of actual articles of litter.

The game will include the following items of litter

        aluminum soft drink cans,

        plastic water bottles,

        snack size chip bags

        paper trays commonly used for serving concession food.

The competing robots will share the field with a robotic adversary that will display the worst habits of a habitual litterbug. This litterbug will disperse litter during the round in a random manner, while chattering in some uniquely robotish dialect. Competitors will increase their score by

- By responding appropriately to the litterbug's chatter, the competitor will have the ability to convince the litterbug to stop disbursing additional pieces of litter of a specific type.
- By successfully removing the litter items from the playing surface and by placing these items in an appropriate bin located to the side of the playing field teams will earn points in a given match.

    We have considered several options to "catch the litterbug in the act" that could have been incorporated into the game. Each seemed to have too much potential to hinder the flow of matches and create more potential for contested results. As of this update, we no longer intend to make changes to the scoring to incorporate this feature into the game.   This capability will no longer be important for winning the competition.

    On the other hand, some competitors may have sensors such as cameras that that can capture and provide evidence of the litterbug in the act of littering. Teams that do provide us with such evidence from an official match will be celebrated in some fashion other than through match scoring.

The contest will be held on Saturday, April 4, 2020 in the One Broadway ballroom of the Sheraton Downtown Oklahoma City. All awards will be based on performance at this event.

Scrimmage events will be held on the campus of Oklahoma Christian University on Saturday, November 16, 2019 and Saturday, February 8, 2020. We hope that the scrimmage events will be fun and exciting, and will lead to a higher quality final competition in April.

A third and final scrimmage event is planned for March 21, 2020 on the campus of the University of North Texas, in Denton Texas. This venue is more accessible for the majority of teams, and is close enough to the final competition date that more teams should have a robot in the final testing phase where scrimmaging can be conducted. Those interested in participating in this event should contact both the 2020 R5 Student Robotics competition chair and the organizer at UNT at addresses already provided to teams.

An IEEE Collabratec workspace is available that is serving as the Q&A forum for this event. In addition to questions and official responses from the game development team, this site will have files listing teams that have expressed interest/intent to compete, teams that have expressed intent to attend the scrimmage events, and more detailed information about the scrimmage events.

Because this is a shared workspace, as opposed to a proper forum, we have elected to not make it publicly available. When teams complete the intent form on the website, the team contact will be sent an invitation to join the workspace. In order to successfully join the workspace a person has to have an IEEE Collabratec account and the email you provide must match the email in the profile of your Collabratec account. IEEE members should be able to create/access their account by default using their IEEE password. Once the team contact has gained access, if you want other team members so have access you can send an email to kenneth.bell@oc.edu with the list of team members and their email addresses that will work with Collabratec, and we will send additional invitations.

The Game

Overview

This section describes the arena, game pieces, the litterbug, and general rules for the 2020 IEEE robotics competition.

The Arena

The arena will be a standard VEX robotics field or equivalent with border walls functionally equivalent to standard VEX borders. The field is roughly 12ft X 12ft. The field will be made of 36 2ft X 2ft foam tiles; 32 grey tiles, 2 red tiles, and 2 blue tiles will be used. The border will be approximately 11.5 inches tall and surround the entire field. The red tiles are possible starting locations for the litterbug. The starting location for the litterbug will be chosen at random by the game management system. The blue tiles are the possible starting locations for the competitor's robot. Once the litterbug has been placed, the competitor will place their robot on the blue starting tile farthest from the chosen litterbug starting location.
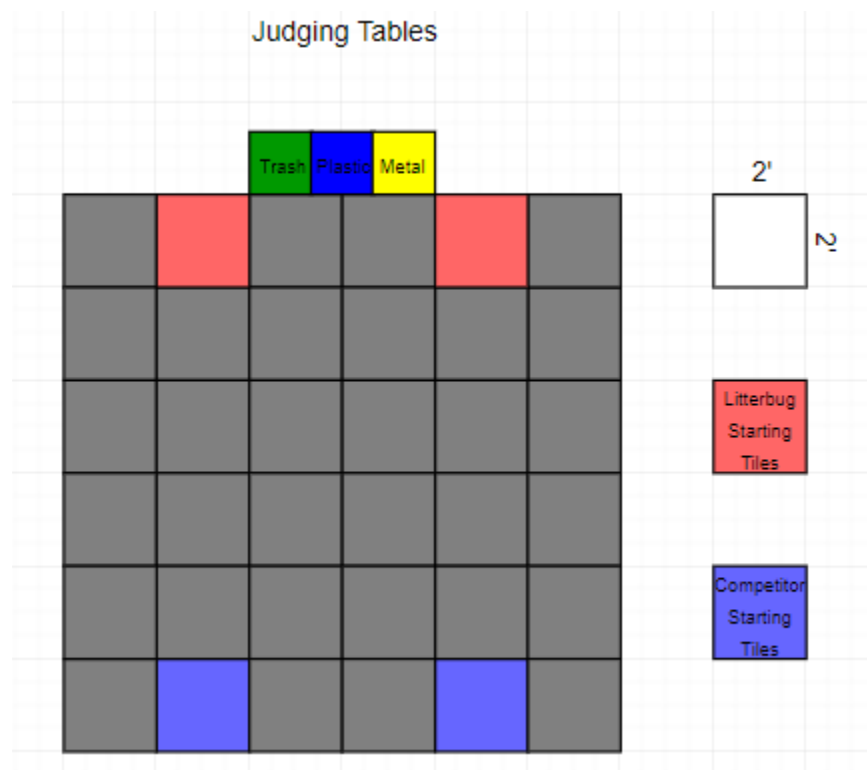
More detailed information about the playing field can be found at the VEX competition products website.

The Tiles:
https://www.vexrobotics.com/278-1502.html
The Border:
https://www.vexrobotics.com/278-1501.html

Real VEX fields are unnecessarily expensive. It could be worth having a real one if you would be interested in hosting a VEX event in the future, either for High School students to acquaint them with your campus, or for the VEX University division, which offers a high quality interactive robotics competition with a path to a world championship every year. If you host an event you can become an "event partner" and can purchase real field parts at a significant discount. Otherwise you may wish to consider a surrogate field.

Less expensive tiles that are functionally equivalent other than coloring can be found at https://www.amazon.com/BalanceFrom-Puzzle-Exercise-Interlocking-Tiles/dp/B01IDRWPGI/ref=sr_1_5?keywords=exercise+pads&qid=1566773179&s=gateway&sr=8-5   We are still considering the best method of coloring these surrogate tiles to be "close enough" to VEX Red and Blue tiles without significantly affecting the surface finish; we have found that this is actually rather challenging since the foam is closed cell and is not absorbent. Dyes, inks, and markers we have tried tend to rub off on wheels and track onto adjacent tiles. The exact coloring of real VEX tiles does change significantly over time, so any strategies based on tile color needs to have a fairly broad tolerance, which should accommodate reasonable surrogates as well.

VEX provides information on a low cost surrogate field perimeter at https://content.vexrobotics.com/docs/LOW-COST-FIELD-PERIMETER%20RevE.20190522.pdf .

The fields at the R5 Event may have real field perimeters or may have surrogate field perimeters. We currently anticipate that any surrogate field perimeters will be closer in design to the real VEX field perimeters than the low cost surrogate above. We will release more details once the design is complete and tested. On the other hand, the intent of the borders is simply to keep the robots and trash within the playing field, and appearing "solid enough" that the Litterbug's sonar sensors can detect their presence and sense distance to them for ranges below 1 foot. We caution teams to avoid strategies that depend on the exact properties of the field borders.

The Bins:

Bins for metal (soft drink cans), plastic (water bottles), and trash (chip bags and paper trays) will be located on the designated side of the field outside of the border. These bins will be
https://www.amazon.com/dp/B000QJEW9K?psc=1&ref=ppx_pop_dt_b_product_details
. The bins will not have the lids in place, and will be positioned with the lowest side protruding over the field border, with the closest edge of the bin lip nominally positioned directly over the inner edge of the field border. The bins will remain within a +/- 1 inch tolerance.
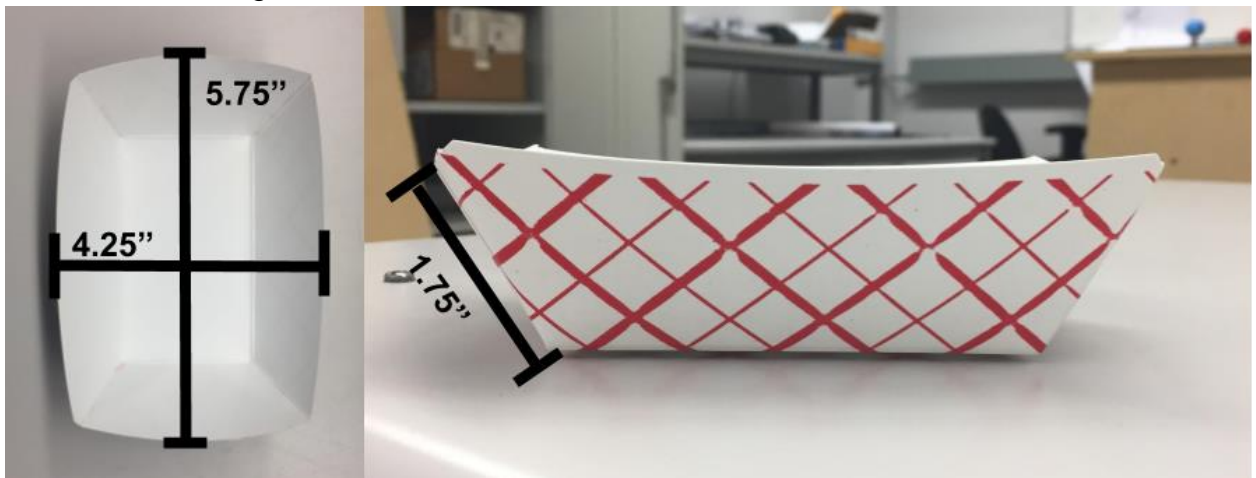

The Game Pieces

1) Aluminum soft drink **cans** will be empty 12 oz aluminum cans. They will be opened, reasonably free of contents, and may or may not still have the opening tab attached. They may be dented, but any that are substantially crushed or torn open other than at the opening tab will be considered damaged. They may have formerly contained any product and brand, and so may be of many different colors.

2) Plastic water **bottles** will be empty 500 ml clear plastic water bottles. They are typically made of PETE (recyclable symbol 1). They may or may not still have a label on them. They will start the match inflated to close to their "full" shape and

will have the cap on to make them somewhat less prone to crushing. If a bottle is torn, crushed, punctured, or can no longer be restored close to its "full" shape, it will be considered damaged.

3) Snack size chip **bags** will be of sizes ranging from 4"x5.25" up to 6"x8.75". They will be substantially free of contents, but are not guaranteed to be free of oils, salt, or fine crumbs. They will be torn open, and some portion of the bag may be missing as a result of opening. Dangling fragments that the referee considers likely to come off during handling will be removed before the start of a match. A bag will be considered damaged if it is shredded or missing approximately 25% or more of the bag surface area. They may be of any product and brand that commonly comes in a bag within this size range, and therefore may have essentially any color scheme. While it is unlikely that a real bag would have a color scheme that is uniform and substantially the same as the field tiles, if such a bag is encountered by the referee or field staff, it will not be used in the game.

4) One-pound paper **trays** commonly used for serving concession food (approximately 5.75"x4.25"x1.75"). These may or may not have been used for actual food, and so cannot be guaranteed to be completely clean. They will not be used for the game if they contain significant deposits of ketchup, mustard, melted cheese, or similar gooey substances, however for real-world use a robot should be designed to be tolerant of such hazards. Ripped trays will be considered damaged.

For example: www.amazon.com/dp/B07LB72QLS

Although the game pieces are litter, competing robots must be designed to not cause the game pieces to become damaged. Not only does this rule facilitate the reuse of game pieces, but it reduces the likelihood of sharp edges that can result on cans and plastic bottles and be a hazard to robots and the field staff. Robots that continue to damage game pieces after a warning will be disqualified, and will have to be modified and inspected prior to resuming competition matches.

The Litterbug

The litterbug is an autonomous robot that will be operating on the field with each competition robot. It will move around the field and dispense litter. It is roughly cylindrical with a diameter of nominally 17 inches and a height of nominally 17 inches. The preliminary operation of the litterbug can be seen in a video demonstrations [here](#).

Litterbug motion

By design, the litterbug will use ultrasonic sensors located around it's front surface to attempt to detect the field borders and the competition robot when they are within 8 inches, and will move to try to avoid contact with any of them. It may also attempt to avoid larger litter items, but that was not a design goal. In the absence of proximity to field borders or the competition robot it will move randomly, but filtered so that the rate of change of speed and direction are limited. While the intent is for the litterbug to avoid contact, it is possible for the competition robot to move in such a way that it will hit or be hit by the litterbug. Teams are responsible for designing their robot to account for this possibility. The litterbug movement is expected to be a continuous slow motion around the field.

Litterbug "littering"

The litterbug will start each match with 4 items of each of the four types of litter. For each type of litter, the litterbug will dispense the 4 items at pseudo-random intervals throughout the match. Littering will not begin until at least 15 seconds into the match, and will be completed (or disabled) before the last 15 seconds of the match. The remaining 90 seconds of the match will be divided into 16, 5.625 second time periods. An item of litter will be dispensed some time within that period. Some litter items may not fall completely free of the litterbug at the time they are dispensed, but will typically fall free later as the litterbug moves. While we have taken steps in the design to make this less common, it will sometimes happen and does not constitute a malfunction.

Litterbug communication

The litterbug will "chatter" in the form of broadcasting four different types of messages. All of the messages on a particular field will be transmitted within a specified 200 kHz band as shown in the table below.

Field	RF CenterFrequency
Field 1	433.6 MHz
Field 2	433.8 MHz
Field 3	434.0 MHz
Field 4	434.2 MHz
Field 5 (practice)	434.4 MHz

We anticipate having three fields (Fields 1-3) that will be used for competition matches, and a 4th field that is equipped with a litterbug for testing and practice during matches. This field could be taken over for competition matches if a problem develops with a primary field, or if doing so is needed to maintain the rhythm required to allow all teams the intended number of match opportunities.

There may be a 5th field available for practice and testing that does not have bins or a litterbug. The above frequencies may ONLY be used on the corresponding field. Teams may use 200 kHz bands above the Field 5 band for testing in their pit area.

Transmission Limitations

All transmissions by the litterbug and competition robots will be designed to be in compliance with the spirit of applicable FCC regulations. In particular this means that there will be at least 10 seconds between the transmissions of a given device, transmissions will be less than 1/3 second (in fact they will be MUCH shorter than that), and that the transmit EIRP will be less than -22 dBm. These MUST be observed in competition, and failure to do so could result in disqualification.

If the 10 second quiet time between transmissions is not going to be observed during testing, the power must be reduced to below -49.2 dBm EIRP.

A "Communications Orientation" document is available through a link from the team Forum that discusses the background behind these rules more thoroughly.

Another document will be available on the forum with representative oscilloscope captures of each type of litterbug transmission.

Litterbug transmissions will use one of 4 different modulation types. The modulations and their parameters are shown in the table below:

Type	1	2	3	4
Modulation	GFSK Gaussian filter with BT=0.5	2-FSK	4-FSK (2 bits/baud)	MSK
Baud rate	38.4kbaud	38.4kbaud	19.2kbaud	38.4kbaud
Deviation	20.6 kHz	20.6 kHz	20.6 kHz max	
Bit assignment	0=Fc-20.6 kHz	0=Fc-20.6 kHz	01=Fc-20.6 kHz 00=Fc-6.87 kHz 10=Fc+6.87 kHz 11=Fc+20.6 kHz	0 = +90deg, 1 = -90deg over 5/8 of symbol
Bit Order	MSB first	MSB first	MSB first	MSB first

The Litterbug will always start each round using type 1 (GFSK). The litterbug will continue to transmit with this format until a valid command is received from the competition robot. Once a valid command is received, the litterbug will disable the requested litter type, turn off the corresponding indicator lights, and beginning with the next transmission the litterbug will use the next modulation type for its broadcasts. Once a valid command has been received on each of the 4 modulation types, the litterbug will stop transmitting.

Although messages use different modulations, all litterbug messages will have the same data format. The packet format will be as shown below:

Preamble 1010…1010	Sync Word 0xFAFA	Length 0x04	Address 0x00	Litterbug Name	Problem	Team ID (as assigned)	CRC-16

- The preamble field will consist of 16 bits of alternating 1 and 0.
- The sync word will consist of 16 bits, always containing 0xFAFA.
- The length field will consist of 8 bits, in litterbug messages always containing 0x04.
- The address field will consist of 8 bits, always containing 0x00.
- The litterbug name field consist of 8 bits, containing one of the following 4 patterns;

Litterbug Name	Field Value
Alpha	0x00
Bravo	0x0F
Charlie	0xF0
Delta	0xFF

The name of the litterbug on a particular field is not provided ahead of the match, and is not guaranteed to be the same for all matches on the same field. This value will have to be recovered from a transmit message in order to form a valid response.

- The Problem field will consist of 8 bits, containing a value between 2 and 15 (0x02 to 0x0F). It will be randomly generated within that range on each transmission, resulting in all transmissions within a match being unique. This field will have to be recovered from a transmitted message in order to form a valid response.

- The team ID filed will consist of 16 bits, containing a unique code that will be assigned to each team the morning of the competition. It will remain fixed for a particular team for the balance of the event. This code will be loaded into the litterbug as part of initializing for each match. It is intended to reduce the likelihood of either the litterbug or competition robot responding to any transmissions from outside their specific field and match. The IDs will be assigned to have a large Hamming distance between any pair of assigned IDs, given the number of teams participating.
- The CRC-16 field consists of a 16 bit CRC checksum over the fields beginning with the length field and going through the team ID. Since the problem field will be unique in each message, the CRC check will also be unique for each message. Teams are not required to receive or process the CRC-16 field, however together with the redundancy or known information in most other fields in the message, a variety of error detection and correction approaches should be possible if desired.

All valid messages from a competition robot to the litterbug will be in response to a particular litterbug message, and will generally be quite similar. A valid response will use the same frequency and modulation as the message it is a response to. It will have the following fields:

Preamble 1010…1010	Sync Word 0xFAFA	Length 0x04	Address 0x00	Litterbug Name	Answer	Litter type	Team ID (as assigned)	CRC-16

- The preamble field will consist of 16 bits of alternating 1 and 0, the same as in the transmitted message.
- The sync word will consist of 16 bits, always containing 0xFAFA, the same as in the transmitted message.
- The length field will consist of 8 bits, in litterbug messages always containing 0x05. This value is different that the transmitted message, since the response has an additional field.
- The address field will consist of 8 bits, always containing 0x00, the same as in the transmitted message.
- The litterbug name field consist of 8 bits, containing one of the following 4 patterns, the same as in the transmitted message;

Litterbug Name	Field Value

Alpha	0x00
Bravo	0x0F
Charlie	0xF0
Delta	0xFF

The name of the litterbug on a particular field is not provided ahead of the match, and is not guaranteed to be the same for all matches on the same field. This value will have to be recovered from a transmit message in order to form a valid response.

- The Answer field will consist of 8 bits, containing a value between 4 and 225 (0x04 to 0x0F). It must contain the square of the value from the most recent transmitted message. The Problem field will have to be recovered from this most recent transmitted message in order to form this response.

- The Litter type field will consist of 8 bits, designating the type of litter that should be disabled in the litterbug. The values must be as shown in the following table:

Litter Type	Field Value
Chip Bags	0x00
Cans	0x0F
Paper trays	0xF0
Water Bottles	0xFF

Teams should take care not to request disabling a litter type they have already disabled. Such a response will be considered invalid and will be ignored, even if otherwise properly formed, and repeated tries will never succeed. This is the field that does not directly correspond to a field in the transmitted message.

- The team ID filed will consist of 16 bits, containing a unique code that will be assigned to each team the morning of the competition. It will remain fixed for a particular team for the balance of the event. This field will match the value in the litterbug message, but should be known in advance.

- The CRC-16 field consists of a 16 bit CRC checksum over the fields beginning with the length field and going through the team ID. Since the Answer field will be unique in each message, the CRC check will also be unique for each message. Teams are not required include the CRC-16 field in a valid response, and present or not, it will be ignored by the litterbug in validating the response.

Response messages must not be sent less than 0.2 sec after the litterbug message was received in order to insure that the litterbug has transitioned to listening for a response. Similarly it must not be sent more than 9.8 sec after the previous message was received in order to insure that the litterbug has not stopped listening in order to prepare for the

next transmission. As noted earlier, response messages also must not start less than 10 seconds from the end a previous response message.

Litterbug status

Lights on the top of the litterbug will indicate which types of litter it is currently enabled to dispense. At the beginning of each match all four lights will be illuminated. It is still possible to persuade the litterbug to stop dispensing a type of litter and have the light go out even if it has already dispensed all of the items of that type. It will not be possible to do this once the litterbug has received the end-of-match signal.

General Rules

<G01> All team members must be enrolled undergraduate students and must be IEEE members at the time of registration for the competition.

<G02> No more than 10 members can be registered as members of any one team. No student may be registered as a member of more than one team.

<G03> The design and construction of the robot must be substantially completed by those 10 members, and operation of the robot must be performed by one of those members. This rule is not intended to limit the following positive behaviors:
   a) Cheering on the performance of a team
   b) Offering advice or suggestions to a team
   c) Members of one team offering technical assistance at the event to another team that is encountering difficulty with their robot
   d) Incorporating design elements and best practices from other teams, and from other robots designed in prior years or for other events.
This rule IS intended to prevent a team from competing with a duplicate of another team's robot that they have not had a substantial role in making.
   Scrimmage events will be exempted from this rule.

<G04> All team members will treat fellow competitors and the event staff with courtesy and respect.
   It is an important life and professional skill to treat others with courtesy and sensitivity even in a directly competitive environment. Particularly remember that ALL competition staff are volunteers who have offered significant amounts of their time in

order to make this event possible, and they are doing their best within the constraints they have to deal with.

<G05> There may be times, especially at scrimmage events, where individuals associated with a team will help in the Referee or Scorekeeper roles. Individuals with emotional investment in the success of particular teams should avoid volunteering to help in this way. In no case should an individual associated with a school serve as referee or scorekeeper for a match of a team associated with that school. This rule does not apply to demonstration matches (for instance by the host team) that are not being counted in any of the event standings.

<G06> Teams must not transmit any RF energy in a way that will compromise the conduct of matches or the operation of the event. This includes interfering with the on field communications to and from Litterbugs, or WiFi, Bluetooth, or other links that are used in support of the event. Particular care must be taken when attempting to test Robot communication capabilities.

The Competition Robot:

Overview

This section describes constraints on the competition robot for the 2020 IEEE robotics competition.

Design Constraints

<R01> The robot must be no larger than 24" by 24" by 24" in its configuration at the start of the match. A robot failing a check of these dimensions will not be allowed to compete in a match until the dimensions have been met and confirmed by inspection. Note that this is considerably larger than robots in most recent IEEE R5 competitions. This is intended to allow robots to hold and process multiple pieces of litter at once, while keeping robots to a size that is practical for our venues.

<R02> Once the match has begun, the robot may extend outside its starting volume, but must not at any time extend outside a 36" diameter vertical cylinder. This rule is intended to reduce the frequency of physical contact with the litterbug, and limit strategies based on using overly long arms to sweep large areas of the field at once.

<R03> The robot must be a single entity and remain that way. Strategies based on splitting into multiple independent entities are prohibited this year. Parts must not be detached and left on the field. After all, we are trying to clean up litter, not add to it! Deliberate violation will result in disqualification for the match. Parts inadvertently left on the field (including hardware such as screws, nuts, zip-ties, belts, or chains) will be penalized by -1 point each, like other litter.

<R04> The robot, as it will be placed on the field, must not weigh more than 25 pounds. Heavier robots create more safety issues and are likely to damage the foam tiles of the field.

<R05> The robot must operate autonomously. It must not respond to any external commands except to configure the field information before the match start, trigger the start match operation and trigger stop match operation. (See <R08> below)

<R06> The robot must have a prominent stop button that will stop all motion by and within the robot, but not necessarily remove power from the control elements. It must be possible for team members or the referee to access this button easily and rapidly at any time regardless of the position of any other mechanisms of the robot. This could be used to stop the robot at the end of the match or in instances where the referee has determined it to be a hazard.

<R07> The robot must not contain any hazards to people or the litterbug, or cause damage to the field or game pieces. Example hazards could include (but are not limited to) sharp edges,

corners, or points that could cut or tear skin or the field tiles, exposed electrical contacts that could deliver a significant shock, mechanisms that could throw litter significantly outside the playing field, or wedge shaped elements that could tip the litterbug. Under no circumstances may highly flammable liquids or gasses, or explosive materials be used in the robot.

<R08> It is permissible (and even encouraged) to have a paired Bluetooth link to your robot that allows you to start match operation and to stop match operation remotely. You may also use the link to receive telemetry from your robot for diagnostic purposes. Otherwise it must remain within <R05>.

<R09> No spillable or flammable battery technology shall be used on the robot.

<R10> No pneumatic pressures greater than 100 Psi shall be used. At inspection teams using pneumatics should be able to provide documentation that all components are rated for the operating pressure used.

<R11> Robots must not leak or drip any fluids, including lubricants. The only exception would be for residual fluids present in the game piece litter.

<R12> The robot will be allowed to extend outside of the field borders to deposit items of litter into the bins. However, at all other places this act should be avoided to ensure the safety of those standing near the field.

<R13> A robot must have a means to know what field it is on that can be conveniently set by the team before each match. This information will be used by the robot to listen on the correct band for the litterbug on that field.

<R14> Robots must not transmit RF in the competition frequency bands except when in a match on the appropriate field. Robots must not transmit RF that exceeds the power levels defined in the appropriate FCC regulations at any time on the event premises.

The Matches

Overview

This section describes how the contest will be carried out and the conduct expectations of the competitors during the rounds of play of the 2020 IEEE robotics competition.

Progression of Play

1. Setup
   a. Prior to competing in a match each team will insure that their robot is set for their competition ID and the field that they will be playing on.
   b. The littterbug will be stocked and set for the field it will be used on and the competition ID for the team it is scheduled to face.
   c. One of the two red tiles will be randomly selected for the litterbug's starting location and the litterbug will be placed on that tile.
   d. The competitor robot will be placed on the blue starting tile furthest from the litterbug.
   e. The playing field will be populated with litter according to the rules outlined in <M05>.
2. Startup
   a. The referee will signal the start of the round and the referee or scorer will trigger the litterbug. The litterbug bill begin operation and will maintain the match time.
   b. At the referee's signal the competitors will start their robot.
3. The round
   a. The litterbug will dispense litter randomly in accordance with "litterbug littering" section above.
   b. The competitor's robot will perform its function.
4. Ending
   a. At the moment the 2 minute timer sounds off the competitor's robot must be stopped. It is encouraged for this to happen automatically but the competitor may stop it manually.
   b. The litterbug will autonomously stop operation.
   c. Scoring will be conducted as listed in <M11>

Match Rules

<M01> Matches shall be scheduled in rounds. Within each round, each team will have a chance to compete it they are ready when their match is up. Match schedules with the order of matches intended for each field will be distributed at the beginning of the competition day. Scheduling will be randomized, such that the order in which teams are scheduled and the field they are assigned to compete on will typically be different in each round. Target match times may be shown, but it is likely that actual match times will vary somewhat from the initial schedule based on events as they unfold. There will not generally be a break between rounds; as soon as all matches of a round have been completed play will proceed directly into the matches scheduled for the next round.

<M02> Each team is responsible for being present at the "on-deck" area for their assigned field prior to the completion of the match preceding theirs on that field. If they are not present they will forfeit that opportunity to compete and will score no points in that round. Teams will need to stay aware of the match sequence and the progress of matches on the field they will be competing on next.

<M03> Prior to the beginning of each match the litterbug will be stocked with the prescribed quantity of litter, the proper competition ID will be set, and the litterbug placed on one of the two RED starting tiles.

<M04> Prior to the beginning of each match the competition robot shall be placed on the BLUE starting tile furthest from the starting location of the Litterbug. At this time the robot shall NOT contact the border wall or any other tiles. The referee may use a measuring tool to confirm that the robot is completely within the prescribed starting volume.

<M05> Prior to the beginning of each match 12 items of litter will be placed on the field. This will include 3 paper trays, 3 plastic bottles, 3 aluminum cans, and 3 chip bags.

<M06> Each field litter item (see <M05>) will be placed on a different field tile that is not a RED or BLUE tile. The tiles used will be randomly selected by the game software before each match. The exact location of each item of litter on each tile is only guaranteed to be completely within the borders of the tile.

<M07> Each match shall have a duration of 2 minutes.

<M08> The referee or another competition staff member shall trigger the litterbug at the end of a verbal countdown. The litterbug will maintain the match time. A team member will be responsible for initiating operation of their robot as soon as practical after the countdown.

<M09> At the end of the match, the litterbug will trigger the end-of-match sound and will stop moving. A team member must disable the competition robot as soon as possible after the sound is played.

<M10> Once the competition robot has been disabled, the match shall be scored. Scoring will be based on the position of all litter once all motion on the field has stopped. If a robot appears to continue to operate after the end-of-match sound has been played, the referee may reverse the position of any affected litter before scoring. The judgement

of the referee will be final. Teams are encouraged to design and operate their robots so that there is minimal chance of this happening.

<M11> The scoring for a match is as follows:
- +1 point for each item of litter loaded in the Litterbug or placed on the field at the start of each match. This should be 28, corresponding to 16 in the litterbug and 12 on the field..
- -1 point for each item of litter on the field at the end of the match. This includes any parts that have come off the competition robot.
- +2 points for each item of litter in the correct bin (Cans in the can bin, bottles in the plastic bin, snack bags and paper trays in the trash bin)
- +1 point for each can or bottle placed in the trash bin. No points are awarded for putting incorrect items in a particular recycle bin.
- -1 point for each piece of litter from the match that is outside the field perimeter and not in a bin or touching the robot
- +2 points for each type of litter that the litterbug has been persuaded to no longer dispense, as indicated by the litterbug lights going out. An additional +2 point bonus will be awarded if the litterbug has been persuaded to no longer dispense any of the types of litter, as indicated by all four lights going out.

<M12> It is our goal to avoid ever needing to restart a match. However, in the event of a major litterbug malfunction, official game timer or scoring malfunction, or other reason that the referee believes necessary, a reset may be declared. The field and its game pieces must be set to the intended beginning state, the game timer reset to two minutes, the match score reset to zero, and the litterbug and competitor robot must be prepared to restart the match.

<M13> The number of rounds completed will depend on the efficiency with which teams and the event staff can complete the required matches, and occurrences outside the control of the event staff. The goal will be to complete at least 6 rounds at each event. If matches must be terminated at a point where some teams have had more opportunities for a match than others, scoring will have to be rolled back to the point where the partial round began, and the scores for the partial round will not be included in the total to determine standings.

<M14> The final score for each competitor will be the sum of the points received for their 3 highest scoring matches (subject to <M13>). In the event that a tie in the standings affects any of the first three places, if possible each of the teams that are tied for one of those positions will compete one more time to resolve that specific tie. (For instance, if three teams are tied for 3rd place, they will each have another match to

break the tie, but the outcome of those matches will not affect the standing of 1st or 2nd place.) If this fails to break the tie, or it is not possible to conduct tiebreaker matches, the following tiebreaker values will be consulted in order until the tie is broken:

- Most points awarded in all scheduled matches for litter placed in the correct bin
- Most points awarded in all scheduled matches for persuading the litterbug to stop littering
- Least points deducted in all scheduled matches for litter remaining on the field or out of the field of play
- Most points awarded in the tiebreaker match for litter placed in the correct bin
- Most points awarded in the tiebreaker match for persuading the litterbug to stop littering
- Least points deducted in the tiebreaker match for litter remaining on the field or out of the field of play

In the highly unlikely event that a tie still remains, the places will be awarded as a tie, and awards will be shared accordingly.

<M15> Actions that appear deliberate that tip or damage the litterbug, or that damage the field will result in disqualification for that match, and no points will be awarded. Before a team that has been disqualified under this rule will be allowed to compete in a later match, the team will be required to demonstrate to an inspector that actions have been taken to prevent this behavior.