

2023 BEST Robotics Classic Competition Rules

V1.0 3 August 2023

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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 should not make parts, perform detailed 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. [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 8-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://game.bestrobotics.org/qna> (or through your Team Workflow page). 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.

The competition has an 8-week schedule from start to finish. Event dates are determined and posted annually by each hub. The required and optional events are shown in Table 1.1. Optional events are offered at the hub's discretion.

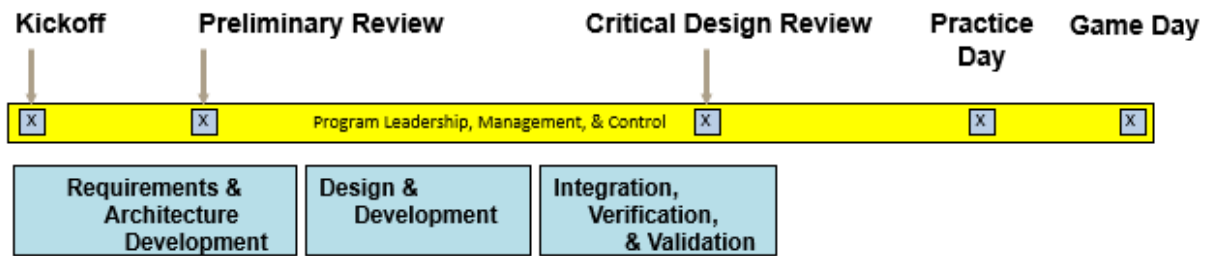
Table 1.1. BEST Robotics Competition Required Events

Event	Schedule	Team Participation (Required/Optional)
Kickoff	1 st event Starts the 8-week clock.	Required
Preliminary Design Review (PDR)	Nominally in week 2	Optional ¹
Critical Design Review (CDR) ²	Nominally in week 5	Required
Practice Day ³	Nominally in week 7	Required
Game Day	Final event At the end of 8-weeks.	Required

¹Check to verify this is offered by the hub.

²Format is at the hub's discretion. Template available.

³Additional practice days are allowed and included at the hub's discretion.



Kickoff

Kickoff is the event where all registered teams receive their kit materials, and the challenge details are revealed for the first time. Additional training may occur on Kickoff Day. It is the first official day of the program and starts the 8-week competition timeline.

Design Reviews

A design review as a general concept is an important part of product development. It is a customer or management control point to communicate requirements, train/guide engineers, and give constructive design feedback leading to a better final product. BEST implements two possible design reviews during the competition: Preliminary Design Review and Critical Design Review

These are collegial two-way discussions between student participants and experienced technical and business leaders. They are offered as mentoring opportunities for the students.

Students are free to share their planning, design activity, robot features and functionality, then ask questions about customer requirements, design tradeoffs, priorities, and design details to verify alignment. Students may discuss choices, resources, and workloads to identify schedule risks. Reviewers may suggest / discuss alternate approaches to investigate to mitigate risk or achieve better performance.

Preliminary Design Review (PDR)

The PDR occurs nominally in week 2, after the team has had a chance to digest requirements, brainstorm, draft a schedule, select software tools, identify key subsystems, and key assignments, etc.

Critical Design Review (CDR)

The CDR occurs nominally around week 5, about two-thirds of the way through development. There is still time to make changes or recover. It is an overview of the design to-date, but mainly a discussion of risks, alternatives, and opportunities.

Practice Day

Practice Day is a required event where participating teams are given practice time on the actual physical field to be used on Game Day.

Game Day

Game Day is 1-2 days of high intensity head-to-head competition, camaraderie, and professional presentation and exhibition. It is a day of celebration of the efforts just completed in the previous 8 weeks. It is the peak of the season where all the hard work pays off and teams are rewarded for their success.

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 1.3.2.3 .

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. Connect and disconnect the 7.2 Volt battery from the Cortex **ONLY** at the red/black power-pole connectors.
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 items may be available from your local hub, upon a justified request. Otherwise, consumable kit items replaced by a team may only be replaced with items that meet the Kit List specification. 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

Four (4) Team Custom Parts (TCP) are allowed.

1. Each part can be made from any uniform (homogeneous) team supplied material. An exception to this rule is that a surface treatment on metals or magnets is allowed. Examples would be an anodization layer on aluminum or a coating (typically nickel) on a neodymium magnet.
2. Each part must be able to fit 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.

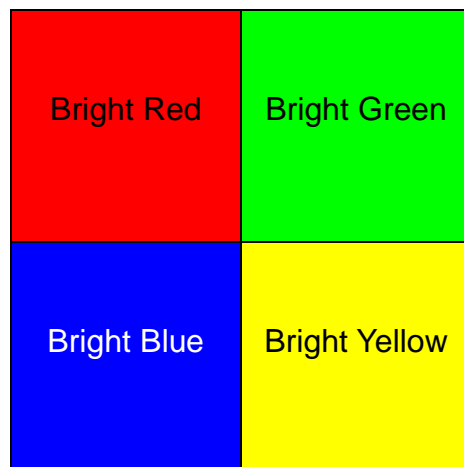
1.4 Head-to-Head Competition Rules

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.
2. 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 present at competition	Minimum 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.

3. 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.
4. The spotter may be any student from the team.
5. Spotters and drivers are not allowed to handle the game pieces prior to a match.
6. During a match, spotters and drivers may not communicate with anyone through 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

1. A 20-second suspension may be assessed for a variety of infractions that are detailed below and in section 3.5.3 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 a minimum of two teams or four teams, depending on the field configuration in use (2-team or 4-team). 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 defines 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 Field Configuration Options

There are two field configuration options for the 2022 season: two-team field or four-team field. The hub will select the configuration they desire to implement for their event.

Competition protocol will remain the same for both with the following modifications. The two-team field will be color-coded such that each team area represents two colors, Blue/Red and Green/Yellow for the purposes of scheduling matches and scoring. For a two-team field configuration, teams assigned to Blue and Green team areas will play first, followed by teams assigned to Red and Yellow team areas. A single match will be complete, and scores updated when four teams (all four colors) have competed. Schedules, scorecards, and spectator displays will be identical to a four-team configuration.

1.4.6.2 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 [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".

1.4.6.3 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.

1.4.6.4 Semi-Finals Phase

During the semi-finals phase, each team will participate in three (3) matches based on the rotation shown in Table 1.2 or Table 1.3. 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 1.2. 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 4	Seed 7
6	Seed 8	Seed 2	Seed 1	Seed 6

Table 1.3. 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

1.4.6.5 Finals Phase

The four (4) top ranked teams will participate in four (4) matches during the finals phase. Field assignments per match will rotate as shown in Table 1.4. The final team ranking will be based on the total points accumulated by the team during these 4 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 four final matches.

Table 1.4. Field Position Assignments for Finals

Finals 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
4	Semi-Final 2	Semi-Final 4	Semi-Final 1	Semi-Final 3

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 Game Day.

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

2023 BEST Returnable Kit List

	Qty	Item Description	Required/ Optional	Source	Part Number
BEST Control System Kit (VEX 270-1605)	1	Cortex Microcontroller	Req'd ³	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 ¹	VEX Robotics/Other	276-1491
	2	Charger Adapter (for Cortex and Battery Charger)	Req'd ^{2,3}	None - Hub Assy Req'd	n/a
	8	Screw Terminal Sensor Interface Cable 3-wire	Req'd ⁴	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 ^{2,3}	VEX Robotics/Other	276-2519, 276- 2520
	1	8-bay AAA Smart Battery Charger & power cord	Req'd ²	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 ²	VEX Robotics/Other	276-1403
	Qty	Item Description	Required/ Optional	Source	Part Number

BEST Servo Kit (VEX 270-1682)	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 ⁵	various	
	16	brass spacer	Opt ⁵	various	
	16	servo mounting screw	Opt ⁵	various	
BEST Motion Components Kit (VEX 270-4395)	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
Hub Provided	1	spare (replacement) servo horn screw	Req'd	various	

3	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 ⁵	various	
1	VEX Programming Hardware Kit	Opt ^{2,5}	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	1/4" shaft coupler, with set screws	Req'd	ServoCity	625104
any	containers, bags, boxes	Req'd ²	Hub Supplied	

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

² These items cannot be used on the robot.

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

⁴ Up to (6) of the three wire sensor interface cables (VEX P/N 276-3071) may be sub'd with old style two-wire sensor cables (VEX P/N 276-1734). A total of (8) sensor interface cables are required.

⁵ 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).

** Refer to the BEST IR Sensor documentation at https://www.bestrobotics.org/IR_Kit/

2.2 Consumables Kit

2023 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	1/8" thick clear polycarbonate 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 24"
	4 ea	piano wire, 0.063" diameter, 12" long
Wood Stock	1 ea	7/16" to 1/2" thick 2' x 4' plywood, any grade, soft or hardwood
	1 ea	3/16" to 1/4" thick 2' x 4' plywood, any grade, soft or hardwood
	2 ea	1" x 4" (nominal) #2 whitewood, 2 ft long
Pipes and Fittings	1 ea	1/2" schedule 40 PVC pipe, 5 ft long
	2 ea	3/4" schedule 40 PVC pipe, 5 ft long
	2 ea	1/2" PVC tee (slip)
	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
Hardware	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	6" x 6" steel turntable, 400 lb to 500 lb capacity
	1 ea	3/4" metal pipe hanger tape, 28 gauge, 10 ft long
Electrical	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*)
	6 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
Tapes and Adhesives	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
	100 ea	#8 flat washer, steel (3/8" OD)
	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
	10 ea	wood screw eyebolts, 0.192 wire dia x .97 shank x .75 thread x .27 id, steel
	100 ea	#8 x 1" sheet metal screw, steel, hex head
	25 ea	#6 x drywall screws, 1 1/4" length, fine
	25 ea	#4 x 3/4" wood screw, steel, slotted drive, round head
Miscellaneous	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)
	2 ft	3/8" thick, 1" wide, adhesive backed, gum rubber strip
	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) ¹

Qty	Item Description
10 ea	wooden spring type clothes pins
3600 sq in	Cardboard sheet, 1/4" maximum thickness (not preformed)
2 ea	empty food/beverage PETE container with screw on cap/lid (2 liter max.) ²
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
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 ea	carpenters wood glue, 4 oz or 8 oz
4 ea	Team Custom Part ³

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.

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

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

³ 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

As the healthcare industry is still recovering from our modern history's most intensive stress test, BEST believes that advances in technology and innovation will continue to improve proficiency and quality in the future of medical care. Minimally invasive surgery is one such advancement that is taking hold in surgery rooms throughout the world. Extending a surgeon's abilities through robotics allows complex surgeries with minimal invasiveness to the patient. Robots enter the body through small incisions and aid the surgeon in performing some otherwise complex tasks requiring great precision. These robots become the eyes and hands of the surgeon, allowing very delicate operations to take place inside the body.

BEST has developed a new training platform for minimally invasive surgery called SimBody. The platform simulates the internal human body and acts as a training ground for several robotic-assisted surgeries. Today's robots support only one surgery at a time. Your challenge is to design and demonstrate a multifunction robot that can aid your surgeons to accomplish several surgeries in a short time. You may be asked to collaborate with surgeons from other teams in performing some tasks. Only the best and most capable robots demonstrated will be selected to advance.

3.1 Objectives

Design and build a robot to assist a surgeon in performing the following minimally invasive surgical tasks:

- Brain biopsy
- Cardiac valve repair
- Coronary artery bypass
- Cardiac ablation
- Pacemaker electrode connection
- Arterial plaque removal
- Cardiac Angioplasty (insertion of artery stent)

- Vein harvesting
- Internal hemorrhaging damage control

3.2 Game Field

Figure 3.1 and Figure 3.2 give a bird's eye overview of the playing field. The field is a simulated body, or SimBody, in which all surgical tasks will take place. SimBody contains the brain, the heart and other arteries/veins that carry blood to these critical organs. The heart is at the center of SimBody, the brain cavity is centered above the shoulders, and arteries/veins are at the opposite end. Robots start near the shoulder area and enter through small incisions in SimBody.

Several minimally invasive robotics surgical procedures can be performed on SimBody. A surgeon and surgical assistant are required to manipulate and guide the robot during these surgical procedures. Some procedures require the use of surgical instruments.

- The brain biopsy procedure takes place on the (head) end of SimBody closest to the surgeons.
- The cardiac valve repair, coronary artery bypass, cardiac ablation, and pacemaker surgeries all take place in or around the simulated heart. The heart has four (4) chambers (left atrium, left ventricle, right atrium, right ventricle) separated by four (4) valves that open and close to allow blood flow into and out of the chambers. Some valves have faulty membranes needing removal and others need new membranes installed.
- The arterial plaque removal procedure is performed on coronary arteries located on either side of SimBody (left or right). An Angioplasty procedure can also be performed on these arteries by inserting an arterial stent to hold the artery open.
- The lower portion of SimBody (opposite the brain cavity) contains two (2) locations simulating the lower extremity group (LEG) veins that are typically harvested and used in coronary artery bypass surgeries.

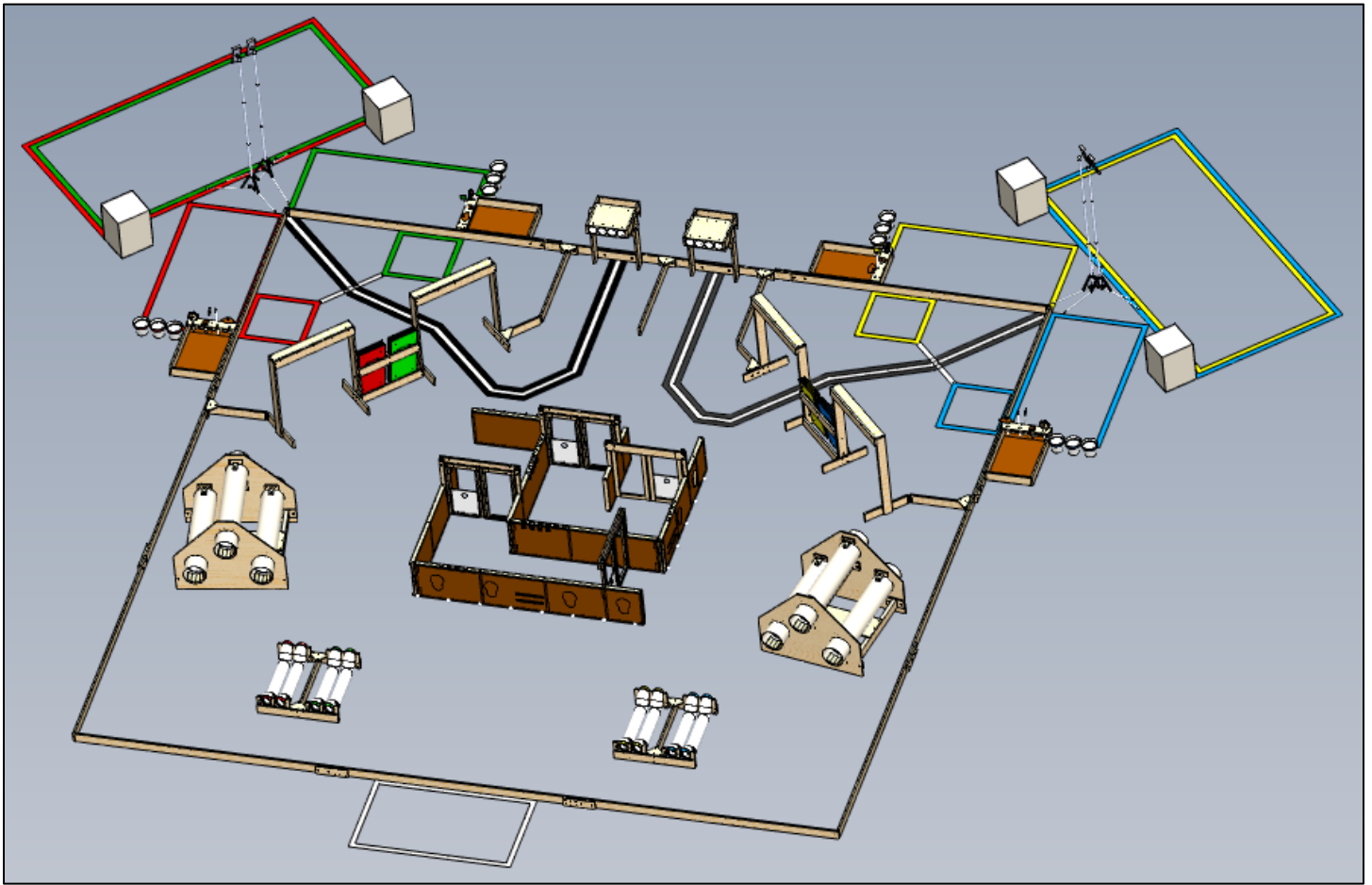


Figure 3.1 Game Field Overview

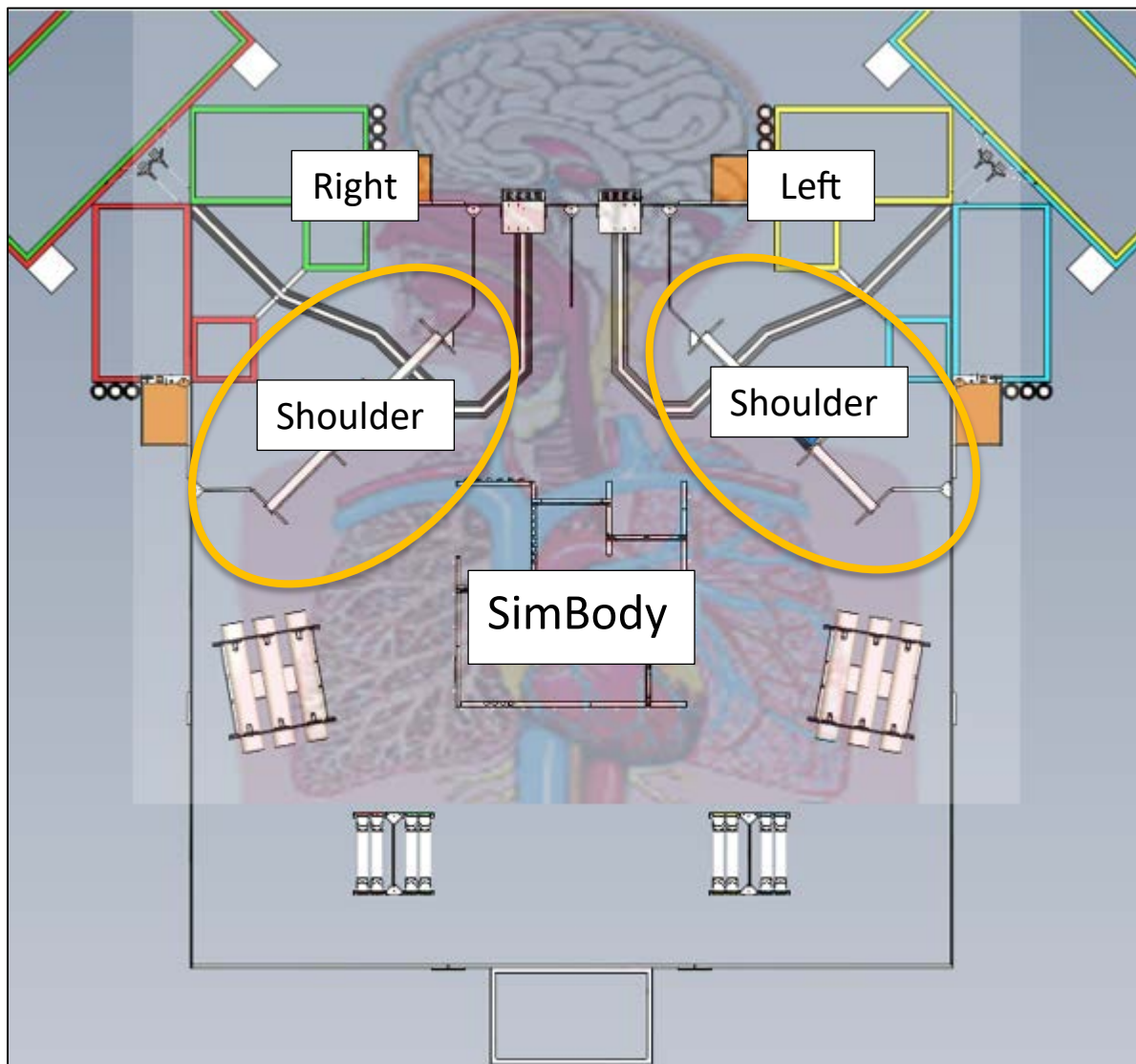


Figure 3.2 Game Field / SimBody Overview

Left and Right designations are from the perspective of the SimBody patient lying on an operating table.

3.2.1 Field Layout

Figure 3.3 provides a top view of the field. The sections that follow provide more detailed descriptions of the field elements.

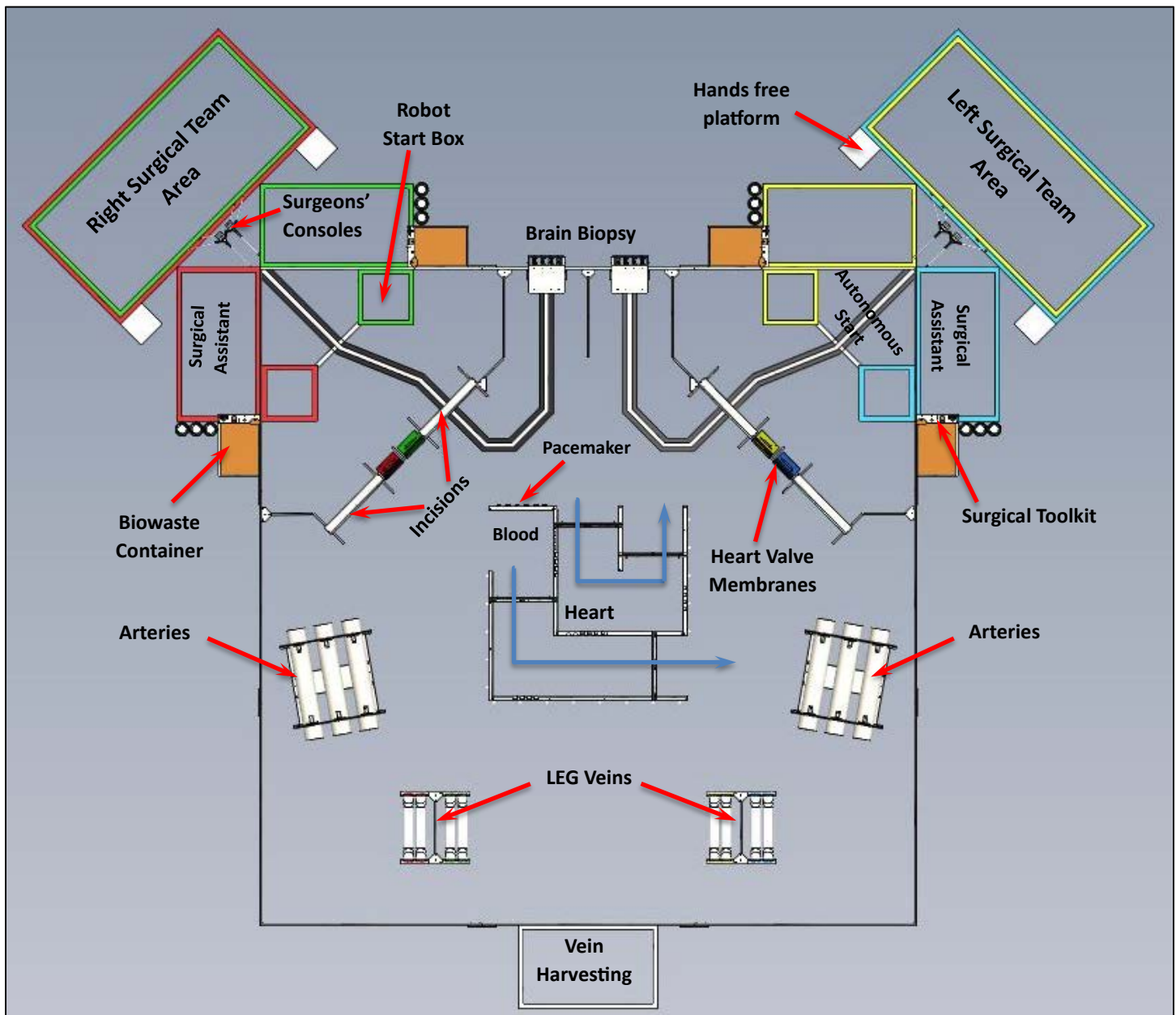


Figure 3.3 Field Layout – Top View

3.2.2 Shoulder Areas

3.2.2.1 Robot Start Box

The Robot Start Boxes are in the Left and Right Shoulder areas. A team's start box is designated by colored tape and measures 24" x 24" from the outside edge of the tape line.

- The robot must remain fully inside the Robot Start Box and in the 24" x 24" x 24" starting configuration until the match begins.

- b. A colored flag ([robot identifier flag](#)) must be installed on each robot prior to the match designating its team ownership.

3.2.2.2 Surgical Assistant's Work Area

A 36" x 66" Surgical Assistant's Work Area exists outside of the field boundary and adjacent to the Robot Start Box. The Surgical Assistant (spotter) will operate in this area and may access instruments and medical supplies from the surgical toolkit.

3.2.2.3 Surgical Team Area (Drivers)

The Yellow and Blue team drivers share a 120" x 60" Surgical Team Area near the left shoulder. The Red and Green team drivers share a Surgical Team Area near the right shoulder. Each surgeon has a Surgeon's console (display) that shows the live video feed from a camera mounted on the robot.

For all surgeries, the surgeon may utilize the live video feed from the console to aid with controlling their robot inside SimBody.

A **hands-free platform** (nominally 17" H x 12" W x 12" D cardboard box) exists for each surgeon as specified in the drawings and is used to hold the robot controller (joystick) during any robot setup procedures.

3.2.2.4 Robot Autonomous Start Area

Robots that perform the autonomous brain biopsy procedure must begin [inside](#) the Robot Autonomous Start Area in the corner of the field between the paired Robot Start Boxes. The area is defined by the tape edges of the two Robot Start Boxes and the tape line that joins these corners. A diagonal tracer line to the brain biopsy area is available to guide your autonomous robot.

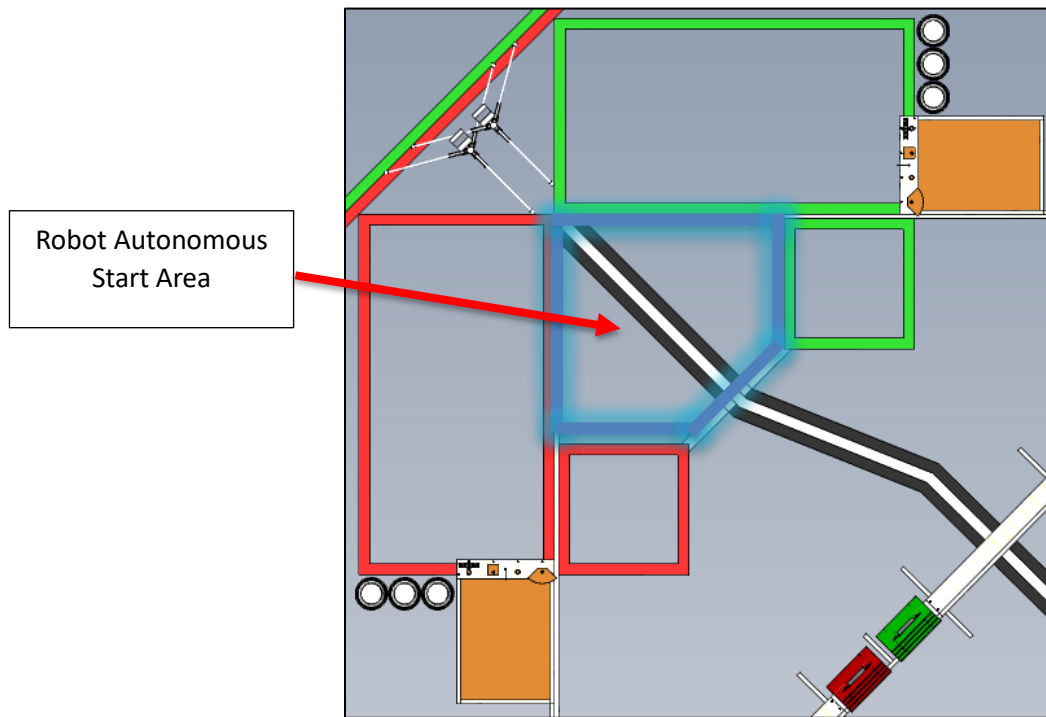


Figure 3.4 Robot Autonomous Start Area

3.2.2.5 Bio Waste Container & Surgical Toolkit

There is one Bio Waste Container for each team, just outside the field boundary of each Shoulder Area and adjacent to the team's Robot Start Box. The container is approximately 22 1/2" L x 16 1/2" W x 3 1/2" H and holds medical waste retrieved from SimBody such as blood droplets, faulty heart valve membranes, and arterial plaque. The Bio Waste container is only accessible by the robot.

At one end of the container is the surgical toolkit holding surgical instruments (robot attachments). A robot identifier flag is also in the surgical toolkit. Stents are part of the toolkit just outside of the surgical assistant's work area. Refer to section 3.4.2 for details regarding the instruments available.

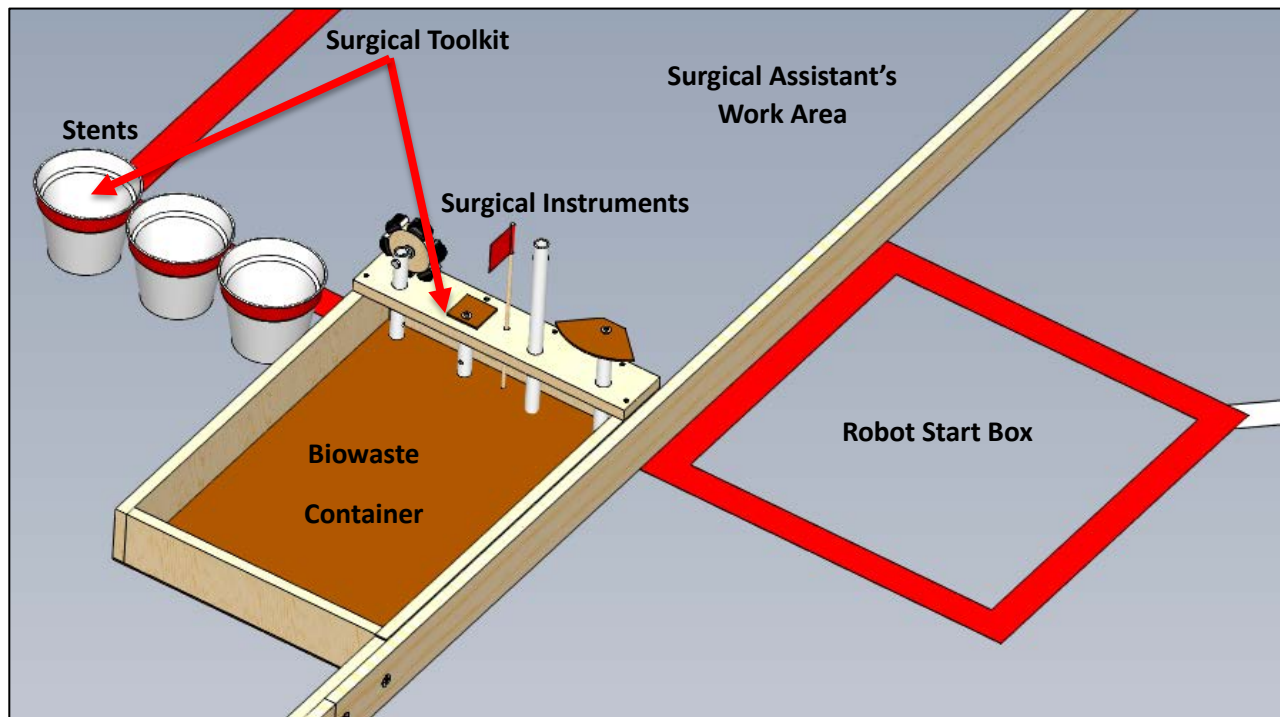


Figure 3.5 Bio Waste Container & Surgical Toolkit

3.2.2.6 SimBody Incisions

There are two incisions at each SimBody shoulder. The pair of robots that start in a shoulder area may use either incision to enter and exit the SimBody field. Each incision is 30" W x 33 ¼" H.

3.2.3 Simulated Heart

The heart sits at the center of the SimBody. It has four (4) total chambers and four (4) valves between the chambers that control blood flow. The Right Atrium chamber feeds the Right Ventricle. The Left Atrium chamber feeds the Left Ventricle. Valves open only in the direction of blood flow through the chambers.

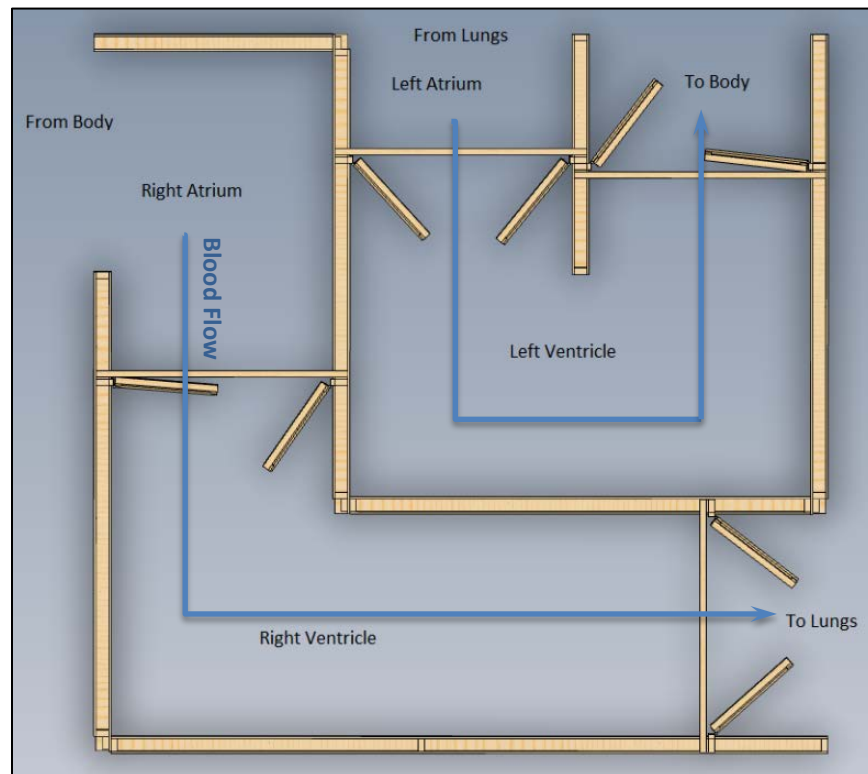


Figure 3.6 Heart and Heart Valves

3.2.3.1 Heart Valves

There are four (4) valves within the heart, each consisting of two frames. Each frame opens only in the direction of blood flow and is self-closing. Each valve starts with one frame having no membrane and the other frame having a faulty membrane.

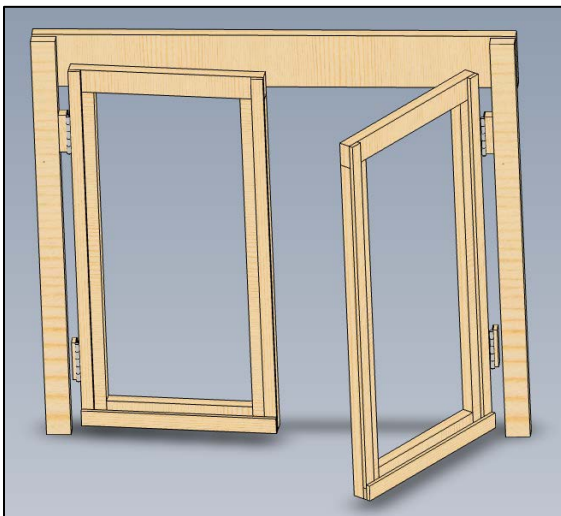


Figure 3.7 Empty Heart Valve Frames

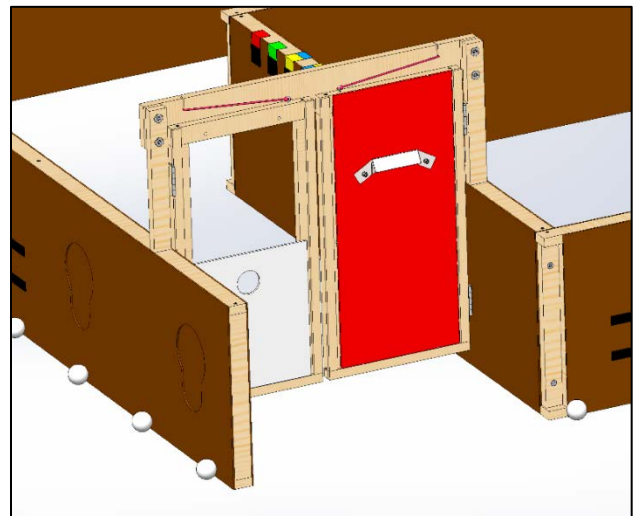


Figure 3.8 Faulty Membrane & Fully Inserted Replacement Membrane

3.2.3.2 Coronary Arteries

There are 3 sections of Coronary Arteries on each side of the SimBody as shown in Figure 3.9. These arteries allow a large amount of blood flow, but that flow can become compromised by plaque build-up on the inner walls of the artery. These arteries are approximately 8" in diameter and 48" in length. Figure 3.9 shows plaque build-up inside each end of each artery that needs to be removed with an atherectomy (at-her-ec-toe-me) tool, commonly referred to as a rake.

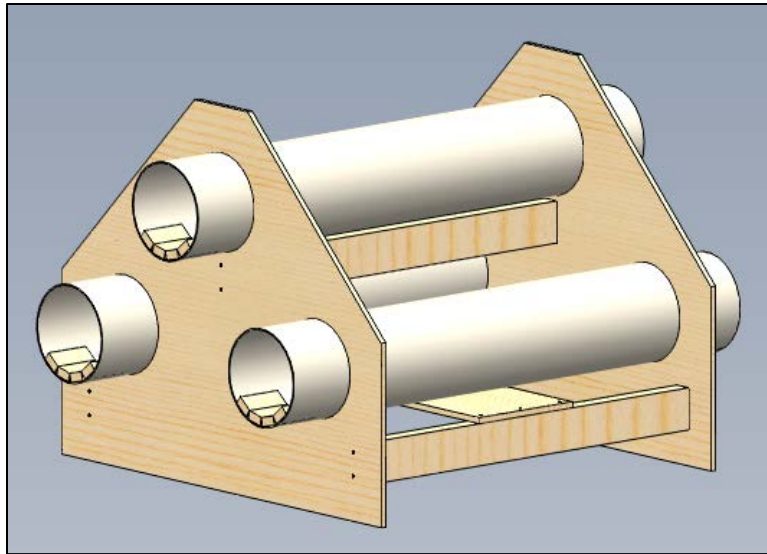


Figure 3.9 Coronary Artery With Plaque

As an alternative or complementary procedure, the robot can insert a stent into the artery to allow the blood to flow freely. This is known as Angioplasty.

3.2.3.3 Coronary Artery Bypass Locations

If the coronary arteries feeding the heart are too clogged to clean, the robot can perform a coronary artery bypass procedure. A vein is harvested from the leg and both ends are attached to the artery bypass locations shown in Figure 3.10.

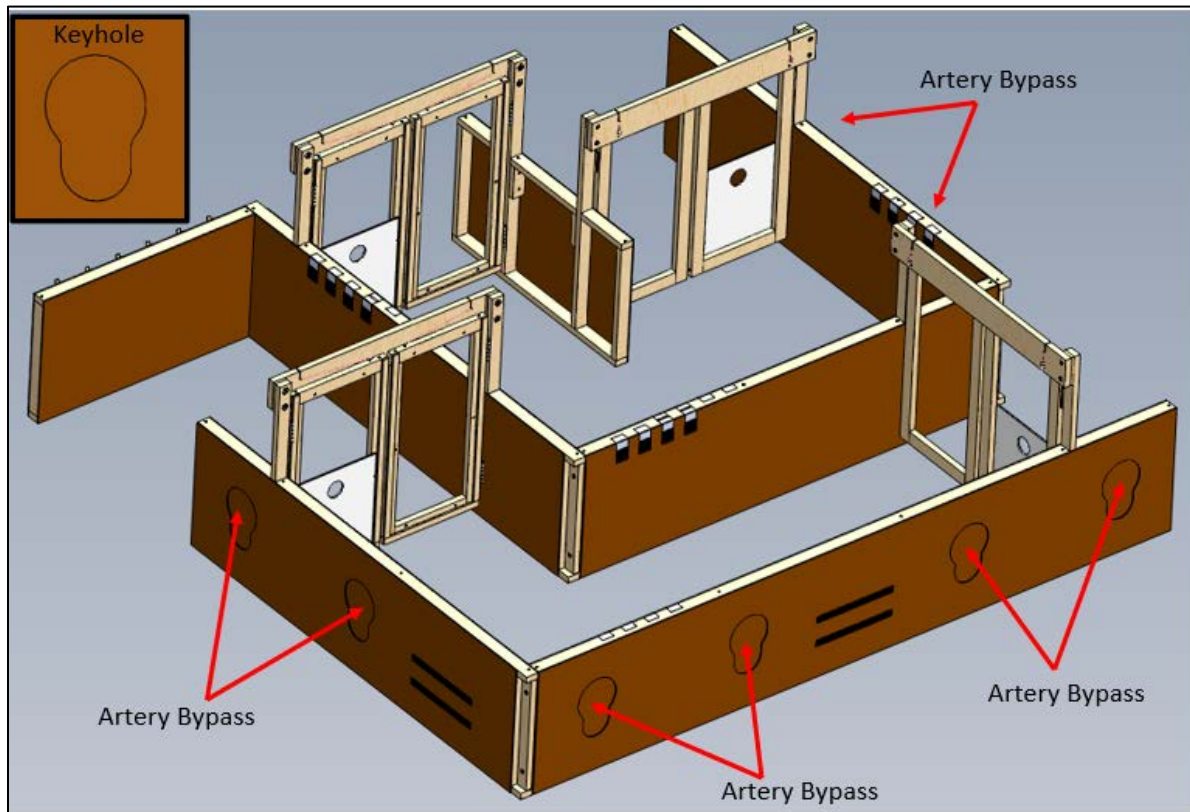


Figure 3.10 Coronary Artery Bypass Locations on the Heart

3.2.3.4 Pacemaker

Electrical pulses from cells near the upper right atrium control the contraction of the atria and ventricles. When the cell pulses are no longer sufficient, an artificial pacemaker can be installed to generate the electrical pulses in the proper rhythm (heartbeat). SimBody has an artificial pacemaker already installed near the right atrium but its electrodes need to be installed at proper locations inside the heart to maintain a proper rhythm. There are six cube-shaped wireless electrodes attached to the outer wall of the heart each with a short antenna attached. Each electrode has a $1\frac{1}{2}'' \times \frac{3}{4}''$ surface area of loop-side Velcro on two sides. These electrodes must be detached and installed at pre-defined (color-coded) electrode receiver pads ($1\frac{1}{2}'' \times 1\frac{1}{2}''$ hook-side Velcro) on the inner walls of the heart.

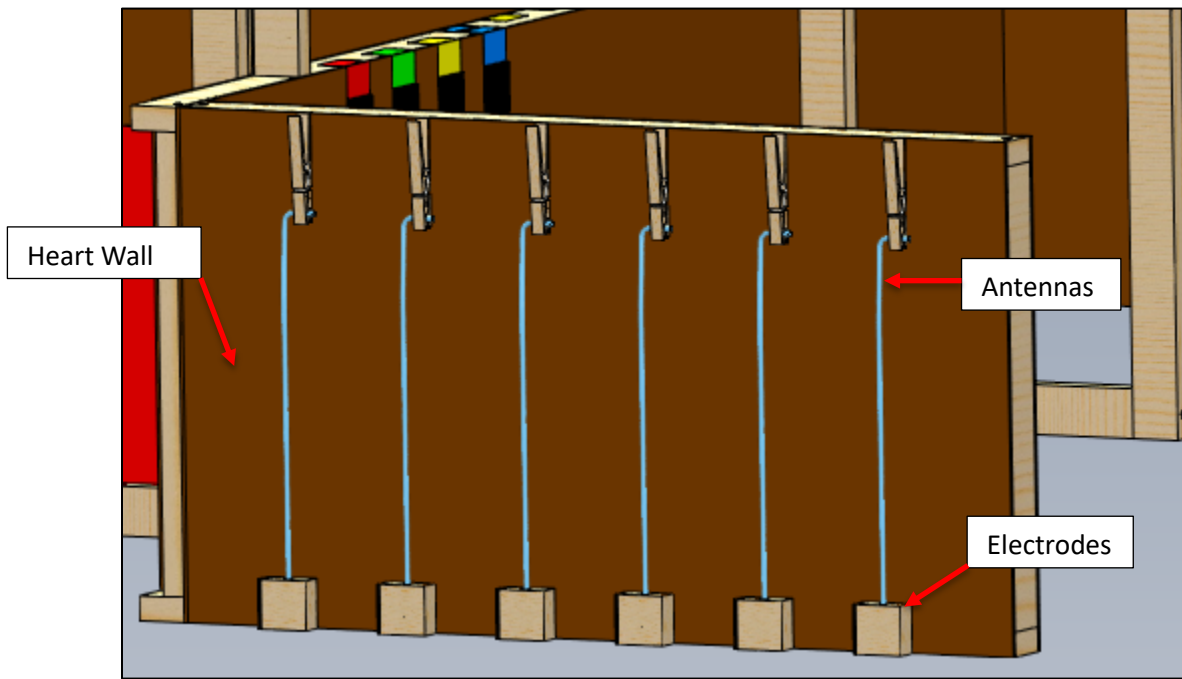


Figure 3.11 Pacemaker Electrodes

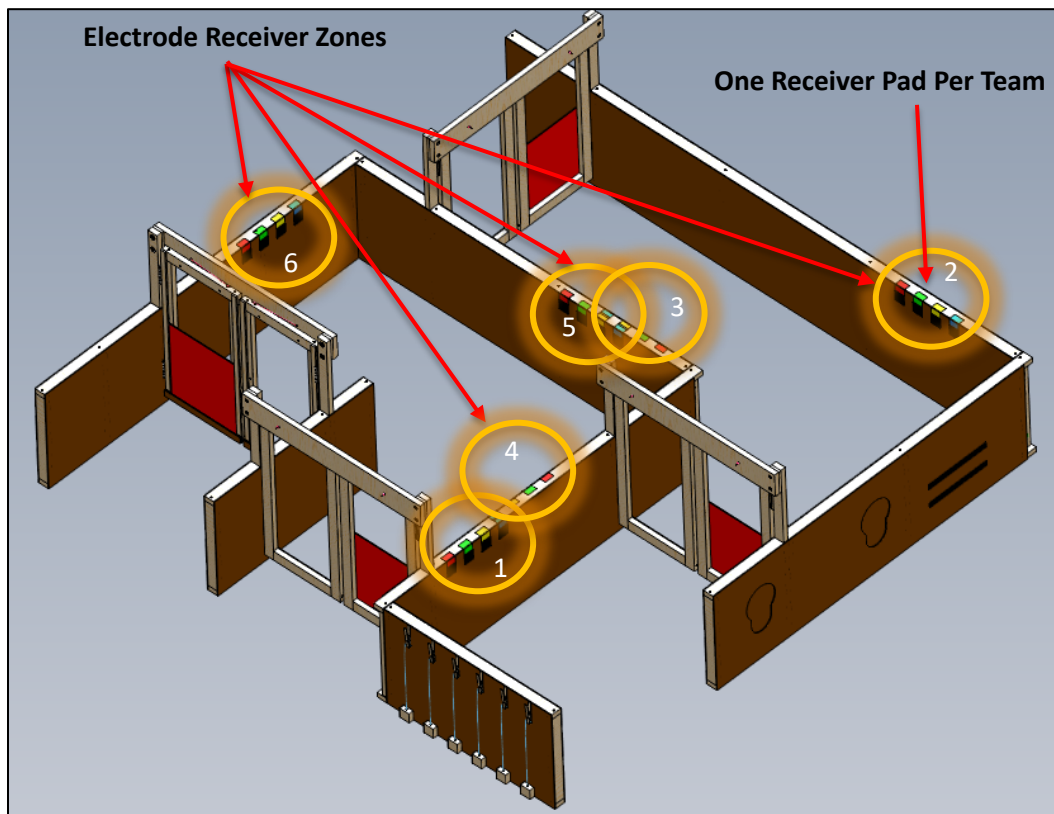


Figure 3.12 Pacemaker Electrode Receiver Pads

3.2.3.5 Cardiac Ablation Locations

When electrical pulses in the heart fire at the wrong time it disrupts the heart rhythm through either skipped heartbeats (palpitations) or extra heartbeats (premature ventricular contractions). Surgeons can correct the irregular heart rhythm by cauterizing the faulty tissue in the heart with a cardiac ablation procedure. There are two (2) ablation locations on each of the three (3) exterior walls of the heart not containing the pacemaker. The ablation locations are made with 10" strips of $\frac{3}{4}$ " loop-side Velcro. Minimally invasive robotic surgery can use a special instrument to ablate the faulty tissue at these locations to restore normal heart rhythm. Each team has such an instrument in their surgical toolkit.

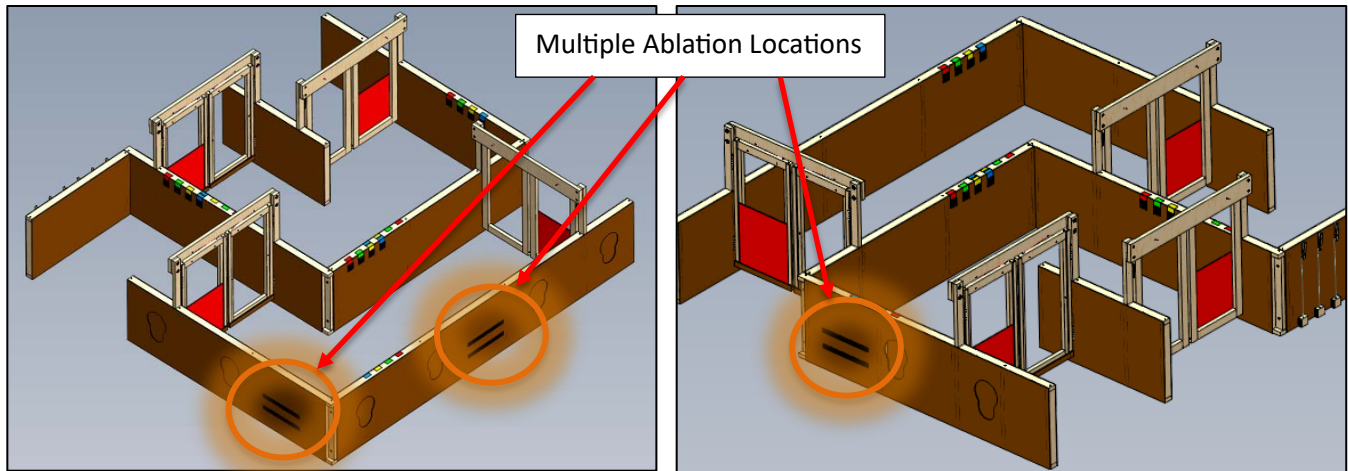


Figure 3.13 Cardiac Ablation Locations

3.2.4 Harvestable Veins

At the lower end of SimBody (farthest from the shoulder areas), there are eight (8) veins in the *Lower Extremity Groups* (LEGs). There are two (2) color-coded veins for each team, that can be harvested by robots and

- a) stored in the vein harvesting area for a future use, or
- b) used in the Coronary Artery Bypass procedure.

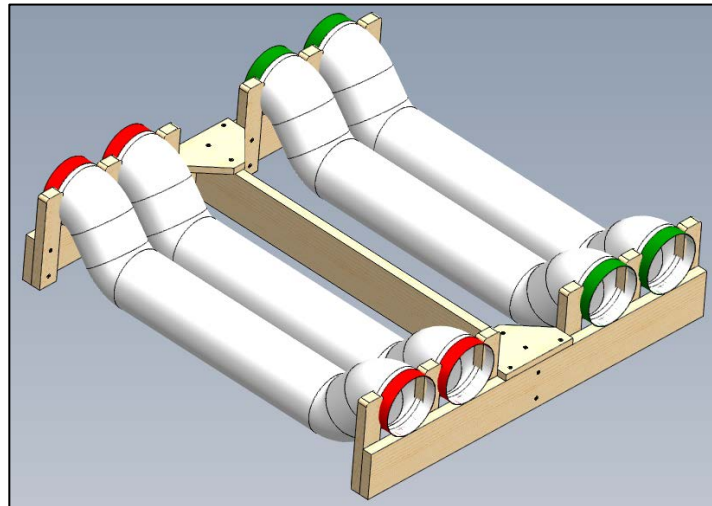


Figure 3.14 Lower Extremity Vein Group

3.2.5 Vein Harvesting Storage Area

A Vein Harvesting Storage Area exists just outside the field border, centered between the left and right LEGs. The 60" L x 36" W taped area is where harvested veins can be stored for future uses.

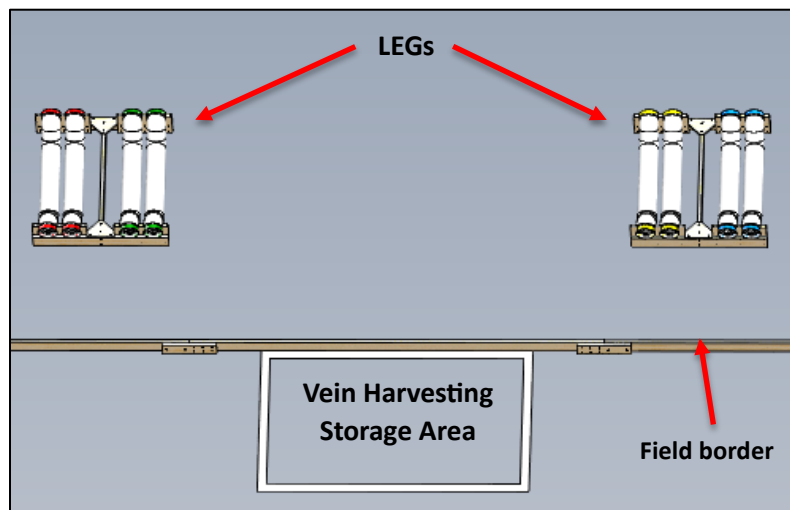


Figure 3.15 Vein Harvesting Storage Area

3.2.6 Brain Cavity

The brain cavity is between the two SimBody shoulder areas. The Left Brain and Right Brain cavities are divided by a 3 ½" high barrier. Each side of the brain is nominally 36" x 36".

A **brain imaging tracer** isotope was injected into SimBody to trace blood flow to the brain. This resulted in a pre-marked tracer path from the Robot Autonomous Start Area to the Brain Biopsy location on either side of the brain cavity. The surgical robot may use the tracer path as a guide to the desired biopsy destination. Robots must enter the brain cavity autonomously but may exit under driver control ([see Brain Biopsy Procedure](#)).

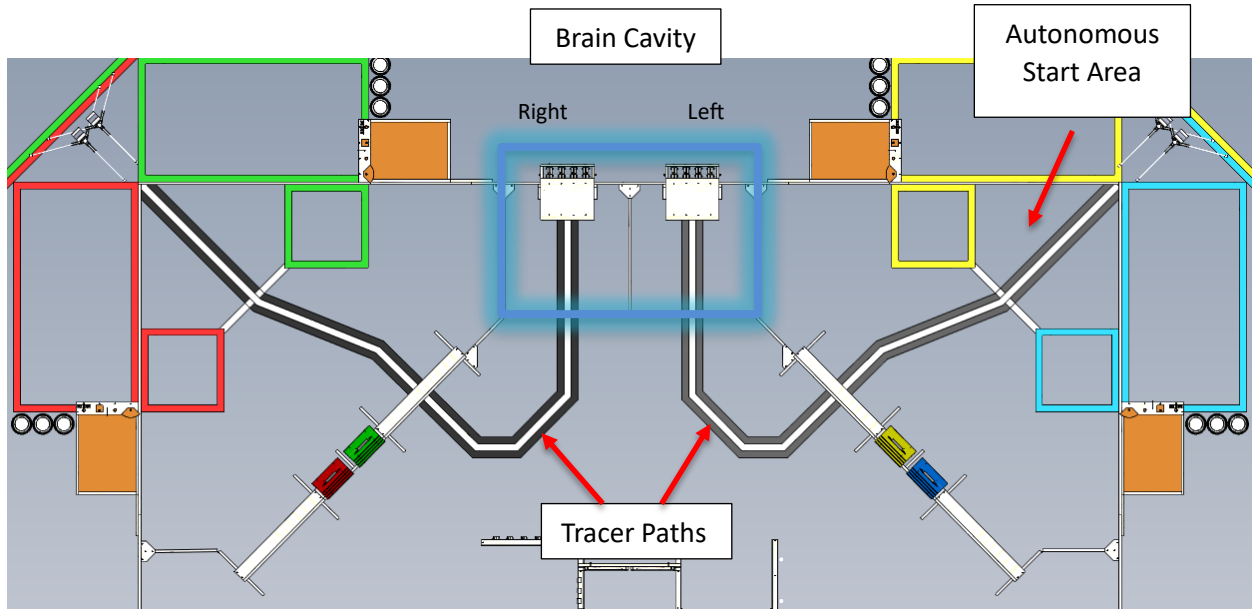


Figure 3.16 Brain Cavity (with tracer paths)

3.2.6.1 Brain Biopsy Location

There are two Brain Biopsy locations. The Red/Green team robots can access the Right Brain Biopsy Location. The Yellow/Blue team robots can access the Left Brain Biopsy location. There are four (4) biopsy sample cavities on each side as shown in Figure 3.17. Robots must use the **Biopsy Needle** (or a [team-built instrument](#)) in their surgical toolkit to access the samples. Pushing the needle far enough into one of the sample cavities will cause the brain biopsy directly below it to be dispensed. Because of the precision required when operating in the brain cavity, human error cannot be tolerated, and robots must perform the biopsy autonomously.

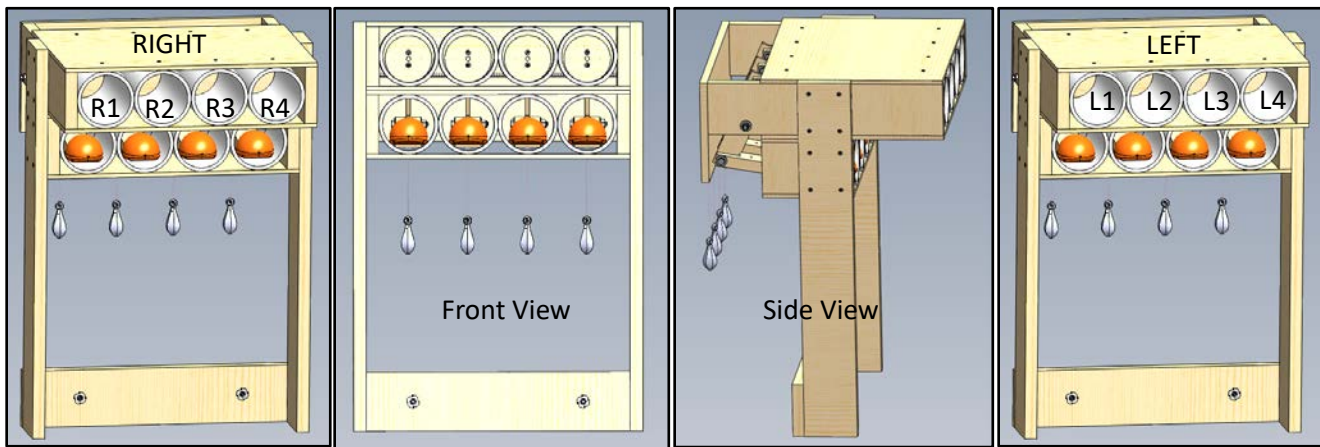


Figure 3.17 Brain Biopsy Location

3.3 Game Pieces

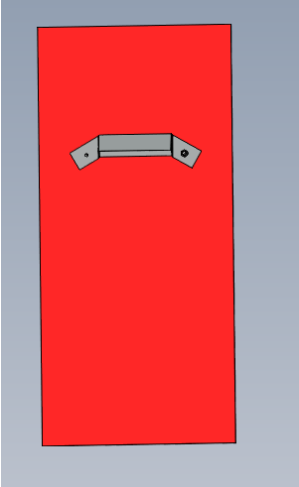
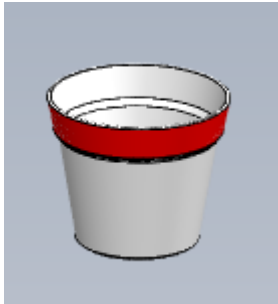
Each team owns certain game pieces throughout the field. These are color-coded by team-assigned color for the match. All other game pieces are available for collection/scoring by any team. Refer to Section 3.5.1 for more information about Team Ownership.

3.3.1 Artificial Replacements

Many surgical procedures involve the replacement of body parts with artificial replacements. Table 3.1 provides a description of each of these items.

Table 3.1 Artificial Replacements


Game Piece	Description	Image
Pacemaker Electrodes	<p>Antenna is 1/2" diameter Poly rope, braided, 12" long. The antenna, pre-connected to the exterior face of the heart, is removable for transport of the electrode.</p> <p>The other end is a cube-shaped electrode ($\frac{3}{4}$" x 1 $\frac{1}{2}$" x 1 $\frac{1}{2}$") with loop-side Velcro on two sides.</p>	

Replacement Heart Valve Membrane	~11" x 23", ¼" CoroPlast sheet, color-coded by team, with a handle ~16" from the bottom.	
Stent	5" tall, ~6" diameter plastic pots with color-coded ends. Stents are part of the surgical toolkit.	

3.3.2 Surgical Supplies

These surgical supplies may be used during surgical procedures.

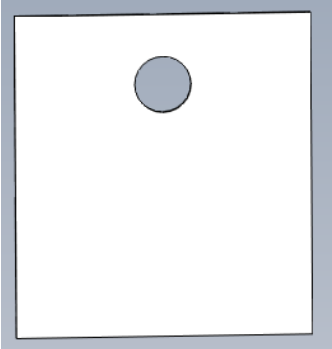

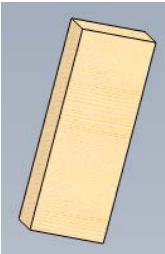
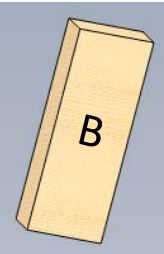
Table 3.2 Surgical Materials

Ablation Tags	<p>¾" x 1 ¼" Velcro strip</p> <p>Color-coded markers are pre-installed into the Ablation Instrument.</p>	
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3.3.3 Biowaste

Some surgical procedures may produce biological waste material that should be removed from the body.


Table 3.3 Bio Waste

Item	Description	Image
Faulty Heart Valve Membrane	~11" x 11", ¼" Coroplast sheet, black, with a 2" hole	
Blood Droplet	~1 ¼" diameter, hollow, dimpled, plastic, practice golf ball (not solid foam, and not "wiffle-ball" style), red	
Arterial Plaque	~1 ½" x 4" x ¼" wooden block, The arterial plaque will be marked as indicated to identify its starting location.	<div>Visible End</div>  <div>Blind End</div> 

3.3.4 Harvested Items

Some surgical procedures involve harvesting veins from the body for a future operation.

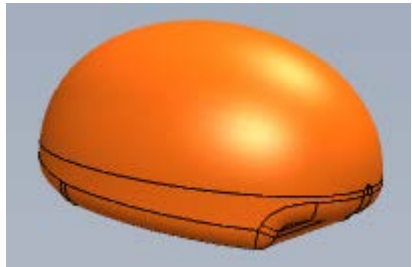
Table 3.4 Harvested Items

Item	Description	Image
Veins	~4" x 48" vinyl dryer vent, with color-coded ends	

3.3.5 Biopsy Sample

Some surgical procedures involve collecting biological tissue to be further analyzed.

Table 3.5 Biopsy Sample

Item	Description	Image
Brain Biopsy Sample	Nominally 3" x 2" x 4", oval shape, foam brain, orange, from igus kit	

3.3.6 Quantity and Starting Locations

Table 3.6 Game Piece Quantity and Starting Locations

Game Piece	Qty @ Match Start	Per Team Scoring Opportunities	Match Starting Location
AVAILABLE TO ANY TEAM (these start on the field)			
Pacemaker Electrodes	6	6	Attached to the outer wall of the heart.
Faulty Heart Valve Membrane	4	4	Partially installed in each of the heart valve frames (one side only).
Arterial Plaque Bricks	48	48	Lying on the inner surface of each end of the arteries.
Blood Droplets	18	18	Along the heart walls, spaced 12" \pm 6".
OWNED BY EACH TEAM (color-coded)			
Replacement Valve Membrane	4	4	Stacked between the two incisions joining the shoulder area and SimBody.
Harvestable Vein	2	4**	Installed on LEGs.
Heart Ablation Markers	6	6	6 color-coded ablation markers are pre-installed on each team's Heart Ablation surgical instrument.
Stent	3	3	In surgical toolkit. Used in the Coronary Artery Angioplasty procedure.
AVAILABLE TO A SPECIFIC SURGICAL TEAM (these start on the field)			
Brain Biopsy Sample	4	2***	In the brain biopsy dispensers.

** 4 scoring opportunities (2 ends) per team if used in Heart Bypass

*** 2 scoring opportunities per team, not counting bonus points

3.4 Special Surgical Equipment

3.4.1 Robot Identifier Flag

For each match, a team's robot will be associated with their field starting position and game pieces via a colored Robot Identifier Flag. The flag assembly consists of a 11-3/4 inch long piece of 1/4-inch dowel with a 2" x 2" colored flag made from gaffer's tape.

- The Robot Identifier Flag will be located on the field in the surgical toolkit.
- The flag must be affixed to the robot vertically, within 12 inches of the Cortex microcontroller, before the match begins.
- The flag is not required to fit within the 24" x 24" x 24" robot starting configuration.
- The flag cannot be used as a functional part of the robot (robot must function the same with the flag removed).
- The flag must be returned to the surgical toolkit after the completion of the match.

3.4.2 Surgical Instruments

Some surgical procedures require the use of specialized surgical instruments.

- Surgical instruments begin the match inside the surgical toolkit within the surgical assistant's work area as shown in Figure 3.18.
- The surgical assistant may attach surgical instruments to the robot via the standard instrument interface only. The standard surgical instrument interface is 1/2" PVC with a 1/4" through-hole at a distance of 1" from the end of the PVC. The exact length of PVC pipe may vary depending on the instrument.

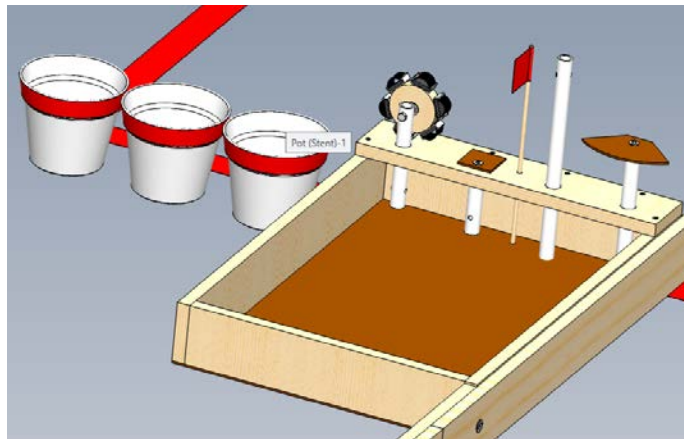


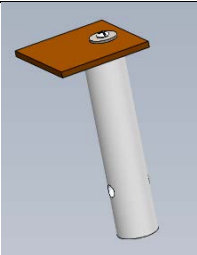



Figure 3.18. Surgical Toolkit & Supplies

Table 3.7 Surgical Instruments Available to each Team

Surgical Instrument	Qty	Surgical procedure using the Instrument	Image
Biopsy Needle, $\frac{1}{2}$ " PVC x 12" long	1	Brain Biopsy	
Ablation Wheel (with 6 color-coded tags) 2 $\frac{3}{4}$ " diameter wheel, $\frac{1}{2}$ " PVC x 6" long	1	Cardiac Ablation	
Valve Clamp $\frac{1}{2}$ " PVC x 4" long, 2" x 2" end effector.	1	Heart valve replacement membrane insertion	
Rake, $\frac{1}{2}$ " PVC x 8" long, nominally 3" x 5" curved end effector.	1	Arterial Plaque Removal	

3.4.2.1 Team Built Surgical Instrument

Four (4) surgical instruments are provided in the surgical toolkit. Teams may replace one (1) of the instruments provided in the surgical toolkit with a team-built surgical instrument. The team-built instrument replaces the field-provided instrument for the match. The field-provided instrument being replaced will be removed from the field.

- a. The team-built instruments must be constructed from kit materials.
- b. The combined materials used for the team-built instruments and robot must not exceed the materials available in the kit.
- c. Team-built instruments may not contain any springs or other stored energy sources other than that which results from gravity and a change in elevation or orientation.
- d. The team-built instrument must maintain a shape at the start of the match that is no larger than the inside dimensions the bio-waste container (all 3 dimensions).
- e. The team-built instrument must use the standard instrument interface for attachment to the robot (see rule 3.4.2 b).
- f. The team-built instrument must be stored in the surgical toolkit at the beginning of the match and stay in its initial configuration (shape) until the robot leaves the Robot Start Box.
- g. Teams may construct more than one team-built instrument; only one team-built instrument is allowed at the field during a match, replacing one of the field-provided instruments.
- h. All team-built instrument(s) collectively count against the 24 lb. maximum robot weight. The field-provided instruments do not count against the robot weight.
- i. A team-built instrument may replace the function of one or more field provided instruments, except for the Ablation Wheel.

3.4.3 Surgeon's POV Camera and Live Video Feed

Each team is provided with a point of view (POV) camera assembly to attach to their robot upon entering the field for the match. Each surgeon has a dedicated video screen (7" minimum diagonal) at the surgeon's console providing a POV live video feed from their robot. The height of the surgeon's console is adjustable. The POV camera can be useful when performing surgeries of blind areas of the field; those areas that are not easily viewable by the Surgeon directly. Such blind locations are indicated in Figure 3.20

- a. The surgical assistant may attach and orient the POV camera assembly anywhere on the robot prior to the match beginning.
- b. The POV camera assembly is attached to the robot via Velcro (loop-side on the camera assembly).
- c. The camera assembly measures approximately 4" W x 6" L x 2" H, weighing approximately 12 oz, and MAY NOT be disassembled in any way.
- d. The camera assembly has a dedicated battery measuring approximately 4.5" x 1.2" x 1.2" that must be secured to the robot by Velcro (loop-side on the battery).
- e. The battery and camera are connected via a 36" USB cable. Battery and camera are not required to be mounted in the same location on the robot.
- f. Damaging the camera, battery, or USB cable due to misuse or improper mounting is equivalent to damaging the field and will result in disqualification of the team for the match.
- g. The surgeon may use the video monitor as an aid when performing surgical procedures with the robot.



Figure 3.19 Surgeon's POV Camera and Display

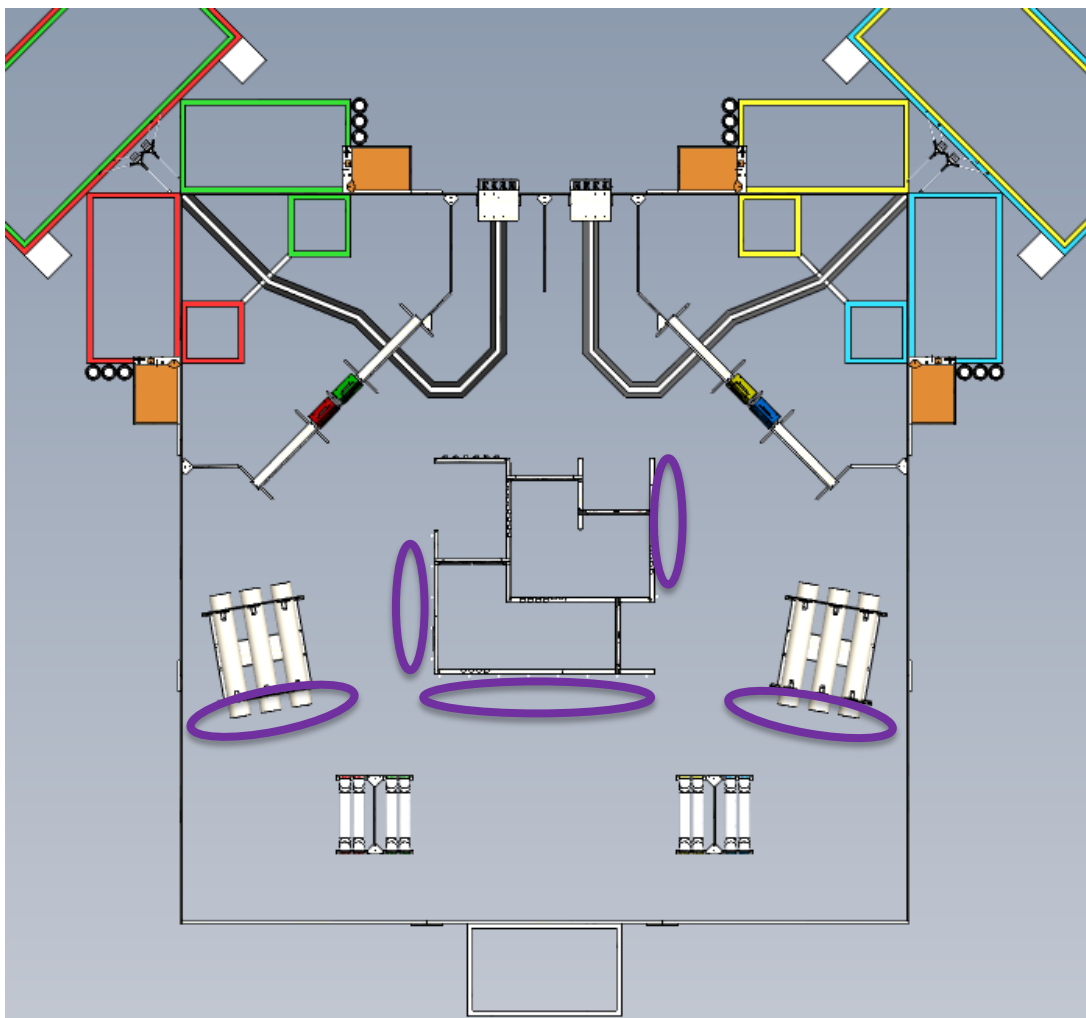


Figure 3.20 Surgeon's Blind Field Locations

3.4.3.1 POV Camera Backup

If one or more components of the POV camera system encounter a non-recoverable failure, as determined by the head referee, a backup solution will be implemented as follows:

- The system will be disabled for all teams.
- Matches that have been played previously will not be replayed.
- The hands-free platforms will be moved to the sides of the surgical team (driver) areas.
- The surgeons' video feed consoles will be removed from the field.
- The surgical assistants' work areas will be expanded to include a virtual area outside the field within three feet of the outside border of the field. No additional tape lines will be added. Figure 3.21 approximates the intended expanded areas.

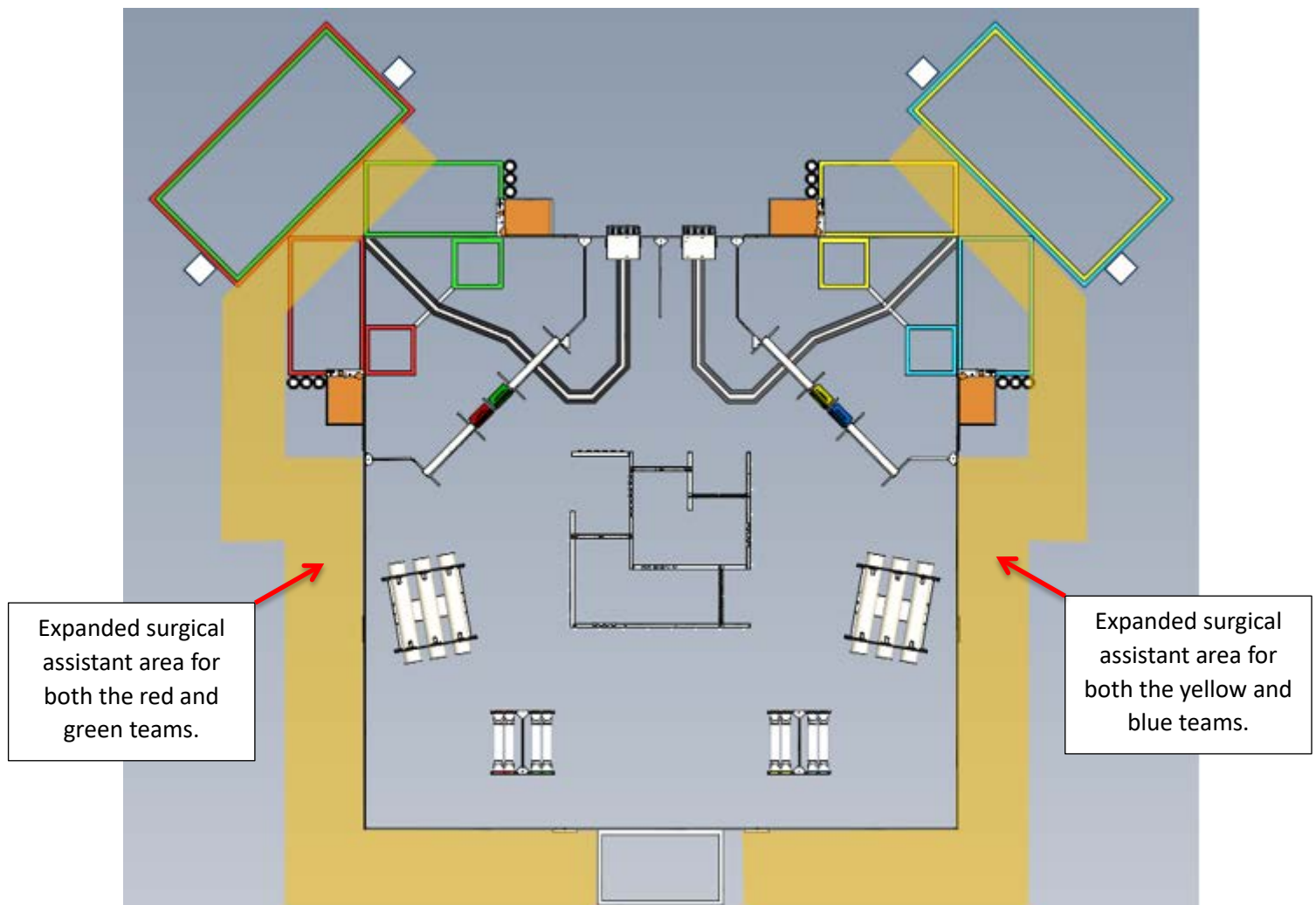


Figure 3.21. Notional Adjusted Surgical Assistant areas

3.5 Ownership, Interaction and Surgeons Rules

3.5.1 Team Ownership

Teams “own” certain field areas and game pieces during the match as defined below.

- a. A team owns any game piece that is color-coded to match the color of the team’s robot start box and robot identifier flag for that match (artificial valve membranes, stents, harvestable veins, heart ablation tags).
- b. A team owns certain field areas (bio waste container, pacemaker receiver pads) that are color-coded to match the color of the team’s robot start box for that match. Items scored in these areas will add to the score of the team that owns the area regardless of how they arrived there.
- c. A team can assume “ownership” of the pacemaker electrodes by making a successful connection to their colored pacemaker receiver pads in any receiver zone on the heart. Connection means any part of the Velcro fibers are touching and holding the electrode in place.

3.5.2 Interaction with Other Robots, the Field, and Game Pieces

The spirit and intent of the tasks is for teams to construct robots capable of completing the assigned objectives in an environment where multiple robots have access to limited game pieces and scoring opportunities. Some scoring locations and game pieces are owned by a specific team (i.e., color-coded) while others may be available to any team (see section 3.5.1). The goal is to complete as many of the surgical procedures as possible; manipulating game pieces that are already in scoring position is not allowed. Violation of any of the following robot interaction rules will result in disqualification for the match. Game pieces that are affected by a violation and were in a scoring position will be treated as “scored”, others will not. There will be no resetting of game pieces under any situation. Each game piece can score only once.

- a. Robots that start the match in the left shoulder area may only enter/exit SimBody through the incisions at the left shoulder.
- b. Robots that start the match in the right shoulder area may only enter/exit SimBody through the incisions at the right shoulder.
- c. Robots may not take game pieces in the grasp of, or contained on, another robot.
- d. Robots may not remove or dislodge game pieces (artificial valve membranes, stents, harvestable veins, heart ablation tags) “owned” by another team.
- e. Robots may not control any game piece “owned” by another team. Pushing a game piece does not demonstrate control. Pulling, dragging, lifting, or carrying a game piece demonstrates control.
- f. Robots may not remove, dislodge, or reposition any game piece in a scoring position placed by another team.
- g. Except for the brain biopsy, game pieces may not be placed into a scoring position by the robot during any [hands-free operation](#).
- h. Intentional contact between robots or occupation of space for the sole purpose of obstructing autonomous biopsy procedures will result in disqualification of the obstructing robot. Contact between robots will occur; it is expected to be incidental, not intentional.
- i. Robots may enter the [brain cavity \(right or left\)](#) only while operating autonomously.

Violation of any of the following robot interaction rules will result in a 20-second penalty.

- j. The Vein Harvesting Area is considered part of the field. Its boundary is considered part of the field boundary.
 - a. Robots may not touch the floor outside the field boundary. Robots MAY touch the floor inside the Vein Harvesting Area.
 - b. Robots may not touch any part of a vein that is outside of the field boundary. Robots MAY touch the portion of a LEG vein that is inside their Vein Harvesting Area.

3.5.3 Surgeon (Driver) and Surgical Assistant (Spotter) Rules

The following rules apply to the Surgeon (Driver) and Surgical Assistant (Spotter). All rules are cumulative and must all be satisfied.

- a. Only the Robot Identifier Flag and camera system may be placed on the robot prior to the start of the match.
- b. The Surgical Assistant may load stents or surgical instruments onto the robot after the match begins when any part of the robot is inside the Robot Start Box.
- c. The Surgical Assistant may reposition the robot into the Autonomous Start Area during the autonomous setup period. Refer to section 3.6.10 .
- d. Except for LEG veins, game pieces that touch the floor outside of the field boundary are considered out of play and will be removed by the referee. LEG veins may touch the floor outside the field boundary.
- e. Surgical instruments that are installed onto the robot by the Surgical Assistant do not need to be completely inside the Robot Start Box when driver control is resumed or the autonomous biopsy procedure starts (i.e., when the joystick is touched by the driver).

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

- f. The Surgeon may not touch any part of the field, any game piece, or the robot during the match.
- g. The Surgical Assistant may not touch any game piece “owned” by another team.
- h. Only stents and surgical instruments may reside inside the Surgical Assistant work area or Robot Start Box during the match. Surgical instruments should remain inside the toolkit unless mounted to the robot.
- i. Other than debugging a non-functioning machine, the Surgical Assistant may not manipulate the robot in any way after the match starts. Specifically, the spotter may not manipulate the robot (move parts, reposition components) to complete the process of loading game pieces onto the robot.
- j. The Surgical Assistant may not touch the field outside of the Robot Start Box or Autonomous Start Area.
- k. The Surgical Assistant may not touch any game piece that does not start in the surgical toolkit. Stents are considered to be part of the surgical toolkit.
- l. Throwing or tossing of game pieces is not allowed.
- m. The robot may not run any autonomous (or time delay) program during the period that the spotter is interacting with the robot in the Robot Start Box or Autonomous Start Area.

Any violation of the following rules (n through t) will result in a **20 second penalty** during the current match.

- n. The Surgeon must keep their feet within the Surgical Team Area during the match.
- o. The Surgical Assistant must keep their feet within the Surgical Assistant work area during the match.
- p. The Surgical Assistant may interact with the robot only when any part of the robot is inside the Robot Start Box or Autonomous Start Area.
- q. The Surgical Assistant may not be touching the robot or any part of the field when the Surgeon is touching the joystick.
- r. The Surgeon must maintain “hands off” the controller while the Surgical Assistant is

- i. loading game pieces onto the robot,
 - ii. manipulating game pieces in the Robot Start Box,
 - iii. attaching surgical instrument(s) to the robot, or
 - iv. manipulating the robot during the autonomous setup period.
- s. The Surgeon must place the joystick on the “hands free” platform before the Surgical Assistant touches the robot and it must remain there during periods of interaction with the robot. “Hands free” means no touching the joystick during this time.
- t. The robot is inside the Robot Start Box when any part of the robot has broken the plane of the Robot Start Box.

3.6 Surgical Procedures

The following rules define the legal actions and scoring for all surgical procedures. The points for each task are awarded at the end of the match unless otherwise stated.

3.6.1 Faulty Heart Valves Disposal

- a. There are four (4) heart valves with the SimBody heart; each valve has two halves (or frames).
- b. At the start of the match, one valve frame has the remnants of a faulty valve membrane. The other frame is empty.
- c. The robot may remove any faulty heart valve membranes on the field and move them to a Biowaste container.
- d. Points are awarded for faulty valve membranes [inside](#) the team’s Biowaste container .

3.6.2 Artificial Heart Valves Installation

- a. Team owned artificial heart valve membranes are brought into SimBody by the robot from their starting position in the shoulder.
- b. The valve clamp medical instrument (or [team-built instrument](#)) must be used to carry and insert valve membranes into the valve frames. The instrument must be touching the handle on the valve membrane.
- c. Points are awarded for a valve membrane that
 - i. is not touching the ground,
 - ii. is supported by the frame,
 - iii. is held in place by at least 1 magnet, and
 - iv. completely covers the 12” x 24” frame opening.

3.6.3 Pacemaker Electrodes Connection

- a. Six (6) pacemaker electrodes exist on the field.
- b. Each electrode has two 1 ½” x ¾” surface areas of loop-side Velcro.
- a. Pacemaker electrodes may be connected to any receiver pad (hook-side Velcro) in the electrode receiver zones located on the inner walls of the heart.
- b. Pacemaker receiver zones are color coded and only accept a single electrode connection per receiver pad.
- c. Points are awarded for electrodes that are [connected](#) to a team’s color-coded electrode receiver pads.

3.6.4 Cardiac Ablation

- a. There are two (2) ablation locations on each of the three (3) exterior walls made with strips of loop-side Velcro.

- b. The robot must use the ablation wheel surgical instrument to tag ablated tissue locations on the heart. Ablation tags within the wheel are color-coded by team color.
- c. The ablation wheel attaches a color-coded ablation tag (hook-side Velcro) to any heart ablation location when the two touch.
- d. Successful ablation tagging will leave a color-coded tag [attached](#) to the ablation location.
- e. Points are awarded for each tag [attached](#) at any ablation location.

3.6.5 Vein Harvesting

Veins are harvested by removing them from the Lower Extremity vein Groups.

- a. Harvested veins may be used to complete the [Coronary Artery Bypass](#) procedure.
- b. Points are awarded for any harvested veins that are [inside](#) the Vein Harvesting Storage Area, defined by the outer edge of the taped lines.

3.6.6 Internal Hemorrhage Damage Control

Surgical hemorrhaging (internal bleeding) has occurred within SimBody. Blood droplets (small red balls) have been released into the body near the walls of the heart. **Damage control** is needed to clean up the hemorrhaging that has occurred before it can cause further damage to SimBody.

- a. Any team may collect blood droplets.
- b. Points are awarded for each drop of blood that is [inside](#) the Robot Start Box.
- c. Points are awarded for each drop of blood that is [inside](#) the Biowaste container.

3.6.7 Coronary Artery Bypass

The coronary artery bypass procedure consists of attaching harvested LEG veins to bypass locations on the exterior wall of the heart.

- a. Harvested LEG veins are used in the Coronary Artery Bypass procedure.
- b. Points are awarded for each end of a harvested vein that is [connected](#) to any Coronary Artery Bypass location.

3.6.8 Artery Plaque Removal and Disposal

The *atherectomy* procedure removes plaque that is clogging the coronary arteries.

- a. There are four (4) plaque bricks clogging each end of each Artery.
- b. Robots must use the *rake* instrument (or [team-built instrument](#)) to remove the plaque from the artery. The instrument must be touching any plaque that is removed.
- c. Points are awarded for each plaque brick fully supported by the robot.
- d. Points are awarded for each plaque brick inside a team's Biowaste container.

3.6.9 Angioplasty Procedure (Stent Insertion)

- a. Each team has three (3) color-coded stents near their surgical toolkit at the beginning of the match.
- b. Stents may be loaded onto the robot by the surgical assistant.
- c. Points are awarded for each stent that is fully [inside](#) a coronary artery.

3.6.10 Brain Biopsy Procedure

A biopsy is a surgical procedure to extract a tissue sample for examination. SimBody has two biopsy locations within the brain cavity; one in the right brain and one in the left brain. A surgical team of two robots (Red/Green; Yellow/Blue) must cooperate as partners to collect the biopsy samples available to them. Because of the extreme sensitivity of operating in the brain cavity, robots must perform the biopsy procedure autonomously, without control by the surgeon. A brain imaging tracer isotope has been injected into the SimBody to trace blood flow to the brain. This results in a color contrasting tracer path (2" white line surrounded by 2" black line on either side) from the Robot Autonomous Start Area to the Brain Biopsy Location on either side of the brain cavity. Biopsy samples are dispensed using the biopsy needle instrument.

Task Description

- a. The Red and Green teams shall collect their biopsy samples only from the cavities designated in the right brain.
- b. The Yellow and Blue teams shall collect their biopsy samples only from the cavities designated in the left brain.
- c. There are four (4) total biopsy samples in each biopsy location at the beginning of the match.
- d. The robot must travel autonomously from the Autonomous Start Area to the Brain Cavity.
- e. Biopsy samples must be collected by the robot using the *biopsy needle* instrument (or [team-built instrument](#)) by inserting the instrument into the cylinder above the sample.
- f. Robots must dispense and collect biopsy samples autonomously (i.e., with no driver control).
- g. Each robot may dispense no more than two (2) biopsy samples. Dispensing more than two will result in disqualification.
- h. Each robot may attempt the biopsy sample collection as many times as desired to dispense a maximum of two (2) samples.
- i. A biopsy sample that touches any part of the robot prior to being dispensed is contaminated and out of play; the number of remaining samples the team may collect is reduced by one.
- j. A biopsy sample that touches the game floor is contaminated and out of play; the number of remaining samples the team may collect is reduced by one.
- k. Each biopsy attempt must begin with the robot [inside](#) the Autonomous Start Area.
- l. The brain imaging tracer path may be used to guide the surgical robot to the biopsy location; following the tracer path is not required.
- m. Each surgical team (Red/Green; Yellow/Blue) must coordinate access to their Autonomous Start Area and the available biopsy samples. Only one robot may be in the Autonomous Start Area at any time.

Procedure

- n. An autonomous setup period may begin when the robot is [inside](#) the Robot Start Box and the driver places the joystick on the hands-free platform and is no longer touching it.
- o. During the autonomous setup period, the Surgical Assistant must move the robot into the Autonomous Start Area.
- p. During the autonomous setup period, the Surgical Assistant may orient the robot prior to the driver initiating the autonomous biopsy operation so long as the robot remains [inside](#) the Autonomous Start Area.
- q. The Surgical Assistant may not be touching the robot or any part of the field when the autonomous biopsy attempt is initiated by the Surgeon.
- r. The Surgeon will initiate autonomous biopsy attempt by pressing any combination of buttons on the joystick (without lifting it from the hands-free platform).
- s. The autonomous biopsy attempt period ends when the Surgeon touches or lifts the joystick from the hands-free platform or the end of match (time=0:00) is reached.

Evaluation

- t. Points are awarded for each brain biopsy sample that is resting on the team's robot at the end of the match.
- u. Bonus points are awarded to the team for each brain biopsy collected by their [surgical team partner](#) robot.

3.7 Scoring

- a. All points are scored at the end of the match.
- b. Any game piece that the robot is touching at the end of the match does not score, except for arterial plaque and brain biopsy samples.
- c. Six (6) pacemaker receiving pads (one in each receiving zone) are color-coded. A pacemaker electrode attached to the pad will be scored for the team of the same color.
- d. Three (3) stents, eight (4) artificial valve membranes, and three (2) harvestable veins are assigned to the team and color-coded to match the assigned team color for the match. These items can be scored in any valid scoring location on the field as defined in Table 3.8.

3.7.1 Scoring Summary

Table 3.8 summarizes the point values for each task.

Table 3.8 Scoring Summary

Task Completed	End of Match Location	Points Each	Max # Possible Per Team	Max Pts Per Team
Heat Valve Replacement				
Faulty Valve Membrane Disposal	Faulty valve membrane is inside the Biowaste container	30	4	120
Artificial Valve Membrane Installed at Ventricle (i.e., outside heart)	Valve membrane is installed in a valve frame at a ventricle opening (i.e., valve frame swinging away from the heart).	125	4	500
Artificial Valve Membrane Installed at Atrium (i.e., inside heart)	Valve membrane is installed in a valve frame at an atrium opening (i.e., valve frame swinging into the heart).	150	4	600
Cardiac Procedures (Heart Electrical System)				
Pacemaker Electrode Attached	Electrode is attached to the receiver pad	22	6	132

Heart Ablation Tag Attached	Ablation tag is attached to the ablation pad	10	6	60
Heart Ablation Tag Attached at blind location	Ablation tag is attached to the ablation pad on the blind side of the heart.	30	6	180
Vein Harvesting and Coronary Artery Bypass				
Harvested Vein Stored	Harvested vein is inside the Vein Harvesting Storage Area.	70	2	140
Heart Bypass Vein Connected (per end)	One end of harvested vein is connected to coronary artery bypass location.	150	2	300
Heart Bypass Vein Connected at blind location (per end)	One end of harvested vein is connected to a coronary artery bypass location on the blind side of the heart.	225	4	900
Hemorrhage Damage Control				
Blood Droplet Removed	Blood droplet is inside the Robot Start Box.	3	18	54
Blood Droplet Disposal	Blood droplet is inside the Biowaste container.	5	18	90
Artery Procedures				
Plaque Brick Removed	Plaque brick is fully supported by the robot	10	24	480
Plaque Brick Disposal	Plaque brick is inside the Biowaste container	20	24	
Stent Inserted (lower)	Stent is fully inserted into a lower artery	25	3	75
Stent Inserted (upper)	Stent is fully inserted into an upper artery	35	2	
Artery Procedures (Blind Side)				
Plaque Brick Removed	Plaque brick is fully supported by the robot	15	24	480
Plaque Brick Disposal	Plaque brick is inside the Biowaste container	30	24	

Stent Inserted (lower)	Stent is fully inserted into a lower artery	40	3	120
Stent Inserted (upper)	Stent is fully inserted into an upper artery	53	2	
Brain Biopsy				
Biopsy Sample Collected	Biopsy sample is resting on the robot.	200	2	400
Bonuses				
Brain Biopsy Surgical Team Bonus	For each biopsy sample resting on the partner 's robot.	50	2	100
Diversity Bonus 3	For completing 3 – 4 procedures.	50	1	50
Diversity Bonus 5	For completing 5 – 6 procedures.	100		100
Diversity Bonus 7	For completing 7 or more procedures.	150		150

3.7.2 Autonomous Brain Biopsy Scoring

Refer to Section 3.6.10 for details of the expected sequence and evaluation of successfully biopsy sample collection.

- An Autonomous Brain Biopsy attempt is successful, and points are awarded when the uncontaminated biopsy sample is resting on the robot at the end of the match.
- If the driver picks up the joystick or touches it prior to collection of the biopsy, the attempt ends and a new attempt must be started from the Robot Autonomous Start Area.

3.7.3 Bonuses

3.7.3.1 Brain Biopsy Surgical Team Bonus

Additional bonus points are awarded to a team for each brain biopsy sample that is collected by their [Surgical Team partner](#).

- 50 bonus points are awarded to the Red team for each brain biopsy sample that is [resting](#) on the Green team's robot at the end of the match.
- 50 bonus points are awarded to the Green team for each brain biopsy sample that is [resting](#) on the Red team's robot at the end of the match.

- c. 50 bonus points are awarded to the Yellow team for each brain biopsy sample that is [resting](#) on the Blue team's robot at the end of the match.
- d. 50 bonus points are awarded to the Blue team for each brain biopsy sample that is [resting](#) on the Yellow teams' robot at the end of the match.

3.7.3.2 Surgical Diversity Bonus

Robots that are diverse in their functionality and can perform multiple surgical procedures may receive additional bonus points in a match. There are 10 possible surgical procedures in SimBody.

1. Faulty heart valve membrane(s) [stored](#).
2. Heart valve replacement membrane(s) [installed](#).
3. Pacemaker electrode(s) [attached](#).
4. Heart [ablation](#).
5. Harvested vein(s) [stored](#).
6. Heart bypass [connected](#).
7. Blood droplet(s) [removed](#) and/or [stored](#).
8. Plaque [removed](#) and/or disposed of.
9. Stent(s) [inserted](#).
10. Brain biopsy sample [collected](#) by the team.

Surgical diversity bonus points are awarded for completing (scoring at least one game piece) in the number of procedures indicated:

- a. 50 points are awarded for completing 3 or 4 procedures.
- b. 100 points are awarded for completing 5 or 6 procedures.
- c. 150 points are awarded for completing 7 or more procedures.

3.7.4 Scoring Definitions

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

Inside – within the imaginary infinite vertical planes defined by the innermost sides of a container/area or the inner edge of a tape line defining the boundaries of an area. The robot start box and Vein Harvesting Storage Area are the exceptions where the boundaries are defined by the outer edge of the tape line.

Connected/Attached – When Velcro attachment is involved, a successful connection simply means that at least one Velcro fiber is connected, and the game piece remains in place. For veins used in the heart bypass procedure, a vein end is connected when it is supported by the bypass keyhole opening (see Figure 3.10).

3.8 Glossary of Terms

- Ablation – the act of marking an ablation location with a colored tag from the ablation wheel instrument.
- Angioplasty – the act of inserting a stent into an artery.
- Arterial – of or relating to arteries.

Biopsy	– the act of collecting a small tissue sample for further analysis.
Cardiac	– of or relating to the heart.
Dispensing	– the act of causing a biopsy sample to be ejected from the brain dispenser.
Electrode	– the small block to be attached to color-coded electrode receiver pads (Velcro) on the walls of the heart.
Harvesting	– to gather or collect.
Hemorrhage	– an escape of blood from a ruptured blood vessel, especially when profuse .
Partner	- One of the surgeons/robots in a surgical team.
SimBody	– The simulated human body platform used to train surgeons in minimally invasive robotic surgeries.
Stent	– A flexible tube used to hold open the arteries and allow blood flow.
Surgical team	– A surgical team consists of the two surgeons (and their robots) that share the Surgical Team Area. The Right Surgical Team consists of the surgeons controlling the Red and Green robots. The Left Surgical Team consists of the surgeons controlling the Yellow and Blue robots. For purposes of the Brain Biopsy Surgical Team Bonus, the surgeons on a surgical team are considered partners.

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)

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
Spirit and Sportsmanship	10 points
Robot Performance	15 points

Total 100 points

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

Refer to the **2022 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 five 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 **2023 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. 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 https://www.bestrobotics.org/simulink_award/ 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 100 point scale. The Simulink model is worth up to 70 points and the video is worth up to 30 points.

Simulink Model		Possible Points
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
	TOTAL	70
(YouTube) Video		Possible Points

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
	TOTAL	30
	Total Possible Points	100

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) and their regional championship website.

4.4 Skills Challenges

Skills challenges may be offered at the hub’s discretion for any competition format. Check your hub’s **2023 Awards and Judging – Hub Logistics** document to see which skills challenges are offered. 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 (National Level)
- Engineering Drawings Challenge
- Website Design Challenge
- Video Design Challenge

4.5 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). A team may submit a revised notebook if that submittal occurs before the due date and time. Once the deadline passes, no more submittals are allowed for that team and the most recently submitted notebook will be judged.
- Any team that submits their notebook after the deadline will be penalized 10% of their notebook score. Only teams that have not yet submitted a notebook by the deadline fall into this category (see prior bullet).
- Please see the [2023 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 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 (but not limited to) 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. Spectators may be permitted to observe the presentation only if the presenting team agrees. If at any time during the team's presentation a spectator coaches, signals, speaks out

loud or otherwise disrupts the presentation, the lead judge in the room shall evict that spectator immediately. The presenting team shall not be penalized for the interruption.

- 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 **2023 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 **2023 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 based on their actual robot.
 - 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 Interview (20 Points)

- The Team Exhibit and 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 company, product, outcomes, and impact including communicating the company brand, student learning and community outreach.
- 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,
 - spotlight community outreach and publicity activities, and
 - communicate/share their experience and lessons learned.

5.3.1 Team Exhibit and Interview Guidelines

- Hubs hosting a Classic competition may choose to implement Physical or Virtual Team Exhibits. Refer to the **2023 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 used.
- 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 **2023 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 official national BEST Robotics logo in plain view. The BEST Robotics logo may not be altered.
- 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 **2023 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 the 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 **2023 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 **2023 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, students 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 (6 points) will be evaluated on:

- Creativity – The team demonstrated creativity in incorporating the game theme into the design and presentation of this exhibit. The exhibit is unique, and the game/industry theme is very prominent.
- Technology – The exhibit effectively balances the use of print, models, multi-media, graphics, and other technology.
- Aesthetics – The exhibit is cohesive, engaging, and interactive. Information is logically arranged. The area is neat, clean, and well-organized.
- Compliance – The team, hub, championship (if the team advanced to a championship), and national logos and branding are clearly visible. All sponsors are clearly displayed. The team adhered to all specifications set forth by the Hub/Championship. The students showed evidence that they were the primary designers and builders of their product (robot), team exhibit and all related materials.

Student Interviews (14 points) will be evaluated on:

- Company Elevator Speech and Branding
 - The team clearly defines what benefits the product (robot) delivers.
 - The team explains their outreach and social responsibility.
 - The team conveys the company's brand through tone and language.
 - The brand promise (the service/reputation your company offers the customer) is evident throughout the exhibit and in the student interviews. The team effectively explains how the product illustrates the company brand.
- Knowledge and Experience with BEST
 - Knowledge – Students easily and thoroughly answer technical questions about the product (robot), team exhibit, and related materials. They show a deep understanding of the design

and construction of the robot and exhibit; adult contributions are mentioned purely in an advisory capacity.

- Learning – The students clearly express an understanding of the game theme/problem and their own learning experience. They clearly articulate lessons learned through experience. It is evident that they understand the game/industry theme well.
- Enthusiasm – Students describe with obvious enthusiasm and positivity their experience in BEST and show a clear understanding of the organization’s mission. Students communicate the impact of the BEST Robotics program on his/her path toward STEM or career choice through testimonials.
- Outreach
 - Sharing – The team demonstrates sharing of information and/or technology resources, and mentoring of other schools, including other BEST teams. There is clear evidence of support (through testimonials or storytelling) to other schools with information, technology, or encouragement.
 - Publicity/Demonstrations – Students effectively communicate their publicity methods (print materials, media/press), media platforms used, and specific presentations/demonstrations to other schools and community groups about BEST to generate excitement.
 - Inclusion – There is evidence of team diversity and that recruitment efforts include multiple grade levels and students from a cross-section of the school population. Specific efforts to promote inclusiveness are clearly identified.
 - Advocacy – Students communicate any fundraising and/or sponsorship efforts they implemented. They describe clear strategies for recruiting sponsors, team fundraisers, and how any funds raised were allocated to support the team (in a team budget that is available for review). The students present and demonstrate strong evidence of executing these efforts.

5.4 Spirit and Sportsmanship (10 Points)

- Spirit and Sportsmanship will be worth 10 points towards the BEST Award.

5.4.1 Spirit and Sportsmanship Guidelines

- Judges will evaluate this category on Game Day.
- Judges will observe the spirit promoted by the team during their head-to-head competition matches as well as the team’s conduct throughout the day in the seating area, team exhibit area, game floor, and pit area.

5.4.2 Spirit and Sportsmanship Evaluation

- Spirit includes the vigor and enthusiasm displayed by team representatives.
- Teams can use posters, props, t-shirts, cheerleaders, musicians, mascots, costumes, and lower-frequency noisemakers to increase the level of spirit (Check the **2023 Awards and Judging – Hub Logistics** document to determine noise-maker restrictions for your local hub competition).

- Cheering and music are encouraged. In general, any noisemaker that interferes with game play (air horns, whistles, etc.) is not allowed. Amplified music may be restricted at times or in volume at the discretion of the head referee. All game venues differ. Ask your hub/championship leaders if you have any questions regarding specific cases. Final decisions or allowances on Game Day rest with the head referee.
- Community involvement: number of team supporters present at competition (other than students)
- Sportsmanship includes outward displays of sportsmanship (e.g., helping other teams in need), grace in winning and losing, and conduct and attitude considered befitting participation in sports.
- Overall team sportsmanship is also demonstrated by students (not mentors) making all robot adjustments and repairs during the competition.

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 a team's final rank in the seeding phase of the head-to-head competition. The rank is from 1 (highest total points) to N (lowest total points where N is the number of teams competing in the head-to-head competition). Unique points are awarded for each level of the ranking.
- A team may receive a maximum of 15 points for robot performance.
- Any team that passes compliance will receive no less than 3 points.
- Any team that fails to pass compliance will receive 0 points.
- A team that does not pass compliance is not eligible to receive head-to-head competition awards or advance to a championship. The hub has discretion to allow the team to participate in the seeding phase only; if allowed, 0 points will be recorded for each match regardless of how the robot performed.

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 Team Advancement to Championship

Each championship determines the total number of teams each hub is allowed to advance to based on several factors, including

- 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.

Teams are advanced to the championship in one of two categories:

1. BEST Award team, and
2. Head-to-Head Competition team.

These categories define what activities they will compete in and what awards they will compete for at the championship.

6.1 General Team Advancement Rules

- Each hub will advance at least one BEST Award team and one Head-to-Head Competition team.
- If a team advances as a BEST Award team, that team **MUST** compete in all BEST Award components at the championship.
- If a team advances as a Head-to-Head Competition team, that team may **NOT** compete in the BEST Award components at the championship even if the team competed in the BEST Award components at the hub.
- Teams are advanced to the championship first based on their final BEST Award score ranking (1 to N) until all hub BEST Award team allocations are exhausted.
- After BEST Award team advancement is completed, remaining teams are advanced to the championship as Head-to-Head Competition teams based on their final ranking in the head-to-head competition (1 to N) until all hub Head-to-Head Competition team allocations are exhausted.

6.2 Texas UIL Teams Only

- Any approved UIL team **MUST** compete in all BEST Award components at the hub and will advance to a championship based only on their BEST Award scores.
- UIL teams are ranked by division (UIL small school, UIL large school, UIL unified school) at the hub and championship. Points accumulated determine the rank within the division for the head-to-head competition and the BEST Award.
- UIL teams from each division will advance to the championship. The number of teams advancing from each UIL division may be different.

- UIL teams that do not advance to the UIL championship based on their UIL divisional rank may still be considered for advancement to the Texas BEST Championship among the non-UIL teams.

Section 7 Standard Awards

7.1 Hub-Level Awards

The following awards will be presented at all Hub competitions, when multiple teams compete in a head-to-head fashion:

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

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. 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.

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:

- 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)

7.2 Regional Championship Awards

The following awards will be presented 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

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 students:

- BEST Robot Modeling Challenge (1st – 3rd place)