INFINITE RECHARGE℠

FIRST ® RISE℠ powered by *Star Wars: Force for Change*

2020 *FIRST* ® Robotics Competition

Game and Season Manual

CONTENTS

1 INTRODUCTION

1.1 About *FIRST*®

FIRST® (For Inspiration and Recognition of Science and Technology) was founded by inventor Dean Kamen to inspire young people's interest in science and technology. Based in Manchester, New Hampshire, *FIRST* is a 501(c)(3) not-for-profit public charity.

FIRST provides four programs:

- *FIRST*® Robotics Competition for grades 9-12, ages 14-18
- *FIRST*® Tech Challenge for grades 7-12, ages 12-18
- *FIRST*® LEGO® League for grades 4-8, ages 9-14 (ages 9-16 outside of North America)
- *FIRST*® LEGO® League Jr. for grades K-4, ages 6-10

Please visit our website: www.firstinspires.org for more information about *FIRST* programs.

1.1 In Memoriam

In October 2019, Dr. Woodie Flowers, an innovator in design and engineering education and an incredible advisor to *FIRST* and supporter of our mission (see right), passed away. As thousands of heartfelt tributes to Woodie have poured in from around the world, it is clear his legacy will live on indefinitely through the gracious nature of our community and our ongoing commitment to empowering educators and building global citizens.

Figure 1-1 Dr. Woodie Flowers, 1943-2019

1.2 *FIRST* Robotics Competition

FIRST Robotics Competition pairs high school students with adult mentors (primarily engineers and teachers) to design and build robots that compete against one another in a high-energy environment.

This varsity Sport for the Mind™ combines the excitement of sport with the rigors of science and technology. Under strict rules, limited resources and time limits, teams of students are challenged to raise funds, design a team "brand," hone teamwork skills, and build and program robots to perform prescribed tasks against a field of competitors. It's as close to "real-world" engineering as a student can get.

Each January at an event known as "Kickoff," a new, challenging game is introduced. These exciting competitions combine the practical application of science and technology with the fun, intense energy and excitement of a championship-style sporting event. Teams are encouraged to display *Gracious Professionalism*®, help other teams, and cooperate while competing. This is known as *Coopertition*®.

In 2020, *FIRST* Robotics Competition will reach 100,000 high-school students representing approximately 4,000 teams. Teams come from nearly every state in the United States, as well as many other countries.

FIRST Robotics Competition teams will participate in 66 Regional Competitions, 105 District Competitions, and 11 District Championships. In addition, approximately 800 teams will qualify to attend the *FIRST* Championship in one of two locations in April and May 2020.

This year's game, and this manual, were presented at the 2020 *FIRST* Robotics Competition Kickoff on Saturday, January 4, 2020.

At the Kickoff, all teams:

- saw the 2020 game, INFINITE RECHARGE℠, for the first time
- learned about the 2020 game rules and regulations
- received a Kickoff Kit that provides a starting point for robot build

1.3 *Gracious Professionalism*®, a *FIRST*® Credo

Gracious Professionalism® is part of the ethos of *FIRST*. It's a way of doing things that encourages high quality work, emphasizes the value of others, and respects individuals and the community.

Gracious Professionalism is not clearly defined for a reason. It can and should mean different things to everyone.

Some possible meanings of *Gracious Professionalism* include:

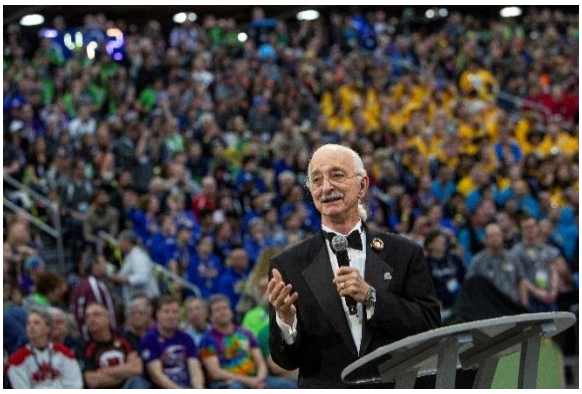
- Gracious attitudes and behaviors are win-win
- Gracious folks respect others and let that respect show in their actions
- Professionals possess special knowledge and are trusted by society to use that knowledge responsibly
- Gracious Professionals make a valued contribution in a manner pleasing to others and to themselves

In the context of *FIRST*, this means that all teams and participants should:

- Learn to be strong competitors, but also treat one another with respect and kindness in the process
- Avoid leaving anyone feeling as if they are excluded or unappreciated

Knowledge, pride and empathy should be comfortably and genuinely blended.

In the end, *Gracious Professionalism* is part of pursuing a meaningful life. When professionals use knowledge in a gracious manner and individuals act with integrity and sensitivity, everyone wins and society benefits.



The FIRST spirit encourages doing high-quality, well-informed work in a manner that leaves everyone feeling valued. Gracious Professionalism seems to be a good descriptor for part of the ethos of FIRST. It is part of what makes FIRST different and wonderful.

- Dr. Woodie Flowers, (1943 – 2019)
Distinguished Advisor to FIRST

It is a good idea to spend time going over this concept with your team and reinforcing it regularly. We recommend providing your team with real-life examples of *Gracious Professionalism* in practice, such as when a team loans valuable materials or expertise to another team that they will later face as an opponent in competition. Routinely highlight opportunities to display *Gracious Professionalism* at events and encourage team members to suggest ways in which they can demonstrate this quality themselves and through outreach activities.

1.4 *Coopertition*®

At *FIRST*, *Coopertition*® is displaying unqualified kindness and respect in the face of fierce competition. *Coopertition* is founded on the concept and philosophy that teams can and should help and cooperate with one another even as they compete. *Coopertition* involves learning from teammates and mentors. *Coopertition* means competing always but assisting and enabling others when you can.

A Message from Woodie Flowers Award Recipients

The Woodie Flowers Award is the most prestigious mentoring award in FIRST. The award recipients as of the 2015 FIRST Championship created an important message for all FIRST Robotics Competition teams to consider as we tackle each season.

Performing at your best is important. Winning is important. This is a competition.

However, winning the right way and being proud of what you have accomplished and how you have accomplished it is more important. FIRST could create rules and penalties to cover almost any scenario or situation, but we prefer an understandable game with simpler rules that allow us to think and be creative in our designs.

We want to know that our partners and opponents are playing at their best in every match. We want to know they are playing with integrity and not using strategies based on questionable behaviors.

As you create your robots and award presentations, prepare for competition and match play, create and implement game strategies, and live your daily lives, remember what Woodie said time and time again, and let's 'Make your Grandmother proud.'

Woodie Flowers

Liz Calef (88)

Mike Bastoni (23)

Ken Patton (51, 65)

Kyle Hughes (27)

Bill Beatty (71)

Dave Verbrugge (5110, 67)

Andy Baker (3940, 45)

Dave Kelso (131)

Paul Copioli (3310, 217)

Rob Mainieri (812, 64, 498, 2735, 6833)

Dan Green (111)

Mark Breadner (188)

John Novak (16, 323)

Chris Fultz (234)

John Larock (365)

Earl Scime (2614)

Fredi Lajvardi (842)

Lane Matheson (932)

Mark Lawrence (1816)

Eric Stokely (258, 360, 2557, & 5295)

Glenn Lee (359)

Gail Drake (1885)

Allen Gregory (3847)

1.5 Spirit of Volunteering

A Message from the Chief Volunteers to the FIRST Community:

"Giving Back" and "Pay It Forward" - these words are what motivates those who mentor, coach, and volunteer their time for FIRST.

We know that volunteering - whether at events or with a team - has enormous, lifelong impacts for everyone involved. Each and every student, teacher, event volunteer, mentor, coach, and family member learns and grows through each season as they interact with each other.

As you attend events and interface with the volunteers there, remember that they are giving up their most precious asset - their time - to ensure that each and every team has a fulfilling, fun, and memorable competition. Volunteers are the lifeblood of FIRST and without them, FIRST would not be where it's at today. We encourage you to remember that "Gracious Professionalism is part of the ethos of FIRST. It's a way of doing things that encourages high-quality work, emphasizes the value of others, and respects individuals and the community." At your next event, give a volunteer a High Five or a Fist Bump and say "Thank You".

Volunteering at events is a rewarding experience, and we encourage everyone to take a break from the daily grind and join us at one in your community.

What makes volunteering at events so much fun:

- *Seeing capable students learning and growing*
- *Making new friends with other awesome volunteers*
- *Being a part of the magic that makes an event happen*
- *Sharing FIRST with folks who didn't know about it*
- *Taking event experiences back to your team*

Please join us and walk a few miles in a volunteer's shoes - YOURS! Come take the opportunity to Pay It Forward and Give Back; we can't wait to see you soon. The FIRST Website is a great resource for finding events that need help and what roles you can fulfill.

Chief Field Supervisors – Paul George & Scott Goering

Chief Judge Advisors – Allen Bancroft & Cindy Stong

Chief Referees – Aidan Browne & Jon Zawislak

Chief Robot Inspectors - Al Skierkiewicz & Chuck Dickerson

Chief Volunteer Coordinators – Laurie Shimizu & Sarah Plemmons

1.6 This Document & Its Conventions

The *2020 Game and Season Manual* is a resource for all *FIRST* Robotics Competition teams for information specific to the 2020 season and the INFINITE RECHARGE game. Its audience will find the following detail:

- a general overview of the INFINITE RECHARGE game
- detail about the INFINITE RECHARGE playing field
- description of how to play the INFINITE RECHARGE game
- all season rules (e.g. safety, conduct, game play, inspection, etc.)
- description of how teams advance at 2020 tournaments and throughout the season

All participants should also study the Event Rules Manual as it details event rules and expectations that perpetuate from season to season. That content complements, and carries the same weight as, this document.

The intent of this manual is that the text means exactly, and only, what it says. Please avoid interpreting the text based on assumptions about intent, implementation of past rules, or how a situation might be in "real life." There are no hidden requirements or restrictions. If you've read everything, you know everything.

Specific methods are used throughout this section to highlight warnings, cautions, key words and phrases. These conventions are used to alert the reader to important information and are intended help teams in constructing a robot that complies with the rules in a safe manner.

Links to other section headings in this manual and external articles appear in blue underlined text.

Key words that have a particular meaning within the context of the *FIRST* Robotics Competition and INFINITE RECHARGE are defined in the Glossary section and indicated in ALL CAPS throughout this document.

The rule numbering scheme uses an indication of the section in which the rule is stated plus a serial numbering system (e.g. safety rules begin with "S," game rules begin with "G," etc.). References to specific rules use this scheme (e.g. "S1" is the Safety Rules section).

> Warnings, cautions and notes appear in blue boxes. Pay close attention to their contents as they're intended to provide insight into the reasoning behind a rule, helpful information on understanding or interpreting a rule, and/or possible "best practices" for use when implementing systems affected by a rule.
>
> While blue boxes are part of the manual, they do not carry the weight of the actual rule (if there is an inadvertent conflict between a rule and its blue box, the rule supersedes the language in the blue box).

Imperial dimensions are followed by comparable metric dimensions in parentheses to provide metric users with the approximate size, weight, etc. Metric conversions for non-rules (e.g. FIELD dimensions) round to the nearest whole unit, e.g. "17 in. (~43 cm)" and "6 ft. 4 in. (~193 cm)." Metric conversions in rules round such that the metric dimension is compliant with the rule (i.e. maximums round down, minimums round up). The metric conversions are offered for convenient reference only and do not overrule or take the place of the imperial dimensions presented in this manual and the field drawings (i.e. field dimensions and rules will always defer to measurements using imperial units).

Some sections and rules include colloquial language, also called headlines, in an effort to convey an abbreviated intent of the rule or rule set. This language is differentiated using **bold blue text**. Any disagreement between the specific language used in the rules and the colloquial language is an error, and the specific rule language is the ultimate authority. If you discover a disparity, please let us know and we will correct it.

Team resources that aren't generally season specific (e.g. what to expect at an event, communication resources, team organization recommendations, robot transportation procedures, and award descriptions) can be found on the *FIRST* Robotics Competition website.

1.7 Translations & Other Versions

The INFINITE RECHARGE manual is originally and officially written in English and is occasionally translated into other languages for the benefit of *FIRST* Robotics Competition teams whose native language may not be English.

A text-based English version can be provided only for use with assistive devices for visually and hearing-impaired persons, and not for redistribution. For more information, please contact frcteamadvocate@firstinspires.org.

In the event that a rule or description is modified in an alternate version of this manual, the English pdf version as published on the *FIRST* Game and Season Materials webpage is the commanding version.

1.8 Team Updates

Team updates are used to notify the *FIRST* Robotics Competition community of revisions to the official season documentation (e.g. the manual, drawings, etc.) or important season news. Between Kickoff and February 21, 2020, Team Updates are posted each Tuesday and Friday. Between February 21, 2020 and April 7, 2020, Team Updates are posted each Tuesday. Team updates are posted on the INFINITE RECHARGE Game and Season Materials web page and are generally posted before 5 pm, Eastern.

Generally, Team Updates follow the following convention:

- Additions are highlighted in yellow. This is an example.
- Deletions are indicated with a strikethrough. ~~This is an example~~.
- Notes that are added for clarity or explanation for the change but are not retained as part of the manual appear in bold. **This is an example**.

1.9 Question and Answer System

Questions about any ***2020 Game and Season Manual*** content and *FIRST* Robotics Competition Event Experience web page content may be asked to *FIRST* using the official Question and Answer System (i.e. "the Q&A"), which opens on January 8, 2020, 12:00 PM Eastern. Details on the Q&A can be found on the INFINITE RECHARGE Game and Season Materials web page. The Q&A is intended to help clarify rules, and sometimes the responses result in revisions to the text in the official document (which is communicated using Team Updates).

The Q&A is not a resource for

- rulings on hypothetical strategies or vague situations,
- challenging decisions made at past events, or
- design reviews of a robot system for legality.

The responses in the Q&A do not supersede the text in the manual, although every effort will be made to eliminate inconsistencies between the two. While responses provided in the Q&A may be used to aid discussion at each event, per Inspection & Eligibility Rules and REFEREE Interaction sections, REFEREES and Inspectors are the ultimate authority on rules. If you have concerns about enforcement trends by volunteer authorities, please notify *FIRST* at firstroboticscompetition@firstinspires.org.

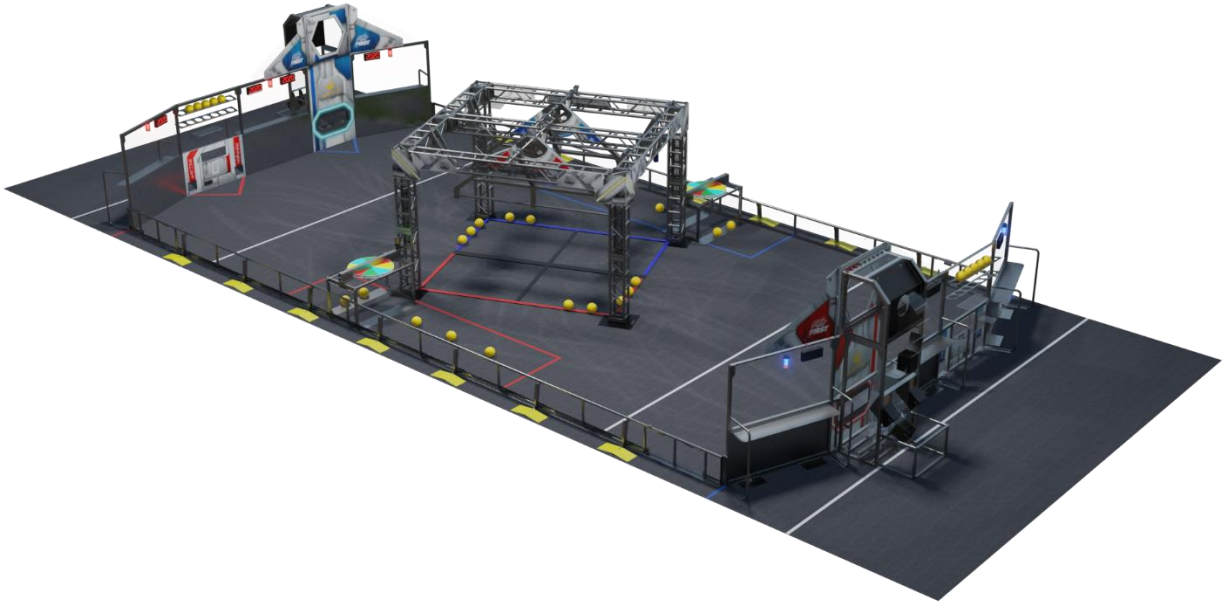
Weak questions are overly broad, vague, and/or include no rule references. Some examples of questions that will not be answered in the Q&A are:

- Is this part/design legal?
- How should the REFEREE have ruled when this specific game play happened?
- Duplicate questions
- Nonsense questions

Good questions ask generically about features of parts or designs, gameplay scenarios, or rules, and often reference one or more relevant rules within the question. Some examples of questions that will likely be answered in the Q&A are:

- A device we are considering using on the ROBOT comes with purple AWG 40 wire, does this comply with R?? and R??
- We're not sure how to interpret how Rule G?? applies if Blue ROBOT A does X and Red ROBOT B does Y, can you please clarify?

2 GAME OVERVIEW



In INFINITE RECHARGE℠, two alliances work to protect *FIRST* City from approaching asteroids caused by a distant space skirmish. Each Alliance, along with their trusty droids, race to collect and score Power Cells in order to energize their Shield Generator for maximum protection. To activate stages of the Shield Generator, droids manipulate their Control Panels after scoring a specific number of Power Cells. Near the end of the match, droids race to their Rendezvous Point to get their Shield Generator operational in order to protect the city!

During the 15 second Autonomous Period, droids follow pre-programmed instructions. Alliances score points by:

1. Scoring Power Cells in the Power Port
2. Moving from the Initiation Line

In the final 2 minutes and 15 seconds of the match, drivers take control of the droids. Alliances score points by:

1. Continue to score Power Cells in the Power Port
2. Completing Rotation Control
3. Completing Position Control
4. Hanging from the Generator Switch
5. Getting the Generator Switch to the level position

The Alliance with the highest score at the end of the Match wins.

3 ARENA

The ARENA includes all elements of the game infrastructure that are required to play INFINITE RECHARGE℠: the FIELD, POWER CELLS, and all equipment needed for FIELD control, ROBOT control, and scorekeeping.

The ARENA is modular and assembled, used, disassembled, and shipped many times during the competition season. It will undergo wear and tear. The ARENA is designed to withstand rigorous play and frequent shipping. Every effort is made to ensure that ARENAs are consistent from event to event. However, ARENAs are assembled in different venues by different event staff and some small variations occur. For details regarding assembly tolerances, please refer to the 2020 ARENA Layout and Marking Diagram. Successful teams will design ROBOTS that are insensitive to these variations.

Illustrations included in this section are for a general visual understanding of the INFINITE RECHARGE ARENA, and dimensions included in the manual are nominal. Please refer to the official drawings for exact dimensions, tolerances, and construction details. The official drawings, CAD models, and drawings for low-cost versions of important elements of the INFINITE RECHARGE FIELD are posted on the 2020 INFINITE RECHARGE Game & Season Materials page on the *FIRST*® website.

3.1 FIELD

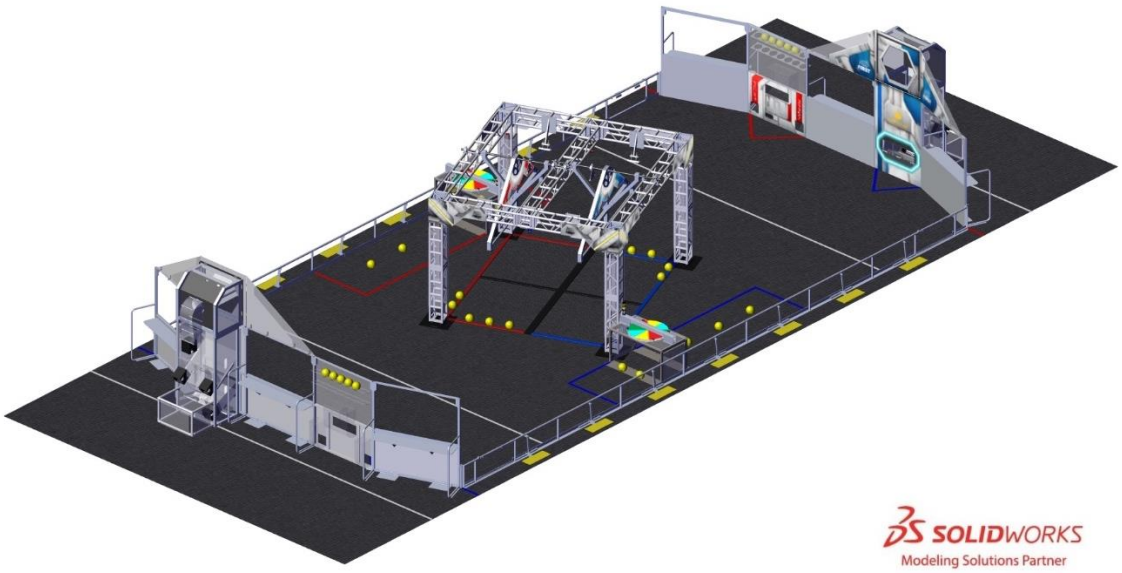


Figure 3-1 INFINITE RECHARGE

Each FIELD for INFINITE RECHARGE is 26 ft. 11¼ in. (~821 cm) by 52 ft. 5¼ in. (~1598 cm) carpeted area bound by and including the inward- and upward-facing surfaces of the guardrails and inward-facing surfaces of the ALLIANCE WALLS (except Chute surfaces and any surface beyond the face of the POWER PORT). It is populated with a SHIELD GENERATOR, TRENCHES, LOADING BAYS, and POWER PORTS.

The SHIELD GENERATOR is located in the center of the FIELD. The SHIELD GENERATOR consists of the structure, the GENERATOR SWITCHES, the BOUNDARIES, and the floor protection.

One (1) Red TRENCH and one (1) Blue TRENCH are located along the guardrail, each spanning the gap between a vertical leg of the SHIELD GENERATOR and the guardrail. Each TRENCH contains a CONTROL PANEL.

One (1) Red POWER PORT and one (1) Blue POWER PORT are located in the ALLIANCE WALLS. The Red POWER PORT is part of the Blue ALLIANCE WALL, and the Blue POWER PORT is part of the Red ALLIANCE WALL.

One (1) Red LOADING BAY and one (1) Blue LOADING BAY are located in their respective ALLIANCE WALLS.

The surface of the FIELD is low pile carpet, Shaw Floors, Philadelphia Commercial, Neyland II 20, “66561 Medallion” (please note that Neyland II carpet is not available for team purchase and the closest equivalent is Neyland III). The edge of the carpet is secured to the venue floor using 3M™ Premium Matte Cloth (Gaffers) Tape (GT2) or comparable gaffers tape.

Guardrails form the long edges of the FIELD and are a 1 ft. 7 in. (~48 cm) tall system of transparent polycarbonate supported on the top and bottom by aluminum extrusion. Guardrails, along with the ALLIANCE WALLS, prevent ROBOTS from inadvertently exiting the FIELD during a MATCH. There are four (4) gates in the guardrail that allow access to the FIELD for placement and removal of ROBOTS. The gate passthrough, when open, is 3 ft. 2 in. (~97 cm) wide. Gates are closed and shielded during the MATCH.

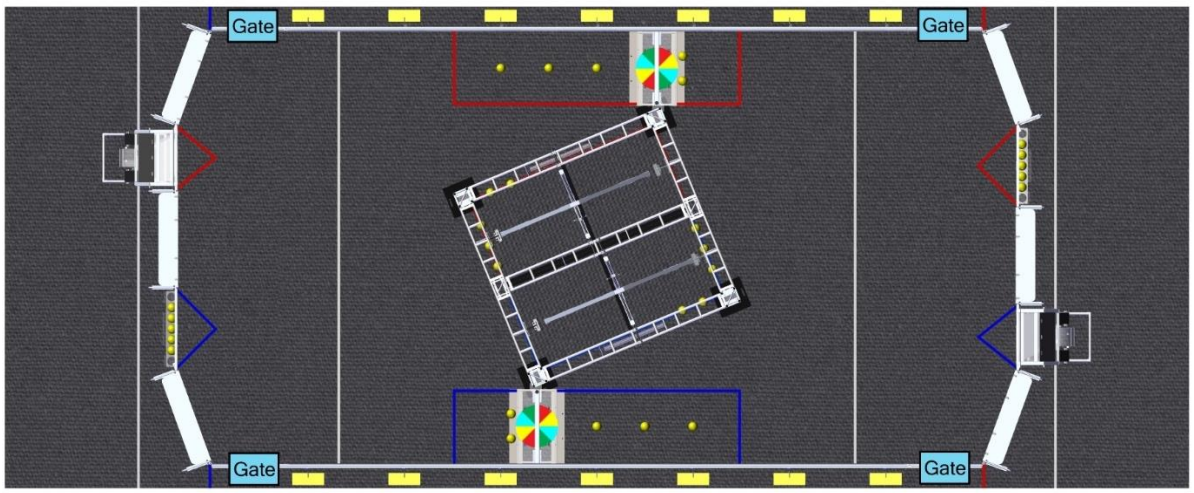


Figure 3-2 Gate locations

There are two versions of guardrails and PLAYER STATIONS used for competitions. One design matches the 2020 Official *FIRST* FIELD Drawings & Models. The other is designed and sold by AndyMark. While the designs are slightly different, the critical dimensions, performance, and expected user experience between the two are the same. Detailed drawings for the AndyMark design are posted on the AndyMark website. All illustrations in this manual show the traditional FIELD design.

3.2 Zones and Markings

FIELD Zones and markings of consequence are described below. Unless otherwise specified, the tape used to mark lines and zones throughout the FIELD is 2-in. (~5cm) 3M™ Premium Matte Cloth (Gaffers) Tape (GT2) or comparable gaffers tape.

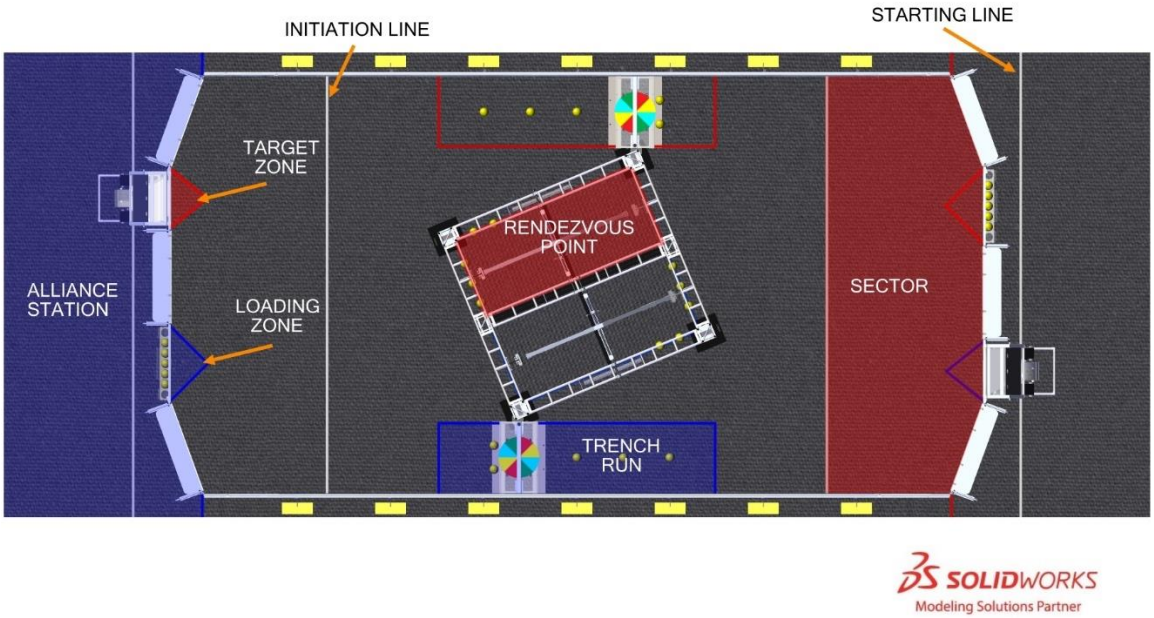


Figure 3-3 INFINITE RECHARGE FIELD

ALLIANCE STATION: a 30-ft. (~914 cm) wide by 10 ft. 9⅛ in. (~328 cm) to 12 ft. 10⅞ in. (~393 cm) deep infinitely tall volume formed by, and including the ALLIANCE WALL, the edge of the carpet, and ALLIANCE colored tape.

INITIATION LINE: a white tape line spanning the width of the FIELD and located 10 ft. (~305 cm) from the face of PLAYER STATION 2 to the near edge of the tape. An ALLIANCE'S INITIATION LINE is located in the opponent's SECTOR.

LOADING ZONE: a 5 ft. (~152 cm) wide, 2 ft. 6 in. (~76 cm) deep infinitely tall volume with a triangular base bounded by the LOADING BAY and ALLIANCE colored tape. The LOADING ZONE includes the ALLIANCE colored tape.

RENDEZVOUS POINT: a 5 ft. 6¾ in. (~170 cm) wide, 12 ft. 6¾ in. (~383 cm) deep, infinitely tall volume formed by the ALLIANCE colored BOUNDARIES and the black BOUNDARY pair that divides the Red and the Blue BOUNDARIES. The RENDEZVOUS POINT includes the ALLIANCE colored BOUNDARIES.

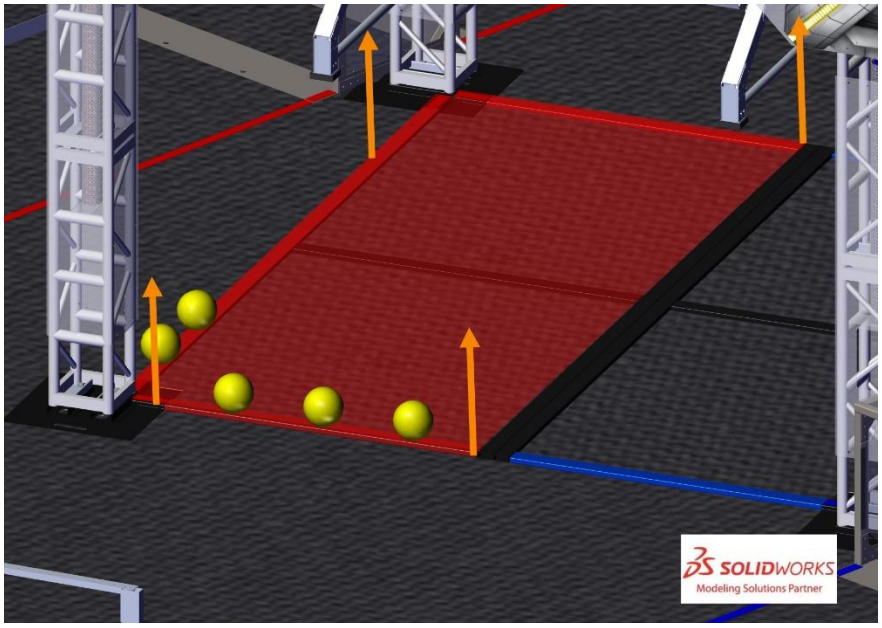


Figure 3-4 Red RENDEZVOUS POINT

SECTOR: A 26 ft. 11¼ in. (~821 cm) wide by 10 ft. 2 in. (~310 cm) deep infinitely tall volume formed by an ALLIANCE'S ALLIANCE WALL, guardrail, and INITIATION LINE. The SECTOR includes the INITIATION LINE.

STARTING LINE: a white tape line spanning the width of the carpet and located 2 ft. 4 in. (~71 cm) from the back of the PLAYER STATION 2 diamond plate panel to the near edge of the tape.

TARGET ZONE: a 4 ft. (~122 cm) wide, 2 ft. 6 in. (~76 cm) deep infinitely tall volume with a triangular base bounded by the POWER PORT and ALLIANCE colored tape. The TARGET ZONE includes the ALLIANCE colored tape.

TRENCH RUN: a 4 ft. 7 ½ in. (~141 cm) wide, 18 ft. (~549 cm) deep, infinitely tall volume that is bounded by the guardrail, the edge of the TRENCH vertical support closest to the center of the FIELD, and ALLIANCE colored tape. The TRENCH RUN includes the ALLIANCE colored tape.

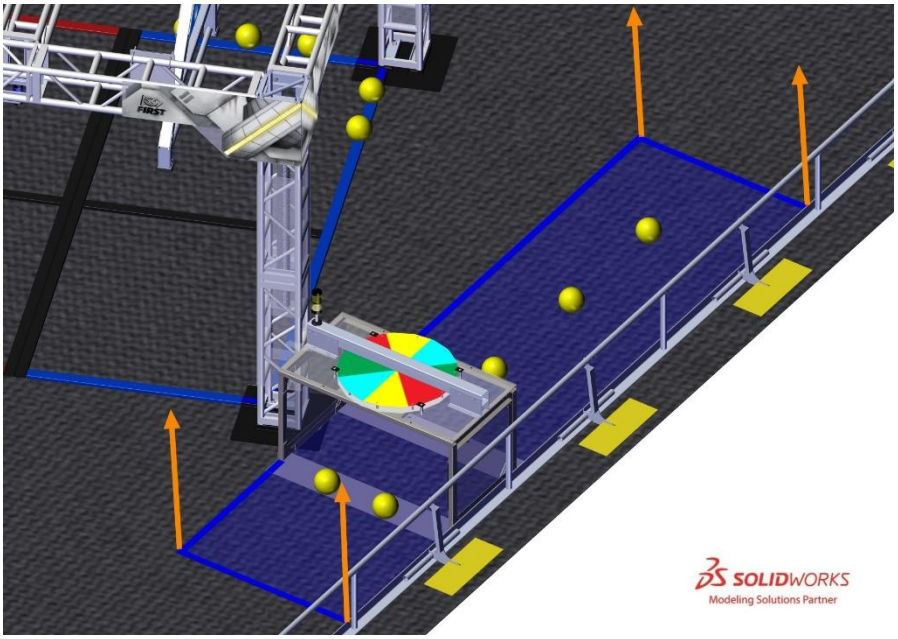


Figure 3-5 Blue TRENCH RUN

3.3 SHIELD GENERATOR

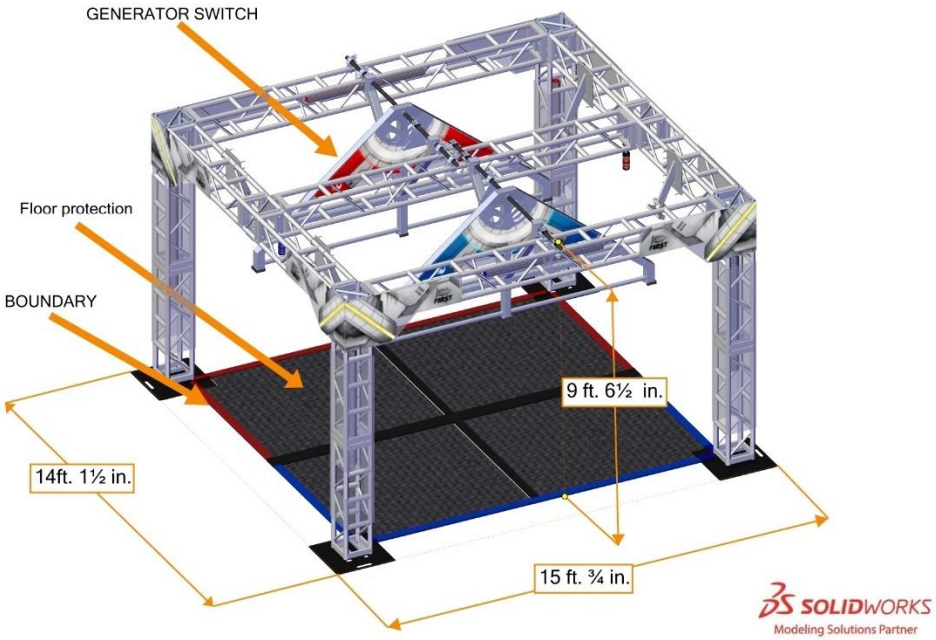


Figure 3-6 SHIELD GENERATOR

The SHIELD GENERATOR is a 14 ft. 1½ in. (~431 cm) wide, 15 ft. ¾ in. (~459 cm) deep, and 9 ft. 6½ in. (~291 cm) tall structure located in the center of the field, oriented at a 22.5 degree angle relative to the guardrails. The SHIELD GENERATOR has one (1) GENERATOR SWITCH per ALLIANCE. BOUNDARIES divide the floor of the SHIELD GENERATOR into sections. Spaces between

BOUNDARIES include flooring protection to prevent floor damage. All flooring between BOUNDARIES is part of the SHIELD GENERATOR.

3.3.1 SHIELD GENERATOR Structure

The SHIELD GENERATOR structure consists of 1 ft. x 1 ft. (~30 cm x ~30 cm) square truss. The truss structure is 13 ft. 1½ in. (~400 cm) wide, 14 ft. ¾ in. (~429 cm) deep, and 9 ft. 2¼ in. (~280 cm) tall. Each of the four vertical truss legs sits on a base. The baseplate extends 6 in. (~15 cm) from each square face and is ⅛ in. (~3 mm) thick.

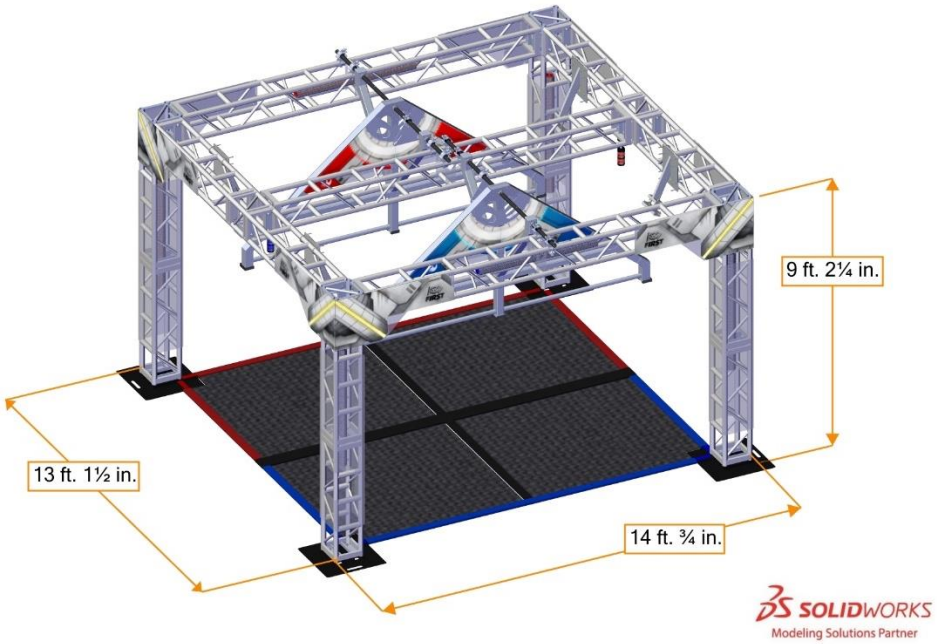


Figure 3-7 SHIELD GENERATOR structure

3.3.2 GENERATOR SWITCH

Each SHIELD GENERATOR has one (1) GENERATOR SWITCH per ALLIANCE. A GENERATOR SWITCH is a 7 ft. 6 in. (~229 cm) wide, 10 ft. 1½ in. deep (~309 cm), and 4 ft. 6 in. (~137 cm) tall assembly that swings from the top of the SHIELD GENERATOR. Each GENERATOR SWITCH has a HANDLE. The HANDLE is a structure that consists of a RUNG and the supporting structure below the horizontal beam of the GENERATOR SWITCH. A RUNG is a 1¼ in. schedule 40 aluminum pipe (1.66 in. (~4 cm) outer diameter) with two (2) exposed 4 ft. 7⅝ in. (~141 cm) long sections. The amount of clearance above the RUNG varies from a minimum of 3½ in (~9 cm) to a maximum of 12 in (~30 cm). For safety, foam corner cushions line the lowest edges of the HANDLE. The HANDLE (green and yellow) and RUNG (yellow) are highlighted in Figure 3-8 for clarity.

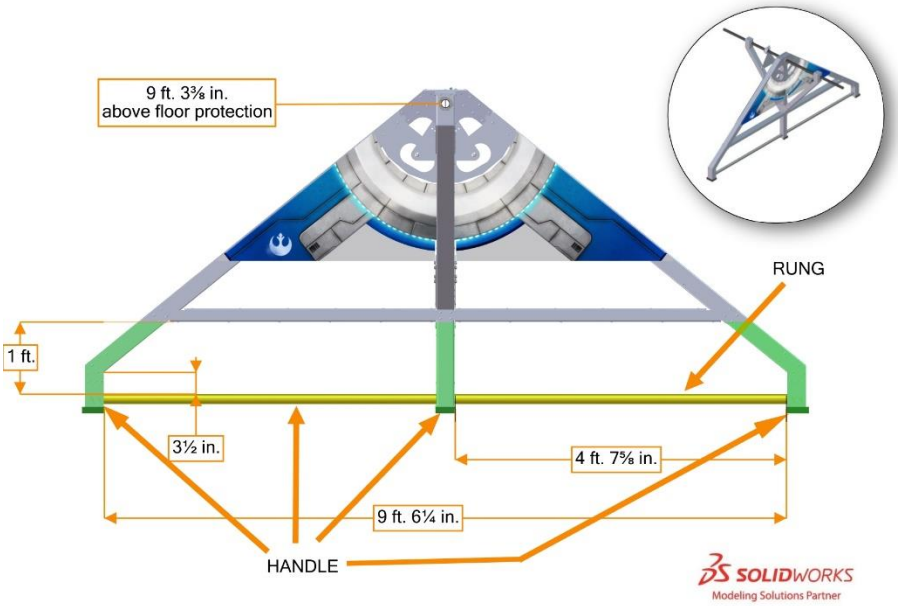


Figure 3-8 GENERATOR SWITCH

At the start of the MATCH, the top of the RUNG is parallel to and 5 ft 3 in. (~160 cm) above the floor protection carpet. The GENERATOR SWITCH can tilt and rest in different positions depending on the number and location of ROBOTS pulling on the HANDLE. For the purposes of scoring (see GENERATOR SWITCH Scoring), LEVEL is evaluated by the magnitude of its tilt as shown in Figure 3-9. The GENERATOR SWITCH is LEVEL if the RUNG is within 8 degrees of horizontal. Hard stops prevent the GENERATOR SWITCH from rotating more than 14.5 degrees in either direction. The rotating portion of the GENERATOR SWITCH has a weight of approximately 93 lbs. (~42 kg) and a center of mass approximately 2 ft. 2 in. (~66 cm) below the center of the shaft from which it is suspended.

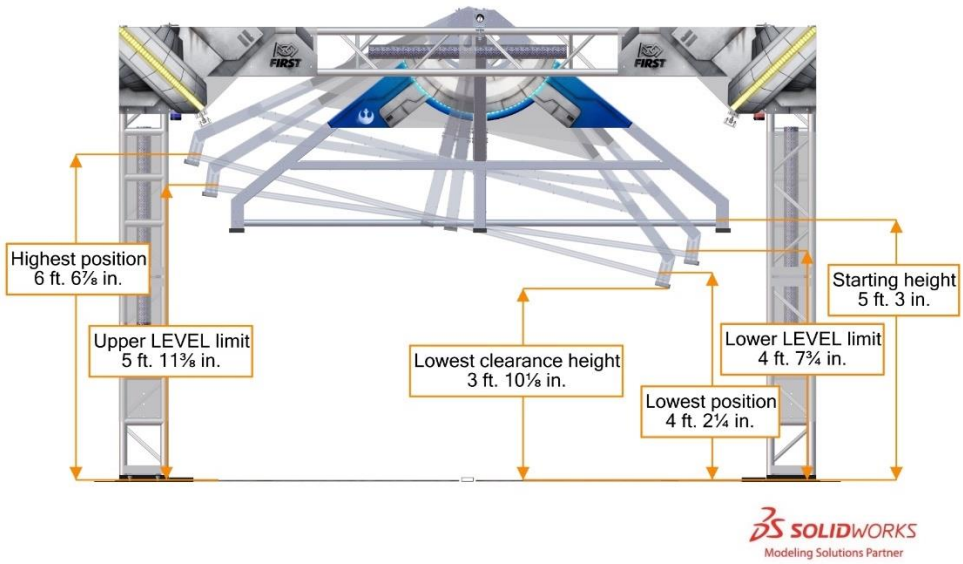


Figure 3-9 GENERATOR SWITCH range of motion.
(note: dimensions are to the top of the flooring protection carpet)

ALLIANCE colored stack lights on the SHIELD GENERATOR display information about the status of the ALLIANCE'S GENERATOR SWITCH. See SHIELD GENERATOR Lighting for more information.

3.3.3 BOUNDARIES

BOUNDARIES are 3 in. (~8 cm) wide, 1 in. (~3 cm) tall steel barriers that divide the area inside the SHIELD GENERATOR into four (4) equal sized rectangles that are 5 ft. 3¾ in. (~162 cm) wide by 5 ft. 10⅞ in. (~180 cm) deep. BOUNDARIES are secured to the carpet using hook fastener which increases the height to approximately $1\frac{1}{16}$ in. (~3 cm). The Red and Blue BOUNDARIES feature 1-in. (~3 cm) diameter holes spaced every 1 ft 4½ in. (~42 cm) for staging of POWER CELLS. A pair of black BOUNDARIES divide the Red and Blue RENDEZVOUS POINTS. Each truss base has two shorter steel barriers, black with ALLIANCE colored tape, mounted to them. These barriers are ALLIANCE colored BOUNDARIES.

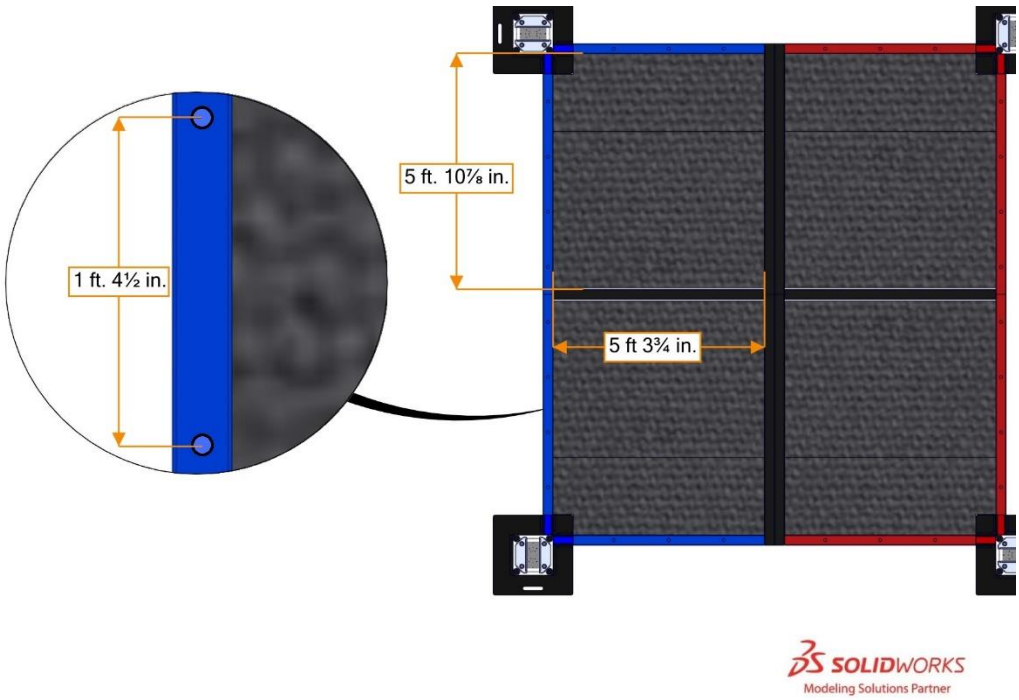


Figure 3-10 BOUNDARY dimensions.

A layer of ⅛ in. (~3 mm) thick hardboard is installed on top of the FIELD carpet and covered with another layer of carpet to protect venue flooring. This flooring protection adds approximately ⅜ in. (~10 mm) of height to the this area.

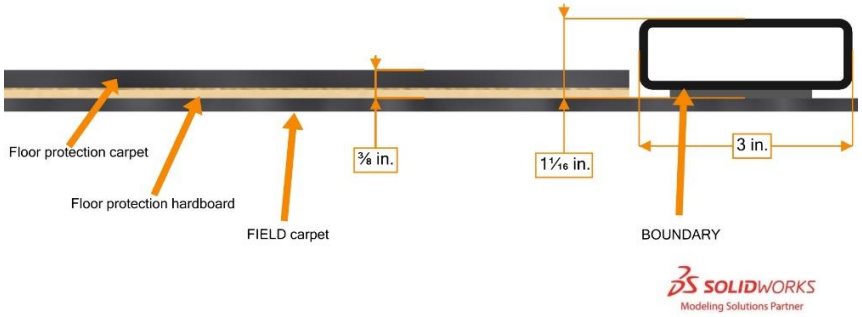


Figure 3-11 Floor protection cross-section

3.3.4 SHIELD GENERATOR Lighting

The SHIELD GENERATOR has a set of stack lights for each ALLIANCE which are enabled from the start of the END GAME until five (5) seconds after the MATCH. These lights illuminate when the corresponding GENERATOR SWITCH is LEVEL.

Each half of the SHIELD GENERATOR features three (3) ALLIANCE colored light bars inside of the truss structure.

- The first light bar, inside the vertical truss section adjacent to the ALLIANCE'S TRENCH, turns on once Stage 1 is ACTIVATED.
- The second light bar, inside the vertical truss section closest to the ALLIANCE'S POWER PORT, turns on once Stage 2 is ACTIVATED.
- The third light bar, inside the horizontal truss connecting the two (2) previous truss sections, turns on once Stage 3 is ACTIVATED.

3.4 ALLIANCE STATION

3.4.1 ALLIANCE WALL

The ALLIANCE WALL is the structure that separates ROBOTS from DRIVERS, COACHES, and HUMAN PLAYERS. It consists of three (3) PLAYER STATIONS, the LOADING BAY, and the POWER PORT. ALLIANCE WALLS define the short edges of the FIELD and, along with the guardrails, prevent ROBOTS from exiting the FIELD during the MATCH.

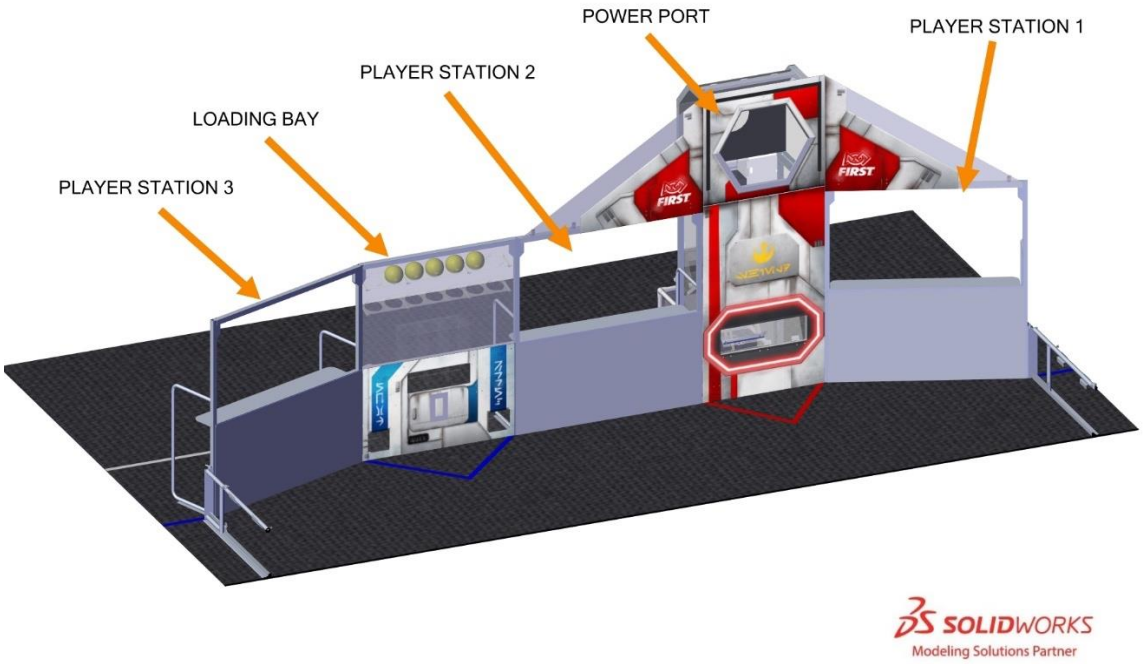


Figure 3-12 ALLIANCE WALL

3.4.1.1 PLAYER STATION

A PLAYER STATION is one (1) of three (3) assigned positions in an ALLIANCE WALL from where a DRIVE TEAM operates their ROBOT. Each PLAYER STATION is made from a 3 ft. (~91 cm) tall diamond plate base topped with a 3 ft. 6 in. (~107 cm) tall transparent plastic sheet and a top rail. An aluminum shelf is attached to each PLAYER STATION to support an OPERATOR CONSOLE. The shelf is 5 ft. 9 in. (~175 cm) wide and 1 ft. ¼ in. (~31 cm) deep. There is a 4 ft. 6 in. (~137 cm) long by 2 in. (nominal) wide strip of hook-and-loop tape ("loop" side) along the center of the support shelf that may be used to secure the OPERATOR CONSOLE to the shelf. PLAYER STATION 1 and PLAYER STATION 3 intersect the guardrail at a 110 degree angle.

Each PLAYER STATION contains the following components for teams:

- one (1) Ethernet cable: attaches to the Ethernet port of the OPERATOR CONSOLE and provides connectivity to the Field Management System (FMS)
- one (1) 120VAC NEMA 5-15R power outlet: located on each PLAYER STATION shelf and protected by its own 2-Amp circuit breaker. It can be used to power the OPERATOR CONSOLE. DRIVE TEAMS are responsible for monitoring their power consumption as a tripped breaker in the outlet does not constitute an ARENA FAULT. For some events in regions that don't use NEMA 5-15 shaped outlets, event organizers may install appropriate plug adapters to be used throughout the event.
- one (1) Emergency Stop (E-Stop) button: located on the left side of the PLAYER STATION shelf and is used to deactivate a ROBOT in an emergency.
- one (1) team sign: displays the team number and located at the top of each PLAYER STATION.
- one (1) team LED: indicates ALLIANCE color, ROBOT status, E-Stop status, and is centered at the top of each PLAYER STATION. Team LED states include:
    - Solid: indicates that the ROBOT is connected and enabled. This only happens during a MATCH.

- Blinking: indicates that either the Field Management System is preset for the MATCH and the ROBOT is not connected yet, or it's during a MATCH and the corresponding ROBOT, is BYPASSED, has lost connectivity or the E-stop was pressed.
- Off: indicates that the ROBOT is linked and DISABLED prior to the start of the MATCH. This light is also off, regardless of ROBOT connection status, after the MATCH has concluded.
- Amber LED Solid: the team or FIELD E-stop button has been pressed.

- one (1) timer (in PLAYER STATION 2): displays the official time remaining in the MATCH and TIMEOUTS. It is marked with white tape along the bottom edge.
- FMS hardware and wiring: mostly located below the PLAYER STATION 2 shelf.

3.4.1.2 LOADING BAY

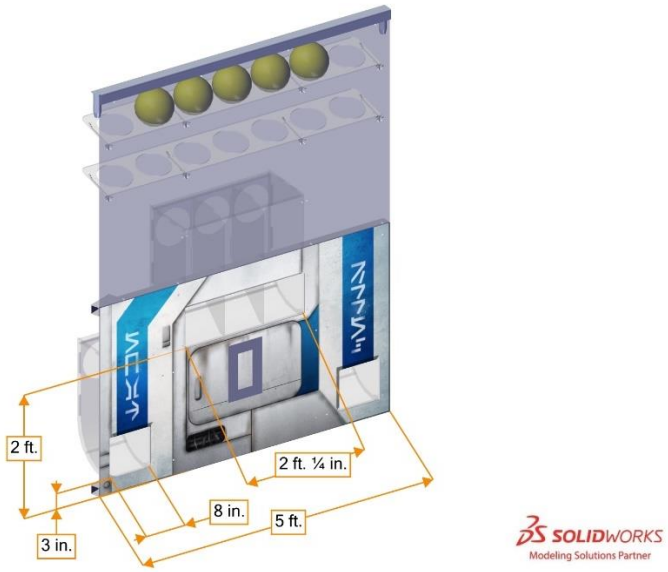


Figure 3-13 LOADING BAY

The LOADING BAY is a 6 ft. 6 in. (~198 cm) tall by 5 ft. (~152 cm) wide structure located between PLAYER STATIONS 2 and 3. HUMAN PLAYERS deliver POWER CELLS through one (1) of the five (5) Chutes in the LOADING BAY.

There are two (2) low Chutes and three (3) high Chutes. Low Chute openings are 3 in. (~8 cm) above the carpet, and high Chute openings are 2 ft. (~61 cm) above the carpet. The high Chutes are adjacent to each other and have a combined width of 2 ft. ¼ in. (~62 cm).

The LOADING BAY also includes two (2) racks for POWER CELL storage. Each rack contains openings for seven (7) POWER CELLS. The racks are 4 ft. 11⅞ in. (~152 cm) and 5 ft. 9⅞ in. (~177 cm) above the carpet.

3.4.1.3 POWER PORT

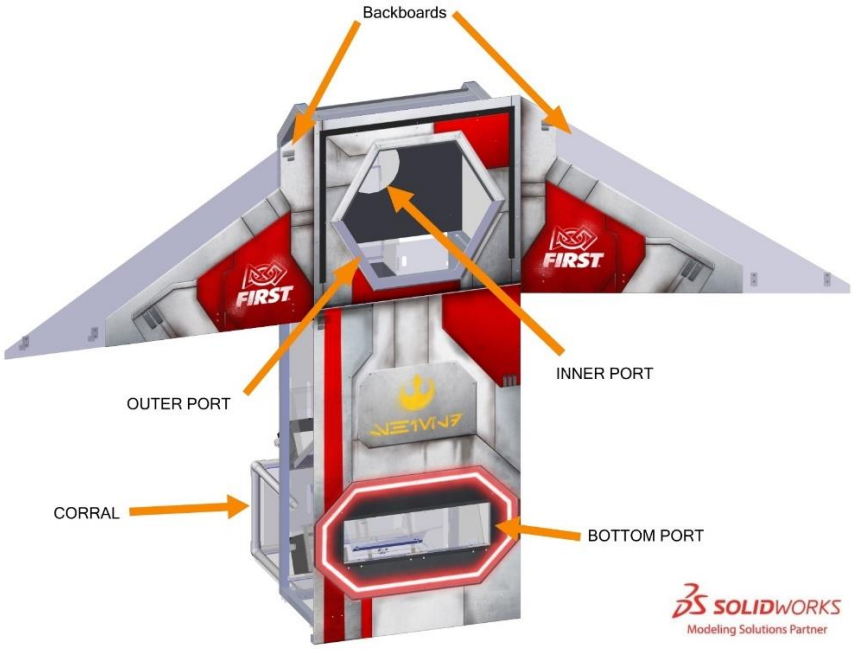


Figure 3-14 POWER PORT

There are two (2) POWER PORTS on the FIELD. The Red POWER PORT is part of the Blue ALLIANCE WALL and the Blue POWER PORT is part of the Red ALLIANCE WALL. Each POWER PORT is a 10 ft. 2¼ in. (~310 cm) tall by 4 ft. (~122 cm) wide (excluding backboards) structure and is located between PLAYER STATIONS 1 and 2. POWER PORTS process POWER CELLS scored in its BOTTOM PORT, OUTER PORT, and INNER PORT.

The BOTTOM PORT is a 10 in. (~25 cm) tall, 2 ft. 10 in. (~86 cm) wide rectangle. The bottom edge is 1 ft. 6 in. (~46 cm) above the carpet.

The OUTER PORT is a regular hexagon that measures 2 ft. 6 in. (~76 cm) in height. The center of the OUTER PORT is 8 ft. 2¼ in. (~249 cm) above the carpet.

The INNER PORT is a 1 ft. 1 in. (~33 cm) diameter circle concentric with and 2 ft. 5¼ in. (~74 cm) behind (i.e. on the ALLIANCE STATION side of) the OUTER PORT. The center is 8 ft. 2¼ in. (~249 cm) above the carpet.

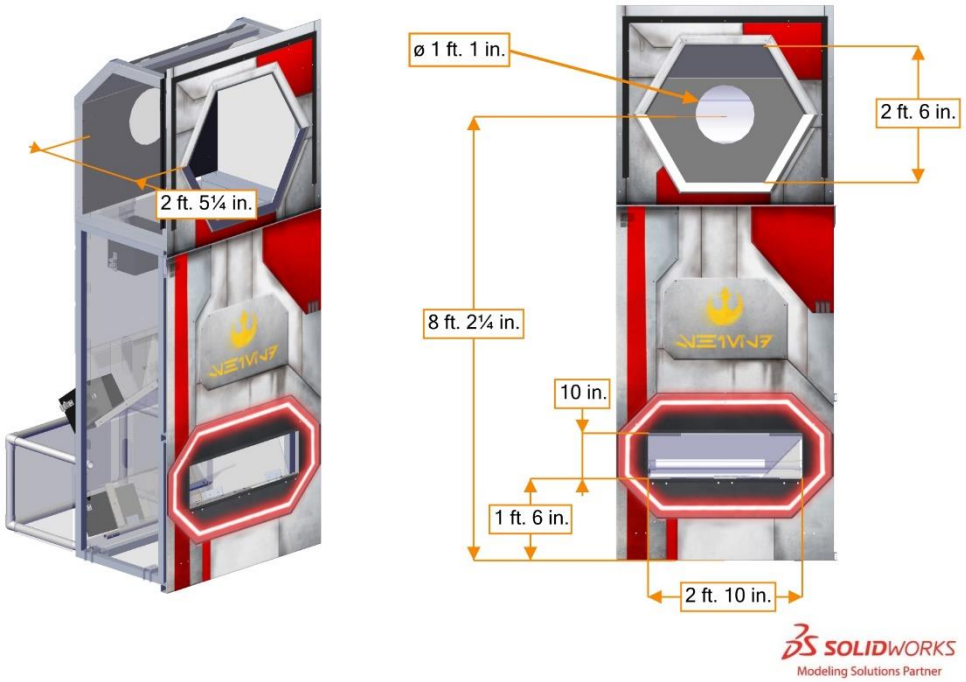


Figure 3-15 POWER PORT dimensions

Each POWER PORT releases scored POWER CELLS into its CORRAL, and POWER CELLS are recycled back to the FIELD by HUMAN PLAYERS.

The POWER PORT features two (2) polycarbonate backboards, attached on either side of the OUTER PORT, to help prevent POWER CELLS from leaving the FIELD. Backboards are 6 ft. (~183 cm) wide and extend 3 ft. 8 in. (~112 cm) above the PLAYER STATIONS.

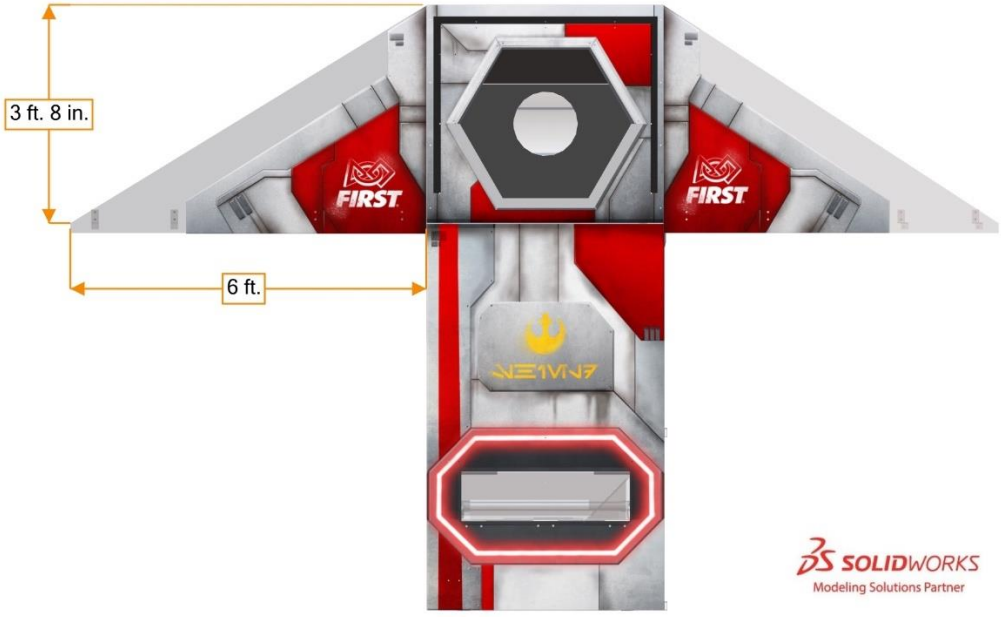


Figure 3-16 Backboard dimensions

Around the OUTER PORT a Phillips Color Kinetics LED Light String is used to indicate the progress towards CAPACITY. The string fills symmetrically starting from the top center and proceeding out, then down. The initial nodes for each Stage (staring from the center) light up in sections that differ depending on the CAPACITY of the current Stage. The bottom four nodes on either side of the OUTER PORT always fill at a rate of one (1) node per POWER CELL scored. Examples are shown in Figure 3-17.

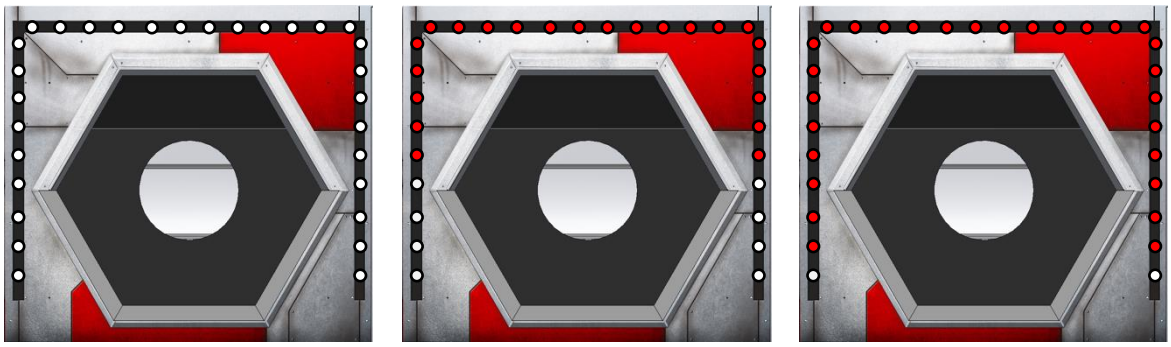


Figure 3-17 POWER PORT CAPACITY progress

A Phillips Color Kinetics LED light string around the OUTER PORT indicates CAPACITY progress. The string fills from the top center toward the side bottom nodes and is mirrored on the left and right. Nodes 1-4 and 27-30 fill per POWER CELL scored. Nodes above them light up in sections that differ depending on the CAPACITY of the current stage, as defined in Table 3-1. A node map is shown in Figure 3-18.

Table 3-1 Node pattern per CAPACITY

CAPACITY	Stage 1 nodes ON	Stage 2 and 3 nodes ON
1	14-17	15 and 16
2	11-13 and 18-20	
3	9-10 and 21-22	14 and 17
4	7-8 and 23-24	
5	5-6 and 25-26	13 and 18
6	4 and 27	
7	3 and 28	12 and 19
8	2 and 29	
9	1 and 30	11 and 20
10	N/A	
11	N/A	10 and 21
12	N/A	9 and 22
13	N/A	8 and 23
14	N/A	7 and 24
15	N/A	6 and 25
16	N/A	5 and 26
17	N/A	4 and 27
18	N/A	3 and 28
19	N/A	2 and 29
20	N/A	1 and 30

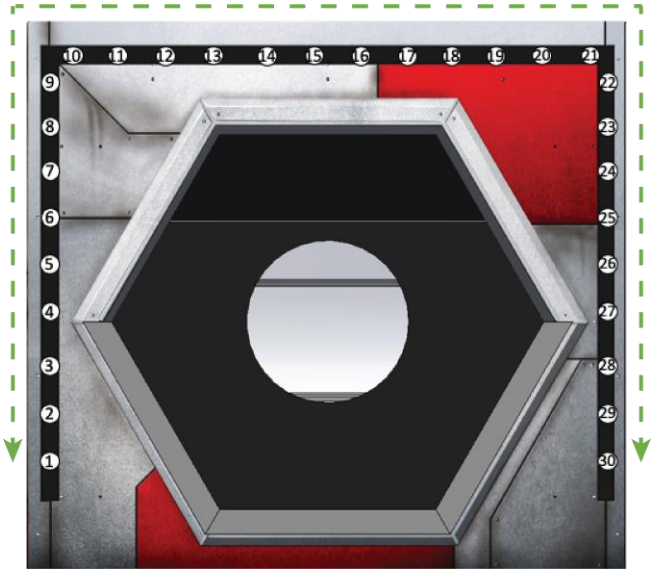


Figure 3-18 Light string node map

Light strings also indicate other FIELD states as shown in Table 3-2 and Figure 3-19.

Table 3-2 additional POWER PORT Light States

Light State	Criteria
Off	Outside of a MATCH: FIELD is MATCH ready In MATCH: current stage not ACTIVATED
Green	Head REFEREE has determined FIELD safe for humans
ALLIANCE color with yellow chase pattern	Stage has reached CAPACITY, but not ACTIVATED
Entire light string is ALLIANCE color	All stages ACTIVATED

Figure 3-19: Additional POWER PORT state examples

3.5 TRENCH

Each ALLIANCE has a TRENCH in their TRENCH RUN that spans the gap between the guardrail and SHIELD GENERATOR. On the top of each TRENCH is an ALLIANCE specific CONTROL PANEL and a yellow stack light.

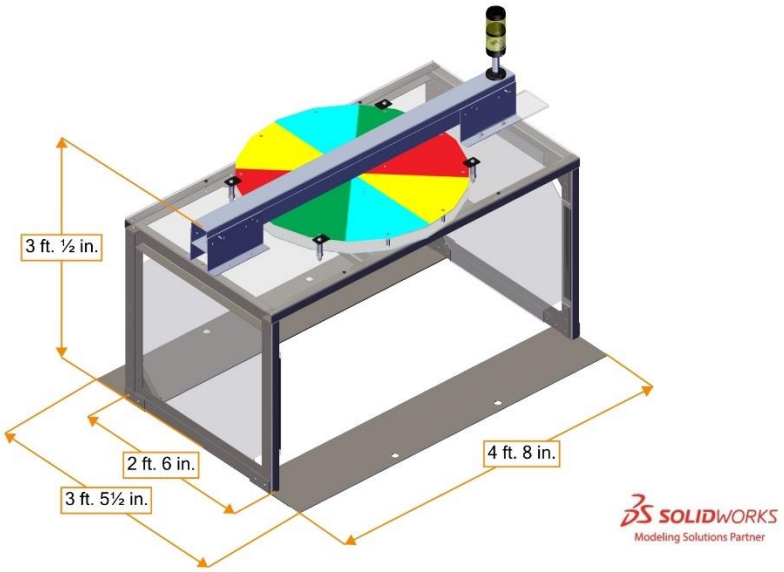


Figure 3-20 TRENCH

Each TRENCH is a 3 ft. ½ in. (~93 cm) tall, 4 ft. 8 in. (~142 cm) wide, and 3 ft. 5½ in. (~105 cm) deep structure that forms a 4 ft. 4 in. (~132 cm) wide, 2 ft. 4 in. (~71 cm) tall, and 2 ft. 6 in. (~76 cm) deep tunnel. Each TRENCH has two (2) ⅛ in. (~3 mm) thick baseplates. Each baseplate has two (2) 1-in. (~3cm) diameter holes used to stage POWER CELLS. Holes are 1 ft. 6½ in. (~47 cm) apart.

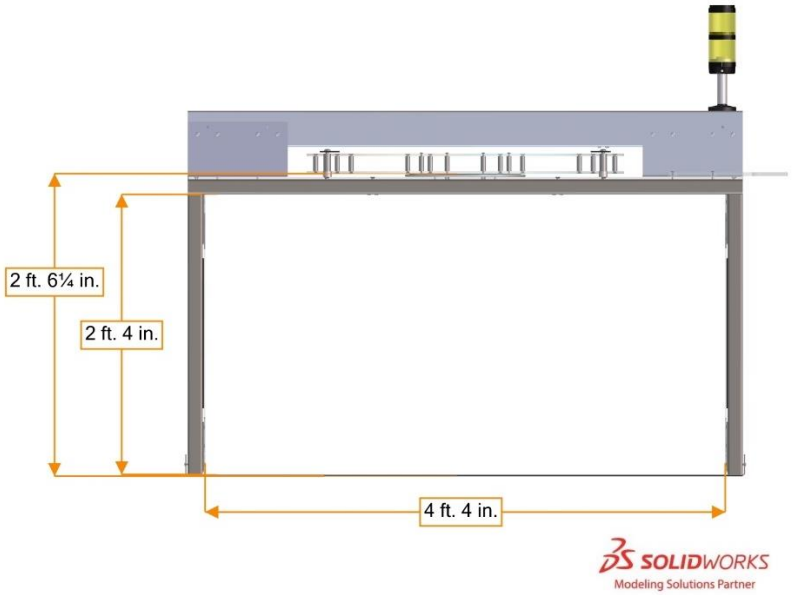


Figure 3-21 TRENCH dimensions

3.5.1 CONTROL PANEL

A CONTROL PANEL is centered on the top of each TRENCH. The CONTROL PANEL is a 2 in. (~5 cm) tall, 2 ft. 8 in. (~81 cm) diameter disk constructed of two pieces of ¼ in. (~6 mm) thick polycarbonate, spaced apart by ten ½ in. (~13 mm) diameter metal spacers at regular intervals. The centers of the spacers are located 1 in. (~3 cm) in from the outer perimeter of the CONTROL PANEL. The bottom edge of the CONTROL PANEL is located 2 ft. 6¼ in. (~77 cm) above the carpet.

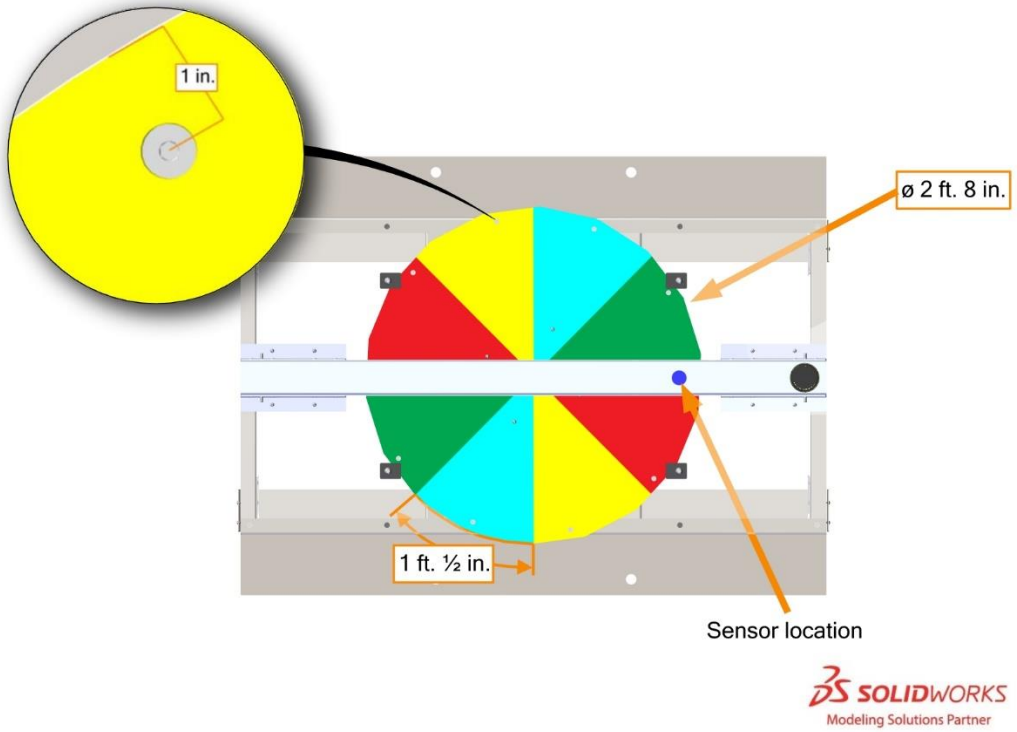


Figure 3-22 TRENCH and CONTROL PANEL dimensions

The CONTROL PANEL is divided into 8 equal size wedges. Wedges are red, green, blue, and yellow (see Table 3-3 for CMYK values) and visible from above and below the CONTROL PANEL. Colors are arranged as shown in Figure 3-23 and line up top and bottom. The arc length of each wedge is 1 ft. ½ in. (~32 cm). Fasteners in the CONTROL PANEL create holes in the colored wedges.

Table 3-3: CONTROL PANEL color chart

CONTROL PANEL color	Cyan	Magenta	Yellow	Black
Blue	100	0	0	0
Green	100	0	100	0
Red	0	100	100	0
Yellow	0	0	100	0

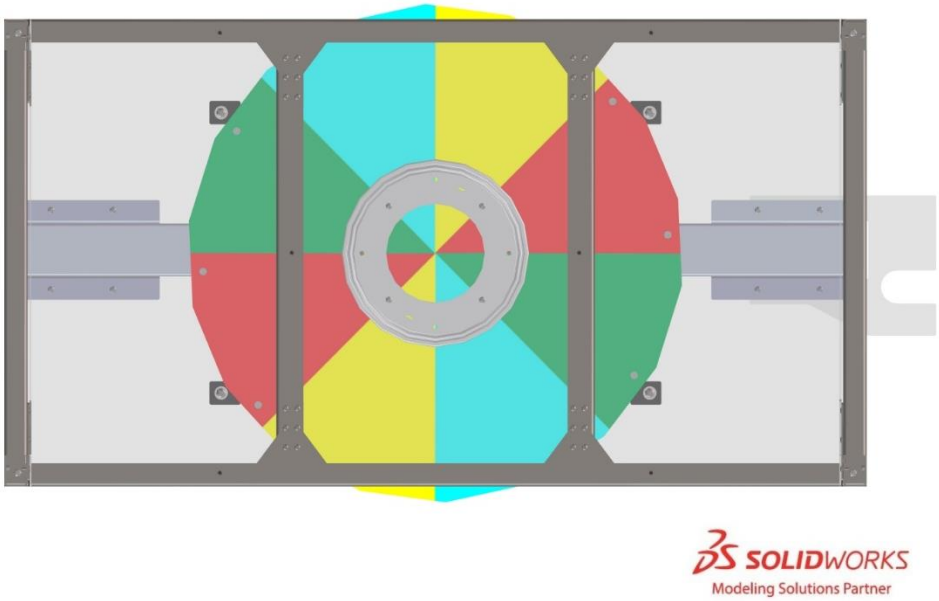


Figure 3-23 TRENCH bottom view

A swatch of identical material and colors to those on the CONTROL PANEL is in each Black Tote of the 2020 Kickoff Kit. The CONTROL PANEL is attached to the TRENCH via a 12 in. (~30 cm) Lazy Susan Bearing (Triangle Manufacturing PN: 12D10346). An identical Lazy Susan Bearing is in each Black Tote of the 2020 Kickoff Kit.

Each CONTROL PANEL has two (2) requirements in order to ENERGIZE the SHIELD GENERATOR, see CONTROL PANEL Scoring for complete details on game play.

- ROTATION CONTROL: Rotate CONTROL PANEL at least three (3) (but no more than five (5)) complete revolutions in the same direction. If the CONTROL PANEL is rotated more than five (5) complete revolutions, the count resets to zero (0). The TRENCH light turns on once Stage 2 CAPACITY is reached (i.e. the CONTROL PANEL is ready for ROTATION CONTROL).

> A CONTROL PANEL spun faster than 60 revolutions per minute may cause FIELD damage. For more details see MATCH Replays.

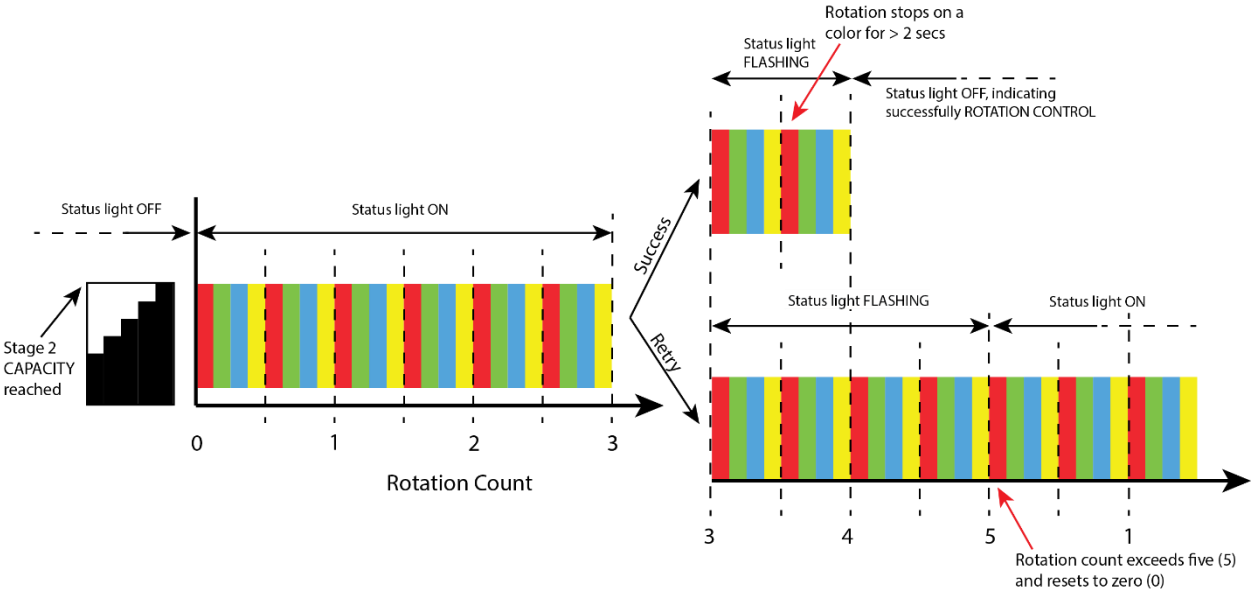


Figure 3-24 CONTROL PANEL ROTATION CONTROL example

- POSITION CONTROL: Rotate CONTROL PANEL so a specified color aligns with the sensor for at least five (5) seconds. Once either ALLIANCE reaches Stage 3 CAPACITY, FMS relays a specified color (randomly selected by FMS and one (1) of the three (3) colors not currently read by the ALLIANCE'S TRENCH color sensor) to all OPERATOR CONSOLES simultaneously. The specified color may not be the same for both ALLIANCES. See Table 3-4 for details on how the TRENCH light is used during POSTION CONTROL.

> Specific details on the format of the data can be found on the 2020 FRC Control System website.
>
> In the unlikely event that the sensor isn't currently reporting one (1) of the four (4) colors when Stage 3 reaches CAPACITY (e.g. the sensor is positioned where two (2) color wedges meet), FMS will randomly select the specified color from one (1) of the four (4) colors.

Each TRENCH has a yellow stack light to indicate CONTROL PANEL status.

Table 3-4 TRENCH light status

Light State	SHIELD GENERATOR Stage	Criteria
Off	1, 2, or 3	Stage not at CAPACITY or Stage 3 ACTIVATED
Solid	2 or 3	The POWER PORT is at CAPACITY, the CONTROL PANEL is ready for use
Flashing	2	The CONTROL PANEL has rotated the required number for ROTATION CONTROL, but has not yet continuously read a single color for two (2) seconds
	3	The CONTROL PANEL has read the required color for POSITION CONTROL for at least three (3) seconds and less than five (5) seconds[1]

[1] If a color change is detected during the two (2) second period when the stack light is flashing, the light returns to solid and the color detection timer resets to zero (0).

3.6 POWER CELL

Figure 3-25 POWER CELL

INFINITE RECHARGE is played with POWER CELLS. A POWER CELL is a yellow 7 in. (~18 cm) diameter Medium Bounce Dino-Skin foam ball. The *FIRST* logo is printed on each ball in black ink. The ball is made by Flaghouse (PN 1892 YEL) and sold by AndyMark (PN AM-4200). A POWER CELL is in each Black Tote of the 2020 Kickoff Kit.

3.7 Vision Targets

Vision targets made from 2 in. (~5 cm) wide strips of 3M 8830 Scotchlite™ Reflective Material are located on the POWER PORTS and LOADING BAYS. On the POWER PORT, they target the location of the INNER and OUTER PORTS and trace the bottom perimeter of the OUTER PORT. The target has an overall height of 1 ft. 5 in. (~43 cm), and a width of 3 ft. 3¼ in. (~100 cm). The bottom of the target is 6 ft. 9¼ in. (~206 cm) above the carpet. A strip of 3M 8830 Scotchlite™ Reflective Material is in *FIRST* Choice.

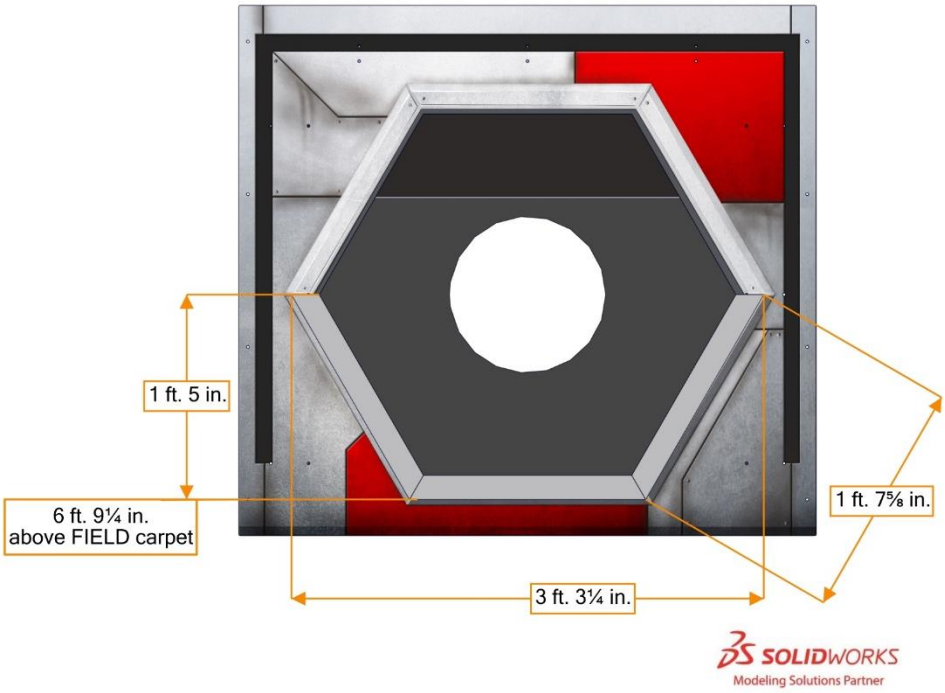


Figure 3-26 POWER PORT Vision Target

The LOADING BAY target is a 7 in. (~18 cm) wide by 11 in. (~28 cm) tall rectangle. The target is centered on the width of the LOADING BAY and located 11 in. (~28 cm) above the carpet.

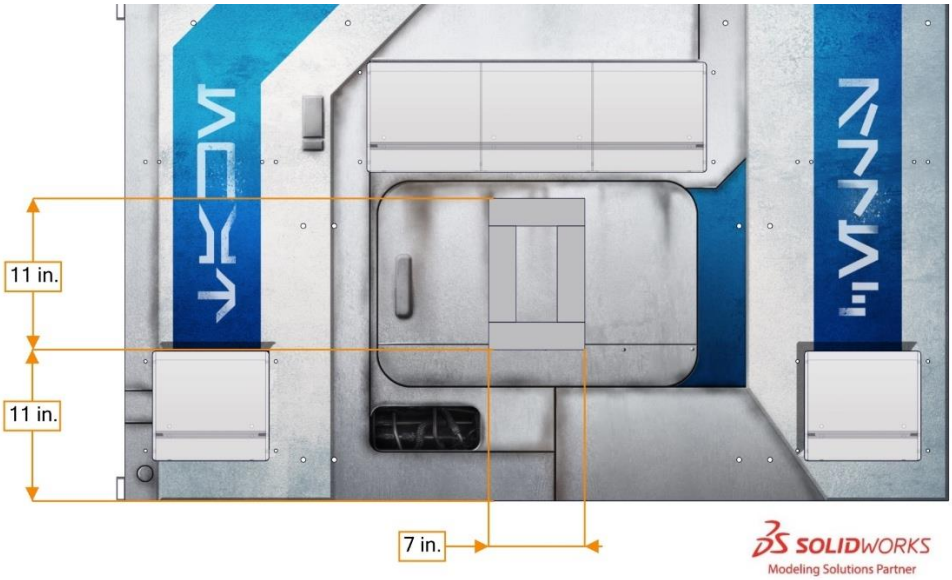


Figure 3-27 LOADING BAY Vision Target

3.8 The FIELD Management System

The Field Management System (FMS) is the electronics core responsible for sensing and controlling the *FIRST* Robotics Competition FIELD. The FMS encompasses all FIELD electronics, including computers, REFEREE touchscreens, wireless access point, sensors, stack lights, E-Stops, etc.

When a DRIVE TEAM connects the Ethernet cable from their assigned PLAYER STATION to their OPERATOR CONSOLE, the Driver Station software on the OPERATOR CONSOLE computer will communicate with FMS. Once connected, the open ports available are described in Table 3-5.

Table 3-5 Open FMS Ports

Port	Designation	Bi-directional?
UDP/TCP 1180-1190	Camera data from the roboRIO to the Driver Station when the camera is connected the roboRIO via USB	Yes
TCP 1735	SmartDashboard	Yes
UDP 1130	Dashboard-to-ROBOT control data	Yes
UDP 1140	ROBOT-to-Dashboard status data	Yes
HTTP 80	Camera connected via switch on the ROBOT	Yes
HTTP 443	Camera connected via switch on the ROBOT	Yes
UDP/TCP 554	Real-Time Streaming Protocol for h.264 camera streaming	Yes
UDP/TCP 1250	CTRE Diagnostics Server	Yes
UDP/TCP 5800-5810	Team use	Yes

Teams may use these ports as they wish if they do not employ them as outlined above (e.g. TCP 1180 can be used to pass data back and forth between the ROBOT and the Driver Station software if the team chooses not to use the camera on USB). Note that ROBOT code cannot be deployed while connected to the FMS. Additional information about the FMS may be found in the FMS Whitepaper.

The FMS provides the specified color for POSITION CONTROL to the Driver Station software, see CONTROL PANEL for additional details.

> While FMS provides the specified color for POSITION CONTROL to each team's Driver Station, teams must write the necessary ROBOT code to make use of the information during a MATCH.

FMS alerts participants to milestones in the MATCH using audio cues detailed in Table 3-6. Please note that audio cues are intended as a courtesy to participants and not intended as official MATCH markers. If there is a discrepancy between an audio cue and the FIELD timers, the FIELD timers are the authority.

Table 3-6 Audio cues

Event	Timer Value	Audio Cue
MATCH Start	0:15 (for AUTO)	"Cavalry Charge"
AUTO Ends	0:00 (for AUTO)	"Buzzer"
TELEOP Begins	2:15	"Three Bells"
ENDGAME warning	0.30	"Imperial Alarm"
MATCH End	0:00	"Buzzer"
MATCH Stopped	n/a	"Foghorn"
ROTATION CONTROL complete	n/a	"Whirring"
POSITION CONTROL complete	n/a	"Charging Up"

4 MATCH PLAY

During INFINITE RECHARGE℠, two (2) ALLIANCES (an ALLIANCE is a cooperative of up to four (4) *FIRST* Robotics Competition teams) play MATCHES, set up and executed per the details described below.

4.1 Setup

4.1.1 POWER CELLS

Forty-eight (48) POWER CELLS are staged as follows:

A. five (5) POWER CELLS in each of the two (2) TRENCH RUNS
   i. two (2) POWER CELLS are placed on each of the TRENCH baseplates further away from the center of the FIELD.
   ii. three (3) POWER CELLS are placed centered in the width of each TRENCH RUN, spaced at 3-ft. (~91 cm) intervals. Small rings are used to keep them in place prior to the start of a match. Rings are ⅛ in. (~3 mm) thick, 1¾ in. (~4 cm) diameter O-rings (McMaster Item#: 9452K63). Rings are secured to the carpet by tape.
B. five (5) POWER CELLS placed on the BOUNDARIES inside each ALLIANCE'S RENDEZVOUS POINT as shown in Figure 4-2.
C. five (5) POWER CELLS on the racks in each ALLIANCE STATION'S LOADING BAY,
D. each of the three (3) teams may preload up to three (3) POWER CELLS in their ROBOT, such that they are fully and solely supported by that ROBOT, and
E. remaining POWER CELLS (zero (0) to nine (9) per ALLIANCE, depending on decisions made in D) in the holes on the BOUNDARIES in the corresponding ALLIANCE'S RENDEZVOUS POINT as shown in Figure 4-2.

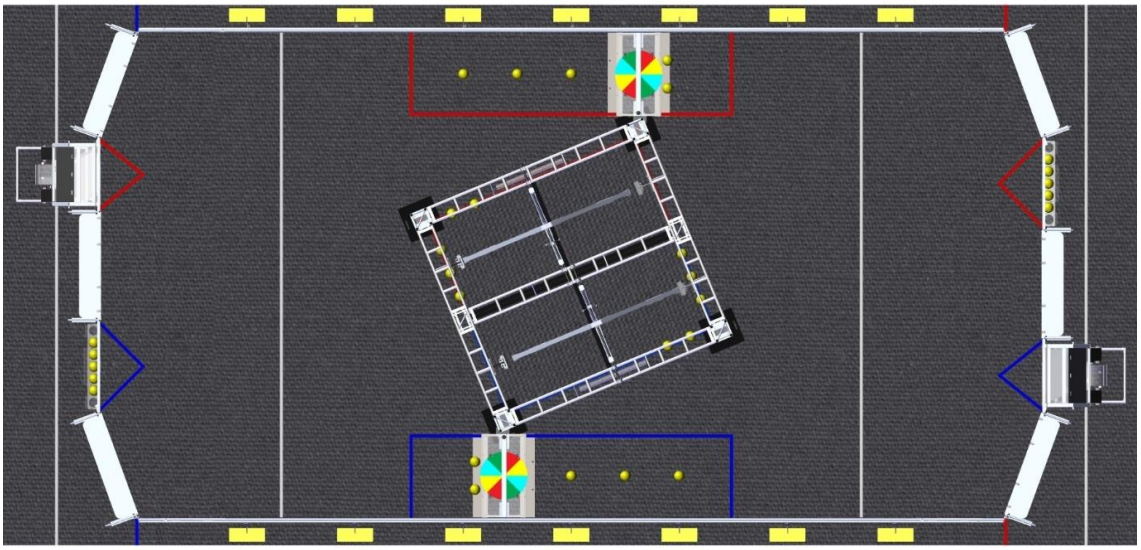


Figure 4-1: POWER CELL Setup

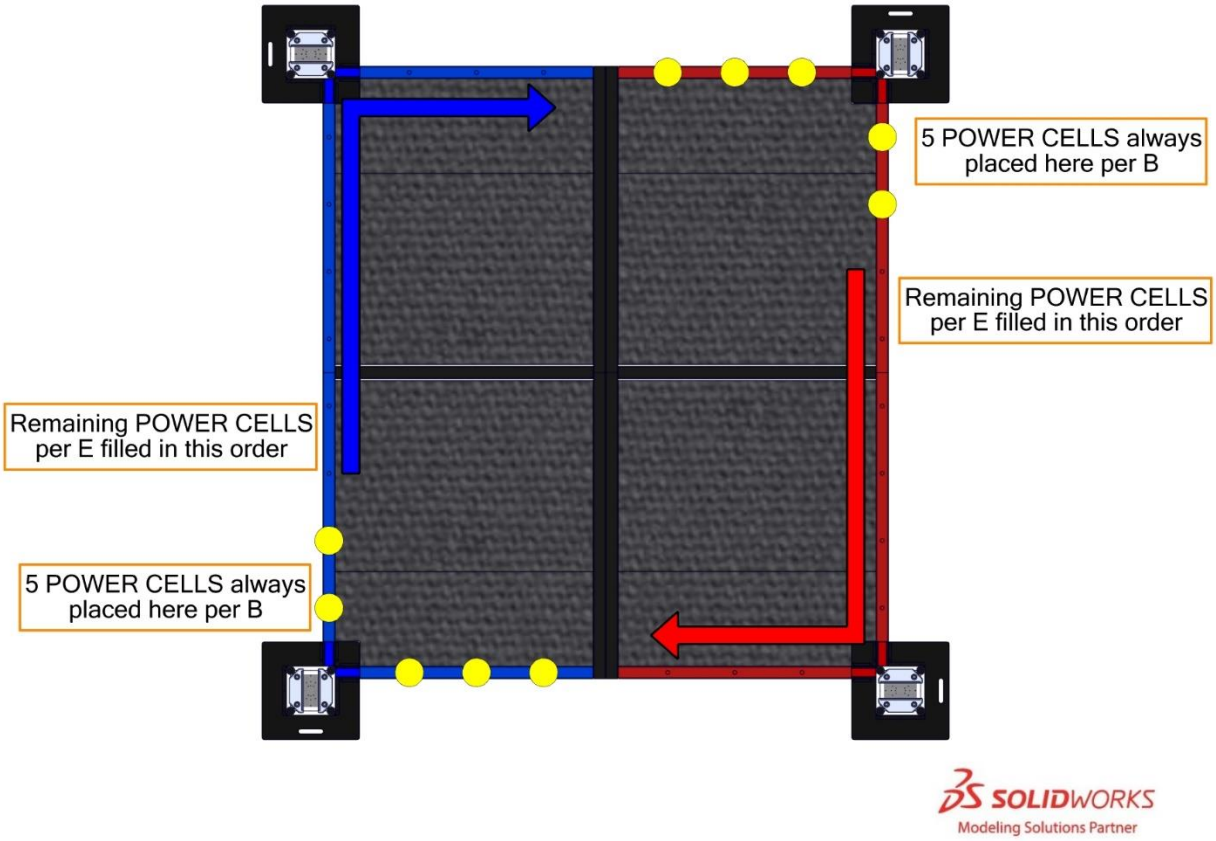


Figure 4-2: POWER CELL setup on BOUNDARIES

4.1.2 ROBOTS

Each TEAM stages their ROBOT such that at least part of its BUMPERS are intersecting the infinite vertical volume created by the corresponding ALLIANCE'S INITIATION LINE.

If order placement matters to either or both ALLIANCES, the ALLIANCE must notify the Head REFEREE during setup for that MATCH. Upon notification, the Head REFEREE will require ALLIANCES to alternate placement of all ROBOTS. In a Qualification MATCH, ROBOTS are placed in the following order: Red Station 1 ROBOT, Blue Station 1 ROBOT, Red Station 2 ROBOT, Blue Station 2 ROBOT, Red Station 3 ROBOT, Blue Station 3 ROBOT. In a PLAYOFF MATCH, the same pattern is applied, but instead of Blue ALLIANCE placing last, the higher seeded ALLIANCE (regardless of color) places last.

4.1.3 Humans

DRIVERS, COACHES, and HUMAN PLAYERS stage behind the STARTING LINE inside their ALLIANCE STATION. TECHNICIANS stage in the event-designated area near the FIELD.

4.2 Autonomous Period

The first phase of each MATCH is called Autonomous (AUTO) and consists of the first fifteen (0:15) seconds. During AUTO, ROBOTS operate without any DRIVE TEAM control or input. ROBOTS attempt to score POWER CELLS in POWER PORTS, retrieve additional POWER CELLS from around the FIELD,

and exit the infinite vertical volume created by the corresponding ALLIANCE'S INITIATION LINE any time before the end of the phase.

4.3 Teleoperated Period

The second phase of each MATCH is called the Teleoperated Period (TELEOP) and consists of the remaining two minutes and fifteen seconds (2:15). During this phase, DRIVERS remotely operate ROBOTS to retrieve and score POWER CELLS in goals and manipulate CONTROL PANELS to ACTIVATE different stages of the SHIELD GENERATOR.

The final thirty (0:30) seconds of TELEOP is the ENDGAME, during which ROBOTS attempt to ENERGIZE the SHIELD GENERATOR.

4.4 Scoring

ALLIANCES are rewarded for accomplishing various actions through the course of a MATCH, including ROBOT movement during AUTO, scoring POWER CELLS in POWER PORTS, manipulating CONTROL PANELS, ACTIVATING stages of the SHIELD GENERATOR, ENERGIZING the SHIELD GENERATOR, and winning or tying MATCHES.

Rewards are granted via either MATCH points (which contribute to the ALLIANCE'S MATCH score) or Ranking Points (which increase the measure used to rank teams in the Qualification Tournament). Such actions, their criteria for completion, and their point values are listed in Table 4-2.

All scores, except ENDGAME bonuses, are assessed and updated throughout the MATCH.

4.4.1 POWER PORT Scoring

ALLIANCES generate energy by scoring POWER CELLS into one of three (3) openings of their POWER PORT. To be considered scored, the POWER CELL must pass through the BOTTOM, OUTER, or INNER PORTS and exit through the respective scoring sensors during the MATCH or within five (5) seconds after the MATCH (regardless of how many POWER CELLS are being processed after the end of the MATCH).

If a POWER CELL becomes jammed in the BOTTOM, INNER, or OUTER PORT, credit for the jammed POWER CELL is granted in the period during which the POWER CELL became stuck.

Lights on the POWER PORT indicate progress towards the CAPACITY of the current Stage of the SHIELD GENERATOR. See POWER PORT for more details.

The final assessment of POWER CELLS scored in POWER PORTS is made five (5) seconds after the ARENA timer displays zero (0) following AUTO and TELEOP, respectively.

> POWER CELLS scored during the five (5) seconds after the ARENA timer displays zero (0) following AUTO earn AUTO points and, if STAGE 1 has been ACTIVATED, count towards STAGE 2 CAPACITY.

4.4.2 SHIELD GENERATOR Scoring

The SHIELD GENERATOR stores energy generated by scored POWER CELLS. ALLIANCES work to make the SHIELD GENERATOR OPERATIONAL and ENERGIZED in order to protect *FIRST* City.

The SHIELD GENERATOR has three (3) stages that need to be charged to CAPACITY and ACTIVATED consecutively. CAPACITY is the number of POWER CELLS, defined in Table 4-1, that must be scored to

charge each stage. Each POWER CELL, regardless of the POWER PORT opening in which it scores, counts equally toward CAPACITY.

Table 4-1: SHIELD GENERATOR ACTIVATION requirements

Stage	CAPACITY	ACTIVATED when…
1	9	nine (9) POWER CELLS are scored & TELEOP has begun
2	20	twenty (20) POWER CELLS are scored in Stage 2 & ROTATION CONTROL is complete
3	20	twenty (20) POWER CELLS are scored in Stage 3 & POSITION CONTROL is complete

As the season progresses, the CAPACITY required for each Stage of the SHIELD GENERATOR may increase. While Stage CAPACITY will not change between weeks of Regional or District Competition play, the Stage CAPACITY may be changed for District Championship and/or *FIRST* Championship play. Teams will be notified of changes in Stage CAPACITY no later than the scheduled Team Update prior to the date of the event.

POWER CELLS scored after a stage is at CAPACITY generate MATCH points but do not contribute to the next stage's CAPACITY. POWER CELLS scored after Stage 3 is ACTIVATED continue to generate MATCH points.

SHIELD GENERATOR lights indicate ACTIVATED Stages. See SHIELD GENERATOR Lighting for more details.

4.4.3 CONTROL PANEL Scoring

CONTROL PANELS ACTIVATE SHIELD GENERATOR stages two (2) and three (3) as described in CONTROL PANEL. CONTROL PANEL requirements (i.e. ROTATION CONTROL AND POSITION CONTROL) are not evaluated until the respective stage is at CAPACITY. A stage may be ACTIVATED once it reaches CAPACITY, and a stage must be ACTIVATED before the next stage can begin charging.

Once all three (3) stages are ACTIVATED, the SHIELD GENERATOR is ENERGIZED (the SHIELD GENERATOR does not need to be OPERATIONAL to be ENERGIZED and vice versa.)

4.4.4 GENERATOR SWITCH Scoring

ALLIANCES use their GENERATOR SWITCH to earn MATCH Points and make the SHIELD GENERATOR OPERATIONAL.

A ROBOT is considered PARKED if, five (5) seconds after the ARENA timer displays zero (0) following TELEOP, it is fully supported (either directly or transitively) by the SHIELD GENERATOR and not in contact with any carpet outside its ALLIANCE'S RENDEZVOUS POINT, but without having met the criteria for HANGING.

A ROBOT is considered HANGING if, five (5) seconds after the ARENA timer displays zero (0) following TELEOP, it is fully supported (either directly or transitively) by its GENERATOR SWITCH.

A GENERATOR SWITCH is considered LEVEL if, five (5) seconds after the ARENA timer displays zero (0) following TELEOP, both following criteria are met:

A. it is in the LEVEL range, and

B. all ALLIANCE ROBOTS contacting the GENERATOR SWITCH are HANGING.

The final assessment of a LEVEL GENERATOR SWITCH and HANGING or PARKED ROBOTS is made five (5) seconds after the ARENA timer displays zero (0) following TELEOP, at which point the Audience Display stops updating and the lights on the SHIELD GENERATOR flash three (3) times.

The SHIELD GENERATOR is considered to be OPERATIONAL when the ALLIANCE'S ENDGAME SCORE is ≥ 65 points.

4.4.5 Point Values

Point values for tasks in INFINITE RECHARGE are detailed in Table 4-2.

Table 4-2: Point Values

Award	Awarded for…	AUTO	TELEOP	Qual.
INITIATION LINE	exit the infinite vertical volume created by the corresponding ALLIANCE'S INITIATION LINE any time before the end of AUTO (per ROBOT)	5	-	-
POWER CELLS	scored in BOTTOM PORT	2	1	-
	scored in OUTER PORT	4	2	-
	scored in INNER PORT	6	3	-
CONTROL PANEL	ROTATION CONTROL	-	10	-
	POSITION CONTROL		20	
ENDGAME Points	HANG (per ROBOT)	-	25	-
	PARK (per ROBOT)	-	5	-
	LEVEL with 1-3 ROBOTS HANGING (per ALLIANCE)		15	
SHIELD GENERATOR OPERATIONAL	earning at least sixty-five (65) ENDGAME points			1 Ranking Point
SHIELD GENERATOR ENERGIZED	Stage 3 ACTIVATED	-	-	1 Ranking Point
Tie	Completing a MATCH with the same number of points as your opponent	-	-	1 Ranking Point
Win	Completing a MATCH with more points than your opponent	-	-	2 Ranking Point

An ALLIANCE can earn up to four (4) Ranking Points (RP) per Qualification MATCH, as described in Table 4-2. There are no RP, or comparable point bonuses, in Playoff MATCHES.

4.5 Rule Violations

Upon a rule violation, one or more of the penalties listed in Table 4-3 will be assessed.

Table 4-3 Rule violations

Penalty	Description
FOUL	a credit of three (3) points towards the opponent's MATCH score
TECH FOUL	a credit of fifteen (15) points toward the opponent's MATCH score
YELLOW CARD	a warning issued by the Head REFEREE for egregious ROBOT or team member behavior or rule violations. A subsequent YELLOW CARD within the same tournament phase results in a RED CARD.
RED CARD	a penalty assessed for egregious ROBOT or team member behavior or rule violations which results in a team being DISQUALIFIED for the MATCH.
DISABLED	ROBOT is commanded to deactivate all outputs, rendering the ROBOT inoperable for the remainder of the MATCH.
DISQUALIFIED	the state of a team in which they receive zero (0) MATCH points and zero (0) Ranking Points in a Qualification MATCH or causes their ALLIANCE to receive zero (0) MATCH points in a Playoff MATCH

Some rule violations escalate if the REFEREE determines an action was "repeated." While there's no official *FIRST* Robotics Competition definition of repeated, it's meant to apply to rule violations that occur more than once within a MATCH.

The official *FIRST* Robotics Competition definition of momentary is fewer than three (3) seconds. The intent of using this word is to provide a reference for our community. It is not the intent for REFEREES to provide a count for these time periods.

See YELLOW and RED CARDS for additional details.

4.5.1 Violation Details

There are several styles of violation wording used in this manual. Below are some example violations and a clarification of the way the violation would be assessed. The examples shown do not represent all possible violations, but rather a representative set of combinations.

Table 4-4: Violation Examples

Example Violation	Expanded Interpretation
FOUL	Upon violation, a FOUL is assessed against the violating ALLIANCE
TECH FOUL and YELLOW CARD	Upon violation, a TECH FOUL is assessed against the violating ALLIANCE. After the MATCH, the Head REFEREE presents the violating team with a YELLOW CARD.
FOUL, if contact with an opponent TECH FOUL	Upon violation, a FOUL is assessed against the violating ALLIANCE. If the secondary condition is additionally met at any point while still in violation of the rule, in this case contact is made with an opponent ROBOT, a TECH FOUL is additionally assessed against the violating ALLIANCE.
FOUL per additional POWER CELL. If egregious, YELLOW CARD	Upon violation, a number of FOULS are assessed against the violating ALLIANCE equal to the number of additional POWER CELLS beyond the permitted quantity. Additionally, if the REFEREES determine that the action was egregious, the Head REFEREE presents the violating team with a YELLOW CARD after the MATCH.

TECH FOUL, plus an additional TECH FOUL for every five (5) seconds in which the situation is not corrected	Upon violation, a TECH FOUL is assessed against the violating ALLIANCE and the REFEREE begins to count. Their count continues until the criteria to discontinue the count are met, and for each five (5) seconds within that time, an additional TECH FOUL is assessed against the violating ALLIANCE. A ROBOT in violation of this type of rule for fifteen (15) seconds would receive a total of four (4) TECH FOULS (assuming no other rules were simultaneously being violated).
RED CARD for the ALLIANCE	After the MATCH, the Head REFEREE presents the violating ALLIANCE with a RED CARD in the following fashion: a) In a PLAYOFF MATCH, a single RED CARD is assessed to the ALLIANCE. b) In all other scenarios, each team on the ALLIANCE is issued a RED CARD.

4.6 DRIVE TEAM

A DRIVE TEAM is a set of up to five (5) people from the same *FIRST* Robotics Competition team responsible for team performance for a specific MATCH. There are four (4) specific roles on a DRIVE TEAM which ALLIANCES can use to assist ROBOTS with INFINITE RECHARGE.

The intent of the definition of DRIVE TEAM and DRIVE TEAM related rules is that, barring extenuating circumstances, the DRIVE TEAM consists of people who arrived at the event affiliated with that team and are responsible for their team's and ROBOT'S performance at the event (this means a person may be affiliated with more than one (1) team). The intent is not to allow teams to "adopt" members of other teams for strategic advantage for the loaning team, borrowing team, and/or their ALLIANCE (e.g. an ALLIANCE CAPTAIN believes one of their DRIVERS has more experience than a DRIVER on their 1st pick, and the teams agree the 1st pick team will "adopt" that DRIVER and make them a member of their DRIVE TEAM for Playoffs).

The definition isn't stricter for two (2) main reasons. First, to avoid additional bureaucratic burden on teams and event volunteers (e.g. requiring that teams submit official rosters that Queuing must check before allowing a DRIVE TEAM into the ARENA). Second, to provide space for exceptional circumstances that give teams the opportunity to display Gracious Professionalism (e.g. a bus is delayed, a COACH has no DRIVERS, and their pit neighbors agree to help by loaning student DRIVERS as temporary members of the team until their bus arrives).

Table 4-5 DRIVE TEAM roles

Role	Description	Max./ DRIVE TEAM	Criteria
COACH	a guide or advisor	1	Pre-college student or adult mentor Must wear "COACH" button
DRIVER	an operator and controller of the ROBOT	3	Pre-college student Must wear one (1) of the three (3) "DRIVE TEAM" buttons
HUMAN PLAYER	a POWER CELL manager		
TECHNICIAN	a resource for ROBOT troubleshooting, setup, and removal from the FIELD	1	Pre-college student Must wear "TECHNICIAN" button

The TECHNICIAN provides teams with a technical resource for pre-MATCH setup, ROBOT connectivity, OPERATOR CONSOLE troubleshooting, and post-MATCH removal of the ROBOT. Some pre-MATCH responsibilities for the TECHNICIAN may include, but are not limited to:

- location of the ROBOT radio, its power connection, and understanding of its indicator lights
- location of the roboRIO and understanding of its indicator lights
- username and password for the OPERATOR CONSOLE
- restarting the Driver Station and Dashboard software on the OPERATOR CONSOLE
- changing the bandwidth utilization (e.g. camera resolution, frame rate, etc.)
- changing a battery
- charging pneumatics

While the TECHNICIAN may be the primary technical member of the DRIVE TEAM, all members of the DRIVE TEAM are encouraged to have knowledge of the basic functionality of the ROBOT, such as the location and operation of the main circuit breaker, connecting and resetting joysticks or gamepads from the OPERATOR CONSOLE, and removing the ROBOT from the FIELD.

4.7 Other Logistics

POWER CELLS that leave the FIELD are placed back into the FIELD approximately at the point of exit by FIELD STAFF (REFEREES, FTAS, or other staff working around the FIELD) at the earliest safe opportunity.

Note that ROBOTS may not deliberately cause POWER CELLS to leave the FIELD (see G7).

An ARENA FAULT is not called for MATCHES that accidentally begin with an incorrect number of, incorrectly positioned, or damaged POWER CELLS. Damaged POWER CELLS are not replaced until the next ARENA reset period. DRIVE TEAMS should alert the FIELD STAFF to any missing or damaged POWER CELLS prior to the start of the MATCH.

Once the MATCH is over and the Head REFEREE determines that the FIELD is safe for FIELD STAFF and DRIVE TEAMS, they or their designee change the LED lights to green and DRIVE TEAMS may retrieve their ROBOT.

In addition to the two minutes and thirty seconds (2:30) of game play, each MATCH also has pre- and post-MATCH time for setup and reset of the ARENA. During ARENA reset, the ARENA is cleared of ROBOTS and OPERATOR CONSOLES from the MATCH that just ended. The ROBOTS and OPERATOR CONSOLES for the subsequent MATCH are loaded into the ARENA by DRIVE TEAMS at this time. FIELD STAFF also use this time to reset ARENA elements and POWER CELLS.

5 SAFETY RULES

Safety is always paramount, and each rule below is intended to establish norms at each event that will mitigate injury risk to all participants.

Event staff have the final decision authority for all safety-related issues within a venue.

> Please refer to *FIRST*® Robotics Competition Event Experience web page for safety, conduct, etc. rules not specific to this game or limited to MATCH play. As with all violations in this document, any Event Experience rules also carry the potential consequence of a YELLOW or RED CARD.

S1. Dangerous ROBOTS: not allowed. ROBOTS whose operation or design is dangerous or unsafe are not permitted.

Violation: If before the MATCH, the offending ROBOT will not be allowed to participate in the MATCH. If during the MATCH, the offending ROBOT will be DISABLED.

> Examples include, but are not limited to:
>
> - Uncontrolled motion that cannot be stopped by the DRIVE TEAM
> - ROBOT parts "flailing" outside of the FIELD
> - ROBOTS dragging their battery
> - ROBOTS that consistently extend beyond the FIELD

S2. Wait for the green lights. Team members may only enter the FIELD if the POWER PORT LEDs are green, unless explicitly instructed by a REFEREE or an FTA.

Violation: Verbal warning. If repeated at any point during the event, YELLOW CARD. If egregious, RED CARD.

> Egregious violations of S2 include, but are not limited to:
>
> a. pushing passed the FIELD reset person blocking an open gate to get on the FIELD
> b. ignoring a warning to not go on the FIELD

S3. Never step/jump over the guardrail. Team members may only enter or exit the FIELD through open gates.

Violation: Verbal warning. If repeated at any point during the event, YELLOW CARD.

> Teams are encouraged to ensure that all members of their DRIVE TEAM are aware of this rule. It's easy to violate, particularly when teams are doing their best to move on and off the FIELD quickly. The violations of S3 are intended to avoid nuisance penalties, but still enforce safety requirements around the FIELD. There is the potential for injury when stepping over the guardrail.
>
> Violations of S3 apply to the entire team, not specifically to any one individual. For example, a member of team 9999 steps over the guardrail prior to MATCH 3, and a different member steps over the guardrail prior to MATCH 25. The team receives a verbal warning for the first violation and a YELLOW CARD for the second.

S4. ROBOTS, stay on the FIELD during the MATCH. ROBOTS and anything they control, e.g. a POWER CELL, may not contact anything outside the FIELD with the exception of momentary incursions into the BOTTOM PORT or LOADING BAY Chutes.

Violation: Offending ROBOT will be DISABLED.

Please be conscious of REFEREES and FIELD STAFF working around the ARENA who may be in close proximity to your ROBOT.

S5. Humans, stay off the FIELD during the MATCH. DRIVE TEAMS may not extend any body part into the FIELD during the MATCH.

Violation: YELLOW CARD

Examples of egregious violations that are likely to escalate the violation to a RED CARD include, but are not limited to, walking onto the FIELD during a MATCH or reaching into the FIELD and grabbing a ROBOT during a MATCH.

S6. Stay out of the Chutes. DRIVE TEAMS may not extend any body part into the LOADING BAY Chute. Momentary encroachment into the Chute is an exception to this rule.

Violation: FOUL

S7. Stay off the SHIELD GENERATOR and CONTROL PANELS. Team members may not sit, climb, or hang on the CONTROL PANELS, SHIELD GENERATOR, or GENERATOR SWITCH.

Violation: Verbal warning. If repeated at any point during the event, YELLOW CARD.

Teams are encouraged to ensure that all members of their DRIVE TEAM are aware of this rule. There is the potential for injury if horseplay ensues around the SHIELD GENERATOR.

Violations of this rule apply to the entire team, not specifically to any one individual. See example in the S3 blue box.

6 CONDUCT RULES

C1. Egregious or exceptional violations. Egregious behavior beyond what is listed in the rules or repeated violations of any rule or procedure during the event is prohibited.

In addition to rule violations explicitly listed in this manual and witnessed by a REFEREE, the Head REFEREE may assign a YELLOW or RED CARD for egregious ROBOT actions or team member behavior at any time during the event. This includes violations of the event rules found on the *FIRST*® Robotics Competition Event Experience web page

Please see YELLOW and RED CARDS for additional detail.

Violation: The Head REFEREE may assign a YELLOW or a RED CARD.

The intent of this rule is to provide the Head REFEREES the flexibility necessary to keep the event running smoothly, as well as keep the safety of all the participants as the highest priority. There are certain behaviors that automatically result in a YELLOW or RED CARD because we believe this behavior puts our community at risk. Those behaviors include, but are not limited to the list below:

a. Inappropriate behavior as outlined in the blue box of C2.
b. Jumping over the FIELD border,
c. Sitting on the SHIELD GENERATOR,
d. PINNING in excess of fifteen (15) seconds
e. Foregoing the use of the LOADING BAY rack in a way that appears to be deliberate to a REFEREE (e.g. hiding POWER CELLS or violating H10 multiple times during an event).

The Head REFEREE may assign a YELLOW or RED CARD for a single instance of a rule violation such as the examples given in items a-e above, or for multiple instances of any single rule violation.

Teams should be aware that any rule in this manual could escalate to a YELLOW or RED CARD. The HEAD REFEREE has final authority on all rules and violations at an event

C2. Be a good person. All teams must be civil toward their team members, other team members, competition personnel, FIELD STAFF, and event attendees while at a *FIRST* Robotics Competition event.

Violation: Behavior will be discussed with team or individual. Violations of this rule are likely to escalate to YELLOW or RED CARDS rapidly (i.e. the threshold for egregious violations is relatively low.)

Examples of inappropriate behavior include, but are not limited to, use of offensive language or other uncivil conduct.

Examples of particularly contemptible behavior that is likely to result in ARENA ejection include, but are not limited to, the following:

a. Assault, e.g. throwing something that hits another person (even if unintended)
b. Threat, e.g. saying something like “if you don’t reverse that call, I’ll make you regret it”
c. Harassment, e.g. badgering someone with no new information after a decision’s been made or a question’s been answered

d. Bullying, e.g. using body or verbal language to cause another person to feel inadequate
e. Insulting, e.g. telling someone they don't deserve to be on a drive team
f. Swearing *at* another person (versus swearing under one's breath or at one's self)
g. Yelling at another person(s) in anger or frustration

C3. Asking other teams to throw a MATCH – not cool. A team may not encourage an ALLIANCE, of which it is not a member, to play beneath its ability.

NOTE: This rule is not intended to prevent an ALLIANCE from planning and/or executing its own strategy in a specific MATCH in which all the teams are members of the ALLIANCE.

Violation: Behavior will be discussed with team or individual. Violations of this rule are likely to escalate rapidly to YELLOW or RED CARDS and may lead to dismissal from the event (i.e. the threshold for egregious violations is relatively low.)

Example 1: A MATCH is being played by Teams A, B, and C, in which Team C is encouraged by Team D to not hang on a GENERATOR SWITCH at the end of the MATCH, resulting in Teams A, B, and C not earning a Ranking Point. Team D's motivation for this behavior is to prevent Team A from rising in the Tournament rankings and negatively affecting Team D's ranking. Team D has violated C3.

Example 2: A MATCH is being played by Teams A, B, and C, in which Team A is assigned to participate as a SURROGATE. Team D encourages Team A to not participate in the MATCH so that Team D gains ranking position over Teams B and C. Team D has violated C3.

FIRST® considers the action of a team influencing another team to throw a MATCH, to deliberately miss Ranking Points, etc. incompatible with *FIRST* values and not a strategy any team should employ.

C4. Letting someone coerce you in to throwing a MATCH – also not cool. A team, as the result of encouragement by a team not on their ALLIANCE, may not play beneath its ability.

NOTE: This rule is not intended to prevent an ALLIANCE from planning and/or executing its own strategy in a specific MATCH in which all the ALLIANCE members are participants.

Violation: Behavior will be discussed with team or individual. Violations of this rule are likely to escalate rapidly to YELLOW or RED CARDS and may lead to dismissal from the event (i.e. the threshold for egregious violations is relatively low.)

Example 1: A MATCH is being played by Teams A, B, and C. Team D requests Team C to intentionally position its CONTROL PANEL such that the color isn't correct, resulting in Teams A, B, and C not earning a Ranking Point. Team C accepts this request from Team D. Team D's motivation for this behavior is to prevent Team A from rising in the Tournament rankings negatively affecting Team D's ranking. Team C has violated C4.

Example 2: A MATCH is being played by Teams A, B, and C, in which Team A is assigned to participate as a SURROGATE. Team A accepts Team D's request to not participate in the MATCH so that Team D gains ranking position over Teams B and C. Team A has violated C4.

FIRST considers the action of a team influencing another team to throw a MATCH, to deliberately miss Ranking Points, etc. incompatible with *FIRST* values and not a strategy any team should employ.

C5. Enter only one (1) ROBOT. Each registered *FIRST* Robotics Competition team may enter only one (1) ROBOT (or 'Robot', a ROBOT-like assembly equipped with most of its drive base, i.e. its MAJOR MECHANISM that enables it to move around a FIELD) into a 2020 *FIRST* Robotics Competition Event.

"Entering" a ROBOT (or Robot) into a *FIRST* Robotics Competition means bringing it to or using it at the event such that it's an aid to your team (e.g. for spare parts, judging material, or for practice).

While "most of its drive base" is a subjective assessment, for the purposes of C5, an assembly whose drive base is missing all wheels/treads, gearboxes, and belts/chains is not considered a "Robot." If any of those components are incorporated, the assembly is now considered a "Robot."

This rule does not prohibit teams from bringing in Robots from other *FIRST* programs for the purposes of awards presentations or pit displays.

Violation: Verbal warning. Egregious or repeated violations at any point during the event will be addressed by the Head REFEREE, the Lead ROBOT Inspector and/or Event Management.

C6. Show up to your MATCHES. Upon each team's ROBOT passing initial, complete Inspection, the team must send at least one (1) member of its DRIVE TEAM to the ARENA and participate in each of the team's assigned Qualification and Playoff MATCHES.

Violation: If ROBOT has passed an initial, complete Inspection, RED CARD.

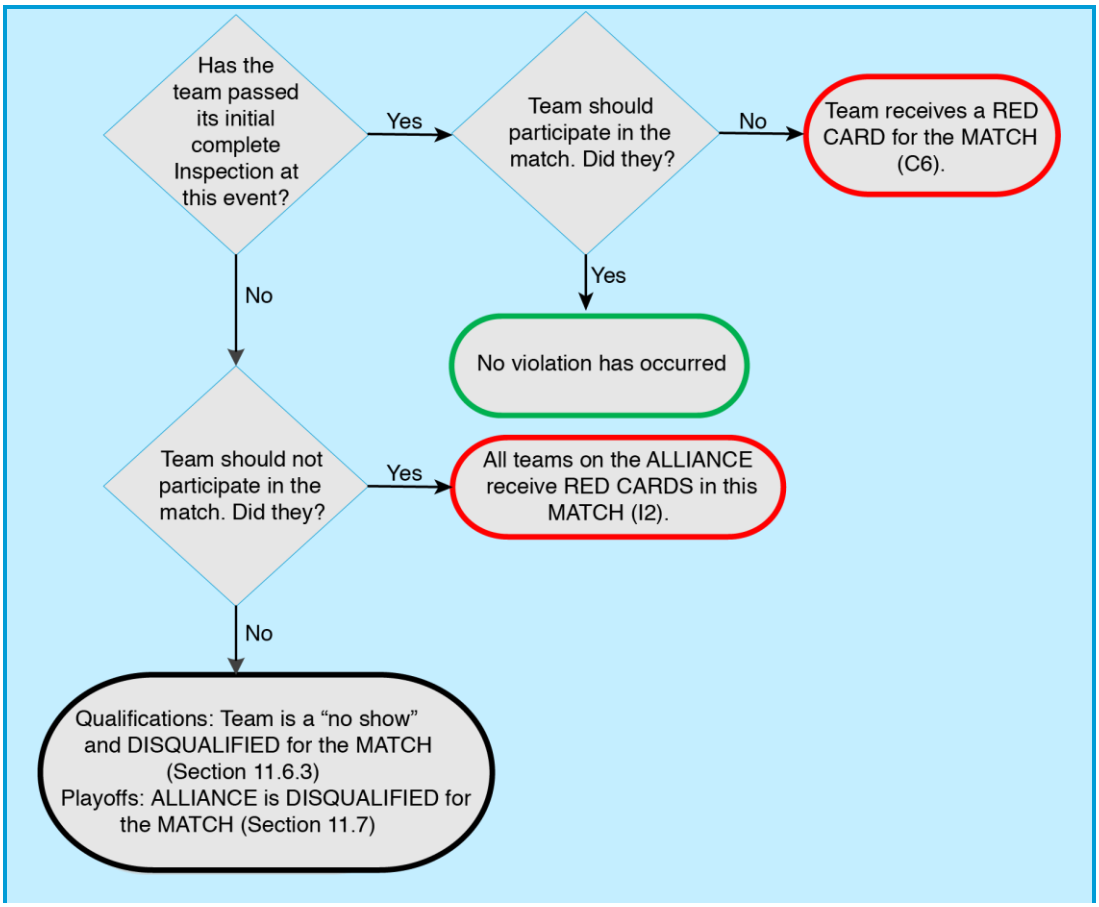


Figure 6-1 MATCH participation flowchart

The team should inform the Lead Queuer if the team's ROBOT is not able to participate.

C7. Be prompt/safe when coming to and going from the FIELD. DRIVE TEAMS may not cause significant or repeated delays during the event to the start of a MATCH, the FIELD reset after a MATCH, or continuation of MATCHES after a TIMEOUT.

Violation: If prior to the MATCH, the offending DRIVE TEAM'S ROBOT will be DISABLED. If after the MATCH, YELLOW CARD.

DRIVE TEAMS are expected to stage their ROBOTS for a MATCH, and remove it from the FIELD afterwards, safely and swiftly. Examples of violations include, but are not limited to:

a. late arrival to the FIELD (including across different MATCHES and after a FIELD or ALLIANCE TIMEOUT)
b. failing to exit the FIELD once a MATCH is ready to begin (indicated by the green LEDs have turned off)
c. installing BUMPERS, charging pneumatic systems, or any other ROBOT maintenance once on the FIELD
d. use of alignment devices that are external to the ROBOT (e.g. a DRIVE TEAM could bring and use a measuring tape, as long as there is no delay to the MATCH by doing so)
e. failing to remove OPERATING CONSOLES from the PLAYER STATIONS in a timely manner

At the conclusion of a TIMEOUT, ROBOTS are expected to be staged on the FIELD prior to the timer displaying zero (0) and ready for the MATCH to start.

C8. Don't expect to gain by doing others harm. Strategies clearly aimed at forcing the opponent ALLIANCE to violate a rule are not in the spirit of *FIRST* Robotics Competition and not allowed. Rule violations forced in this manner will not result in an assignment of a penalty to the targeted ALLIANCE.

Violation: FOUL. If repeated during the MATCH, TECH FOUL.

C8 does not apply for strategies consistent with standard gameplay, for example, a Blue ALLIANCE ROBOT contacts a Red ALLIANCE ROBOT in the Blue ALLIANCE'S LOADING ZONE.

C8 requires an intentional act with limited or no opportunity for the TEAM being acted on to avoid the penalty, such as:

a. a Blue ALLIANCE ROBOT forcing a Red ALLIANCE ROBOT to have greater than momentary CONTROL of five (5) POWER CELLS.
b. a Blue ALLIANCE ROBOT pushing a Red ALLIANCE ROBOT from fully outside the Blue ALLIANCE TRENCH RUN into the Blue ALLIANCE CONTROL PANEL.

C9. One student, one Head REFEREE. A team may only send one (1) pre-college student from its DRIVE TEAM to address the Head REFEREE.

Violation: The Head REFEREE will not address additional, non-compliant team members or peripheral conversations.

Please see REFEREE Interaction for more information about process and expectations.

C10. Plug in to/be in your PLAYER STATION. The OPERATOR CONSOLE must be used in the PLAYER STATION to which the team is assigned, as indicated on the team sign.

Violation: The MATCH will not start until the situation is corrected. If during a MATCH, DISABLED.

One intent of C10 is to prevent unsafe situations where long tethers to OPERATOR CONSOLE devices increase tripping hazards as the operator moves about the ALLIANCE STATION. In the interest of avoiding nuisance penalties associated with an operator stepping outside of a prescribed area, we prefer to offer a general guideline as to what it means to use the OPERATOR CONSOLE in the ALLIANCE STATION. Provided the operator is within close proximity of their PLAYER STATION, there will be no repercussions. However, an operator located more than approximately ½ PLAYER STATION width away from their own PLAYER STATION, is likely violating C10.

7 GAME RULES: ROBOTS

7.1 Before/After the MATCH

G1. Know your ROBOT setup. When placed on the FIELD for a MATCH, each ROBOT must be:

- **A.** in compliance with all ROBOT rules, i.e. has passed Inspection (for exceptions regarding Practice MATCHES, see Inspection & Eligibility Rules),
- **B.** the only team-provided item left on the FIELD by the DRIVE TEAM,
- **C.** confined to its STARTING CONFIGURATION,
- **D.** positioned such that its BUMPERS are intersecting the infinite vertical volume created by the corresponding ALLIANCE'S INITIATION LINE, and
- **E.** fully and solely supporting not more than three (3) POWER CELLS (as described in Setup.)

Violation: If fix is a quick remedy, the MATCH won't start until all requirements are met. If it is not a quick remedy the offending ROBOT will be DISABLED and, at the discretion of the Head REFEREE, must be re-inspected.

> Teams are encouraged to position ROBOTS such that it is clear to REFEREES that G1-D is not violated.
>
> If a ROBOT is BYPASSED prior to the start of the MATCH, the DRIVE TEAM may not remove the ROBOT from the FIELD without permission from the Head REFEREE or the *FIRST* Technical Advisor (FTA).

G2. Teams may not enable their ROBOTS on the FIELD. Teams may not tether to the ROBOT while on the FIELD except in special circumstances (e.g. during TIMEOUTS, after Opening Ceremonies, before an immediate MATCH replay, etc.) and with the express permission from the FTA or a REFEREE.

Violation: YELLOW CARD.

> FMS will not enable ROBOTS after the conclusion of the MATCH.
>
> Tethering includes any wired or wireless connection used to electrically energize and/or control elements on the ROBOT. The safety of teams and volunteers in close proximity to ROBOTS and ARENA elements on the FIELD is of the utmost importance, therefore ROBOTS or ROBOT COMPONENTS may not be enabled in any way on the FIELD once the MATCH has concluded.
>
> ROBOTS need to be safely transported off the FIELD and back to the pits after the MATCH, and there may be bystanders, doorways or height restrictions along the route.

7.2 During the MATCH

7.2.1 During AUTO Only

G3. During AUTO, no defense. During AUTO, a ROBOT's BUMPERS may not break the plane of their ALLIANCE's SECTOR (see Figure 3-3.)

Violation: FOUL. If contact with an opponent ROBOT, either directly or transitively through another ROBOT or POWER CELL, TECH FOUL per instance.

G4. During AUTO, behind the lines. During AUTO, DRIVE TEAM members in ALLIANCE STATIONS may not contact anything in front of the STARTING LINES, unless for personal or equipment safety.

Violation: FOUL per item contacted.

> Pointing, gesturing, or otherwise extending across the STARTING LINE such that contact is not made with carpet or other ARENA elements is not a violation of this rule.
>
> One example of an exception for equipment safety is if an OPERATOR CONSOLE starts to slide from, or has already fallen off of, the PLAYER STATION shelf. In that circumstance, DRIVE TEAM members may step forward to catch or pick it up off the ground and return it to the shelf.

G5. During AUTO, let the ROBOT do its thing. During AUTO, DRIVE TEAMS may not directly or indirectly interact with ROBOTS or OPERATOR CONSOLES unless for personal safety, OPERATOR CONSOLE safety, or pressing an E-Stop.

Violation: FOUL and YELLOW CARD

7.2.2 POWER CELL Interaction

G6. No more than five (5) POWER CELLS at a time. ROBOTS may not have greater-than-momentary CONTROL of more than five (5) POWER CELLS at a time, either directly or transitively through other objects.

A ROBOT is in CONTROL of a POWER CELL if:

A. the POWER CELL is fully supported by the ROBOT,

B. the POWER CELL travels across the FIELD such that when the ROBOT changes direction, the POWER CELL travels with the ROBOT, or

C. the ROBOT is holding a POWER CELL against a FIELD element in attempt to guard or shield it.

Violation: FOUL per additional POWER CELL. If egregious, YELLOW CARD.

> Egregious examples include, but are not limited to:
>
> a. CONTROLLING ten (10) POWER CELLS
> b. Repeatedly moving more than five (5) POWER CELLS across one half of the FIELD to the other.

G7. Keep POWER CELLS in bounds. ROBOTS may not intentionally eject POWER CELLS from the FIELD other than through the POWER PORT.

Violation: FOUL per POWER CELL.

G8. POWER CELLS: use as directed. ROBOTS may not deliberately use POWER CELLS in an attempt to ease or amplify the challenge associated with FIELD elements.

Violation: TECH FOUL per POWER CELL.

> Examples include, but are not limited to:
>
> a. shooting POWER CELLS at HANGING ROBOTS
> b. pushing/placing POWER CELLS into the opponent's TRENCH to make it harder to pass through it

c. placing/shooting POWER CELLS onto the opponent's CONTROL PANEL

7.2.3 Zone Specific Restrictions

G9. No full court shots. A ROBOT whose BUMPERS are fully contained by their SECTOR may not cause POWER CELLS to travel into or through their opponent's SECTOR.

Violation: TECH FOUL per POWER CELL.

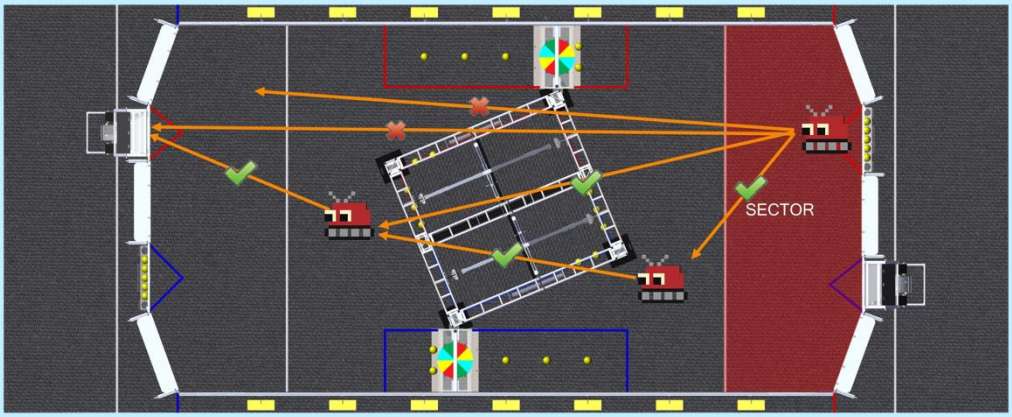


Figure 7-1 POWER CELL movement limitations

REFEREES are not expected to track the movement of POWER CELLS throughout the MATCH. Teams are encouraged to launch POWER CELLS such that it is clear to REFEREES that G9 is not violated.

For the purposes of G9, "travel" means "to move through the air, bounce across the floor, or roll." A POWER CELL is no longer "travelling" once it stops, contacts an opponent ROBOT, or is CONTROLLED by a ROBOT on their ALLIANCE. The cause (i.e. responsibility for) a POWER CELL "travelling" may transfer from ROBOT to ROBOT as assessed by the REFEREE.

G10. Right of Way. A ROBOT whose BUMPERS are intersecting the opponent's TARGET ZONE, TRENCH RUN, or LOADING ZONE may not contact opponent ROBOTS, regardless of who initiates contact.

Violation: TECH FOUL per instance.

The initiator of the contact is not a factor when determining violations of this rule.

Teams should take note that they are putting themselves at great risk for TECH FOULS if they choose to enter their opponent's TARGET ZONE, TRENCH RUN or LOADING ZONE.

G11. Give Opponents some space. An opponent ROBOT may not contact a ROBOT whose BUMPERS are intersecting its TARGET ZONE or LOADING ZONE, regardless of who initiates contact. ROBOTS in violation of G10 are exempt from this rule.

Violation: TECH FOUL per instance.

The initiator of the contact is not a factor when determining violations of this rule.

Teams should take note that they are putting themselves at great risk for TECH FOULS if they choose to approach an opponent ROBOT intersecting its TARGET ZONE or LOADING ZONE.

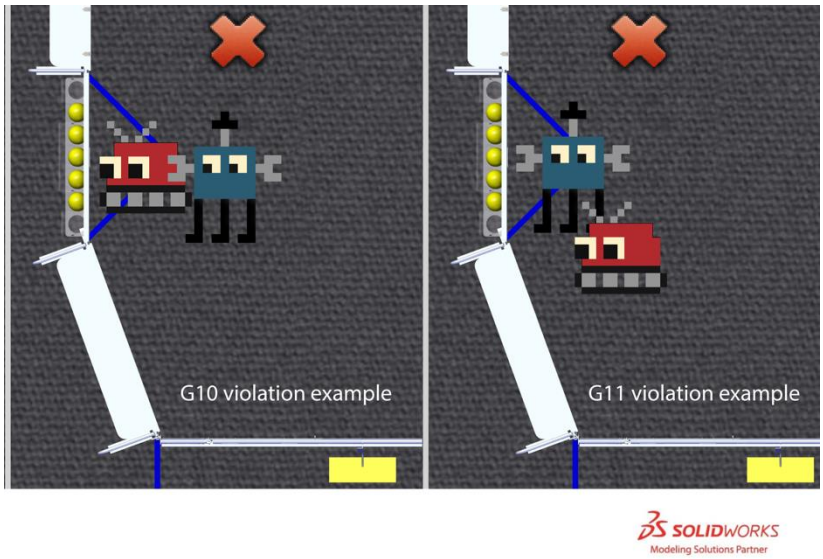


Figure 7-2 G10 and G11 examples

G12. Leave the opponent's CONTROL PANEL alone. A ROBOT may not contact the opponent's CONTROL PANEL, either directly, or transitively through a POWER CELL, if

A. the opponent ROBOT is contacting that CONTROL PANEL, and
B. the opponent's POWER PORT has reached CAPACITY

Violation: In Qualifications MATCHES, opponents are awarded one (1) SHIELD GENERATOR ENERGIZED Ranking Point if not completed at the conclusion of the MATCH. In Playoff MATCHES, TECH FOUL.

G13. Don't climb on each other unless at the RENDEZVOUS POINT. A ROBOT may not be fully supported by a partner ROBOT unless the partner ROBOT'S BUMPERS are intersecting its RENDEZVOUS POINT.

Violation: TECH FOUL per instance.

G14. During the ENDGAME, don't touch ROBOTS in their RENDEZVOUS POINT. During the ENDGAME, a ROBOT may not contact, either directly or transitively through a POWER CELL, an opponent ROBOT whose BUMPERS are completely contained in its RENDEZVOUS POINT and not in contact with its GENERATOR SWITCH.

Violation: TECH FOUL

The initiator of the contact is not a factor when determining violations of this rule.

Teams are encouraged to consider rule C8 when developing their strategies, such as attempting to draw violations of this rule.

G15. During the ENDGAME, don't mess with HANGING opponents. During the ENDGAME, a ROBOT may not contact, either directly or transitively through a POWER CELL, an opponent's ROBOT that is contacting its GENERATOR SWITCH and not in their opponent's RENDEZVOUS POINT.

Violation: The contacted opponent ROBOT, and any partners its supporting, will be considered HANGING, and the opponent's GENERATOR SWITCH will be considered LEVEL.

The initiator of the contact is not a factor when determining violations of this rule.

Teams are encouraged to consider rule C8 when developing their strategies, such as attempting to draw violations of this rule.

For example, during the ENDGAME, a Blue ALLIANCE ROBOT is in violation of G15 if it is contacting a Red ALLIANCE ROBOT that is both fully contained within the Red ALLIANCE'S RENDEZVOUS POINT and HANGING from the Red ALLIANCE GENERATOR SWITCH.

G15-A. During the ENDGAME, don't mess with the opponent's GENERATOR SWITCH. During the ENDGAME, a ROBOT may not contact, either directly or transitively through a POWER CELL, the opponent's GENERATOR SWITCH.

Violation: Any opponent ROBOTS contacting their GENERATOR SWITCH when the violation occurred, and any partners its supporting, will be considered HANGING, and the opponent's GENERATOR SWITCH will be considered LEVEL.

7.2.4 ROBOT Restrictions

G16. Keep your BUMPERS low. BUMPERS must be in the BUMPER ZONE (see R18) during the MATCH, unless during the ENDGAME and

- **A.** a ROBOT's BUMPERS are intersecting its RENDEZVOUS POINT or
- **B.** a ROBOT is supported by a partner ROBOT whose BUMPERS are intersecting its RENDEZVOUS POINT.

Violation: FOUL. If strategic, RED CARD.

An example of a strategic violation of G16 includes, but is not limited to, hitting other ROBOTS with the ROBOT frame.

G17. Tall ROBOTS not allowed. ROBOT height, as measured when it's resting normally on a flat floor, may not exceed 45 in. (~114 cm) above the carpet during the MATCH, with the exception of ROBOTS intersecting their ALLIANCE'S RENDEZVOUS POINT during the ENDGAME.

Violation: TECH FOUL. If the extension blocks a goal, blocks an opponent's shot, or scores a goal, additional TECH FOUL per instance.

This measurement is intended to be made as if the ROBOT is resting on a flat floor, not relative to the height of the ROBOT from the FIELD carpet.

For example, a ROBOT that is at an angle while traversing a BOUNDARY may actually exceed the height limit when compared to the carpet of the FIELD.

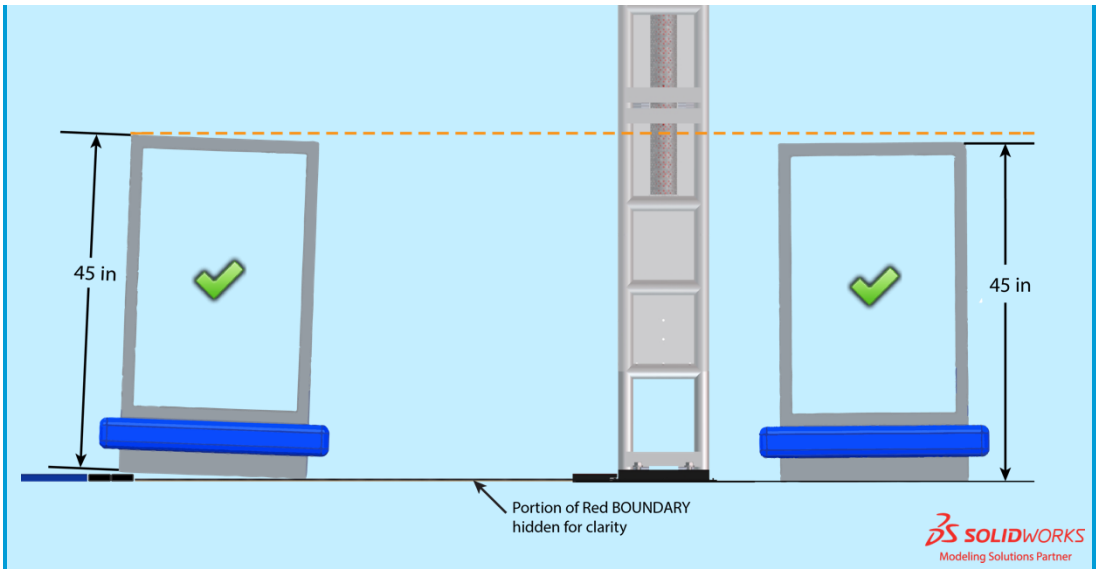


Figure 7-3 G17 Example

G18. Don't overextend yourself. ROBOTS may not extend more than 12 inches (~30 cm) beyond their FRAME PERIMETER.

Violation: FOUL. If egregious, RED CARD.

Examples of compliance and non-compliance of G18 are shown in Figure 7-3.

Yellow bars represent the limits of the FRAME PERIMETER and are drawn in the same orientation of the ROBOT'S FRAME PERIMETER. Green bars represent a measured extension from the FRAME PERIMETER that does not violate G18. Red bars represent a measured extension from the FRAME PERIMETER that exceeds the limit in G18). ROBOTS A and C violate G18, whereas ROBOT B does not.

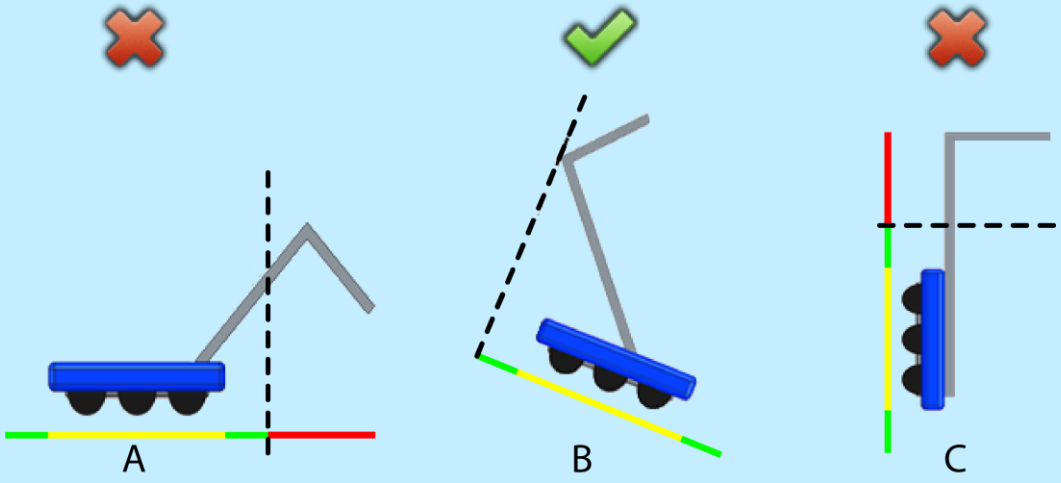


Figure 7-4 Examples of G18 compliance and non-compliance

Egregious examples of G18 violations include:

a. extending more than 12 inches (~30 cm) beyond the FRAME PERIMETER to score a POWER CELL
b. extending more than 12 inches (~30 cm) beyond the FRAME PERIMETER to score a HANG

c. expanding to block opponent access to a FIELD element, e.g. GENERATOR SWITCH or POWER PORT.
d. expanding into the BOTTOM PORT to disrupt the scoring mechanism

G19. Keep it together. ROBOTS may not intentionally detach or leave parts on the FIELD.

Violation: RED CARD.

G20. Keep your BUMPERS together. BUMPERS may not fail such that a segment completely detaches, any side of a ROBOT's FRAME PERIMETER is exposed, or the team number or ALLIANCE color are indeterminate.

Violation: DISABLED.

7.2.5 ROBOT to ROBOT Interaction

G21. There's a 5-count on pins. ROBOTS may not PIN an opponent's ROBOT for more than five (5) seconds. A ROBOT is PINNING if it is preventing the movement of an opponent ROBOT by contact, either direct or transitive (such as against a FIELD element). A ROBOT is considered PINNED until the ROBOTS have separated by at least six feet from each other or either ROBOT has moved six feet from where the PIN initiated, whichever comes first. The PINNING ROBOT(S) must then wait for at least three (3) seconds before attempting to PIN the same ROBOT again.

Violation: FOUL, plus an additional TECH FOUL for every five (5) seconds in which the situation is not corrected.

A Team's desired direction of travel is not a consideration when determining if a ROBOT is PINNED.

G22. Don't collude with your partners to shut down major parts of game play. Two or more ROBOTS that appear to a REFEREE to be working together may not isolate or close off any major component of MATCH play.

Violation: TECH FOUL, plus an additional TECH FOUL for every five (5) seconds in which the situation is not corrected.

Examples of violations of this rule include but are not limited to:

a. blocking an opponent's TRENCH
b. blocking all the opponent LOADING BAY Chutes
c. blocking the opponent BOTTOM PORT
d. shutting down access to all POWER CELLS
e. quarantining all opponents to a small area of the FIELD

A single ROBOT blocking access to a particular area of the FIELD is not a violation of this rule.

Two ROBOTS independently playing defense on two opponent ROBOTS is not a violation of this rule.

G23. Don't tear others down to lift yourself up. ROBOT actions that appear to be deliberate to a REFEREE and that cause damage or inhibition via attaching, tipping, or entangling to an opponent ROBOT are not allowed.

Violation: TECH FOUL and YELLOW CARD. If harm or incapacitation occurs as a result of the strategy, RED CARD.

MECHANISMS outside the FRAME PERIMETER are particularly susceptible to causing damage, drawing this penalty and/or drawing penalties associated with violations of G24 and G25. Teams are encouraged to be cautious of their use of such MECHANISMS when engaging in ROBOT to ROBOT MATCH play.

Examples of violations of this rule include, but are not limited to:

a. using a wedge-like mechanism to tip opponent ROBOTS
b. making BUMPER-to-BUMPER contact with an opponent ROBOT that is attempting to right itself after previously falling over and causing them to fall over again

G24. Stay out of other ROBOTS. A ROBOT with a COMPONENT(S) outside its FRAME PERIMETER, other than BUMPERS, may not initiate direct contact with an opponent ROBOT inside the vertical projection of its FRAME PERIMETER using that COMPONENT.

Violation: FOUL per contact.

For the purposes of G24 “initiate direct contact” requires movement towards an opponent ROBOT.

In a collision, it’s possible for both ROBOTS to initiate direct contact.

G25. Damaging other ROBOTS, not allowed. Regardless of intent, a ROBOT may not initiate direct contact inside the vertical projection of an opponent ROBOT’S FRAME PERIMETER that damages or functionally impairs the opponent ROBOT.

ROBOTS with BUMPER gaps are at their own risk regarding damaging contact in these areas by ROBOTS that remain completely inside their own FRAME PERIMETER, as they are not in violation of this rule.

Violation: TECH FOUL and YELLOW CARD

Some examples of violations of this rule include, but are not limited to:

a. an extension damages a COMPONENT inside an opponent ROBOT’s FRAME PERIMETER
b. an extension powers off an opponent’s ROBOT
c. an extension relieves an opponent’s ROBOT’s air pressure.
d. a ROBOT that unintentionally extends outside its FRAME PERIMETER while tipping and damages a COMPONENT inside an opponent ROBOT’s FRAME PERIMETER

At the conclusion of the MATCH, the HEAD REFEREE may elect to visually inspect a ROBOT to confirm violations of G25 made during a MATCH and remove the violation if the damage cannot be verified.

For the purposes of G25, “initiate direct contact” requires movement towards an opponent ROBOT.

In a collision, it’s possible for both ROBOTS to initiate direct contact.

7.2.6 FIELD Interaction

G26. Be careful what you interact with. ROBOTS and OPERATOR CONSOLES are prohibited from the following actions with regards to interaction with ARENA elements. Items A – C exclude POWER CELLS, HANDLE, and the ALLIANCE’S CONTROL PANEL. Item G excludes the HANDLE.

A. Grabbing
B. Grasping

C. Attaching (including the use of a vacuum or hook tape to anchor to the FIELD carpet and excluding use of the PLAYER STATION hook-and-loop tape, plugging in to the provided power outlet, and plugging the provided Ethernet cable into the OPERATOR CONSOLE)
D. Deforming
E. Becoming Entangled
F. Damaging
G. Suspending from

Violation: MATCH will not start until the situation is corrected. If during a MATCH, TECH FOUL. If during a MATCH and longer than momentary or repeated, YELLOW CARD. If offense is via a ROBOT and the Head REFEREE determines that further damage is likely to occur, offending ROBOT will be DISABLED. Corrective action (such as eliminating sharp edges, removing the damaging MECHANISM, and/or re-Inspection) may be required before the ROBOT will be allowed to compete in subsequent MATCHES.

POWER CELLS are expected to undergo a reasonable amount of wear and tear as they are handled by ROBOTS, such as scratching or marking. Gouging, tearing off pieces, or routinely marking POWER CELLS are violations of this rule.

8 GAME RULES: HUMANS

8.1 Before the MATCH

H1. You can't bring/use anything you want. The only equipment that may be brought to the ARENA and used by DRIVE TEAMS during a MATCH is listed below. Regardless if equipment fits criteria below, it may not be employed in a way that breaks any other rules, introduces a safety hazard, blocks visibility for FIELD STAFF or audience members, or jams or interferes with the remote sensing capabilities of another team or the FIELD.

- **A.** the OPERATOR CONSOLE,
- **B.** non-powered signaling devices,
- **C.** reasonable decorative items,
- **D.** special clothing and/or equipment required due to a disability,
- **E.** devices used solely for planning or tracking strategy,
- **F.** devices used solely to record gameplay,
- **G.** non-powered Personal Protective Equipment (examples include, but aren't limited to, gloves, eye protection, and hearing protection)

Items brought to the ARENA under allowances B-G must meet all of the following conditions:

- **i.** do not connect or attach to the OPERATOR CONSOLE, FIELD, or ARENA
- **ii.** do not connect or attach to another ALLIANCE member (other than items in category G)
- **iii.** do not communicate with anything or anyone outside of the ARENA
- **iv.** do not communicate with the TECHNICIAN
- **v.** do not include any form of enabled wireless electronic communication
- **vi.** do not in any way affect the outcome of a MATCH, other than by allowing the DRIVE TEAM to
  a. plan or track strategy for the purposes of communication of that strategy to other ALLIANCE members or
  b. use items allowed per part B to communicate with the ROBOT.

Violation: MATCH will not start until situation remedied. If discovered or used inappropriately during a MATCH, YELLOW CARD.

Examples of equipment that may be considered a safety hazard in the confined space of the ALLIANCE STATION include, but are not limited to, a step stool or a large signaling device.

Examples of remote sensing capabilities include, but are not limited to, vision systems, acoustic range finders, sonars, and infrared proximity sensors.

Use of imagery that, to a reasonably astute observer, mimics the Vision Targets employed on the FIELD is a violation of H1.

Examples of wireless communication include, but are not limited to, radios, walkie-talkies, cell phones, Bluetooth communications, and Wi-Fi.)

H2. Know your DRIVE TEAM positions. Prior to the start of the MATCH, DRIVE TEAMS and any control devices worn or held by HUMAN PLAYERS and/or DRIVERS must be positioned as follows:

- **A.** HUMAN PLAYERS, DRIVERS, and COACHES in their ALLIANCE STATION,

B. TECHNICIANS in the designated area outside the ALLIANCE STATION
C. not in contact with the OPERATOR CONSOLE

Violation: MATCH won't start until situation is corrected.

For the purposes of *FIRST* Robotics Competition, any device connected to the OPERATOR CONSOLE is considered a control device because REFEREES are not expected to differentiate between devices that can or cannot control the ROBOT.

H3. Leave the POWER CELLS alone. Prior to the start of the MATCH, DRIVE TEAMS may not rearrange the POWER CELLS within the ALLIANCE STATION or staged on the FIELD (that are not staged inside a ROBOT).

Violation: MATCH will not start until the situation is corrected.

8.1.1 During the MATCH

H4. COACHES and other teams: hands off the controls. A ROBOT shall be operated only by the DRIVERS and/or HUMAN PLAYERS of that team.

Violation: DISABLED.

Exceptions may be made before a MATCH for major conflicts, e.g. religious holidays, major testing, transportations issues, etc.

H5. No wandering. During the MATCH, DRIVERS, COACHES, and HUMAN PLAYERS may not contact anything outside the ALLIANCE STATION and TECHNICIANS may not contact anything outside their designated area. Exceptions are granted in cases concerning safety and for actions that are inadvertent, momentary, and inconsequential.

Violation: FOUL per instance.

H6. POWER CELLS through LOADING BAYS only. POWER CELLS may only be introduced to the FIELD

A. during TELEOP,
B. by a DRIVER or HUMAN PLAYER, and
C. through the LOADING BAY.

Violation: FOUL per POWER CELL.

H7. COACHES, no POWER CELLS. During a MATCH, COACHES may not touch POWER CELLS, unless for safety purposes.

Violation: FOUL per POWER CELL.

H8. Don't trick the sensors. Teams may not interfere with any automated scoring hardware.

Violation: RED CARD for the ALLIANCE.

H9. POWER CELLS, recycle. During TELEOP, an ALLIANCE may not have more than fifteen (15) POWER CELLS in their ALLIANCE STATION.

Violation: FOUL per POWER CELL.

If the POWER CELL count exceeds fifteen (15), excess POWER CELLS must be introduced into the FIELD immediately.

As soon as a sixteenth POWER CELL arrives in the ALLIANCE STATION, the ALLIANCE should be making a concerted good will effort to enter any extra POWER CELLS back on to the FIELD as quickly and as safely as possible.

There is no intent to issue penalties for delays due to DRIVERS or HUMAN PLAYERS having to move around their ALLIANCE partners while attempting to clear surplus POWER CELLS or because TELEOP began with more than fifteen (15) POWER CELLS in the ALLIANCE STATION due to scoring by opponents during AUTO. However, if a team is perceived as lagging in the judgement of a REFEREE, they will be issued a penalty.

It is the HUMAN PLAYERS' responsibility to be aware of their surroundings.

H10. POWER CELLS go on the rack. POWER CELLS must be stored on the LOADING BAY racks. An ALLIANCE making a concerted, good-will effort to transport POWER CELLS from the CORRAL to a rack or Chute is not in violation of this rule.

VIOLATION: FOUL. If repeated, TECH FOUL.

The LOADING BAY rack holds fourteen (14) POWER CELLS and enables teams and REFEREES to count POWER CELLS in an ALLIANCE STATION. An ALLIANCE holding the fifteenth POWER CELL is not in violation of H10.

H10 means that POWER CELLS may neither be stored in the CORRAL during the MATCH nor are they required to contact the LOADING BAY rack before entering the FIELD.

As G4 prohibits using the rack during AUTO, an ALLIANCE that removes POWER CELLS from the CORRAL during AUTO and waits to place them on the rack until the start of TELEOP is making a "concerted good-will effort."

Teams are encouraged to make it clear to REFEREES that H10 is not violated.

8.2 In the ARENA

H11. By invitation only. Only DRIVE TEAMS for the current MATCH are allowed in their respective ALLIANCE STATIONS.

Violation: MATCH will not start until the situation is corrected.

H12. Identify yourself. DRIVE TEAMS must wear proper identification while in the ARENA. Proper identification consists of:

- **A.** All DRIVE TEAM members wearing their designated buttons above the waist in a clear visible location at all times while in the ARENA.
- **B.** The COACH wearing the "COACH" button
- **C.** The DRIVERS and HUMAN PLAYERS each wearing a "DRIVE TEAM" button
- **D.** The TECHNICIAN wearing the "TECHNICIAN" button
- **E.** During a Playoff MATCH, the ALLIANCE CAPTAIN clearly displaying the designated ALLIANCE CAPTAIN identifier (e.g. hat or armband).

Violation: MATCH will not start until the situation is corrected. Those not displaying identification must leave the ARENA.

H13. Don't abuse ARENA access. Team members (except DRIVERS, HUMAN PLAYERS, and COACHES) who are granted access to restricted areas in and around the ARENA (e.g. via

TECHNICIAN button, event issued Media badges, etc.) may not coach or use signaling devices during the MATCH. Exceptions will be granted for inconsequential infractions and in cases concerning safety.

Violation: YELLOW CARD.

The TECHNICIAN'S role is to help the team prepare the ROBOT so it can perform at its full potential during a MATCH. The TECHNICIAN is not an additional COACH, DRIVER, or HUMAN PLAYER.

Team members in open-access spectator seating areas are not considered to be in a restricted area and are not prevented from coaching or using signaling devices. See E2 for related details.

H14. Don't mess with POWER CELLS. Teams may not modify POWER CELLS in any way. Temporary deformation to pre-load a ROBOT is an exception to this rule.

Violation: RED CARD.

Marking, cutting or standing on POWER CELLS are examples of violations.

H15. Don't bang on the glass. Team members may never strike or hit the PLAYER STATION plastic windows.

Violation: Verbal warning. If subsequent violations in more than one MATCH, YELLOW CARD.

H16. Be careful what you interact with. DRIVE TEAMS are prohibited from the following actions with regards to interaction with ARENA elements.

- **A.** Climbing
- **B.** Hanging
- **C.** Deforming
- **D.** Damaging

Violation: MATCH will not start until situation is corrected. If during a MATCH, TECH FOUL.

9 ROBOT CONSTRUCTION RULES

This section of the 2020 *FIRST*® Robotics Competition Game Manual presents rules relevant to the construction of a 2020 *FIRST* Robotics Competition ROBOT. ROBOTS must pass Inspection at each *FIRST* Robotics Competition event to confirm compliance before being allowed to compete in a Qualification or Playoff MATCH, per Inspection & Eligibility Rules.

9.1 Overview

The rules listed below explicitly address legal parts and materials and how those parts and materials may be used on a 2020 ROBOT. A ROBOT is an electromechanical assembly built by the *FIRST* Robotics Competition team to play the current season's game and includes all the basic systems required to be an active participant in the game –power, communications, control, BUMPERS, and movement about the field.

There are many reasons for the structure of the rules, including safety, reliability, parity, creation of a reasonable design challenge, adherence to professional standards, impact on the competition, and compatibility with the Kit of Parts (KOP). The KOP is the collection of items listed on the current season's Kickoff Kit Checklists, distributed to the team via *FIRST* Choice in the current season, or paid for completely (except shipping) with a Product Donation Voucher (PDV) from the current season.

Another intent of these rules is to have all energy sources and active actuation systems on the ROBOT (e.g. batteries, compressors, motors, servos, cylinders, and their controllers) drawn from a well-defined set of options. This is to ensure that all teams have access to the same actuation resources and that the Inspectors are able to accurately and efficiently assess the legality of a given part.

ROBOTS are made up of COMPONENTS and MECHANISMS. A COMPONENT is any part in its most basic configuration, which cannot be disassembled without damaging or destroying the part or altering its fundamental function. A MECHANISM is a COTS or custom assembly of COMPONENTS that provide specific functionality on the ROBOT. A MECHANISM can be disassembled (and then reassembled) into individual COMPONENTS without damage to the parts.

Many rules in this section reference Commercial-Off-The-Shelf (COTS) items. A COTS item must be a standard (i.e. not custom order) part commonly available from a VENDOR for all teams for purchase. To be a COTS item, the COMPONENT or MECHANISM must be in an unaltered, unmodified state (with the exception of installation or modification of any software). Items that are no longer commercially available but are functionally equivalent to the original condition as delivered from the VENDOR are considered COTS and may be used.

> Example 1: A team orders two (2) ROBOT grippers from RoboHands Corp. and receives both items. They put one in their storeroom and plan to use it later. Into the other, they drill "lightening holes" to reduce weight. The first gripper is still classified as a COTS item, but the second gripper is now a FABRICATED ITEM, as it has been modified.
>
> Example 2: A team obtains openly available blueprints of a drive module commonly available from Wheels-R-Us Inc. and has local machine shop "We-Make-It, Inc." manufacture a copy of the part for them. The produced part is NOT a COTS item, because it is not commonly carried as part of the standard stock of We-Make-It, Inc.

Example 3: A team obtains openly available design drawings from a professional publication during the pre-season, and uses them to fabricate a gearbox for their ROBOT during the build period following Kickoff. The design drawings are considered a COTS item, and may be used as "raw material" to fabricate the gearbox. The finished gearbox itself would be a FABRICATED ITEM, and not a COTS item.

Example 4: A COTS part that has non-functional label markings added would still be considered a COTS part, but a COTS part that has device-specific mounting holes added is a FABRICATED ITEM.

Example 5: A team has a COTS single-board processor version 1.0, which can no longer be purchased. Only the COTS single-board processor version 2.0 may be purchased. If the COTS single-board processor version 1.0 is functionally equivalent to its original condition, it may be used.

Example 6: A team has a COTS gearbox which has been discontinued. If the COTS gearbox is functionally equivalent to its original condition, it may be used.

A VENDOR is a legitimate business source for COTS items that satisfies all the following criteria:

- **A.** has a Federal Tax Identification number. In cases where the VENDOR is outside of the United States, they must possess an equivalent form of registration or license with the government of their home nation that establishes and validates their status as a legitimate business licensed to operate within that country.
- **B.** is not a "wholly owned subsidiary" of a *FIRST* Robotics Competition team or collection of teams. While there may be some individuals affiliated with both a team and the VENDOR, the business and activities of the team and VENDOR must be completely separable.
- **C.** must be able to ship any general (i.e., non-*FIRST* unique) product within five business days of receiving a valid purchase request. It is recognized that certain unusual circumstances (such as 1,000 *FIRST* teams all ordering the same part at once from the same VENDOR) may cause atypical delays in shipping due to backorders for even the largest VENDORS. Such delays due to higher-than-normal order rates are excused.
- **D.** should maintain sufficient stock or production capability to fill teams' orders within a reasonable period during the season (less than 1 week). (Note that this criterion may not apply to custom-built items from a source that is both a VENDOR and a fabricator. For example, a VENDOR may sell flexible belting that the team wishes to procure to use as treads on their drive system. The VENDOR cuts the belting to a custom length from standard shelf stock that is typically available, welds it into a loop to make a tread, and ships it to a team. The fabrication of the tread takes the VENDOR two weeks. This would be considered a FABRICATED ITEM, and the two-week ship time is acceptable.) Alternately, the team may decide to fabricate the treads themselves. To satisfy this criterion, the VENDOR would just have to ship a length of belting from shelf stock (i.e. a COTS item) to the team within five business days and leave the welding of the cuts to the team.
- **E.** makes their products available to all *FIRST* Robotics Competition teams. A VENDOR must not limit supply or make a product available to just a limited number of *FIRST* Robotics Competition teams.

The intent of this definition it to be as inclusive as possible to permit access to all legitimate sources, while preventing ad hoc organizations from providing special-purpose products to a limited subset of teams in an attempt to circumvent the cost accounting rules.

> *FIRST* desires to permit teams to have the broadest choice of legitimate sources possible, and to obtain COTS items from the sources that provide them with the best prices and level of service available. Teams also need to protect against long delays in availability of parts that will impact their ability to complete their ROBOT. The build season is brief, so the VENDOR must be able to get their product, particularly *FIRST* unique items, to a team in a timely manner.
>
> Ideally, chosen VENDORS should have national distributors (e.g. Home Depot, Lowes, MSC, McMaster-Carr, etc.). Remember, *FIRST* Robotics Competition events are not always near home – when parts fail, local access to replacement materials is often critical.

A FABRICATED ITEM is any COMPONENT or MECHANISM that has been altered, built, cast, constructed, concocted, created, cut, heat treated, machined, manufactured, modified, painted, produced, surface coated, or conjured partially or completely into the final form in which it will be used on the ROBOT.

> Note that it is possible for an item (typically raw materials) to be neither COTS nor a FABRICATED ITEM. For example, a 20 ft. (~610 cm) length of aluminum which has been cut into 5 ft. (~152 cm) pieces by the team for storage or transport is neither COTS (it's not in the state received from the VENDOR), nor a FABRICATED ITEM (the cuts were not made to advance the part towards its final form on the ROBOT).

Teams may be asked to provide documentation proving legality of non-2020 KOP items during Inspection where a Rule specifies limits for a legal part (e.g. pneumatic items, current limits, COTS electronics, etc.).

Some of these rules make use of English unit requirements for parts. If your team has a question about a metric-equivalent part's legality, please e-mail your question to frcparts@firstinspires.org for an official ruling. To seek approval for alternate devices for inclusion in future *FIRST* Robotic Competition seasons, please contact frcparts@firstinspires.org with item specifications.

Teams should acknowledge the support provided by the corporate Sponsors and Mentors with an appropriate display of their school and Sponsors names and/or logos (or the name of the supporting youth organization, if appropriate).

FIRST Robotics Competition can be a full-contact competition and may include rigorous game play. While the rules aim to limit severe damage to ROBOTS, teams should design their ROBOTS to be robust.

9.2 General ROBOT Design

R1. The ROBOT (excluding BUMPERS) must have a FRAME PERIMETER, contained within the BUMPER ZONE and established while in the ROBOT'S STARTING CONFIGURATION, that is comprised of fixed, non-articulated structural elements of the ROBOT. Minor protrusions no greater than ¼ in. (~6 mm) such as bolt heads, fastener ends, weld beads, and rivets are not considered part of the FRAME PERIMETER.

> To determine the FRAME PERIMETER, wrap a piece of string around the ROBOT (excluding BUMPERS) at the BUMPER ZONE described in R18 and pull it taut. The string outlines the FRAME PERIMETER.
>
> Example: A ROBOT'S chassis is shaped like the letter 'V', with a large gap between chassis elements on the front of the ROBOT. When wrapping a taut string around this chassis, the string extends across the gap and the resulting FRAME PERIMETER is a triangle with three sides.

R2. In the STARTING CONFIGURATION (the physical configuration in which a ROBOT starts a MATCH), no part of the ROBOT shall extend outside the vertical projection of the FRAME PERIMETER, with the exception of its BUMPERS and minor protrusions such as bolt heads, fastener ends, rivets, cable ties, etc.

> If a ROBOT is designed as intended and each side is pushed up against a vertical wall (in STARTING CONFIGURATION and with BUMPERS removed), only the FRAME PERIMETER (or minor protrusions) will be in contact with the wall.
>
> The allowance for minor protrusions in R2 is intended to allow protrusions that are both minor in extension from the FRAME PERIMETER and cross sectional area.
>
> If a ROBOT uses interchangeable MECHANISMS per I3, Teams should be prepared to show compliance with R2 and R4 in all configurations.

R3. A ROBOT'S STARTING CONFIGURATION may not have a FRAME PERIMETER greater than 120 in. (~304 cm) and may not be more than 45 in. (~114 cm) tall.

> Be sure to consider the size of the ROBOT on its cart to make sure it will fit through doors. Also consider the size of the ROBOT to ensure that it will fit into a shipping crate, vehicle, etc.
>
> Note that the BUMPER Rules contained in BUMPER Rules may impose additional restrictions on ROBOT design

R4. ROBOTS may not extend more than 12 in. (~30 cm) beyond their FRAME PERIMETER (see Figure 9-1)

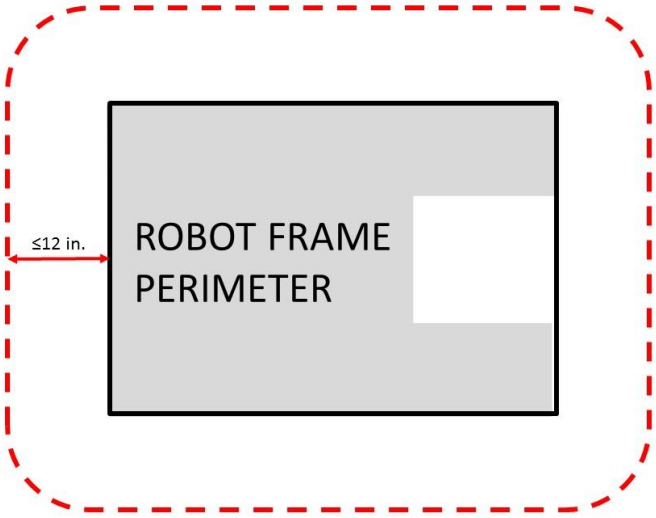


Figure 9-1 FRAME PERIMETER extension

> Expect to have to demonstrate a ROBOT'S ability to constrain itself per above during Inspection. Constraints may be implemented with either hardware or software.
>
> See Game Rules: ROBOTS for height and extension restrictions for various areas of the FIELD.

R5. The ROBOT weight must not exceed 125 lbs. (~56 kg). When determining weight, the basic ROBOT structure and all elements of all additional MECHANISMS that might be used in a single configuration of the ROBOT shall be weighed together (see I3).

For the purposes of determining compliance with the weight limitations, the following items are excluded:

- **A.** ROBOT BUMPERS
- **B.** ROBOT battery and its associated half of the Anderson cable quick connect/disconnect pair (including no more than 12 in. (~30 cm) of cable per leg, the associated cable lugs, connecting bolts, and insulation)
- **C.** tags used for location detection systems if provided by the event

9.3 ROBOT Safety & Damage Prevention

R6. Traction devices must not have surface features that could damage the ARENA (e.g. metal, sandpaper, hard plastic studs, cleats, hook-loop fasteners or similar attachments). Traction devices include all parts of the ROBOT that are designed to transmit any propulsive and/or braking forces between the ROBOT and FIELD carpet.

R7. Protrusions from the ROBOT and exposed surfaces on the ROBOT shall not pose hazards to the ARENA elements (including the POWER CELLS) or people.

R8. ROBOT parts shall not be made from hazardous materials, be unsafe, cause an unsafe condition, or interfere with the operation of other ROBOTS.

Examples of items that will violate R8 include (but are not limited to):

a. Shields, curtains, or any other devices or materials designed or used to obstruct or limit the vision of any DRIVERS and/or COACHES and/or interfere with their ability to safely control their ROBOT
b. Speakers, sirens, air horns, or other audio devices that generate sound at a level sufficient to be a distraction
c. Any devices or decorations specifically intended to jam or interfere with the remote sensing capabilities of another ROBOT, including vision systems, acoustic range finders, sonars, infrared proximity detectors, etc. (e.g. including imagery on your ROBOT that, to a reasonably astute observer, mimics the retro-reflective features of vision targets described in Vision Targets)
d. Exposed lasers other than Class I.
e. Flammable gasses
f. Any device intended to produce flames or pyrotechnics
g. Hydraulic fluids or hydraulic items
h. Switches or contacts containing liquid mercury
i. Circuitry used to create voltages in excess of 24 Volts
j. Any ballast not secured sufficiently, including loose ballast e.g. sand, ball bearings, etc., such that it may become loose during a MATCH.
k. Exposed, untreated hazardous materials (e.g. lead weights) used on the ROBOT. These materials may be permitted if painted, encapsulated or otherwise sealed to prevent contact. These materials may not be machined in any way at an event.
l. Tire sealant
m. High intensity light sources used on the ROBOT (e.g. super bright LED sources marketed as ‘military grade’ or ‘self-defense’) may only be illuminated for a brief time while targeting and may need to be shrouded to prevent any exposure to participants. Complaints about the use of such light sources will be followed by re-inspection and possible disablement of the device.

Teams should provide MSD Sheets for any materials they use that might be considered questionable during ROBOT Inspection.

R9. ROBOTS must allow removal of game pieces from the ROBOT and the ROBOT from FIELD elements while DISABLED and powered off.

ROBOTS will not be re-enabled after the MATCH, so teams must be sure that game pieces and ROBOTS can be quickly, simply, and safely removed.

R10. Lubricants may be used only to reduce friction within the ROBOT. Lubricants must not contaminate the FIELD or other ROBOTS.

9.4 Budget Constraints & Fabrication Schedule

R11. The total cost of all items on the ROBOT (i.e. all items presented at Inspection per I3: MECHANISMS, configurations, and decorations that will be used on the ROBOT in MATCHES without re-inspection), including software, shall not exceed $5000 USD. All costs are to be determined as explained in Budget Constraints & Fabrication Schedule. Exceptions are as follows:

- **A.** individual items that are less than $5 USD each, as purchasable from a VENDOR,
- **B.** items from the team's current year's KOP (identical functional replacements may be used to meet this criteria), up to the KOP quantity (including the rookie KOP items), and
- **C.** Specific exempt items:
  - i. One (1) Inertial Measurement Unit (Note that R12 still applies)
  - ii. Rockwell Automation sensors available through *FIRST* Choice in any season
  - iii. tags used for location detection systems if provided by the event

An item is considered an IMU if it includes "IMU" or "Inertial Measurement Unit" in the VENDOR'S product description.

Teams should be prepared to disclose to Inspectors the cost of any non-KOP item and the total cost of the ROBOT. Teams should also be prepared to show that a particular item was received from *FIRST* Choice or a voucher in the current season if necessary.

Per I6, teams must be prepared to display a Bill of Material (BOM) to Inspectors during Inspection. The BOM may be displayed in either printed or electronic form.

Individual COMPONENTS or MECHANISMS, not excluded in R11, that are retrieved from previous ROBOTS and used on 2020 ROBOTS must have their un-depreciated cost included in the 2020 BOM and applied to the overall cost assessment.

Example 1: The Kickoff KOP checklist lists two (2) of motor controller XYZ in the Gray Tote distributed to rookie teams. Any team, including a veteran team that did not receive these items, can account for up to two (2) of them on the KOP checklist at a $0 cost. Additional quantity of the same item would have to be accounted at the Fair Market Value.

Example 2: A team uses *FIRST* Choice credits, or a voucher, to acquire part ABC. This part, in the quantity obtained by the team via the KOP may be accounted at $0. Additional quantity of the same item would have to be accounted at the Fair Market Value.

Example 3: Part ABC is available in *FIRST* Choice, but a team decides they have enough already on hand and does not acquire any through *FIRST* Choice. All of these items used

on the ROBOT need to be accounted for at Fair Market Value as they did not come from the current year's KOP.

An "identical functional replacement" is an item which, to any reasonably astute observer, has the same form, fit, feature set, and function as the original component.

For example, any CIM motor can replace a CIM motor or a sheet of polycarbonate paid for completely by a voucher can be replaced with a sheet of polycarbonate of the same parameters (thickness, color, size, etc.). As another example, a motor controller that has the same form, fit, and function (i.e. controlling motors) as the original motor controller, but a different feature set (i.e. can communicate over CAN vs. the original controller which was PWM only) is not an identical functional replacement because the controllers' feature sets differ.

R12. No individual, non-KOP item or software shall have a Fair Market Value that exceeds $500 USD. The total cost of COMPONENTS purchased in bulk may exceed $500 USD as long as the cost of an individual COMPONENT does not exceed $500 USD.

The Analog Devices ADIS16448 IMU MXP Breakout Board does not have a published Fair Market Value (FMV). This device is considered to comply with R12 regardless of its true FMV.

If a COTS item is part of a modular system that can be assembled in several possible configurations, then each individual module must fit within the price constraints defined in R12.

If the modules are designed to assemble into a single configuration, and the assembly is functional in only that configuration, then the total cost of the complete assembly including all modules must fit within the price constraints defined in R12.

In summary, if a VENDOR sells a system or a kit, a team must use the entire system/kit Fair Market Value and not the value of its COMPONENT pieces.

Example 1: VENDOR A sells a gearbox that can be used with a number of different gear sets, and can mate with two different motors they sell. A team purchases the gearbox, a gear set, and a motor (which are not offered together as an assembly or kit), then assembles them together. Each part is treated separately for the purpose of BOM costing, since the purchased pieces can each be used in various configurations.

Example 2: VENDOR B sells a robotic arm assembly that the team wants to use. However, it costs $700 USD, so they cannot use it. The VENDOR sells the "hand", "wrist", and "arm" as separate assemblies, for $200 USD each. A team wishes to purchase the three items separately, then reassemble them. This would not be legal, as they are really buying and using the entire assembly, which has a Fair Market Value of $700 USD.

Example 3: VENDOR C sells a set of wheels or wheel modules that are often used in groups of four. The wheels or modules can be used in other quantities or configurations. A team purchases four and uses them in the most common configuration. Each part is treated separately for the purpose of BOM costing, since the purchased pieces can be used in various configurations.

R13. The BOM cost of each non-KOP item must be calculated based on the unit Fair Market Value for the material and/or labor, except for labor provided by team members (including sponsor employees who are members of the team), members of other teams, event provided Machine Shops and shipping.

The Fair Market Value of a COTS item is its price defined by a VENDOR for the part or an identical functional replacement. This price must be generally available to all FIRST Robotics Competition teams throughout the build and competition season (i.e. short-term sale prices or coupons do not reflect Fair Market Value), however teams are only expected to make a good faith effort at determining the item price and are not expected to monitor prices of ROBOT items throughout the season in response to price fluctuations. The Fair Market Value is the cost of the item itself and does not include any duties, taxes, tariffs, shipping, or other costs that may vary by locality. If COTS parts were sourced in bulk, the cost may be scaled proportionally to assess the Fair Market Value of one unit.

The Fair Market Value of COTS software is the price, set by the VENDOR, to license the software (or component of the software) that runs on the ROBOT for the period from Kickoff to the end of the *FIRST* Championship. The Fair Market Value of software licensed free-of-cost, including through the Virtual KOP, for use on the ROBOT is $0.

The Fair Market Value of raw material used to construct FABRICATED parts may be accounted for in one of two ways:

- The cost of any purchasable quantity that can be used to make the individual part (i.e. the purchasable raw material is larger than the FABRICATED part).
- Grouping parts made from the same raw material and accounting for the cost of a single quantity that can produce all of those parts.

Example 1: A team orders a custom bracket made by a company to the team's specification. The company's material cost and normally charged labor rate apply.

Example 2: A team receives a donated sensor. The company would normally sell this item for $52 USD, which is therefore its Fair Market Value.

Example 3: Special price discounts from National Instruments and other *FIRST* Suppliers are being offered to all teams for the whole season. The discounted purchase price of items from these sources may be used in the additional parts accounting calculations.

Example 4: A team purchases steel bar stock for $10 USD and has it machined by a local machine shop. The machine shop is not considered a team Sponsor but donates two (2) hours of expended labor anyway. The team must include the estimated normal cost of the labor as if it were paid to the machine shop and add it to the $10 USD.

Example 5: A team purchases steel bar stock for $10 USD and has it machined by a local machine shop that is a recognized Sponsor of the team. If the machinists are considered members of the team, their labor costs do not apply. The total applicable cost for the part would be $10 USD.

It is in the best interests of the teams and *FIRST* to form relationships with as many organizations as possible. Teams are encouraged to be expansive in recruiting and including organizations in their team, as that exposes more people and organizations to *FIRST*. Recognizing supporting companies as Sponsors of, and members in, the team is encouraged, even if the involvement of the Sponsor is solely through the donation of fabrication labor.

Example 6: A team purchases steel bar stock for $10 USD and has it machined by another team. The total applicable cost for the part would be $10 USD.

Example 7: A team purchases a 4 ft. by 4 ft. (~122 cm by 122 cm) sheet of aluminum, but only uses a piece 10 in. by 10 in. (~25 cm by 25 cm) on their ROBOT. The team identifies a source that sells aluminum sheet in 1 by 1 ft. (~30 cm by 30 cm) pieces. The team may

cost their part based on a 1 by 1 ft. (~30 cm by 30 cm) piece, even though they cut the piece from a larger bulk purchase. They do not have to account for the entire 4 by 4 ft. (~122 cm by 122 cm) bulk purchase item.

Example 8: A team purchases a widget at a garage sale or online auction for $3, but it's available for sale from a VENDOR for $13. The Fair Market Value that gets reported on the BOM is $13.

Example 9: A team 3D prints multiple parts for their ROBOT from a single spool of material. The cost of the spool (in the smallest available size able to produce the parts) may be included just once on the BOM to account for all parts.

R14. FABRICATED ITEMS created before Kickoff are not permitted. Exceptions are:

- **A.** OPERATOR CONSOLE,
- **B.** BUMPERS (a protective assembly designed to attach to the exterior of the ROBOT and constructed as specified in BUMPER Rules),
- **C.** battery assemblies as described in R5-B,
- **D.** FABRICATED ITEMS consisting of one COTS electrical device (e.g. a motor or motor controller) and attached COMPONENTS associated with any of the following modifications:
  - i. wires modified to facilitate connection to a ROBOT (including removal of existing connectors)
  - ii. connectors and any materials to secure and insulate those connectors added (Note: passive PCBs such as those used to adapt motor terminals to connectors are considered connectors)
  - iii. motor shafts modified and/or gears, pulleys, or sprockets added
  - iv. motors modified with a filtering capacitor as described in the Blue Box below R56
- **E.** COTS items with any of the following modifications:
  - i. Non-functional decoration or labeling
  - ii. Assembly of COTS items per manufacturer specs, unless the result constitutes a MAJOR MECHANISM as defined in I1
  - iii. Work that could be reasonably accomplished in fewer than 30 minutes with the use of handheld tools (e.g. drilling a small number of holes in a COTS part)

Please note that this means FABRICATED ITEMS from ROBOTS entered in previous *FIRST* competitions may not be used on ROBOTS in the 2020 *FIRST* Robotics Competition (other than those allowed per R14-B through -E). Before the formal start of the Build Season, teams are encouraged to think as much as they please about their ROBOTS. They may develop prototypes, create proof-of-concept models, and conduct design exercises. Teams may gather all the raw stock materials and COTS COMPONENTS they want.

Parts with precision machined (mill, CNC, etc.) features may still meet R14-E part iii if functionally equivalent features could reasonably be made within the restrictions specified.

Example 1: A team designs and builds a two-speed shifting transmission during the fall as a training exercise. After Kickoff, they utilize all the design principles they learned in the fall to design their ROBOT. To optimize the transmission design for their ROBOT, they change the transmission gear ratios and reduce the size, and build two new transmissions, and place them on the ROBOT. All parts of this process are permitted activities.

Example 2: A team re-uses a 2020-legal motor from a previous ROBOT which has had connectors added to the wires. This is permitted, per exception D, because the motor is a COTS electrical COMPONENT.

Example 3: A team re-uses a piece of aluminum tubing from a previous ROBOT which has a precision machined bearing hole in it. On the current ROBOT, the bearing hole is not used. As the only function of the hole on the current ROBOT is material removal, which does not require precise tolerancing, a functionally equivalent hole could be made with a hand drill in under 30 minutes and the part is permitted per R14-E iii.

R15. Software and mechanical/electrical designs created before Kickoff are only permitted if the source files (complete information sufficient to produce the design) are available publicly prior to Kickoff.

Example 1: A team realizes that the transmission designed and built in the fall perfectly fits their need for a transmission to drive the ROBOT arm. They build an exact copy of the transmission from the original design plans, and bolt it to the ROBOT. This would be prohibited, as the transmission – although made during the competition season – was built from detailed designs developed prior to Kickoff.

Example 2: A team developed an omni-directional drive system for the 2019 competition. In July 2019 they refined and improved the control software (written in C++) to add more precision and capabilities. They decided to use a similar system for the 2020 competition. They copied large sections of unmodified code over into the control software of the new ROBOT (also written in C++). This would be a violation of the schedule constraint and is not allowed.

Example 3: The same team decides to use LabVIEW as their software environment for 2020. Following Kickoff, they use the previously-developed C++ code as a reference for the algorithms and calculations required to implement their omni-directional control solution. Because they developed new LabVIEW code as they ported over their algorithms, this is permitted.

Example 4: A different team develops a similar solution during the fall and plans to use the developed software on their competition ROBOT. After completing the software, they post it in a generally accessible public forum and make the code available to all teams. Because they have made their software publicly available before Kickoff, they can use it on their ROBOT.

Example 5: A team develops a transmission prior to Kickoff. After completing the project, they publish the CAD files on a generally accessible public forum and make them available to all teams. Because they have made the design publicly available before Kickoff, they can use the design to create an identical transmission, fabricated after Kickoff, for use on their 2020 ROBOT.

R16. During an event a team is attending (regardless of whether the team is physically at the event location), the team may neither work on nor practice with their ROBOT or ROBOT elements outside of the hours that pits are open, with the following exceptions:

- **A.** Exceptions listed in R14, other than R14-E iii
- **B.** Software development
- **C.** Batteries may be charged during the designated Load-in time

For the purposes of this rule, official events begin as follows:

- Regionals, District Championships, and *FIRST* Championship: at the start of the first designated Load-in period, according to the Public Schedule. If the Public Schedule

is not available or there is no designated Load-in period, the events begin at 4pm on the day prior to pits opening.
- District Events: when pits open

Examples of activity prohibited by R16 include:

a. Working on the ROBOT at the team's shop after Load-in for the event has begun
b. Working on ROBOT parts at night at the team's hotel.

Note that E8 and E20 impose additional restrictions on work done on the ROBOT or ROBOT materials while attending an event.

One purpose of R16 is to increase equity between teams with significant travel to an event and those nearby (close teams would otherwise have an advantage by being able to work on their ROBOT, in their shop, until it's time to go to the event).

9.5 BUMPER Rules

A BUMPER is a required assembly which attaches to the ROBOT frame. BUMPERS protect ROBOTS from damaging/being damaged by other ROBOTS and FIELD elements. Criteria used in writing these rules includes the following:

- Minimize variety of BUMPERS so teams can expect consistency
- Minimize the amount of design challenge in creating BUMPERS
- Minimize cost of BUMPER materials
- Maximize use of relatively ubiquitous materials

R17. ROBOTS are required to use BUMPERS to protect all outside corners of the FRAME PERIMETER. For adequate protection, at least 6 in. (~16 cm) of BUMPER must be placed on each side of each outside corner (see Figure 9-2 BUMPER corner examples) and must extend to within ¼ in. (~6 mm) of the FRAME PERIMETER corner. If a FRAME PERIMETER side is shorter than 12 in. (~31 cm), that entire side must be protected by BUMPER (see Figure 9-3). A round or circular FRAME PERIMETER, or segment of the FRAME PERIMETER, is considered to have an infinite number of corners, therefore the entire frame or frame segment must be completely protected by BUMPER(S).

The dimension defined in R17 is measured along the FRAME PERIMETER. The portion of the BUMPER that extends beyond the corner of the FRAME PERIMETER is not included in the 6 in. (~16 cm) requirement. See Figure 9-2.

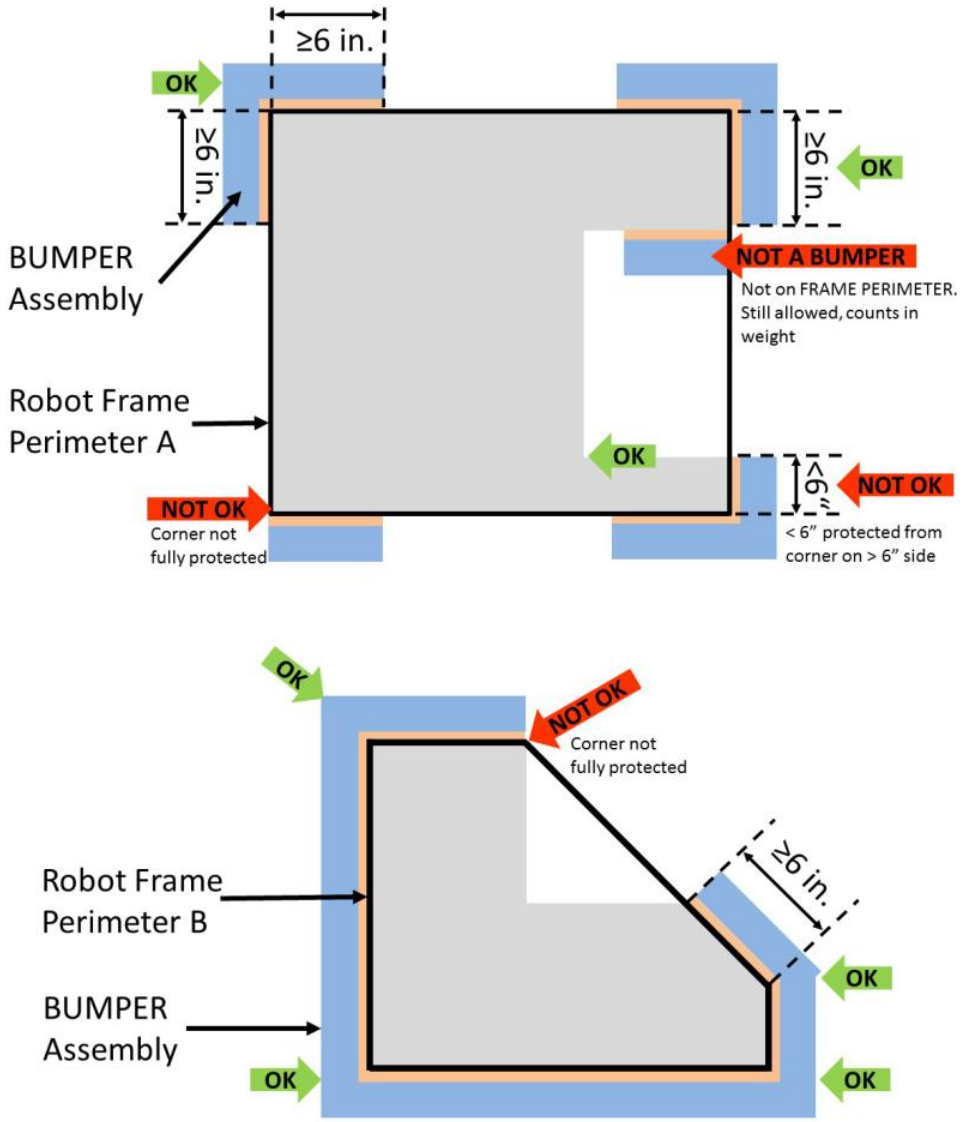


Figure 9-2 BUMPER corner examples

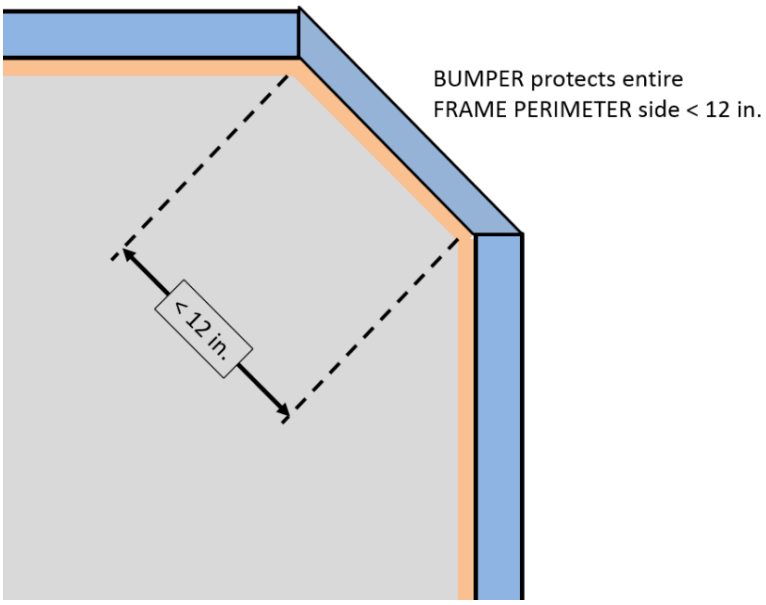


Figure 9-3 BUMPER around full side/corner.

R18. Except as allowed per G16, BUMPERS must be located entirely within the BUMPER ZONE, which is the volume contained between the floor and a virtual horizontal plane 7½ in. (~19 cm) above the floor in reference to the ROBOT standing normally on a flat floor. BUMPERS do not have to be parallel to the floor.

> This measurement is intended to be made as if the ROBOT is resting on a flat floor (without changing the ROBOT configuration), not relative to the height of the ROBOT from the FIELD carpet. Examples include:
>
> Example 1: A ROBOT that is at an angle while navigating the FIELD has its BUMPERS outside the BUMPER ZONE. If this ROBOT were virtually transposed onto a flat floor, and its BUMPERS are in the BUMPER ZONE, it meets the requirements of R18.
>
> Example 2: A ROBOT deploys a MECHANISM which lifts the BUMPERS outside the BUMPER ZONE (when virtually transposed onto a flat floor). This violates R18.

R19. BUMPERS must not be articulated (relative to the FRAME PERIMETER).

R20. BUMPERS (the entire BUMPER, not just the cover) must be designed for quick and easy installation and removal to facilitate inspection and weighing.

> As a guideline, BUMPERS should be able to be installed or removed by two (2) people in fewer than five (5) minutes.

R21. Each ROBOT must be able to display Red or Blue BUMPERS to MATCH their ALLIANCE color, as assigned in the MATCH schedule distributed at the event (as described in MATCH Schedules). BUMPER Markings visible when installed on the ROBOT, other than the following, are prohibited:

- **A.** those required per R22,
- **B.** hook-and-loop fastener or snap fasteners backed by the hard parts of the BUMPER, and
- **C.** solid white *FIRST* logos between 4¾ in. (~12 cm) and 5¼ in. wide (~13 cm) (i.e. comparable to those available in the 2020 Virtual Kit.

> The FRAME PERIMETER facing surfaces of BUMPERS are not "displayed" and thus R21 does not apply.

R22. Team numbers must be displayed and positioned on the BUMPERS such that an observer walking around the perimeter of the ROBOT can unambiguously tell the team's number from any point of view and meet the following additional criteria:

A. consist of only Arabic numerals at least 4 in. (~11 cm) high, at least ½ in. (~13 mm) in stroke width, and be either white in color or outlined in white with a minimum 1/16 in. (~2 mm) outline

> The ½ in. (~13 mm) stroke width requirement applies to the majority of the stroke. Font elements less than ½ in. (~13 mm) such as serifs, rounded edges, small hairlines or gaps, etc. are permitted as long as the majority of the stroke meets the sizing requirement and the numbers are unambiguous.

B. must not wrap around sharp corners (less than 160 degrees) of the FRAME PERIMETER

C. may not substitute logos or icons for numerals

> There is no prohibition against splitting team numbers onto different sections of BUMPER. The intent is that the team's number is clearly visible and unambiguous so that Judges, REFEREES, Announcers, and other teams can easily identify competing ROBOTS.
>
> This marking is intended to display the team number only, not to intentionally change the surface characteristics of the BUMPER. Excessive material usage as part of any team number marking will invite close scrutiny.

R23. Each set of BUMPERS (including any fasteners and/or structures that attach them to the ROBOT) must weigh no more than 15 lbs. (~6 kg).

> If a multi-part attachment system is utilized (e.g. interlocking brackets on the ROBOT and the BUMPER), then the elements permanently attached to the ROBOT will be considered part of the ROBOT, and the elements attached to the BUMPERS will be considered part of the BUMPER. Each element must satisfy all applicable rules for the relevant system.

R24. BUMPERS must be constructed as follows (see Figure 9-6):

A. be backed by ¾ in. (nominal) thick (~19mm) by 5 in. ± ½ in. (~127 mm ± 12.7 mm) tall plywood, Oriented Strand Board (OSB) or solid wood (with the exception of balsa). Small clearance pockets and/or access holes in the wood backing are permitted, as long as they do not significantly affect the structural integrity of the BUMPER.

> ¾" Plywood and OSB refer to items sold by VENDORS as that material and thickness, teams may not fabricate their own plywood or OSB. Other engineered woods such as Fiberboard or Particle Board are not likely to survive the rigors of *FIRST* Robotics Competition gameplay and thus not permitted in R24-A.
>
> Note: ¾" plywood is now often marked according to the actual dimension ($^{23}/_{32}$") not the nominal size. Plywood sold as $^{23}/_{32}$" meets the requirements of R24-A.

B. hard BUMPER parts allowed per R24-A, -E, -F, and -G must not extend more than 1 in. (~25 mm) beyond the FRAME PERIMETER (measured as shown in Figure 9-4).

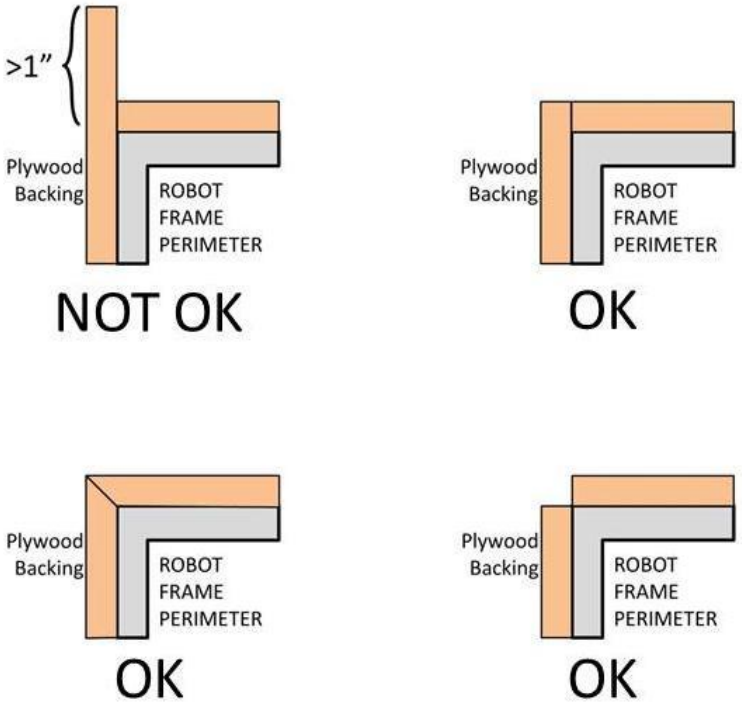


Figure 9-4 Hard Parts of BUMPER Corners

C. use a stacked pair of approximately 2½ in. (nominal, ~63mm) round, petal, or hex "pool noodles" (solid or hollow) as the BUMPER cushion material (see Figure 9-6). All pool noodles used in a BUMPER set (e.g. Red set of BUMPERS) may not be modified (with the exception of cutting to length or cutting to facilitate mating pool noodles at the corners as required by R25) or deformed and must be the same diameter, cross-section, and density (e.g. all round hollow or all hex solid). Cushion material may extend up to 2½ in. (~63 mm) beyond the end of the plywood (see Figure 9-7). To assist in applying the fabric covering, soft fasteners may be used to attach the pool noodles to the wood backing, so long as the cross section in Figure 9-6 is not significantly altered (e.g. tape compressing the pool noodles).

All pool noodles used on a ROBOT must be the same in order to maintain the desired interaction between ROBOTS in the cases of BUMPER-to-BUMPER contact. BUMPERS containing pool noodles of vastly different construction may cause a "ramp" effect when interacting with other BUMPERS.

Minor noodle compression as a result of smoothing BUMPER fabric or rounding a FRAME PERIMETER corner is not considered deformed. Any compression beyond that, e.g. for the purposes of flattening the noodle, is deformation and a violation of R24-C.

D. be covered with a rugged, smooth cloth. (multiple layers of cloth and seams are permitted if needed to accommodate R21 and/or R22, provided the cross section in Figure 9-6 is not significantly altered).

Silk and bedding are not considered rugged cloths, however 1000D Cordura is. Tape (e.g. gaffer's tape) matching the BUMPER color is allowed to patch small holes on a temporary basis.

It is expected that there may be multiple layers of cloth as fabric is folded to accommodate the corners and seams of BUMPERS.

The cloth must completely enclose all exterior surfaces of the wood and pool noodle material when the BUMPER is installed on the ROBOT. The fabric covering the BUMPERS must be solid in color.

E. optionally use metal angle, as shown in Figure 9-6 or other fasteners (e.g. staples, screws, adhesives, etc.) to clamp cloth.

F. optionally use metal brackets (i.e. angle or sheet metal) or other fasteners (e.g. staples, screws, adhesives, etc.) to attach BUMPER segments to each other (see Figure 9-5).

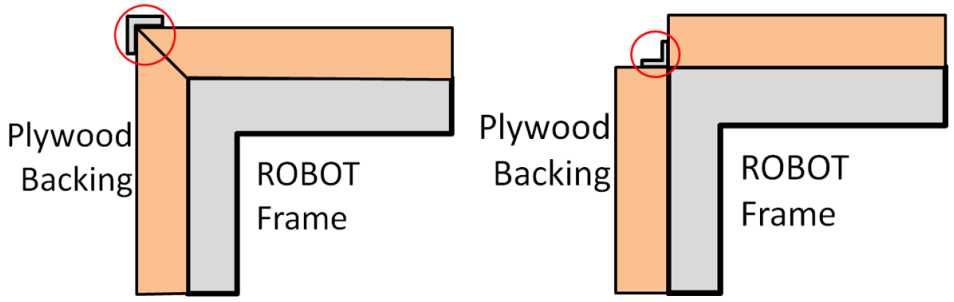


Figure 9-5 Hard Parts of BUMPER Corners

G. must attach to the FRAME PERIMETER of the ROBOT with a rigid fastening system to form a tight, robust connection to the main structure/frame (e.g. not attached with hook-and-loop, tape, or tie-wraps). The attachment system must be designed to withstand vigorous game play. All removable fasteners (e.g. bolts, locking pins, pip-pins, etc.) will be considered part of the BUMPERS.

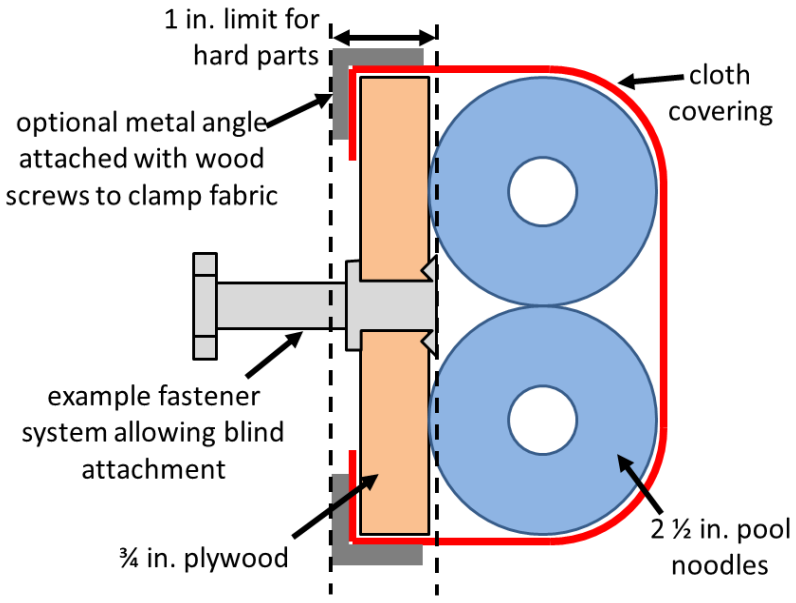


Figure 9-6 BUMPER Vertical Cross Section

R25. Corner joints between BUMPERS must be filled with pool noodle material. Examples of implementation are shown in Figure 9-7.

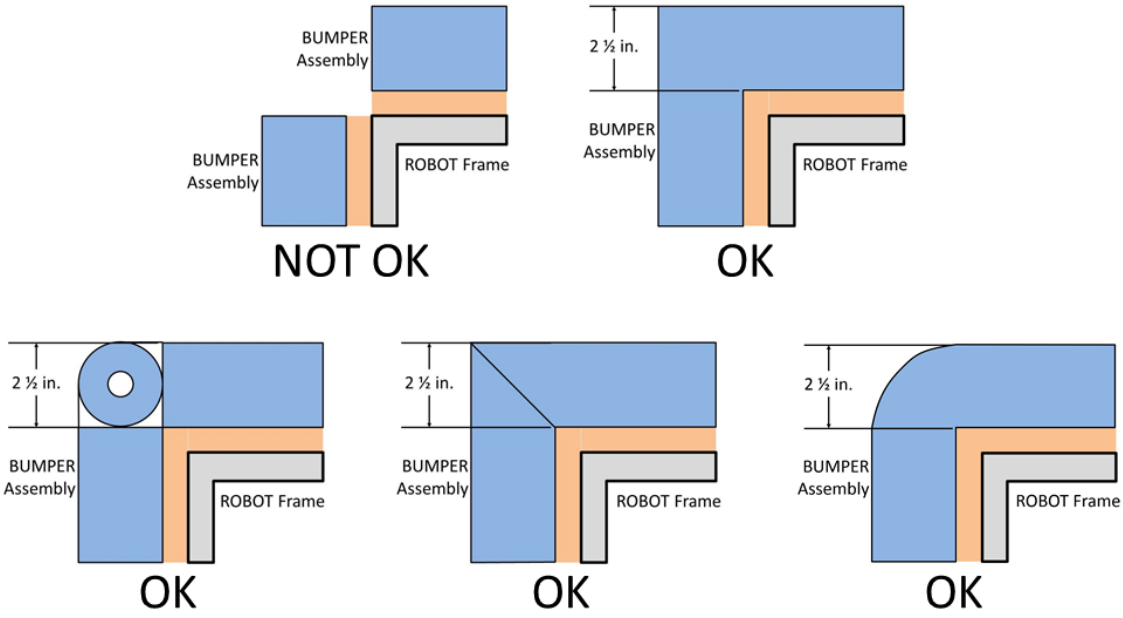


Figure 9-7 Soft Parts of BUMPER Corners

R26. BUMPERS must be supported by the structure/frame of the ROBOT (see Figure 9-8). To be considered supported, a minimum of ½ in. (~13 mm) at each end of each BUMPER wood segment must be backed by the FRAME PERIMETER (≤¼ in. gap, ~6mm). "Ends" exclude hard BUMPER parts which extend past the FRAME PERIMETER permitted by R24-B. Additionally, any gap between the backing material and the frame:

- **A.** must not be greater than ¼ in. (~6 mm) deep, or
- **B.** not more than 8 in. (~20 cm) wide

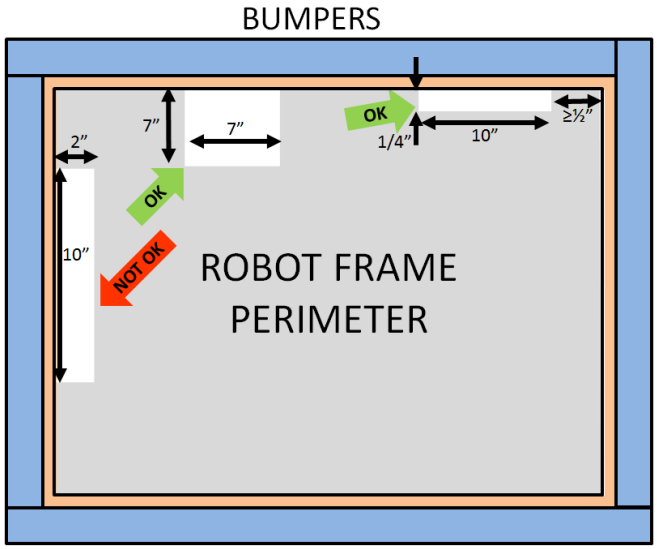


Figure 9-8 BUMPER support examples

The intent of this rule is to make sure the BUMPER wood is properly supported to minimize the likelihood of breakage on impact. Flexible ROBOT elements, such as thin plastic, do not accomplish this intent and are not considered “structure/frame” of the ROBOT.

9.6 Motors & Actuators

R27. The only motors and actuators permitted on 2020 ROBOTS include the following (in any quantity):

Table 9-1 Motor allowances

Motor Name	Part Numbers Available	
AndyMark 9015	am-0912	AndyMark 9015
AndyMark NeveRest	am-3104	
AndyMark PG	am-2161 (alt. PN am-2765)	am-2194 (alt. PN am-2766)
AndyMark RedLine Motor	am-3775	am-3775a
AndyMark Snow Blower Motor	am-2235	am-2235a
Banebots	am-3830 M7-RS775-18 RS775WC-8514	M5 – RS550-12 RS550VC-7527 RS550
CIM	FR801-001 M4-R0062-12 AM802-001A 217-2000 PM25R-44F-1005	PM25R-45F-1004 PM25R-45F-1003 PMR25R-45F-1003 PMR25R-44F-1005 am-0255
CTR Electronics/VEX Robotics Falcon 500	217-6515 am-6515	19-708850 am-6515_Short
Current/former KOP Automotive motors	Denso AE235100-0160 Denso 5-163800-RC1 Denso 262100-3030	Denso 262100-3040 Bosch 6 004 RA3 194-06 Johnson Electric JE-PLG-149
Nidec Dynamo BLDC Motor	am-3740	DM3012-1063
Playing with Fusion Venom	BDC-10001	
REV Robotics NEO Brushless	REV-21-1650	
REV Robotics NEO 550	REV-21-1651	
VEX BAG	217-3351	
VEX Mini-CIM	217-3371	
West Coast Products RS775 Pro	217-4347	
Electrical solenoid actuators, no greater than 1 in. (nominal) stroke and rated electrical input power no greater than 10 watts (W) continuous duty at 12 volts (VDC)		
Fans, no greater than 120mm (nominal) size and rated electrical input power no greater than 10 watts (W) continuous duty at 12 volts (VDC)		
Hard drive motors part of a legal COTS computing device		
Factory installed vibration and autofocus motors resident in COTS computing devices (e.g. rumble motor in a smartphone).		
PWM COTS servos with a retail cost < $75.		
Motors integral to a COTS sensor (e.g. LIDAR, scanning sonar, etc.), provided the device is not modified except to facilitate mounting		
One (1) compressor compliant with R79 and used to compress air for the ROBOT'S pneumatic system		

For servos, note that the roboRIO is limited to a max current output of 2.2A on the 6V rail (12.4W of electrical input power). Teams should make sure that their total servo power usage remains below this limit at all times.

Given the extensive amount of motors allowed on the ROBOT, teams are encouraged to consider the total power available from the ROBOT battery during the design and build of the ROBOT. Drawing large amounts of current from many motors at the same time could lead to drops in ROBOT battery voltage that may result in tripping the main breaker or

trigger the brownout protection of the roboRIO. For more information about the roboRIO brownout protection and measuring current draw using the PDP, see roboRIO Brownout and Understanding Current Draw.

AndyMark PG Gearmotors are sold with labeling based on the entire assembly. Assemblies labeled am-3651 through am-3656 contain legal motors specified in the table above. These motors may be used with or without the provided gearbox.

R28. The integral mechanical and electrical system of any motor must not be modified. Motors, servos, and electric solenoids used on the ROBOT shall not be modified in any way, except as follows:

- **A.** The mounting brackets and/or output shaft/interface may be modified to facilitate the physical connection of the motor to the ROBOT and actuated part.
- **B.** The electrical leads may be trimmed to length as necessary and connectors or splices to additional wiring may be added.
- **C.** The locking pins on the window motors (P/N: 262100-3030 and 262100-3040) may be removed.
- **D.** The connector housings on KOP Automotive motors listed in Table 9-1 may be modified to facilitate lead connections.
- **E.** Servos may be modified as specified by the manufacturer (e.g. re-programming or modification for continuous rotation).
- **F.** The wiring harness of the Nidec Dynamo BLDC Motor may be modified as documented by *FIRST* in the "Nidec Dynamo BLDC Motor with Controller" article.
- **G.** Minimal labeling applied to indicate device purpose, connectivity, functional performance, etc.
- **H.** Any number of #10-32 plug screws may be removed from the Falcon 500.
- **I.** Insulation may be applied to electrical terminals.

The intent of this rule is to allow teams to modify mounting tabs and the like, not to gain a weight reduction by potentially compromising the structural integrity of any motor.

R29. With the exception of servos, fans, or motors integral to sensors of COTS computing devices permitted in R27, each actuator must be controlled by a power regulating device. The only power regulating devices for actuators permitted on the ROBOT include:

- **A.** Motor Controllers

  i. DMC 60/DMC 60c Motor Controller (P/N: 410-334-1, 410-334-2)
  ii. Jaguar Motor Controller (P/N: MDL-BDC, MDL-BDC24, and 217-3367) connected to PWM only
  iii. Nidec Dynamo BLDC Motor with Controller to control integral actuator only (P/N 840205-000, am-3740)
  iv. SD540 Motor Controller (P/N: SD540x1, SD540x2, SD540x4, SD540Bx1, SD540Bx2, SD540Bx4, SD540C)
  v. Spark Motor Controller (P/N: REV-11-1200)
  vi. Spark MAX Motor Controller (P/N: REV-11-2158)
  vii. Talon FX Motor Controller (P/N: 217-6515, 19-708850, am-6515, am-6515_Short) for controlling integral Falcon 500 only.
  viii. Talon Motor Controller (P/N: CTRE_Talon, CTRE_Talon_SR, and am-2195)
  ix. Talon SRX Motor Controller (P/N: 217-8080, am-2854, 14-838288)
  x. Venom Motor with Controller (P/N: BDC-10001) for controlling integral motor only
  xi. Victor 884 Motor Controller (P/N: VICTOR-884-12/12)
  xii. Victor 888 Motor Controller (P/N: 217-2769)

xiii. Victor SP Motor Controller (P/N: 217-9090, am-2855, 14-868380)
xiv. Victor SPX Motor Controller (P/N: 217-9191, 17-868388, am-3748)

B. Relay Modules

i. Spike H-Bridge Relay (P/N: 217-0220 and SPIKE-RELAY-H)
ii. Automation Direct Relay (P/N: AD-SSR6M12-DC-200D, AD-SSRM6M25-DC-200D, AD-SSR6M45-DC-200D)

C. Pneumatics controllers

i. Pneumatics Control Module (P/N: am-2858, 217-4243)

Note: The Automation Direct Relays are single directional. Per R30 they may not be wired together in an attempt to provide bi-directional control.

R30. Each power regulating device may control electrical loads per Table 9-2. Unless otherwise noted, each power regulating device shall control one and only one electrical load.

Table 9-2 Power regulating device allotments

Electrical Load	Motor Controller	Relay Module	Pneumatics Controller
AndyMark RedLine Motor **Banebots** **CIM** **REV Robotics NEO Brushless** **REV Robotics NEO 550** **VEX Mini-CIM** **WCP RS775 Pro**	Yes	No	No
AndyMark 9015 **VEXpro BAG**	Yes (up to 2 per controller)	No	No
AndyMark PG **KOP Automotive Motors** **NeverRest** **Snow Blower Motor**	Yes (up to 2 per controller)	Yes	No
CTR Electronics/VEX Falcon 500 **Nidec Dynamo BLDC Motor w/ Controller** **Playing With Fusion Venom**	Yes (integrated controller only)	No	No
Compressor	No	Yes	Yes
Pneumatic Solenoid Valves	No	Yes[1]	Yes (1 per channel)
Electric Solenoids	Yes[1]	Yes[1]	Yes (1 per channel
CUSTOM CIRCUITS[2]	Yes[1]	Yes[1]	Yes (1 per channel)

[1] Multiple low-load, pneumatic solenoid valves (relay only), electric solenoids or CUSTOM CIRCUITS may be connected to a single relay module or motor controller. This would allow one (1) relay module or motor controller to drive multiple pneumatic actions or multiple CUSTOM CIRCUITS. No other electrical load can be connected to a relay module used in this manner.

[2] A CUSTOM CIRCUIT is any electrical COMPONENT of the ROBOT other than motors, pneumatic solenoids, roboRIO, PDP, PCM, VRM, RSL, 120A breaker, motor controllers, relay modules (per R29-B), wireless bridge, electrical solenoid actuators, or batteries.

R31. Servos must be connected to, and only to, one of the following:

- **A.** PWM PORTS on the roboRIO
- **B.** PWM PORTS on a WCP Spartan Sensor Board (P/N: WCP-0045)
- **C.** REV Robotics Servo Power Module (P/N: REV-11-1144)

9.7 Power Distribution

In order to maintain safety, the rules in this section apply at all times while at the event, not just while the ROBOT is on the FIELD for MATCHES.

R32. The only legal source of electrical energy for the ROBOT during the competition, the ROBOT battery, must be one and only one non-spillable sealed lead acid (SLA) battery with the following specifications:

- **A.** Nominal voltage: 12V
- **B.** Nominal capacity at 20-hour discharge rate: minimum 17Ah, maximum 18.2Ah
- **C.** Shape: Rectangular
- **D.** Nominal Dimensions:7.1 in. x 3 in. x 6.6 in., +/- .1 in. for each dimension (~ 180 mm x 76mm x 168 mm, +/- 2.5 mm for each dimension)
- **E.** Nominal weight: 11lbs. to 14.5 lbs. (~5 kg. to 6.5 kg.)
- **F.** Terminals: Nut and bolt style

Examples of batteries which meet these criteria include:

a. Enersys (P/N: NP18-12, NP18-12B, NP18-12BFR)
b. MK Battery (P/N: ES17-12)
c. Battery Mart (P/N: SLA-12V18)
d. Sigma (P/N: SP12-18)
e. Universal Battery (P/N: UB12180)
f. Power Patrol (P/N: SLA1116)
g. Werker Battery (P/N: WKA12-18NB)
h. Power Sonic (P/N: PS-12180NB)
i. Yuasa (P/N: NP18-12B)
j. Panasonic (P/N: LC-RD-1217)
k. Interstate Batteries (P/N: BSL1116)
l. Duracell Ultra Battery (P/N: DURA12-18NB)

Teams should be aware that they may be asked to provide documentation of the specifications of any battery not listed above.

Batteries should be charged in accordance with manufacturer's specification. (Please see the *FIRST* Safety Manual for additional information.)

R33. COTS USB battery packs with a capacity of 100Wh or less (20000mAh at 5V) and 2.5 Amp max output per port, or batteries integral to and part of a COTS computing device or self-contained camera (e.g. laptop batteries, GoPro style camera, etc.) may be used to power COTS computing devices and any peripheral COTS input or output devices connected to the COTS computing device provided they are:

- **A.** securely fastened to the ROBOT.
- **B.** connected only using unmodified COTS cables

C. charged according to manufacturer recommendations

R34. Any battery charger used to charge a ROBOT battery must have the corresponding Anderson SB connector installed.

R35. Any battery charger used to charge a ROBOT battery may not be used such that it exceeds 6-Amp peak charge current.

R36. No batteries other than those allowed per R32 and R33 are allowed on the ROBOT, whether or not they are being used to supply power.

> For example, teams may not use additional batteries as extra weight on their ROBOTS.

R37. The ROBOT battery must be secured such that it will not dislodge during vigorous ROBOT interaction including if the ROBOT is turned over or placed in any arbitrary orientation.

R38. Each electrical terminal on the ROBOT battery, main breaker, and their connections (lugs, stripped wire ends, etc.) to the wire must be fully insulated at all times.

R39. Non-electrical sources of energy used by the ROBOT, (i.e., stored at the start of a MATCH), shall come only from the following sources:

A. compressed air stored in the pneumatic system that has been charged in compliance with R79 and R80,
B. a change in the altitude of the ROBOT center of gravity,
C. storage achieved by deformation of ROBOT parts,
D. closed-loop COTS pneumatic (gas) shocks, and
E. air-filled (pneumatic) wheels.

R40. The one (1) ROBOT battery, a single pair of Anderson Power Products (or APP) 2-pole SB type connectors, the one (1) main 120-amp (120A) surface mount circuit breaker (Cooper Bussman P/N: CB185-120, CB185F-120, CB285-120), and the one (1) CTR Electronics Power Distribution Panel (PDP, P/N: am-2856, 217-4244, 14-806880) shall be connected with 6 AWG (7 SWG or 16 mm2) copper wire or larger, with no additional devices or modifications, as shown in Figure 9-9.

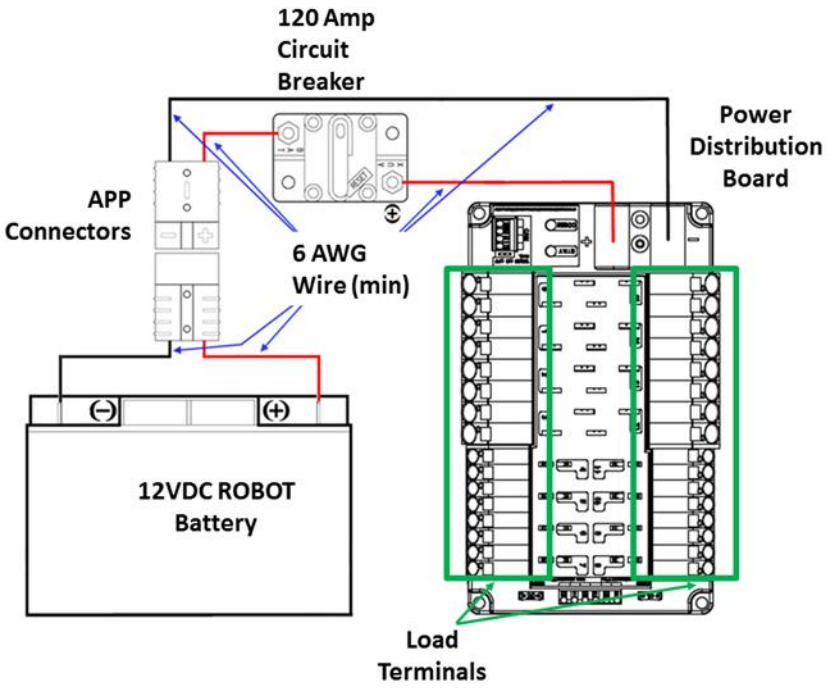


Figure 9-9 Electrical connection diagram

"SB type" refers to SB type only (e.g. SB-50, SB-120, etc.), not SBS or any other part type beginning with SB. All batteries supplied by *FIRST* (such as Spare Parts and international batteries) will have a Red or Pink SB50 connector installed which may not be removed.

The pink connectors included in the 2020 KOP mate with the Red SB50 connector.

R41. All circuits, with the exceptions of those listed in R46 and R48, must connect to, and have power sourced solely by, a single protected 12VDC WAGO connector pair (i.e. the Load Terminals, as shown in Figure 9-9) of the one (1) CTR Electronics Power Distribution Panel, not the M6 cap screws.

R42. All wiring and electrical devices, including all Control System COMPONENTS, shall be electrically isolated from the ROBOT frame. The ROBOT frame must not be used to carry electrical current.

R42 is checked by observing a >3kΩ resistance between either the (+) or (-) post within the APP connector that is attached to the PDP and any point on the ROBOT.

All legal motor controllers with metal cases are electrically isolated. They may be mounted directly to ROBOT frame COMPONENTS.

Note that some cameras, decorative lights and sensors (e.g. some encoders, some IR sensors, etc.) have grounded enclosures or are manufactured with conductive plastics. These devices must be electrically isolated from the ROBOT frame to ensure compliance with R42.

R43. The 120A circuit breaker must be quickly and safely accessible from the exterior of the ROBOT. This is the only 120A circuit breaker allowed on the ROBOT.

Examples considered not “quickly and safely accessible” include breakers covered by an access panel or door, or mounted on, underneath or immediately adjacent to moving COMPONENTS.

It is strongly recommended that the 120A circuit breaker location be clearly and obviously labeled so it can be easily found by FIELD STAFF during a MATCH.

R44. The PDP, associated wiring, and all circuit breakers must be visible for Inspection.

R45. Any active electrical item that is not an actuator (specified in R27) or core Control System item (specified in R66) is considered a CUSTOM CIRCUIT. CUSTOM CIRCUITS shall not produce voltages exceeding 24V.

R46. The roboRIO power input must be connected to the dedicated supply terminals on the PDP shown in Figure 9-10. No other electrical load shall be connected to these terminals.

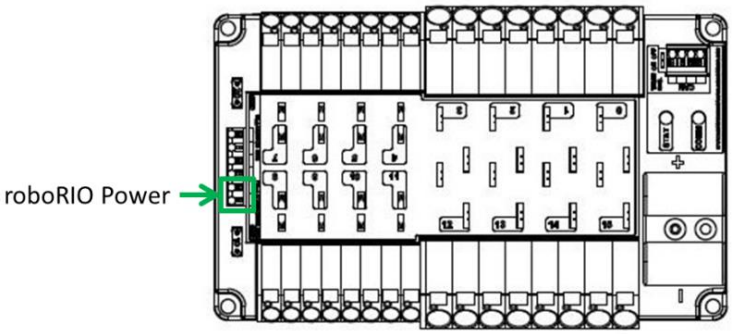


Figure 9-10 roboRIO power source

R47. The Wireless Bridge (Radio) power must be supplied directly by the 12V 2A output of a CTR Electronics Voltage Regulator Module (VRM) (P/N: am-2857, 217-4245) and must be the only load connected to those terminals.

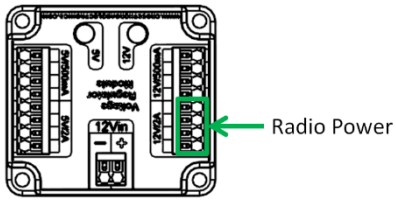


Figure 9-11 Radio power source

Note that this wiring is different from the wiring for the radio used in 2015, but is identical to the wiring from 2016-2019. When using a 2015 VRM with the OM5P-AN or OM5P-AC radio, the radio should be connected as described above, not to the terminals labeled “Radio”.

Note that this prohibits using any active POE Injector device to power the radio but does not prohibit using any PASSIVE CONDUCTORS to inject the VRM power into an Ethernet cable plugged into the radio port labeled “18-24v POE”.

R48. The VRM supplying power to the Wireless Bridge per R47 must be connected to the designated supply terminals at the end of the PDP, and not the main WAGO connectors along the sides of the

PDP as shown in Figure 9-12. With the exception of a single CTR Electronics Pneumatics Control Module (PCM, P/N: am-2858), no other electrical load shall be connected to these PDP terminals.

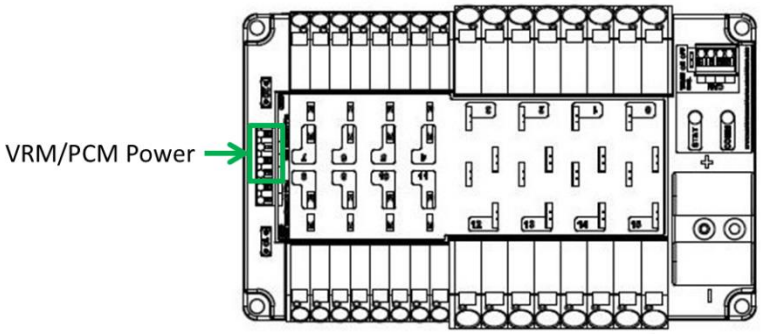


Figure 9-12 VRM and PCM power source

Please reference How to Wire an FRC Robot for Wireless Bridge wiring information.

R49. Only one wire shall be connected to each WAGO connector on the PDP.

If multi-point distribution of circuit power is needed (e.g. to provide power to multiple PCMs and/or VRMs from one 20A circuit), then all incoming wires may be appropriately spliced into the main lead (e.g. using an insulated terminal block, crimped splice or soldered wire splice), and the single main lead inserted into the WAGO connector to power the circuit.

R50. The only circuit breakers permitted for use in the PDP are:

- **A.** Snap Action VB3-A Series, terminal style F57
- **B.** Snap Action MX5-A or MX5-L Series, 40A rating or lower

R51. The fuses in the PDP shall only be replaced with functionally identical fuses (mini automotive blade fuses with values matching those printed on the PDP).

Note that these fuses must be pressed very firmly to seat properly. Improper seating can cause component reboots during impacts.

R52. Each branch circuit must be protected by one and only one circuit breaker on the PDP per Table 9-3. No other electrical load can be connected to the breaker supplying this circuit.

Table 9-3 Branch circuit protection requirements

Branch Circuit	Circuit Breaker Value	Quantity Allowed Per Breaker
Motor Controller	Up to 40A	1
CUSTOM CIRCUIT	Up to 40A	1
Automation Direct Relay 40A (*6M40*)	Up to 40A	1
Fans permitted per Table 9-1 and not already part of COTS computing devices	Up to 20A	No limit
Spike Relay Module	Up to 20A	1

Automation Direct Relay 25A (*6M25*)	Up to 20A	1
PCM – with compressor	20A	1
Additional VRM (non-radio)/Additional PCM (non-compressor)	20A	3 total
Automation Direct Relay 12A (*6M12*)	Up to 10A	1

R52 does not prohibit the use of smaller value breakers in the PDP or any fuses or breakers within CUSTOM CIRCUITS for additional protection.

R53. All circuits shall be wired with appropriately sized insulated copper wire (SIGNAL LEVEL cables don't have to be copper):

Table 9-4 Breaker and Wire Sizing

Application	Minimum Wire Size
31 – 40A protected circuit	12 AWG (13 SWG or 4 mm2)
21 – 30A protected circuit	14 AWG (16 SWG or 2.5 mm2)
6 – 20A protected circuit **Between the PDP dedicated terminals and the VRM or PCM Compressor outputs from the PCM**	18 AWG (19 SWG or 1 mm2)
Between the PDP and the roboRIO **≤5A protected circuit**	22 AWG (22 SWG or 0.5 mm2)
VRM 2A circuits	24 AWG (24 SWG or .25mm2)
roboRIO PWM port outputs	26 AWG (27 SWG or 0.14 mm2)
SIGNAL LEVEL circuits (i.e. circuits which draw ≤1A continuous and have a source incapable of delivering >1A, including but not limited to roboRIO non-PWM outputs, CAN signals, PCM Solenoid outputs, VRM 500mA outputs and Arduino outputs)	28 AWG (29 SWG or .08 mm2)

Wires that are recommended by the device manufacturer or originally attached to legal devices are considered part of the device and by default legal. Such wires are exempt from R53.

In order to show compliance with these rules, teams should use wire with clearly labeled sizes if possible. If unlabeled wiring is used, teams should be prepared to demonstrate that the wire used meets the requirements of R53 (e.g. wire samples and evidence that they are the required size).

R54. Branch circuits may include intermediate elements such as COTS connectors, splices, COTS flexible/rolling/sliding contacts, and COTS slip rings, as long as the entire electrical pathway is via appropriately gauged/rated elements.

Slip rings containing mercury are prohibited per R8.

R55. All non-SIGNAL LEVEL wiring with a constant polarity (i.e., except for outputs of relay modules, motor controllers, or sensors) shall be color-coded along their entire length from the manufacturer as follows:

A. Red, yellow, white, brown, or black-with-stripe on the positive (e.g. +24VDC, +12VDC, +5VDC, etc.) connections
B. Black or blue for the common or negative side (-) of the connections.

Exceptions to this rule include:

C. Wires that are originally attached to legal devices and any extensions to these wires using the same color as the manufacturer.
D. Ethernet cable used in POE cables.

R56. CUSTOM CIRCUITS shall not directly alter the power pathways between the ROBOT battery, PDP, motor controllers, relays (per R29-B), motors and actuators (per R27), pneumatic solenoid valves, or other elements of the ROBOT control system (items explicitly mentioned in R66). Custom high impedance voltage monitoring or low impedance current monitoring circuitry connected to the ROBOT'S electrical system is acceptable, if the effect on the ROBOT outputs is inconsequential.

A noise filter may be wired across motor leads or PWM leads. Such filters will not be considered CUSTOM CIRCUITS and will not be considered a violation of R56 or R73.

Acceptable signal filters must be fully insulated and must be one of the following:

- A one microfarad (1 µF) or less, non-polarized, capacitor may be applied across the power leads of any motor on your ROBOT (as close to the actual motor leads as reasonably possible).
- A resistor may be used as a shunt load for the PWM control signal feeding a servo.

9.8 Control, Command & Signals System

R57. ROBOTS must be controlled via one (1) programmable National Instruments roboRIO (P/N: am3000), with image version FRC_roboRIO_2020_v10 or later.

There are no rules that prohibit co-processors, provided commands originate from the roboRIO to enable and disable all power regulating devices. This includes motor controllers legally wired to the CAN-bus.

R58. One (1) OpenMesh Wireless Bridge (P/N: OM5P-AN or OM5P-AC), that has been configured with the appropriate encryption key for your team number at each event, is the only permitted device for communicating to and from the ROBOT during the MATCH.

R59. The roboRIO Ethernet PORT must be connected to the Wireless Bridge PORT labeled "18-24 vPOE," closest to the power connector (either directly, via a network switch, or via a CAT5 Ethernet pigtail).

Note: Placing a switch between the roboRIO and radio may impede the ability for FIELD STAFF to troubleshoot roboRIO connection issues on the FIELD. Teams may be asked to try directly connecting from the radio to roboRIO as part of troubleshooting efforts.

R60. Communication between the ROBOT and the OPERATOR CONSOLE is restricted as follows:

A. Network ports:

i. HTTP 80: Camera connected via switch on the ROBOT, bi-directional
ii. HTTP 443: Camera connected via switch on the ROBOT, bi-directional
iii. UDP/TCP 554: Real-Time Streaming Protocol for h.264 camera streaming, bi-directional
iv. UDP 1130: Dashboard-to-ROBOT control data, uni-directional

v. UDP 1140: ROBOT-to-Dashboard status data, uni-directional
vi. UDP/TCP 1180-1190: Camera data from the roboRIO to the Driver Station when the camera is connected the roboRIO via USB, bi-directional.
vii. TCP/UDP 1250: CTRE Diagnostics Server, bi-directional
viii. TCP 1735: SmartDashboard, bi-directional
ix. UDP/TCP 5800-5810: Team Use, bi-directional

Teams may use these ports as they wish if they do not employ them as outlined above (i.e. TCP 1180 can be used to pass data back and forth between the ROBOT and the DS if the team chooses not to use the camera on USB).

B. Bandwidth: no more than 4 Mbits/second.

> Note that the 4 Mbit limit will be strictly enforced by the Wireless Bridge.
>
> The FMS Whitepaper has more details on how to check and optimize bandwidth usage.
>
> While *FIRST* makes every effort to provide a wireless environment that allows teams access to a full 4 Mbits/second data rate (with about 100 Kbit used for ROBOT control and status), at some events wireless conditions may not accommodate this.

R61. The roboRIO, DRIVER Station software, and Wireless Bridge must be configured to correspond to the correct team number, per the procedures defined in Getting Started with the 2020 Control System.

R62. All signals must originate from the OPERATOR CONSOLE and be transmitted to the ROBOT via the ARENA Ethernet network.

R63. No form of wireless communication shall be used to communicate to, from, or within the ROBOT, except those required per R58, R62, and tags used for location detection systems if provided by the event.

> Devices that employ signals in the visual spectrum (e.g. cameras) and non-RF sensors that don't receive human-originated commands (e.g. "beam break" sensors or IR sensors on the ROBOT used to detect FIELD elements) are not wireless communication devices and thus R63 doesn't apply.

R64. The Wireless Bridge must be mounted on the ROBOT such that the diagnostic lights are visible to ARENA personnel.

> Teams are encouraged to mount the wireless bridge away from noise generating devices such as motors, PCM(s), and VRM(s).

R65. ROBOTS must use at least one (1), but no more than two (2), diagnostic ROBOT Signal Lights (RSL) (P/N: 855PB-B12ME522).

Any RSL must be:

A. mounted on the ROBOT such that it is easily visible while standing 3 ft. (~ 100 cm) in front of the ROBOT,
B. connected to the "RSL" supply terminals on the roboRIO,
C. wired for solid light operation, by placing a jumper between the "La" and "Lb" terminals on the light per Figure 9-13.

> Please see How to Wire an FRC Robot for connection details.

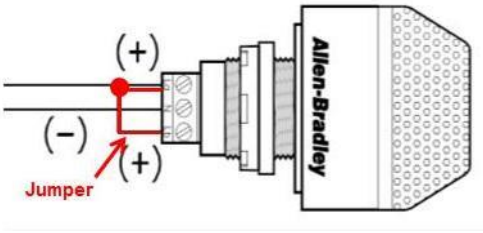


Figure 9-13 RSL jumper wiring

R66. The Driver Station software, roboRIO, Power Distribution Panel, Pneumatics Control Modules, Voltage Regulator Modules, RSL, 120A breaker, motor controllers, relay modules (per R29-B), Wireless Bridge, and batteries shall not be tampered with, modified, or adjusted in any way (tampering includes drilling, cutting, machining, rewiring, disassembling, painting, etc.), with the following exceptions:

Please note that the Driver Station application is a separate application from the Dashboard. The Driver Station software may not be modified, while teams are expected to customize their Dashboard code.

- **A.** User programmable code in the roboRIO may be customized.
- **B.** Motor controllers may be calibrated as described in owner's manuals.
- **C.** Fans may be attached to motor controllers and may be powered from the power input terminals.
- **D.** If powering the compressor, the fuse on a Spike H-Bridge Relay may be replaced with a VB3A-20A Snap-Action circuit breaker.
- **E.** Wires, cables, and signal lines may be connected via the standard connection points provided on the devices.
- **F.** Fasteners (including adhesives) may be used to attach the device to the OPERATOR CONSOLE or ROBOT or to secure cables to the device.
- **G.** Thermal interface material may be used to improve heat conduction.
- **H.** Labeling may be applied to indicate device purpose, connectivity, functional performance, etc.
- **I.** Jumpers may be changed from their default location.
- **J.** Limit switch jumpers may be removed from a Jaguar motor controller and a custom limit switch circuit may be substituted.
- **K.** Device firmware may be updated with manufacturer supplied firmware.
- **L.** Integral wires on motor controllers may be cut, stripped, and/or connectorized.
- **M.** Devices may be repaired, provided the performance and specifications of the device after the repair are identical to those before the repair.
- **N.** The cover may be removed from the Talon SRX data port.
- **O.** Electrical tape may be applied to the aluminum plate inside the Wireless Bridge.
- **P.** The input terminal cover from the Power Distribution Panel may be omitted (no other element may be installed using the threaded holes to install something in place of the PDP terminal cover).

Please note that while repairs are permitted, the allowance is independent of any manufacturer's warranty. Teams make repairs at their own risk and should assume that any warranty or RMA options are forfeited. Be aware that diagnosing and repairing COMPONENTS such as these can be difficult.

For more information about modification O, please see this article.

R67. Neither 12VDC power nor relay module or motor controller outputs shall be directly connected to the roboRIO (with the exception of the designated 12VDC input).

R68. Every relay module (per R29-B), servo controller, and PWM motor controller shall be connected to a corresponding port (relays to Relay ports, servo controllers and PWM controllers to PWM ports) on the roboRIO (either directly or through a WCP Spartan Sensor Board) or via a legal MXP connection (per R69). They shall not be controlled by signals from any other source, with the exception of the Nidec Dynamo motor controller which must also be connected to the roboRIO Digital I/O.

R69. If a motor is controlled via the MXP, its power regulating device must be connected by one of the following methods:

- **A.** directly to any PWM pins,
- **B.** via a network of PASSIVE CONDUCTORS used to extend the PWM pins, or
- **C.** via one approved active device:

  i. Kauai Labs navX MXP
  ii. RCAL MXP Daughterboard
  iii. REV Robotics RIOduino
  iv. REV Robotics Digit Board
  v. West Coast Products Spartan Sensor Board
  vi. Huskie Robotics HUSKIE 2.0 Board

> A PASSIVE CONDUCTOR is any device or circuit whose capability is limited to the conduction and/or static regulation of the electrical energy applied to it (e.g. wire, splices, connectors, printed wiring board, etc.).
>
> An “active device” is any device capable of dynamically controlling and/or converting a source of electrical energy by the application of external electrical stimulus.
>
> The “network of PASSIVE CONDUCTORS” only applies to the pins being used for PWM output to motors or servos. This means that connecting an active device, such as a sensor to one MXP pin does not prevent other MXP pins from being used in accordance with R69-B.

R70. Each CAN motor controller must be controlled with signal inputs sourced from the roboRIO and passed via either a PWM (wired per R68) or CAN-bus (either directly or daisy-chained via another CAN-bus device) signal, but both shall not be wired simultaneously on the same device.

> As long as the CAN bus is wired legally so that the heartbeat from the roboRIO is maintained, all closed loop control features of the CAN motor controller may be used. (That is, commands originating from the roboRIO to configure, enable, and specify an operating point for all CAN motor controller closed loop modes fit the intent of R57).

R71. Each PCM must be controlled with signal inputs sourced from the roboRIO and passed via a CAN-bus connection from the roboRIO (either directly or daisy-chained via another CAN-bus device).

R72. The PDP CAN interface must be connected to the CAN-bus on the roboRIO (either directly or daisy-chained via another CAN-bus device).

> For documentation on how to wire the CAN-bus connections of the PDP see How to Wire an FRC Robot.

R73. The CAN-bus must be connected to the roboRIO CAN port.

A. Additional switches, sensor modules, CUSTOM CIRCUITS, third-party modules, etc. may also be placed on the CAN-bus.
B. No device that interferes with, alters, or blocks communications among the roboRIO and the PDP, PCMs, and/or CAN Motor Controllers on the bus will be permitted.

Only one wire should be inserted into each Weidmuller CAN connector terminal. For documentation on how to wire the CAN-bus connections of the roboRIO, PCM, PDP and CAN motor controllers, see How to Wire an FRC Robot.

9.9 Pneumatic System

In order to maintain safety, the rules in this section apply at all times while at the event, not just while the ROBOT is on the FIELD for MATCHES.

R74. To satisfy multiple constraints associated with safety, consistency, Inspection, and constructive innovation, no pneumatic parts other than those explicitly permitted in this section shall be used on the ROBOT.

R75. All pneumatic items must be COTS pneumatic devices and either:

A. rated by their manufacturers for pressure of at least 125psi (~862 kPa), or
B. installed downstream of the primary relieving regulator (see R82), and rated for pressure of at least 70psi (~483 kPa)

Any pressure specification such as “working,” “operating,” “maximum,” etc. may be used to satisfy the requirements of R75.

It is recommended that all pneumatic items be rated by their manufacturers for a working pressure of at least 60 psi (~414 kPa).

R76. All pneumatic COMPONENTS must be used in their original, unaltered condition. Exceptions are as follows:

A. tubing may be cut,
B. wiring for pneumatic devices may be modified to interface with the control system,
C. assembling and connecting pneumatic COMPONENTS using the pre-existing threads, mounting brackets, quick-connect fittings, etc.,
D. removing the mounting pin from a pneumatic cylinder, provided the cylinder itself is not modified,
E. labeling applied to indicate device purpose, connectivity, functional performance, etc.

Do not, for example, paint, file, machine, or abrasively remove any part of a pneumatic COMPONENT – this would cause the part to become a prohibited item. Consider pneumatic COMPONENTS sacred.

R77. The only pneumatic system items permitted on ROBOTS include the items listed below.

A. Pneumatic pressure vent plug valves functionally equivalent to those provided in the KOP,

Examples of acceptable valves include Parker PV609-2 or MV709-2.

B. Pressure relief valves functionally equivalent to those provided in the KOP,

> Examples of acceptable valves include Norgren 16-004-011, 16-004-003 or McMaster-Carr 48435K714.
>
> To be considered functionally equivalent the valve must be preset or adjustable to 125 psi (~862 kPA) and capable of relieving at least 1 scfm (~472 cm3/s).

C. Solenoid valves with a maximum ⅛ in. (nominal, ~3 mm) NPT, BSPP, or BSPT port diameter or integrated quick connect ¼ in. (nominal, ~6mm) outside diameter tubing connection,
D. Additional pneumatic tubing, with a maximum ¼ in. (nominal, ~6 mm) outside diameter,
E. Pressure transducers, pressure gauges, passive flow control valves (specifically "needle valve"), manifolds, and connecting fittings (including COTS pneumatic U-tubes),
F. Check and quick exhaust valves, provided that the requirements of R86-A are still met.
G. Shutoff valves which relieve downstream pressure to atmosphere when closed (may also be known as 3-way or 3-way exhausting valves).
H. Pressure regulators with the maximum outlet pressure adjusted to no more than 60 psi (~413 kPa),
I. Pneumatic cylinders, pneumatic linear actuators, and rotary actuators,
J. Pneumatic storage tanks (with the exception of White Clippard tanks P/N: AVT-PP-41),
K. One (1) compressor that is compliant with R79,
L. Debris or coalescing (water) filters, and
M. Venturi valves (note: the high-pressure side of a Venturi valve is considered a pneumatic device and must follow all pneumatic rules. The vacuum side of a Venturi valve is exempt from the pneumatic rules per "a" in the Blue Box below).

> The following devices are not considered pneumatic devices and are not subject to pneumatic rules (though they must satisfy all other rules):
>
> a. a device that creates a vacuum
> b. closed-loop COTS pneumatic (gas) shocks
> c. air-filled (pneumatic) wheels
> d. pneumatic devices not used as part of a pneumatic system (i.e. used in a way that does not allow them to contain pressurized air)

R78. If pneumatic COMPONENTS are used, the following items are required as part of the pneumatic circuit and must be used in accordance with this section, as illustrated in Figure 9-14.

A. One (1) *FIRST* Robotics Competition legal compressor (per R79)
B. Pressure relief valve (per R77-B) connected via legal rigid fittings (e.g. brass, nylon, etc.)
C. Nason pressure switch, P/N SM-2B-115R/443
D. At least one pressure vent plug
E. Stored pressure gauge (upstream from Primary Regulator, must show psi or kPa)
F. Working pressure gauge (downstream from Primary Regulator, must show psi or kPa)
G. Working pressure regulator

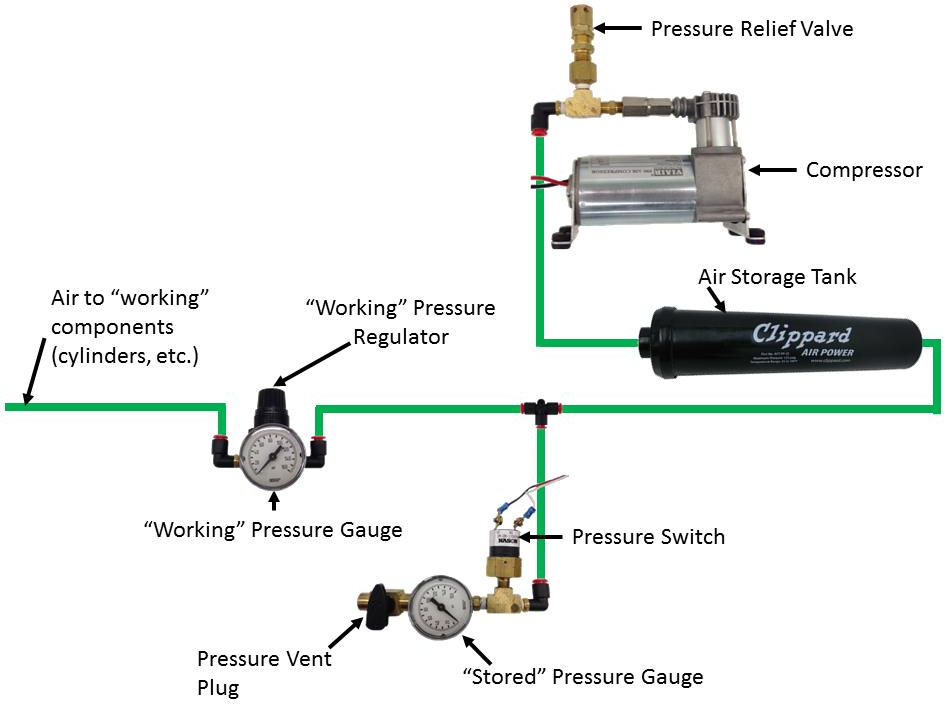


Figure 9-14 Pneumatic circuitry

R79. Throughout an event, compressed air on the ROBOT must be provided by its one onboard compressor only. Compressor specifications must not exceed nominal 1.1 cfm (~519 cm3/s) flow rate @ 12VDC at any pressure.

> A ROBOT'S compressor may be substituted by another compressor, but a ROBOT may only have one designated compressor at a time, and all compressed air on the ROBOT must be sourced from a single compressor.
>
> Note: Viair C-series compressors, which have a max working pressure of 120 PSI, are rated for intermittent pressures greater than 125 PSI and therefore meet the requirements of R75.

R80. Stored air pressure on the ROBOT must be no greater than 120 psi (~827 kPa). No stored air pressure intended for the ROBOT may be located off-board the ROBOT.

R81. Working air pressure (air pressure used to actuate devices) on the ROBOT must be no greater than 60 psi (~413 kPa) and must be provided through a single primary adjustable, relieving, pressure regulator.

> Examples of acceptable valves include: Norgren regulator P/N: R07-100-RNEA or Monnier P/N: 101-3002-1.

R82. Only the compressor, relief valve, pressure switch, pressure vent plug, pressure gauge, storage tanks, tubing, pressure transducers, filters, and connecting fittings may be in the high-pressure pneumatic circuit upstream from the regulator.

> It is recommended that all COMPONENTS in the high-pressure pneumatic circuit upstream from the regulator be rated for at least 115 psi (~793 kPa) working pressure.

R83. Pressure gauges must be placed in easily visible locations upstream and downstream of the regulator to display the stored and working pressures.

R84. The relief valve must be attached directly to the compressor or attached by legal hard fittings (e.g. brass, nylon, etc.) connected to the compressor output port.

Teams are required to check and/or adjust the relief valve to release air at 125 psi (~861 kPa). The valve may or may not have been calibrated prior to being supplied to teams.

Instructions for adjusting the pressure relief valve can be found in the Pneumatics Manual.

R85. The pressure switch requirements are:

- **A.** It must be Nason P/N: SM-2B-115R/443
- **B.** It must be connected to the high-pressure side of the pneumatic circuit (i.e. prior to the pressure regulator) to sense the stored pressure of the circuit.
- **C.** The two wires from the pressure switch must be connected directly to the pressure switch input of the PCM controlling the compressor or, if controlled using the roboRIO and a relay, to the roboRIO.
- **D.** If connected to the roboRIO, the roboRIO must be programmed to sense the state of the switch and operate the relay module that powers the compressor to prevent over-pressuring the system.

R86. Any pressure vent plug must be:

- **A.** connected to the pneumatic circuit such that, when manually operated, it will vent to the atmosphere to relieve all stored pressure in a reasonable amount of time, and
- **B.** placed on the ROBOT so that it is visible and easily accessible.

R87. The outputs from multiple solenoid valves must not be plumbed together.

9.10 OPERATOR CONSOLE

R88. The DRIVER Station software provided by National Instruments (install instructions found here) is the only application permitted to specify and communicate the operating mode (i.e. Autonomous/Teleoperated) and operating state (Enable/Disable) to the ROBOT. The DRIVER Station software must be revision 20.0 or newer.

Teams are permitted to use a portable computing device of their choice (laptop computer, tablet, etc.) to host the DRIVER Station software while participating in competition MATCHES.

R89. The OPERATOR CONSOLE, the set of COMPONENTS and MECHANISMS used by the DRIVERS and/or HUMAN PLAYER to relay commands to the ROBOT, must include a graphic display to present the DRIVER Station diagnostic information. It must be positioned within the OPERATOR CONSOLE so that the screen display can be clearly seen during Inspection and in a MATCH.

R90. Devices hosting the DRIVER Station software must only interface with the Field Management System (FMS) via the Ethernet cable provided at the PLAYER STATION (e.g. not through a switch). Teams may connect the FMS Ethernet cable to their DRIVER Station device directly via an Ethernet pigtail, or with a single-port Ethernet converter (e.g. docking station, USB-Ethernet converter,

Thunderbolt-Ethernet converter, etc.). The Ethernet port on the OPERATOR CONSOLE must be easily and quickly accessible.

> Teams are strongly encouraged to use pigtails on the Ethernet port used to connect to the FMS. Such pigtails will reduce wear and tear on the device's port and, with proper strain relief employed, will protect the port from accidental damage.

R91. The OPERATOR CONSOLE must not

- **A.** be longer than 60 in. (~152 cm)
- **B.** be deeper than 14 in. (~35 cm) (excluding any items that are held or worn by the DRIVERS during the MATCH)
- **C.** extend more than 6 ft. 6 in. (~198 cm) above the floor
- **D.** attach to the FIELD (except as permitted by G26)

> There is a 54 in. (~137 cm) long by 2 in. (nominal) wide strip of hook-and-loop tape ("loop" side) along the center of the PLAYER STATION support shelf that should be used to secure the OPERATOR CONSOLE to the shelf, per G26. See PLAYER STATION for details.
>
> Please note that while there is no hard weight limit, OPERATOR CONSOLES that weigh more than 30 lbs. (~13 kg.) will invite extra scrutiny as they are likely to present unsafe circumstances.

R92. Other than the system provided by the FIELD, no other form of wireless communications shall be used to communicate to, from, or within the OPERATOR CONSOLE.

> Examples of prohibited wireless systems include, but are not limited to, active wireless network cards and Bluetooth devices. For the case of the *FIRST* Robotics Competition, a motion sensing input device (e.g. Microsoft Kinect) is not considered wireless communication and is allowed.

R93. OPERATOR CONSOLES shall not be made using hazardous materials, be unsafe, cause an unsafe condition, or interfere with other DRIVE TEAMS or the operation of other ROBOTS.

10 INSPECTION & ELIGIBILITY RULES

This section describes the rules governing MATCH participation. A team has participated in a MATCH if any member of their DRIVE TEAM is in the ALLIANCE STATION, with or without the ROBOT on the FIELD, at the start of the MATCH.

At each event, the Lead ROBOT Inspector (LRI) has final authority on the legality of any COMPONENT, MECHANISM, or ROBOT. Inspectors may re-Inspect ROBOTS at any time to ensure compliance with the rules. Teams are encouraged to consult with Inspectors or the LRI if they have any questions regarding the legality of a ROBOT or about how to make a ROBOT legal.

While there is no specific defined procedure in place for teams to be re-inspected prior to PLAYOFF MATCHES, it is typical for Inspectors to use the re-inspection discretion described above to do a limited re-inspection on all ROBOTS near the end of QUALIFICATIONS or beginning of PLAYOFFS to help identify any modifications that should be re-inspected per I4.

ROBOTS are permitted to participate in scheduled Practice MATCHES prior to passing Inspection. However, the *FIRST* Technical Advisor (FTA), LRI, or Head REFEREE may determine at any time that the ROBOT is unsafe, per Safety Rules, and may prohibit further participation in Practice MATCHES until the condition is corrected and/or the ROBOT passes Inspection.

Prior to the start of a MATCH, any ROBOT which is unable or ineligible to participate in that MATCH as determined by the FTA, LRI, or Head REFEREE is declared to be BYPASSED and is DISABLED. A team whose ROBOT is BYPASSED remains eligible to receive Qualification Ranking Points or Playoff MATCH points provided that its ROBOT has passed Inspection, per I2.

I1. It's your team's ROBOT. The ROBOT and its MAJOR MECHANISMS must be built by the *FIRST* Robotics Competition team.

A MAJOR MECHANISM is a group of COMPONENTS and/or MECHANISMS assembled together to address at least one (1) game challenge: robot movement, game piece control, field element manipulation, or performance of a scorable task without the assistance of another ROBOT.

I1 requires that the ROBOT and its MAJOR MECHANISMS were built by its team, but isn't intended to prohibit or discourage assistance from other teams (e.g. fabricating elements, supporting construction, writing software, developing game strategy, contributing COMPONENTS and/or MECHANISMS, etc.)

Examples of MAJOR MECHANISMS include, but are not limited to, assemblies listed below:

a. an assembly used to manipulate a game piece
b. an assembly used to position a ROBOT for an end game task
c. an assembly used to manipulate a FIELD element
d. an assembly used to move the ROBOT around the FIELD

Examples that would generally not be considered MAJOR MECHANISMS, and thus probably aren't subject to I1 include, but are not limited to, the following:

a. a gearbox assembly
b. a COMPONENT or MECHANISM that's part of a MAJOR MECHANISM
c. COTS items

Neither I1 nor the language in its Blue Box define specific thresholds for how much of a MAJOR MECHANISM must be the result of the team's effort. I1 expects and requires the team's honest assessment of whether they built the MAJOR MECHANISMS of their ROBOT.

Attempts to exploit loopholes in the definition of MAJOR MECHANISM in order to bypass this requirement are not in the spirit of I1 or the *FIRST* Robotics Competition. Examples of exploitation include:

a. assembling pieces of a MAJOR MECHANISM provided by another team, except COTS kits
b. receiving a mostly complete MAJOR MECHANISM from another team and providing a small piece

I2. Get inspected before playing a Qualification/Playoff MATCH. A team is only permitted to participate in a Qualification or Playoff MATCH and receive Ranking or MATCH Points respectively if their ROBOT has passed an initial, complete Inspection.

Violation: If prior to the start of the MATCH, the team is DISQUALIFIED and not eligible to participate in the MATCH. If after the start of the MATCH, the entire ALLIANCE receives a RED CARD for that MATCH.

Please take note of this rule. It is important that *FIRST* Robotics Competition teams ensure their ALLIANCE partners have passed Inspection. Allowing a partner that has not passed Inspection to play puts the ALLIANCE at risk of RED CARDS. Teams should check with their ALLIANCE partners early and help them pass Inspection before competing.

I3. Bring it all to Inspection. At the time of Inspection, the OPERATOR CONSOLE and the ROBOT must be presented with all MECHANISMS (including all COMPONENTS of each MECHANISM), configurations, and decorations that will be used on the ROBOT in MATCHES without re-inspection (per I4) and may not exceed 150 lbs. (~68kg) (note that while up to 150 lbs. of ROBOT MECHANISMS may be inspected together, the ROBOT configuration used in a MATCH may not violate R5). The OPERATOR CONSOLE and exceptions listed in R5 are not included in this weight.

I4. Unless the change is listed below, any change to a ROBOT must get re-inspected. A ROBOT may play MATCHES with a subset of the MECHANISMS that were present during Inspection provided the reconfigured ROBOT still meets all ROBOT Rules. Only MECHANISMS that were present during the Inspection may be added, removed, or reconfigured between MATCHES without re-inspection per I4. If a ROBOT is modified after its most recent passed Inspection, it must be re-inspected before it is eligible to participate in a MATCH. A ROBOT that plays in a MATCH with an un-inspected modification is subject to retro-active DISQUALIFICATION at the discretion of the LRI and Head REFEREE.

Exceptions are listed in A through F (unless they result in a significant change to the ROBOT'S size, weight, legality, or safety).

A. addition, relocation, or removal of fasteners (e.g. cable ties, tape, and rivets)
B. addition, relocation, or removal of labeling or marking
C. revision of ROBOT code
D. replacement of a COTS COMPONENT with an identical COTS COMPONENT
E. replacement of a MECHANISM with an identical MECHANISM (size, weight, material)
F. additions, removals, or reconfiguration of ROBOT with a subset of MECHANISMS already inspected per I3.

I5. Don't exploit I4. Teams may not use the re-inspection process in I4 to circumvent the weight limit in I3.

This restriction is not intended to prevent a team from returning to a previous configuration (e.g. due to an unsuccessful upgrade or failure of a new component). If a team is believed to be violating this rule, the LRI will discuss the situation with the team to understand the changes and, if appropriate, the LRI in conjunction with the team will select a single configuration with which the team will compete for the duration of the event.

Example 1: A ROBOT passes initial Inspection (which includes MECHANISM A). Its team then decides they want to use MECHANISM B, which was not Inspected. The weight of the ROBOT, A, and B is less than the weight limit in I3, but more than that in R5. I4 requires the ROBOT be re-inspected, and I5 allows the ROBOT, A, and B to be inspected collectively. If passed, the ROBOT may then compete in subsequent matches with A or B.

Example 2: A ROBOT passes initial Inspection (which includes MECHANISM A). Its team then decides they want to use MECHANISM B, which was not Inspected. The weight of the ROBOT, A, and B is greater than the weight limit in I3. This requires re-inspection per I4 and A is excluded to satisfy I3. B breaks, and the team decides to switch back to A. The ROBOT must be re-inspected per I4, and the team is not violating I5.

Example 3: A team arrives at an event with a ROBOT, MECHANISM A, and MECHANISM B, which collectively weigh 175 lbs. The ROBOT passes initial Inspection with A and plays a MATCH. The team switches to B, gets re-inspected, and plays again. The team switches back to A, gets re-inspected, and plays again. The team switches back to B and asks to be re-inspected. At this point, the LRI suspects the team may be violating I5 and has a discussion with the team to understand the changes being made. The team reveals that I5 has been violated, and the LRI works with them to select A or B for use for the remainder of the event.

I6. Document your costs. A Bill of Materials (BOM), listing all items on the ROBOT except those listed in R11 and their relevant costs per Budget Constraints & Fabrication Schedule, must be presented at the time of Inspection.

Teams are encouraged to use the BOM Template posted on the *FIRST* website. Please note that while BOMs must be shown to Inspectors, teams are not required to submit their BOMs to the Inspectors.

I7. ROBOTS are off for Inspection, mostly. For the safety of all those involved, ROBOTS, must be presented for Inspection with the ROBOT powered off, pneumatics unpressurized, and springs or other stored energy devices in their lowest potential energy states (e.g. battery removed).

Power and air pressure should only be enabled on the ROBOT during those portions of the Inspection process where it is absolutely required to validate certain system functionality and compliance with specific rules (firmware check, etc.). Inspectors may allow the ROBOT to be powered beyond the parameters above if both criteria below are met.

A. The ROBOT design requires power or a charged stored energy device in order to confirm that the ROBOT meets volume requirements, and
B. The team has included safety interlocks that mitigate unexpected release of such stored energy.

The team may be asked to demonstrate these interlocks during the inspection process.

I8. No student, no Inspection. At least one student team member must accompany the ROBOT for any Inspection efforts.

Exceptions may be made for major conflicts, e.g. religious holidays, major testing, transportation issues, etc.

11 TOURNAMENTS

Each 2020 *FIRST*® Robotics Competition event is played in a tournament format. Each tournament consists of three sets of MATCHES called Practice MATCHES (not necessarily played at all District Events), Qualification MATCHES, and Playoff MATCHES.

Practice MATCHES provide each team with an opportunity to operate its ROBOT on the FIELD prior to the start of the Qualification MATCHES.

Qualification MATCHES allow each team to earn Ranking Points which determine their seeding position and may qualify them for participation in the Playoff MATCHES.

Playoff MATCHES determine the event Champions.

11.1 MATCH Schedules

A MATCH schedule is used to coordinate MATCHES at an Event. Figure 11-1 details information shown on each schedule.

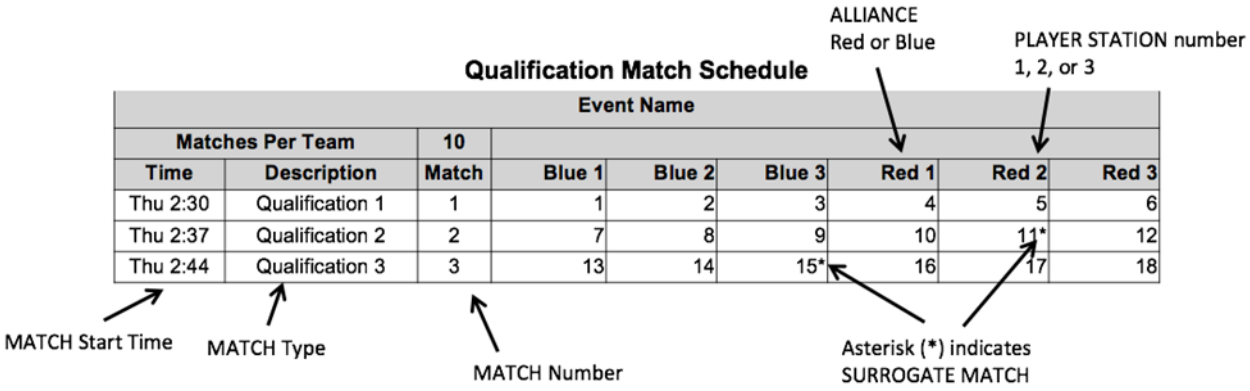


Figure 11-1 Sample MATCH Schedule

11.2 REFEREE Interaction

The Head REFEREE has the ultimate authority in the ARENA during the event, but may receive input from additional sources, e.g. Game Designers, *FIRST* personnel, FTA, and technical staff. The Head REFEREE rulings are final. No event personnel, including the Head REFEREE, will review video, photos, artistic renderings, etc. of any MATCH, from any source, under any circumstances.

If a DRIVE TEAM needs clarification on a ruling or score, per C9, one (1) pre-college student from that DRIVE TEAM should address the Head REFEREE after the ARENA Reset Signal (e.g. FIELD lights turn green). A DRIVE TEAM member signals their desire to speak with the Head REFEREE by standing in the corresponding Red or Blue Question Box, which are located on the floor near each end of the scoring table. Depending on timing, the Head REFEREE may postpone any requested discussion until the end of the subsequent MATCH as necessary.

While FMS tracks quantities of FOULS, *FIRST* instructs REFEREES to not self-track details about FOULS; as a result, we don't expect REFEREES to recall details about what FOULS were made, when they occurred, and against whom.

Any reasonable question is fair game in the Question Box, and Head REFEREES will do good faith efforts to provide helpful feedback (e.g. how/why certain FOULS are being called, why a particular ROBOT may be susceptible to certain FOULS based on its design or game play, how specific rules are being called or interpreted), but please know that they will likely not be able to supply specific details

11.2.1 YELLOW and RED CARDS

In addition to rule violations explicitly listed throughout the 2020 Game and Season Manual, YELLOW CARDS and RED CARDS are used in *FIRST* Robotics Competition to address team and ROBOT behavior that does not align with the mission, values, and culture of *FIRST*.

As noted in Rule Violations and C1, the Head REFEREE may assign a YELLOW CARD as a warning, or a RED CARD for DISQUALIFICATION in MATCH for egregious behavior inappropriate at a *FIRST* Robotics Competition event.

A YELLOW or RED CARD is indicated by the Head REFEREE standing in front of the team's PLAYER STATION and holding a YELLOW and/or RED CARD in the air.

YELLOW CARDS are additive, meaning that a second YELLOW CARD is automatically converted to a RED CARD. A team is issued a RED CARD for any subsequent incident in which they receive an additional YELLOW CARD, including earning a second YELLOW CARD during a single MATCH. A second YELLOW CARD is indicated by the Head REFEREE standing in front of the team's PLAYER STATION and holding a YELLOW CARD and RED CARD in the air simultaneously after the completion of the MATCH. A team that has received either a YELLOW CARD or a RED CARD carries a YELLOW CARD into subsequent MATCHES, except as noted below.

Once a team receives a YELLOW or RED CARD, its team number is presented with a yellow background on the Audience Screen at the beginning of all subsequent MATCHES, including any replays, as a reminder to the team, the REFEREES, and the audience that they carry a YELLOW CARD.

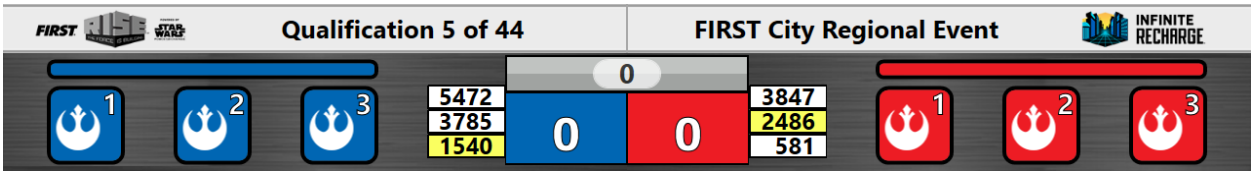


Figure 11-2 Audience Screen graphic showing YELLOW CARD Indicators

All YELLOW CARDS are cleared in FMS at the conclusion of Practice, Qualification, and Division Playoff MATCHES. The Head REFEREE may opt to perpetuate a YELLOW CARD earned during Practice MATCHES through to Qualification MATCHES for particularly egregious behavior.

During the Playoff MATCHES, a team receives a YELLOW or RED CARD for their entire ALLIANCE. If two (2) YELLOW CARDS are accrued by an ALLIANCE, the entire ALLIANCE is issued a RED CARD. A RED CARD results in DISQUALIFICATION and the ALLIANCE loses the MATCH. If both ALLIANCES receive RED CARDS, the ALLIANCE which committed the action earning the RED CARD first chronologically is DISQUALIFIED and loses the MATCH.

YELLOW and RED CARDS are applied based on the following:

Table 11-1 YELLOW and RED CARD application

Time YELLOW or RED CARD earned:	MATCH to which CARD is applied:
prior to the start of Qualification MATCHES	Team's first Qualification MATCH
during the Qualification MATCHES	Team's current (or just-completed) MATCH. In the case where the team participated as a SURROGATE in the current (or just completed) MATCH, the card is applied to the team's previous MATCH (i.e. the team's second Qualification MATCH.)
between the end of Qualification MATCHES and the start of Playoff MATCHES	ALLIANCE'S first Playoff MATCH
during the Playoff MATCHES	ALLIANCE'S current (or just-completed) MATCH.

Please see examples of the application of YELLOW AND RED CARDS as shown in Violation Details.

11.3 MATCH Replays

Over the course of the Tournament it may be necessary for a MATCH to be replayed. Typical causes for replays are MATCHES that end in a tie during the Playoffs, MATCHES that are stopped because FIELD STAFF anticipated FIELD damage or personal injury, or if there is an ARENA FAULT. An ARENA FAULT is an error in ARENA operation that includes, but is not limited to:

A. broken FIELD elements due to
    a. normal, expected game play or
    b. ROBOT abuse of FIELD elements that affects the outcome of the MATCH for their opponents.

A broken FIELD element caused by ROBOT abuse that affects the outcome of the MATCH for their ALLIANCE is not an ARENA FAULT.

B. power failure to a portion of the FIELD (tripping the circuit breaker in the PLAYER STATION is not considered a power failure)
C. improper activation by the FMS
D. errors by FIELD STAFF (except those listed in Other Logistics)

If, in the judgment of the Head REFEREE, an ARENA FAULT occurs that affects the outcome of the MATCH and any team on the affected ALLIANCE desires a replay, the MATCH will be replayed.

The outcome of the MATCH is affected if an error occurs that, in the judgement of the Head REFEREE, changes which ALLIANCE would have won the MATCH and/or the assignment of Ranking Points.

All reasonable effort is made to create the same conditions when replaying a MATCH. This means, for example, that a team that was BYPASSED prior to the start of the MATCH which is to be replayed, is BYPASSED for the replay MATCH. ROBOT and DRIVE TEAM starting locations do not need to be replicated when replaying a MATCH.

Note that an ARENA FAULT that does not affect MATCH outcome in the judgement of the Head REFEREE does not lead to a MATCH replay. Examples include, but are not limited to:

a. a piece of FIELD plastic falls into the FIELD, far away from any human or ROBOT activity, and in such a way that it does not affect MATCH outcome
b. delay in the playing of an ARENA sound
c. mismatch between the timer on the Audience Screen and the ARENA Timer
d. any adjustment or delay in assignment of a penalty (including those made after the MATCH)

11.4 Measurement

At each event, the ARENA will be open for at least thirty (30) minutes prior to the start of Qualification MATCHES, during which time teams may survey and/or measure the ARENA and bring ROBOTS on the FIELD to perform sensor calibration. The specific time that the FIELD is open will be communicated to teams at the event. Teams may bring specific questions or comments to the FTA.

T1. Freeze, ROBOT. During the period when the ARENA is open for measurement, ROBOTS can be enabled, but cannot move (i.e. neither the ROBOT, nor anything on the ROBOT, can move), nor can they interact with (e.g. shoot, push, pickup, etc.) POWER CELLS, POWER PORTS, GENERATOR SWITCHES, CONTROL PANELS, or other FIELD elements.

Violation: Verbal warning. If repeated at any point during the event or egregious YELLOW CARD.

11.5 Practice MATCHES

Practice MATCHES are played before Qualification Matches. The Practice MATCH schedule is available as soon as possible, but no later than the start of Practice MATCHES. For Regional events, it will also be published and available online at the *FIRST* Robotics Event Results site, except during exceptional circumstances. Practice MATCHES are randomly assigned, and teams may not switch scheduled Practice MATCHES. Each team is assigned an equal number of Practice MATCHES unless the number of teams multiplied by number of Practice MATCHES is not divisible by six. In this case, the Field Management System (FMS) randomly selects some teams to play an extra Practice MATCH.

Practice MATCHES are not guaranteed at District Events due to event schedule constraints.

11.5.1 Filler Line

A Filler Line is used to fill open slots at events that employ scheduled Practice MATCHES or all slots at events with an open Practice MATCH schedule. Teams from the Filler Line are used on a first come, first served basis to fill empty spots in Practice MATCHES left by other teams that do not report to Queueing. The number of teams in the Filler Line is dependent upon space at venues.

Only teams that meet all criteria below qualify for the Filler Line:

A. ROBOTS in the Filler Line must have passed Inspection (this requirement may be waived for events with open Practice MATCH schedules);
B. DRIVE TEAMS must join the Filler Line with their ROBOT;
C. Teams may not work on their ROBOT while in the Filler Line;
D. Teams may not occupy more than one spot in the Filler Line; and
E. If a team is queued for their Practice MATCH, they may not also join the Filler Line.

11.6 Qualification MATCHES

11.6.1 Schedule

The Qualification MATCH schedule is made available as soon as possible, but no later than one (1) hour before Qualification MATCHES are scheduled to begin. Teams receive one (1) hard copy and it is available at the *FIRST* Robotics Event Results site, except during exceptional circumstances. Each Qualification schedule consists of a series of rounds in which each team plays one (1) MATCH per round.

11.6.2 MATCH Assignment

FMS assigns each team two (2) ALLIANCE partners for each Qualification MATCH using a predefined algorithm, and teams may not switch Qualification MATCH assignments. The algorithm employs the following criteria, listed in order of priority:

1. maximize time between each MATCH played for all teams
2. minimize the number of times a team plays opposite any team
3. minimize the number of times a team is allied with any team
4. minimize the use of SURROGATES (teams randomly assigned by the FMS to play an extra Qualification MATCH)
5. provide even distribution of MATCHES played on Blue and Red ALLIANCE
6. provide even distribution of MATCHES played in each PLAYER STATION number.

All teams are assigned the same number of Qualification MATCHES, equal to the number of rounds, unless the number of teams multiplied by number of MATCHES is not divisible by six. In this case, the FMS randomly selects some teams to play an extra MATCH. For the purpose of seeding calculations, those teams are designated as SURROGATES for the extra MATCH. If a team plays a MATCH as a SURROGATE, it is indicated on the MATCH schedule, it is always their third Qualification MATCH, and the outcome of the MATCH has no effect on the team's ranking. YELLOW and RED CARDS assigned to SURROGATES, however, do carry forward to subsequent MATCHES.

11.6.3 Qualification Ranking

Ranking Points (RP) are units credited to a team based on their ALLIANCE'S performance in Qualification MATCHES. Ranking Points are awarded to each eligible team at the completion of each Qualification MATCH per Table 4-2.

Exceptions to Ranking Point assignment are as follows:

A. A SURROGATE receives zero (0) Ranking Points.
B. A DISQUALIFIED team, as determined by the Head REFEREE, receives zero (0) Ranking Points in a Qualification MATCH or causes their ALLIANCE to receive zero (0) MATCH points in a Playoff MATCH.
C. A "no-show" team is either DISQUALIFIED from or issued a RED CARD for that MATCH (see C6). A team is declared a no-show if no member of the DRIVE TEAM is in the ALLIANCE STATION at the start of the MATCH.

The total number of Ranking Points earned by a team throughout their Qualification MATCHES divided by the number of MATCHES they've been scheduled to play (minus any SURROGATE MATCH), then truncated to two (2) decimal places, is their Ranking Score (RS).

All teams participating in Qualification MATCHES are ranked by Ranking Score. If the number of teams in attendance is 'n', they are ranked '1' through 'n', with '1' being the team with the highest Ranking Score and 'n' being the team with the lowest Ranking Score.

Teams are ranked in order, using the sorting criteria defined in Table 11-2.

Table 11-2 Qualification MATCH ranking criteria

Order Sort	Criteria
1st	Ranking Score
2nd	Cumulative AUTO points
3rd	Cumulative ENDGAME points
4th	Cumulative TELEOP POWER CELL and CONTROL PANEL points
5th	Random sorting by the FMS

11.7 Playoff MATCHES

In Playoff MATCHES, teams do not earn Ranking Points; they earn a Win, Loss or Tie. Within each series of the Playoff MATCH Bracket, the first ALLIANCE to win two (2) MATCHES advances.

In the case where the Quarterfinal or Semifinal MATCH scores for both ALLIANCES are equal, the Win is awarded to the ALLIANCE per criteria listed in Table 11-3. A DISQUALIFIED team, as determined by the Head REFEREE, causes their ALLIANCE to receive zero (0) MATCH points in a Playoff MATCH.

In Finals MATCHES, the Champion ALLIANCE is the first ALLIANCE to win two (2) MATCHES. In the case where an ALLIANCE hasn't won two (2) MATCHES after three (3) MATCHES, the Playoffs proceed with up to three (3) additional Finals MATCHES, called Overtime MATCHES, until an ALLIANCE has won two (2) Finals MATCHES. In the case where the Overtime MATCH scores for both ALLIANCES are equal, the win for that Overtime MATCH is awarded based on the criteria listed in Table 11-3.

Table 11-3 Playoff MATCH Tiebreaker Criteria

Order Sort	Criteria
1st	Cumulative FOUL and TECH FOUL points due to opponent rule violations
2nd	Cumulative AUTO points
3rd	Cumulative ENDGAME points
4th	Cumulative TELEOP POWER CELL and CONTROL PANEL points
5th	MATCH is replayed

11.7.1 ALLIANCE Selection Process

At the end of the Qualification MATCHES, the top eight (8) seeded teams become the ALLIANCE Leads. The seeded ALLIANCES are designated, in order, ALLIANCE One, ALLIANCE Two, etc., down to ALLIANCE Eight. Using the ALLIANCE selection process described in this section, each ALLIANCE Lead chooses two (2) other teams to join their ALLIANCE.

If a team declines the ALLIANCE Lead position or doesn't send a student representative for ALLIANCE selection, they are ineligible to participate in the Playoff Tournament. If the declining/absent team would have been an ALLIANCE Lead, all lower ranked ALLIANCE Leads are promoted one spot. The next highest-ranked team moves up to become the ALLIANCE Eight Lead.

Each team chooses a student team representative who proceeds to the ARENA at the designated time (typically before the lunch break on the final day of the event) to represent their team. The designated student representative from each ALLIANCE in a Playoff MATCH is called the ALLIANCE CAPTAIN.

The ALLIANCE selection process consists of two (2) rounds during which each ALLIANCE CAPTAIN invites a team seeded below them in the standings to join their ALLIANCE. The invited team must not already have declined an invitation.

Round 1: In descending order (ALLIANCE One to ALLIANCE Eight), each ALLIANCE CAPTAIN invites a single team. The invited team's representative steps forward and either accepts or declines the invitation.

If the team accepts, it becomes a member of that ALLIANCE. If an invitation from a top eight ALLIANCE to another ALLIANCE Lead is accepted, all lower ALLIANCE Leads are promoted one spot. The next highest-seeded, unselected team moves up to become the ALLIANCE Eight Lead.

If the team declines, that team is not eligible to be picked again or to be a BACKUP TEAM (see Playoff MATCH Bracket), and the ALLIANCE CAPTAIN extends another invitation to a different team. If an invitation from a top eight ALLIANCE to another ALLIANCE Lead is declined, the declining team may still invite teams to join their ALLIANCE; however, it cannot accept invitations from other ALLIANCES.

The process continues until ALLIANCE Eight makes a successful invitation.

Round 2: The same method is used for each ALLIANCE CAPTAIN'S second choice except the selection order is reversed, with ALLIANCE Eight picking first and ALLIANCE One picking last. This process results in eight (8) ALLIANCES of three (3) teams each.

Of the remaining eligible teams, the highest seeded teams must either accept or decline to be included in a pool of available teams until there are up to eight (8) teams that accept to be added into the pool. FIELD STAFF will coordinate the assembly of this BACKUP pool immediately after the top ranked ALLIANCE has made their final pick. If a team is not available to accept inclusion in the BACKUP pool, it will be assumed they have declined the invitation.

11.7.2 Playoff MATCH Bracket

The Playoff MATCHES take place following the completion of the Qualification MATCHES and the ALLIANCE selection process. Playoff MATCHES are played in a bracket format as shown in Figure 11-3.

ALLIANCE Leads are assigned to PLAYER STATION 2, the first picks are assigned to their left in PLAYER STATION 1, and second picks are assigned to the ALLIANCE Lead's right in PLAYER STATION 3. If a BACKUP TEAM is in play, they will be assigned to the PLAYER STATION that was assigned to the DRIVE TEAM they're replacing. Teams cannot change assignments.

For Quarterfinal MATCHES, the higher seeded ALLIANCE is assigned to the Red ALLIANCE. Beyond the Quarterfinal MATCHES, the ALLIANCE on the top of each MATCH in Figure 11-3 is assigned to the Red ALLIANCE, regardless of whether they are the higher seeded ALLIANCE in that particular MATCH.

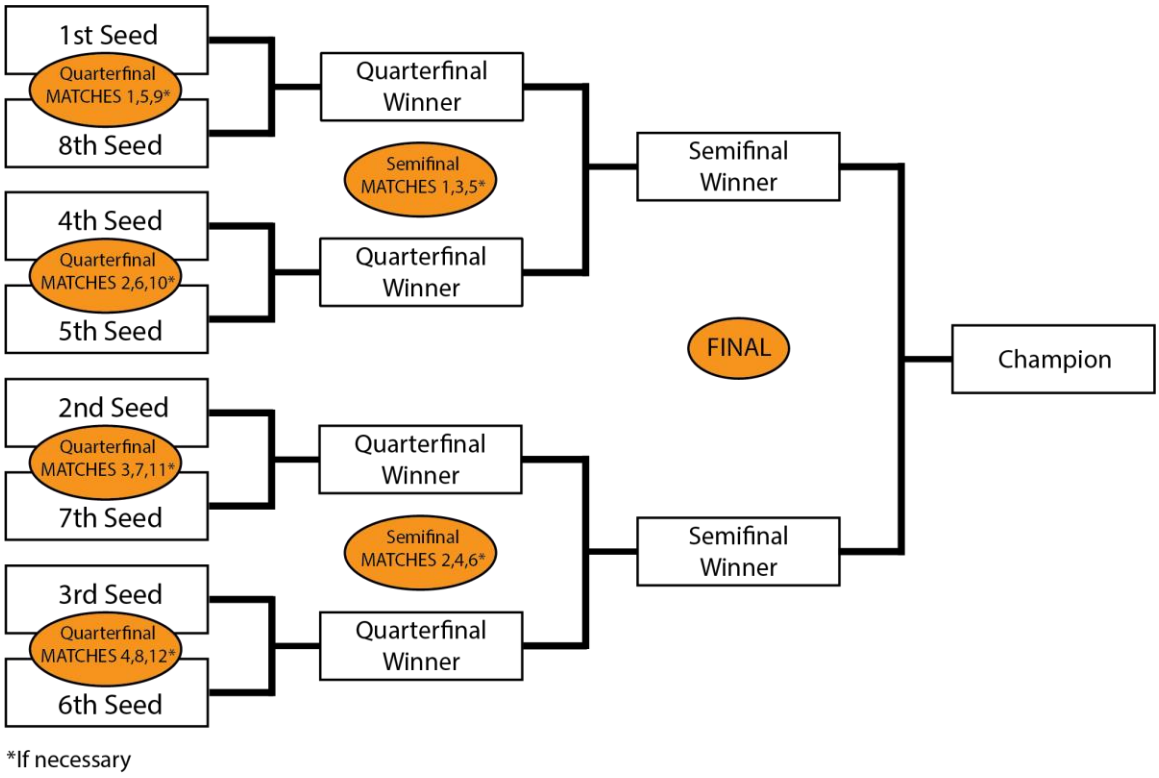


Figure 11-3 Playoff MATCH Bracket

In order to allow time between MATCHES for all ALLIANCES, the order of play is as follows:

Table 11-4 Playoff Order

Quarterfinal Round 1	Quarterfinal Round 2	Quarterfinal Round 3	Semifinals	Finals
Quarterfinal 1 (1 vs.8)	Quarterfinal 5 (1 vs.8)	Quarterfinal Tiebreaker 1[1]	Semifinal 1	Final 1
Quarterfinal 2 (4 vs.5)	Quarterfinal 6 (4 vs.5)	Quarterfinal Tiebreaker 2[1]	Semifinal 2	FIELD TIMEOUT
Quarterfinal 3 (2 vs.7)	Quarterfinal 7 (2 vs.7)	Quarterfinal Tiebreaker 3[1]	Semifinal 3	Final 2
Quarterfinal 4 (3 vs.6)	Quarterfinal 8 (3 vs.6)	Quarterfinal Tiebreaker 4[1]	Semifinal 4	FIELD TIMEOUT
	FIELD TIMEOUT[1]	FIELD TIMEOUT[1]	Semifinal Tiebreaker 1[1]	Final Tiebreakers (Overtime) [1]
		Any Replays due to ties[1]	Semifinal Tiebreaker 2[1]	Any Replays due to ties[1]
			FIELD TIMEOUT[1]	
			Any Replays due to ties[1]	

[1] - if required

11.7.3 Pit Crews

During the Playoff MATCHES, extra team members may be needed to maintain the ROBOT between MATCHES because of the distance between the FIELD and the pit area. Each team is permitted to have three (3) additional pit crew members who can also help with needed ROBOT repairs/maintenance.

11.7.4 TIMEOUTS

A TIMEOUT is a period of up to six (6) minutes between MATCHES which is used to pause Playoff MATCH progression.

During a TIMEOUT, the ARENA Timer displays the time remaining in the TIMEOUT. Both ALLIANCES enjoy the complete six (6) minute window. If an ALLIANCE completes their repairs before the ARENA Timer expires, the ALLIANCE CAPTAIN is encouraged to inform the Head REFEREE that they are ready to play. If both ALLIANCES are ready to play before the TIMEOUT expires, the next MATCH will start.

There are no TIMEOUTS for Practice or Qualification MATCHES.

If circumstances require an ALLIANCE to play in back-to-back MATCHES during the Playoff MATCHES, the Head REFEREE will issue a FIELD TIMEOUT to allow teams to prepare for the next MATCH. FIELD TIMEOUTS are the same time duration as TIMEOUTS.

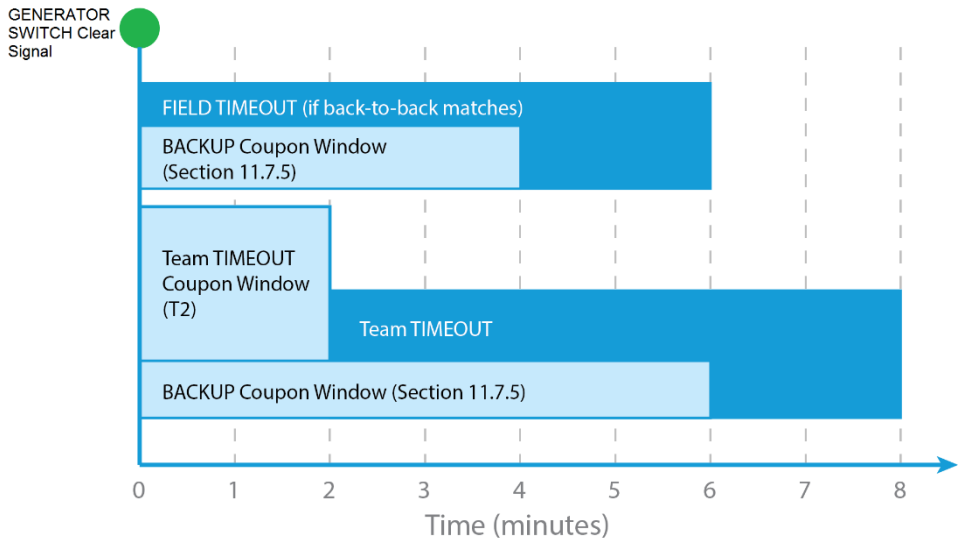


Figure 11-4 TIMEOUT Timeline

Each ALLIANCE in the Playoff tournament is issued (1) TIMEOUT.

Teams are expected to have their ROBOTS staged on the FIELD by the end of the TIMEOUT. Teams that cause a delay to the start of a MATCH after a TIMEOUT are at risk of being in violation of C7.

T2. If an ALLIANCE wishes to use their TIMEOUT, the ALLIANCE CAPTAIN must submit their TIMEOUT coupon to the Head REFEREE within two (2) minutes of the GENERATOR SWITCH Clear signal preceding their MATCH. If there is no preceding MATCH, the TIMEOUT coupon must be submitted no later than two (2) minutes before the scheduled MATCH time. The TIMEOUT will begin two (2) minutes after the GENERATOR SWITCH Clear signal (i.e. at the end of the Team TIMEOUT Coupon Window depicted in Figure 11-4)

A request presented outside the defined parameters in T2 will be denied.

There are no cascading TIMEOUTS. If an ALLIANCE calls a TIMEOUT during a FIELD TIMEOUT, the FIELD TIMEOUT will expire two (2) minutes after the GENERATOR SWITCH Clear signal and the ALLIANCE'S TIMEOUT will begin.

If an ALLIANCE wishes to call a TIMEOUT during a FIELD TIMEOUT, it must still do so within two (2) minutes of the GENERATOR SWITCH Clear signal preceding their MATCH, per T2.

TIMEOUTS are not transferrable between ALLIANCES, meaning an ALLIANCE cannot hand their designated TIMEOUT coupon to another ALLIANCE to use, however an ALLIANCE may use their own coupon for any purpose they wish.

If a Playoff MATCH is replayed because of an ARENA FAULT which rendered a ROBOT inoperable, the Head REFEREE has the option of calling a FIELD TIMEOUT.

11.7.5 BACKUP TEAMS

In the Playoff MATCHES, it may be necessary for an ALLIANCE to replace one of its members due to a faulty ROBOT. ROBOT faults include but are not limited to:

1. mechanical damage,

2. electrical issues, or
3. software problems.

In this situation, the ALLIANCE CAPTAIN has the option to bring in only the highest seeded team from the pool of available teams to join its ALLIANCE. The team whose ROBOT and DRIVE TEAM replaces another ROBOT and DRIVE TEAM on an ALLIANCE during the Playoff MATCHES is called the BACKUP TEAM.

The resulting ALLIANCE is then composed of four (4) teams. The replaced team remains a member of the ALLIANCE for awards, but cannot return to play, even if their ROBOT is repaired.

Each ALLIANCE is allotted one (1) BACKUP TEAM Coupon during the Playoff MATCHES. If a second ROBOT from the ALLIANCE becomes inoperable, then the ALLIANCE must play the following MATCHES with only two (2) (or even one (1)) ROBOTS.

> Example: Three (3) teams, A, B and C, form an ALLIANCE going into the Playoff MATCHES. The highest seeded team not on one of the eight (8) ALLIANCES is Team D. During one of the Playoff MATCHES, Team C's ROBOT suffers damage to its mechanical arm. The ALLIANCE CAPTAIN decides to bring in Team D to replace Team C. Team C and their ROBOT are not eligible to play in any subsequent Playoff MATCHES. The new ALLIANCE of Teams A, B, and D are successful in advancing to the Finals and win the event. Teams A, B, C, and D are all recognized as members of the Winning ALLIANCE and receive awards

In the case where a BACKUP TEAM is part of the Winning or Finalist ALLIANCE, there will be a four (4)-team Winning or Finalist ALLIANCE.

If during a TIMEOUT an ALLIANCE CAPTAIN determines that they need to call up a BACKUP TEAM, they must submit their BACKUP TEAM coupon to the Head REFEREE while there are still at least two (2) minutes remaining on the ARENA Timer. After that point, they will not be allowed to utilize the BACKUP TEAM.

Alternatively, an ALLIANCE CAPTAIN may choose to call up a BACKUP TEAM without using their TIMEOUT by informing the Head REFEREE directly within two (2) minutes of the Head REFEREE issuing the GENERATOR SWITCH Clear signal preceding their MATCH. If there is no preceding MATCH, the BACKUP TEAM coupon must be submitted no later than two (2) minutes before the scheduled MATCH time.

In the case where the ALLIANCE CAPTAIN'S ROBOT is replaced by a BACKUP TEAM, the ALLIANCE CAPTAIN is allowed as a sixteenth ALLIANCE DRIVE TEAM member. This additional representative may only serve in an advisory role and is considered a COACH (e.g. can't be a HUMAN PLAYER)

The Head REFEREE will not accept the BACKUP TEAM coupon unless it lists the number of the team whose ROBOT is being replaced and is initialed by the ALLIANCE CAPTAIN. Once a BACKUP TEAM coupon is submitted and accepted by the Head REFEREE, the BACKUP TEAM coupon may not be withdrawn by the ALLIANCE.

T3. An ALLIANCE may not request a TIMEOUT or a BACKUP TEAM after a Playoff MATCH is stopped by the Head REFEREE (e.g. due to an ARENA FAULT or a safety issue). The sole exception is if the replay is due to an ARENA FAULT that rendered a ROBOT inoperable.

Violation: A request presented outside parameters defined will be denied.

> If a Playoff MATCH is replayed per T3, the Head REFEREE has the option of calling a FIELD TIMEOUT.

11.8 Advancement Through the District Model

Teams advance through the season depending on the events at which they compete: Regional or District. This section details how teams advance from Regional events to the *FIRST* Championship, or from District qualifying events, to their District Championship, to the *FIRST* Championship.

11.8.1 District Events

District teams are ranked throughout the season based on the points they earn at their first two (2) home District events they attend, as well as at their District Championship. Points are awarded to teams as follows:

Table 11-5 District Point Assignment

Category	Points
Qualification Round Performance	$QualificationPoints\,(R,N,\alpha) = \left\lfloor InvERF\left(\frac{N-2R+2}{\alpha N}\right)\left(\frac{10}{InvERF\left(\frac{1}{\alpha}\right)}\right)+12 \right\rfloor$ (For a typically sized District event, this will result in a minimum of four (4) points being awarded for Qualification round performance. For events of all sizes, a maximum of twenty-two (22) points will be awarded.)
ALLIANCE CAPTAINS	Equal to 17 minus the ALLIANCE CAPTAIN number (e.g. 14 points for ALLIANCE #3 Captain)
Draft Order Acceptance	Equal to 17 minus the Draft Order Acceptance Number (e.g. 12 points for the team that is 5th to accept an invitation)
Playoff Advancement	Points awarded based on team participation in individual playoff rounds, and whether or not the ALLIANCE advances. See details below.
Judged Team Awards	10 points for Chairman's Award 8 points each for Engineering Inspiration and Rookie All Star Awards 5 points each for all other judged team awards
Team Age	10 points for Rookie teams 5 points for second-year teams

Points earned at District Championships are multiplied by three (3) and then added to points earned at District events, to determine the final season point total for the team.

If there is a tie in the season point total between teams, those items are broken using the following sorting criteria:

Table 11-6 District team sort criteria

Order Sort	Criteria
1st	Total Playoff Round Performance Points
2nd	Best Playoff Round Finish at a single event
3rd	Total ALLIANCE Selection Results Points
4th	Highest Qualification Round Seed or Draft Order Acceptance (i.e. Highest ALLIANCE Selection points at a single event)
5th	Total Qualification Round Performance Points
6th	Highest Individual MATCH Score, regardless of whether that score occurred in a Qualification or Playoff MATCH
7th	Second Highest Individual MATCH Score, regardless of whether that score occurred in a Qualification or Playoff MATCH
8th	Third Highest Individual MATCH Score, regardless of whether that score occurred in a Qualification or Playoff MATCH
9th	Random Selection

11.8.1.1 Qualification Round Performance

The calculation of Qualification performance points is done using the equation (an inverse error function) in the table above. The equation utilizes the following variables:

- R – the qualification rank of the team at the event at the conclusion of Qualification MATCHES (as reported by FMS)
- N – the number of *FIRST* Robotics Competition teams participating in the Qualification rounds at the event
- Alpha (α) – a static value (1.07) used to standardize the distribution of points at events

This formula generates an approximately normal distribution of Qualification Round Performance points at an event, based on rank, with most teams getting a moderate number of points, and fewer teams getting the highest or lowest numbers of points available.

Table 11-7 displays sample Qualification Round Performance points for variously ranked teams at a forty (40) team event. The system will automatically generate the appropriate points for each team based on their rank and the number of teams at the event.

Table 11-7 Sample Qualification Round point assignments

Rank	1	2	3	4	…	19	20	21	…	37	38	39	40
Points	22	21	20	19	…	13	13	12	…	6	6	5	4

11.8.1.2 ALLIANCE Selection Results

This attribute measures both individual team qualification round seeding performance and recognition by peers.

ALLIANCE CAPTAINS are recognized based on their qualification round seeding rank. This rank is a result of the rules of the game, which typically incorporate several team performance attributes, and are designed to eliminate ties in rank. Non-ALLIANCE CAPTAINS are rewarded based on peer recognition. To be invited to join an ALLIANCE, a team's peers have decided that the team has attributes that are desirable. Giving points for ALLIANCE selection also supports come-from-behind teams. A team taking several MATCHES to optimize their performance may be recognized as a late bloomer by a top seeded team, even if that performance isn't reflected in the rankings because of poor performance in early MATCHES. These points also have the potential to recognize teams employing a minority strategy with

their ROBOT. Teams with unique or divergent ROBOT capabilities that complement the strengths of other ALLIANCE members may be selected to fill a strategic niche.

Note also that ALLIANCE CAPTAINS are given the same number of points as the team drafted in the same sequence. For example, the third ALLIANCE CAPTAIN gets the same number of points as the third draft. Numerical analysis supports the idea that ALLIANCE CAPTAINS are about as strong in ROBOT performance as equivalently drafted teams. As an additional minor benefit, awarding the same points for ALLIANCE CAPTAINS and equivalent drafts lubricates the acceptance of draft offers between ALLIANCE CAPTAINS, which gives teams out of the top eight the chance to experience being ALLIANCE CAPTAINS themselves.

11.8.1.3 Playoff Round Performance

This attribute measures team performance as part of an ALLIANCE.

All teams on the ALLIANCE winning a particular playoff series, who participate in MATCHES with their ROBOTS, receive five (5) points per MATCH won. In most cases, teams receive ten (10) points at each of the Quarterfinal, Semifinal, and Final levels, unless a BACKUP ROBOT is called in to play.

11.8.1.4 Awards

This attribute measures team performance with respect to team awards judged at the event.

The points earned for team awards in this system are not intended to capture the full value of the award to the team winning the award, or to represent the full value of the award to *FIRST*. In many ways, the team's experience in being selected for awards, especially the Chairman's Award, the Engineering Inspiration Award, and the Rookie All Star Award, is beyond measure, and could not be fully captured in its entirety by any points-based system. Points are being assigned to awards in this system only to help teams recognize that *FIRST* continues to be "More than Robots[SM]," with the emphasis on our cultural awards, and to assist in elevating award-winning teams above non-award-winning teams in the ranking system.

Teams only get points for team awards judged at the event. If an award is not judged, e.g. Rookie Highest Seed, is not for a team, e.g. the Dean's List Award, or is not judged at the event, e.g. Safety Animation Award, sponsored by UL, no points are earned.

11.8.1.5 Team Age

This attribute recognizes the difficulty in being a rookie or second-year team.

Points are awarded to rookie and second year teams in recognition of the unique challenges teams face in those early years, and to increase the chance that they will make it to the District Championship to compete with their ROBOTS. Like our dedicated Rookie awards, these additional points are intended to recognize and motivate newer participants in *FIRST* Robotics Competition. These points are awarded once at the beginning of the season. Rookie year is calculated based on the year in which *FIRST* recognizes the team as a rookie.

11.8.1.6 Regional Participation

District teams do not earn points for their actions at any Regionals they may attend, nor are eligible for *FIRST* Championship qualifying judged awards at those events. However, if a District team does earn a slot at the *FIRST* Championship while attending a Regional event, that slot does count as part of the total Championship allocation the District is receiving for the season.

11.8.2 District Championship Eligibility

A team competing in a District qualifies for their District Championship by meeting one of the following criteria:

A. District Chairman's Award Winner
B. District Ranking; based on total points earned at their first two home District events as detailed in District Events.

> Teams do not earn points at third or subsequent District events, nor at any inter-district or Regional events at which they compete during the season.
>
> If a team declines an invitation to the District Championship, the next highest uninvited team on the list is invited, and so on, until the event capacity is filled.

C. District Engineering Inspiration winner (qualifies to compete for the award only)
D. District Rookie All Star winner (qualifies to compete for the award only)

The capacity of each District Championship is shown in Table 11-8. Each District determines the number of teams that qualify for their District Championship. These limits are based on factors including but not limited to the total number of teams in the District, available venue capacity, etc.

Table 11-8 2020 District Championship Capacities

District Championship	Capacity
FIRST Chesapeake District Championship	80
FIRST Israel District Championship	45
FIRST Mid-Atlantic District Championship	60
FIRST North Carolina State Championship	32
FIRST Ontario Provincial Championship	80
FIRST in Texas District Championship	64
Indiana State Championship	32
Michigan State Championship	200
New England District Championship	64
Pacific Northwest District Championship	64
Peachtree District State Championship	45

11.8.3 District Championships with Multiple Divisions

Some District Championships have a sufficient number of teams to justify using more than one division. Teams are assigned divisions by *FIRST* using a process developed by *FIRST* in Michigan.

The process employs a "brute force iterative randomizer" and is executed as follows:

1. The district team list is sorted in order of cumulative district points earned as described in District Events.
2. The list is divided into quartiles based on rank (e.g. the 1st quartile has the top 25% ranked teams)
3. Division assignments are randomly generated using equal contribution from each quartile
4. Three (3) criteria are calculated for each division:
    a. Average strength: The arithmetic mean of the district point values of teams in a division

b. Distribution of strength: The Signal to Noise Ratio (SNR) of the district point values of teams in a division. SNR is calculated as follows:

$$SNR = 10(\log\frac{\bar{x}^2}{\sigma^2})$$

$\bar{x}$ = arithmetic mean of the district points in a division

σ = standard deviation of the district points in a division

c. Distribution of strength for "top" teams: The SNR of the district point values of teams in the 1st quartile of a division.

5. The three (3) criteria for each division are compared to the other division(s). If the difference between the division's value and any other division's value exceeds the limits in Table 11-9, the criteria is not met.

Table 11-9 District Championship Division Evaluation Limits

	Two (2) Divisions	Four (4) Divisions
Average strength	1	2
Distribution of strength	1	2.5
Distribution of strength for "top" teams	1.5	2

6. If all three (3) criteria met, event organizers publish the assignments. If any of the three (3) criteria are not met, assignments are rejected, and the process returns to Step 3.

In these cases:

- Division winning ALLIANCES play each other in District Championship Playoffs, employing the bracket below that corresponds to their District, until a winning ALLIANCE for the event is determined.

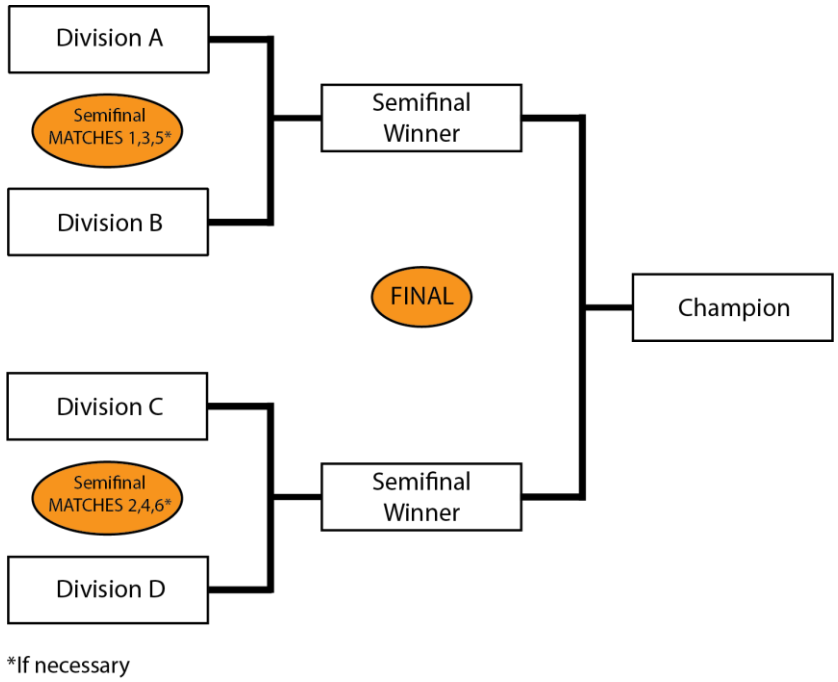


Figure 11-5 FIRST in Michigan District Championship Playoff Bracket

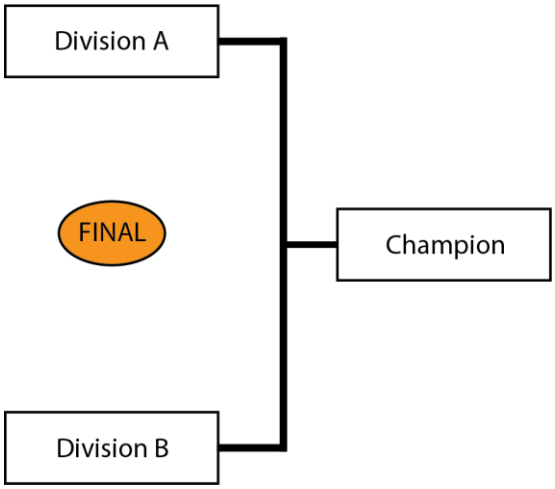


Figure 11-6 Chesapeake District Championship Playoff Bracket

- Teams participating in District Championship Playoffs earn Playoff round performance District points as described in Playoff Round Performance.
- If an ALLIANCE in a District Championship Playoff has not yet adopted a BACKUP ROBOT per BACKUP TEAMS, the ALLIANCE CAPTAIN may bring in only the highest seeded team from their Division's pool of available teams to join its ALLIANCE.

11.9 Advancement to the *FIRST* Championship

FIRST invites teams listed below the *FIRST* Championship:

A. Prequalified teams

members of the *FIRST* Hall of Fame
original and sustaining teams since 1992
2019 *FIRST* Championship winners
2019 *FIRST* Championship Engineering Inspiration Award winners
2019 *FIRST* Championship Chairman's Award Finalists

B. 2020 Regional Qualifying teams

Qualifying Award Winners (excluding District teams participating at the Regional)
a) Regional Chairman's Award
b) Engineering Inspiration Award
c) Rookie All-Star Award
Regional Winners
Wild Card recipients

C. 2020 District Championship Qualifying teams

Qualifying Award Winners
a) Chairman's Award
b) Engineering Inspiration Award
c) Rookie All Star winners
District Championship Winners
Teams on the final District ranking list, as deep in the ranking list as the District needs to go to fill their allocation.

11.9.1 Wild Cards

Wild cards are used to qualify additional teams for the *FIRST* Championship from Regional events.

All Regional events have a minimum of one (1) Wild Card slot. Additional Wild Cards are generated as follows:

- **A.** any team that has already qualified for the *FIRST* Championship (per Advancement to the *FIRST* Championship, parts A and B) that earns an additional spot (per Advancement to the *FIRST* Championship, part B) generates one (1) Wild Card.
- **B.** any team earning two (2) qualifying spots at a single Regional (per Advancement to the *FIRST* Championship, part B, e.g. by being on the Winning ALLIANCE and earning the Chairman's Award) generates one (1) Wild Card.
- **C.** any team that has already qualified for the *FIRST* Championship (per Advancement to the *FIRST* Championship, parts A and B), and earns two (2) qualifying spots (per Advancement to the *FIRST* Championship, part B) generates two (2) Wild Card slots.

Wild Card slots are distributed to the Finalist ALLIANCE, in the order of team selection per ALLIANCE Selection Process, until either all Wild Card slots generated at that event are distributed or the Finalist ALLIANCE is out of teams, whichever comes first.

If a member of the Finalist ALLIANCE has already qualified for the *FIRST* Championship they are skipped and the next member of the ALLIANCE is awarded the available Wild Card.

Unused Wild Card slots are neither backfilled nor replaced.

> A team may decline a Wild Card, but this does not pass the Wild Card slot down to the next available team. The Wild Card goes unused.

Teams selected from the *FIRST* Championship Waitlist to participate at the *FIRST* Championship do not generate Wild Cards.

11.9.2 *FIRST* Championship Eligibility for District Teams

Districts receive the percentage of 'available slots' at their assigned *FIRST* Championship location, rounded up to the nearest whole slot, equal to the percentage of teams they have in their District compared to the total of all *FIRST* Robotics Competition teams in the current season who would normally be assigned to their *FIRST* Championship location. 'Available slots' are calculated by taking the total number of slots at each *FIRST* Championship location, subtracting the number of pre-qualified teams assigned to that location, and also subtracting a 10% allowance for waitlisted teams, as Districts are still allowed to send waitlisted teams to the *FIRST* Championship. Further, this overall calculation uses a 'snapshot' of teams that have registered and paid as of a specific day a week or so after season payment due.

If a District team earns a slot to the *FIRST* Championship within the season, but is not able to attend, the top ranked team who has not yet been offered a slot is given the opportunity, and so on, until all slots are filled. Slots for pre-qualified teams will not be backfilled.

Table 11-10 outlines the District Championship allocations for 2020. Districts determine the number of Dean's List, Chairman's, Rookie All Star, and Engineering Inspiration Awards to present at their Championship, within a range established by *FIRST*. The team counts are based on the team representation of the respective District at the respective Championship. For the awards, ranges are developed by using ratios agreed upon by *FIRST* and District Leadership. These ranges allow each District to represent their own community as they see fit.

For the Chairman's Award, the ratios range from one (1) Chairman's Award team for every eighteen (18) Championship District teams to one (1) Chairman's Award team for every nine (9) Championship District teams.

For the Dean's List Award, the ratios range from one (1) Dean's List Finalist for every nine (9) Championship District teams to one (1) Dean's List Finalist for every six (6) Championship District teams.

Table 11-10 District slot allocation for FIRST Championship

			Chairman's Award			Dean's List Award			Engineering Inspiration Award			Rookie All Star Award		
	FIRST Championship Slots	*FIRST* Championship Normalized Slots	Max Ratio	Min Ratio	District Selection	Max Ratio	Min Ratio	District Selection	Min	Max	District Selection	Min	Max	District Selection
			18	**9**		**9**	**6**							
***FIRST* Championship: Detroit**														
***FIRST* Chesapeake**	20		1	2	2	2	3	3	1	2	2	1	2	1
***FIRST* in Michigan**	90		5	10	5	10	15	15	1	2	1	1	2	2
***FIRST* Mid-Atlantic**	21		1	2	2	2	4	4	1	2	2	1	2	1
Indiana *FIRST*	10		1	1	1	2	2	2	1	2	1	1	2	1
NE *FIRST*	33		2	4	4	4	6	6	1	2	2	1	2	1
Ontario	27		2	3	3	3	5	5	1	2	1	1	2	1
***FIRST* Championship: Houston**														
***FIRST* Israel**	13	11	1	1	1	1	2	2	1	2	1	1	2	1
***FIRST* in Texas**	37	32	2	4	4	4	5	5	1	2	2	1	2	2
***FIRST* North Carolina**	14	11	1	1	1	2	2	2	1	2	2	1	2	1
Pacific Northwest	28	12	1	3	3	3	4	4	1	2	2	1	2	1
Peachtree	16	24	1	2	2	2	2	2	1	2	2	1	2	2

All Districts, regardless of Championship Slot allocation, may award one (1) or two (2) Engineering Inspiration and Rookie All-Star Awards.

Chairman's Award and Dean's List Award maximums and minimums are determined by ratios applied to a given District's Championship Slot allocations. However, Districts assigned to Houston have relatively larger Championship slot allocations for a given team count compared to Districts assigned to Detroit, and we did not want these larger allocations to skew award allocations. So, for the purposes of award allocations only, Championship slots for Houston Districts were 'normalized', as shown in the table, reducing the slots allocated to what they would have been if both Championship geographies had the same total number of *FIRST* Robotics Competition teams. This 'normalized' slot allocation was then used to determine award minimums and maximums. As noted, these normalized slot values are used only for

award allocations. The Houston-assigned Districts still retain the full Championship Slots Allocated (the larger number) shown in the table.

11.10 *FIRST* Championship: Additions and Exceptions

At the 2020 *FIRST* Championship events, teams are split into six (6) Divisions. The process used to assign teams to their Division is as follows:

1. Rookies are assigned randomly, team by team, sequentially to Divisions (i.e. a team in Division 1, a team in Division 2, a team in Division 3, a team in Division 4, a team in Division 5, a team in Division 6, then back to Division 1 again, until Rookies are all assigned to a Division.
2. Step 1 is repeated with Veteran teams.

Each Division plays a standard Tournament as described in Qualification MATCHES and Playoff MATCHES to produce the Division Champions. Those six (6) Division Champions proceed to the Championship Playoffs, on the Einstein FIELDS, to determine the 2020 *FIRST* Robotics Competition Championship Winners, per *FIRST* Championship Playoffs .

11.10.1 Four ROBOT ALLIANCES

There is no provision for BACKUP TEAMS at the Championship.

Instead, before each Division Playoff Tournament, ALLIANCES are selected per the process as described in ALLIANCE Selection Process, however the process continues with a 3rd round of selection as follows.

Round 3: The same method is used for each ALLIANCE CAPTAIN'S third choice except the selection order is reversed again, with ALLIANCE One picking first and ALLIANCE Eight picking last. This process results in eight (8) ALLIANCES of four (4) teams each.

ALLIANCES may start with any three (3) of the four (4) ROBOTS on their ALLIANCE during Division Playoff MATCHES and during the Championship Playoffs. The list of three (3) teams participating in the MATCH and their selected PLAYER STATIONS is called the LINEUP. One representative from the team not on the LINEUP is allowed as a sixteenth ALLIANCE member. This additional representative may only serve in an advisory role and will be considered a COACH (e.g. can't be a HUMAN PLAYER).

The LINEUP is kept confidential until the FIELD is set for the MATCH, at which point each ALLIANCE'S LINEUP appears on the Team Signs.

If an ALLIANCE does not submit a LINEUP for their first of the Division Playoffs or the Championship Playoffs within two (2) minutes before the scheduled MATCH time, the LINEUP is the ALLIANCE Lead, 1st ALLIANCE selection, and 2nd ALLIANCE selection. If any of these three (3) ROBOTS are unable to play, the ALLIANCE must play the MATCH with only two (2) (or even one (1)) ROBOT(S).

If an ALLIANCE would like to change their LINEUP after their 1st Division Playoff or Championship Playoff MATCH, the ALLIANCE CAPTAIN must report the LINEUP to the Head REFEREE, or their designee, in writing prior to end of the preceding MATCH (e.g. the LINEUPS for Quarterfinal 2 must be submitted before the end of Quarterfinal 1). If the HEAD REFEREE is busy and there is no designee defined, the ALLIANCE CAPTAIN waits in the question box to report the LINEUP.

Once the LINEUP is declared, it cannot be changed unless there is a team or FIELD TIMEOUT. If there is a TIMEOUT, the ALLIANCE CAPTAIN may submit a different LINEUP, but must do so while there are still more than two (2) minutes remaining in the TIMEOUT.

> Example: Four (4) teams, A, B, C and D, form an ALLIANCE going into the Playoff MATCHES on their Division FIELD. During one of the Playoff MATCHES, Team C's ROBOT becomes inoperable. The ALLIANCE decides to bring in Team D to replace Team C. Team C repairs their ROBOT and may play in any subsequent Playoff MATCHES replacing Team A, B, or D. All four (4) ALLIANCE members are also eligible to play MATCHES during the Championship Playoffs should the ALLIANCE win the Division Tournament.

If a MATCH must be replayed due to an ARENA FAULT, the LINEUP for the replayed MATCH is the same as the original MATCH. The sole exception is if the ARENA FAULT rendered a ROBOT inoperable, in which case the LINEUP can be changed.

11.10.2 *FIRST* Championship Pit Crews

FIRST distributes buttons to the ALLIANCE CAPTAINS during the ALLIANCE CAPTAIN meeting, which takes place on the Division FIELDS. These buttons provide the necessary access to the ARENA for pit crew members.

T4. Only team members wearing proper buttons are allowed on the ARENA floor during Division and Championship Playoff MATCHES.

Violation: MATCH will not start until the situation is corrected. Those not displaying identification must leave the ARENA.

> Teams should assume they may be chosen for an ALLIANCE and think about the logistics of button distribution and set a plan prior to the ALLIANCE selection process. It is each ALLIANCE CAPTAIN'S responsibility to distribute buttons to their pit crew members.

11.10.3 *FIRST* Championship Playoffs

The six (6) Division Champions play a round-robin style tournament to determine the 2020 *FIRST* Robotics Competition Champions. In this format, each Division Champion plays one MATCH against each of the other Division Champions. The order of MATCHES is shown in Table 11-11.

Table 11-11 Championship MATCH order

Round	MATCH	Houston				Detroit			
		Mass		Energy		Mass		Energy	
		Red	Blue	Red	Blue	Red	Blue	Red	Blue
1	1	Carver	Turing			Archimedes	Tesla		
	2			Galileo	Roebling			Carson	Darwin
	3	Hopper	Newton			Curie	Daly		
2	4			Carver	Roebling			Archimedes	Darwin
	5	Turing	Newton			Tesla	Daly		
	6			Galileo	Hopper			Carson	Curie
3	7	Carver	Newton			Archimedes	Daly		
	8			Roebling	Hopper			Darwin	Curie
	9	Turing	Galileo			Tesla	Carson		
4	10			Hopper	Carver			Curie	Archimedes
	11	Newton	Galileo			Daly	Carson		
	12			Roebling	Turing			Darwin	Tesla
5	13	Galileo	Carver			Carson	Archimedes		
	14			Hopper	Turing			Curie	Tesla
	15	Newton	Roebling			Daly	Darwin		

In the Championship Playoffs, ALLIANCES do not earn Ranking Points; they earn Championship Points. Championship Points are units credited to an ALLIANCE based on their performance in each MATCH and are awarded at the completion of each Round Robin tournament MATCH.

- **A.** The winning ALLIANCE receives two (2) Championship Points
- **B.** The losing ALLIANCE receives zero (0) Championship Points
- **C.** In the event of a tied score, each ALLIANCE receives one (1) Championship Point

Exceptions to A-C are as follows:

- **D.** A DISQUALIFIED team, as determined by the Head REFEREE, causes their ALLIANCE to receive zero (0) Championship points.

The total number of Championship Points earned by a team throughout the round robin MATCHES divided by the number of round robin MATCHES in which they've been scheduled is their Championship Score (CS).

All teams participating in round robin MATCHES are ranked by Championship Score. If the number of teams in attendance is 'n', they are ranked '1' through 'n', with '1' being the team with the highest Championship Score and 'n' being the team with the lowest Championship Score.

Table 11-12 Einstein Tournament Ranking Criteria

Order Sort	Criteria
1st	Championship Score
2nd	Cumulative AUTO points
3rd	Cumulative ENDGAME points
4th	Cumulative TELEOP POWER CELL and CONTROL PANEL points
5th	If tie affects which ALLIANCES advance to Playoffs, a tiebreaker MATCH is played between the affected ALLIANCES. If tie is between ALLIANCES advancing to Playoffs, FMS randomly seeds tied ALLIANCES to determine ALLIANCE color.

The two (2) ALLIANCES with the highest Championship Scores at the conclusion of the round robin tournament advance to the Einstein Finals. In the Einstein Finals, ALLIANCES do not earn points, they earn a Win, Loss or Tie. The first ALLIANCE to win two (2) MATCHES is declared the 2020 *FIRST* Robotics Competition Champions.

During the Einstein Finals, if the MATCH score of each ALLIANCE is equal, the MATCH is replayed. In this circumstance, the LINEUP may be changed

11.10.4 *FIRST* Championship TIMEOUTS

There are no TIMEOUTS for teams in the Einstein tournament.

12 GLOSSARY

Term	Definition
ACTIVATED	During TELEOP, the state of a SHIELD GENERATOR Stage that has reached CAPACITY and, if required, has the corresponding CONTROL PANEL action successfully completed.
ACTIVE DEVICE	any device capable of dynamically controlling and/or converting a source of electrical energy by the application of external electrical stimulus
ALLIANCE	a cooperative of up to four (4) *FIRST* Robotics Competition teams
ALLIANCE CAPTAIN	The designated student representative from each ALLIANCE in a Playoff MATCH
ALLIANCE STATION	a 30-ft. (~914 cm) wide by 10 ft. 9⅛ in. (~328 cm) to 12 ft. 10⅞ in. (~393 cm) deep infinitely tall volume formed by, and including the ALLIANCE WALL, the edge of the carpet, and ALLIANCE colored tape
ALLIANCE WALL	The ALLIANCE WALL is the structure that separates ROBOTS from DRIVERS, COACHES, and HUMAN PLAYERS. It consists of three (3) PLAYER STATIONS, the LOADING BAY, and the POWER PORT. ALLIANCE WALLS define the short edges of the FIELD and, along with the guardrails, prevent ROBOTS from exiting the FIELD during the MATCH
ARENA	all elements of the game infrastructure that are required to play INFINITE RECHARGE℠: the FIELD, POWER CELLS, and all equipment needed for FIELD control, ROBOT control, and scorekeeping
ARENA FAULT	an error in ARENA operation
AUTO	The first phase of each MATCH is called Autonomous (AUTO) and consists of the first fifteen (0:15) seconds.
BACKUP TEAM	The team whose ROBOT and DRIVE TEAM replaces another ROBOT and DRIVE TEAM on an ALLIANCE during the Playoff MATCHES
BOM	Bill of Material
BOTTOM PORT	a 10 in. (~25 cm) tall, 2 ft. 10 in. (~86 cm) wide rectangle. The bottom edge is 1 ft. 6 in. (~46 cm) above the carpet.
BOUNDARIES	3 in. (~8 cm) wide, 1 in. (~3 cm) tall steel barriers that divide the area inside the SHIELD GENERATOR into four (4) equal sized rectangles that are 5 ft. 3¾ in. (~162 cm) wide by 5 ft. 10⅞ in. (~180 cm) deep.
BUMPERS	a required assembly which attaches to the ROBOT frame
BUMPER ZONE	the volume contained between the floor and a virtual horizontal plane 7½ in. (~19 cm) above the floor in reference to the ROBOT standing normally on a flat floor
BYPASSED	the state assigned to any ROBOT which is unable or ineligible to participate in that MATCH as determined by the FTA, LRI, or Head REFEREE
CAPACITY	the number of POWER CELLS, defined in Table 4-1, that must be scored to charge each stage.

Term	Definition
COACH	a precollege student or adult mentor member of the DRIVE TEAM who acts as a guide or advisor
COMPONENT	any part in its most basic configuration, which cannot be disassembled without damaging or destroying the part or altering its fundamental function
CONTROL	A ROBOT is in CONTROL of a POWER CELL if: **A.** the POWER CELL is fully supported by the ROBOT, **B.** the POWER CELL travels across the FIELD such that when the ROBOT changes direction, the POWER CELL travels with the ROBOT, or **C.** the ROBOT is holding a POWER CELL against a FIELD element in attempt to guard or shield it.
CONTROL PANEL	a 2 in. (~5 cm) tall, 2 ft. 8 in. (~81 cm) diameter disk constructed of two pieces of ¼ in. (~6 mm) thick polycarbonate, spaced apart by ten ½ in. (~13 mm) diameter metal spacers at regular intervals.
CORRAL	the collection area for scored POWER CELLS located at the rear base of the POWER PORT
COTS	Commercial off the Shelf, a standard (i.e. not custom order) part commonly available from a VENDOR for all teams for purchase
CUSTOM CIRCUIT	any electrical COMPONENT of the ROBOT other than motors, pneumatic solenoids, roboRIO, PDP, PCM, VRM, RSL, 120A breaker, motor controllers, relay modules (per R29-B), wireless bridge, electrical solenoid actuators, or batteries
DISABLED	the state in which a ROBOT is commanded to deactivate all outputs, rendering the ROBOT inoperable for the remainder of the MATCH
DISQUALIFIED	the state of a team in which they receive zero (0) MATCH points and zero (0) Ranking Points in a Qualification MATCH or causes their ALLIANCE to receive zero (0) MATCH points in a Playoff MATCH
DRIVER	a precollege student member of the DRIVE TEAM who is an operator and controller of the ROBOT
DRIVE TEAM	a set of up to five (5) people from the same *FIRST* Robotics Competition team responsible for team performance for a specific MATCH.
ENDGAME	The final thirty (0:30) seconds of TELEOP
ENERGIZED	Stage 3 ACTIVATED
FABRICATED ITEM	any COMPONENT or MECHANISM that has been altered, built, cast, constructed, concocted, created, cut, heat treated, machined, manufactured, modified, painted, produced, surface coated, or conjured partially or completely into the final form in which it will be used on the ROBOT
FIELD	26 ft. 11¼ in. (~821 cm) by 52 ft. 5¼ in. (~1598 cm) carpeted area bound by and including the inward- and upward-facing surfaces of the guardrails and inward-facing surfaces of the ALLIANCE WALLS (except Chute surfaces and any surface beyond the face of the POWER PORT).
FIELD STAFF	REFEREES, FTAS, or other staff working around the FIELD

Term	Definition
FMS	the electronics core responsible for sensing and controlling the *FIRST* Robotics Competition FIELD. The FMS encompasses all FIELD electronics, including computers, REFEREE touchscreens, wireless access point, sensors, stack lights, E-Stops, etc.
FOUL	a credit of three (3) points towards the opponent's MATCH score
FRAME PERIMETER	fixed, non-articulated structural elements of the ROBOT contained within the BUMPER ZONE
FTA	a *FIRST* Technical Advisor
GENERATOR SWITCH	a 7 ft. 6 in. (~229 cm) wide, 10 ft. 1½ in. deep (~309 cm), and 4 ft. 6 in. (~137 cm) tall assembly that swings from the top of the SHIELD GENERATOR.
HANDLE	a structure that consists of a RUNG and the supporting structure below the horizontal beam of the GENERATOR SWITCH.
HANGING	A ROBOT that five (5) seconds after the ARENA timer displays zero (0) following TELEOP, it is fully supported (either directly or transitively) by its GENERATOR SWITCH.
HUMAN PLAYER	a pre-college student DRIVE TEAM member who acts as a POWER CELL manager
INITIATION LINE	a white tape line spanning the width of the FIELD and located 10 ft. (~305 cm) from the face of PLAYER STATION 2 to the near edge of the tape.
INNER PORT	a 1 ft. 1 in. (~33 cm) diameter circle concentric with and 2 ft. 5¼ in. (~74 cm) behind (i.e. on the ALLIANCE STATION side of) the OUTER PORT. The center is 8 ft. 2¼ in. (~249 cm) above the carpet.
KOP	Kit of Parts, the collection of items listed on the current season's Kickoff Kit Checklists, distributed to the team via *FIRST* Choice in the current season, or paid for completely (except shipping) with a Product Donation Voucher (PDV) from the current season
LEVEL	the RUNG is within 8 degrees of horizontal.
LINEUP	The list of three (3) teams participating in the MATCH and their selected PLAYER STATIONS
LOADING BAY	a 6 ft. 6 in. (~198 cm) tall by 5 ft. (~152 cm) wide structure located between PLAYER STATIONS 2 and 3.
LOADING ZONE	a 5 ft. (~152 cm) wide, 2 ft. 6 in. (~76 cm) deep infinitely tall volume with a triangular base bounded by the LOADING BAY and ALLIANCE colored tape.
LRI	a Lead ROBOT Inspector
MAJOR MECHANISM	a group of COMPONENTS and/or MECHANISMS assembled together to address at least one (1) game challenge: robot movement, game piece control, field element manipulation, or performance of a scorable task without the assistance of another ROBOT.
MATCH	a two (2) minute and thirty (30) second period of time in which ALLIANCES play INFINITE RECHARGE
MECHANISM	a COTS or custom assembly of COMPONENTS that provide specific functionality on the ROBOT
MXP	myRIO Expansion port, the expansion port on the roboRIO
OPERATIONAL	the ALLIANCE'S ENDGAME SCORE is ≥ 65 points.

Term	Definition
OPERATOR CONSOLE	the set of COMPONENTS and MECHANISMS used by the DRIVERS and/or HUMAN PLAYER to relay commands to the ROBOT
OUTER PORT	a regular hexagon that measures 2 ft. 6 in. (~76 cm) in height. The center of the OUTER PORT is 8 ft. 2¼ in. (~249 cm) above the carpet.
PASSIVE CONDUCTORS	any device or circuit whose capability is limited to the conduction and/or static regulation of the electrical energy applied to it (e.g. wire, splices, connectors, printed wiring board, etc.)
PCM	a Pneumatic Control Module
PDP	a Power Distribution Panel
PINNING	preventing the movement of an opponent ROBOT by contact
PLAYER STATION	one (1) of three (3) assigned positions in an ALLIANCE WALL from where a DRIVE TEAM operates their ROBOT.
POSITION CONTROL	Rotate CONTROL PANEL so a specified color aligns with the sensor for at least five (5) seconds.
POWER CELL	a yellow 7 in. (~18 cm) diameter Medium Bounce Dino-Skin foam ball. The *FIRST* logo is printed on each ball in black ink. The ball is made by Flaghouse (PN 1892 YEL) and sold by AndyMark (PN AM-4200)
POWER PORT	a 10 ft. 2¼ in. (~310 cm) tall by 4 ft. (~122 cm) wide (excluding backboards) structure and is located between PLAYER STATIONS 1 and 2.
RED CARD	a penalty assessed for egregious ROBOT or team member behavior or rule violations which results in a team being DISQUALIFIED for the MATCH
REFEREE	an official who is certified by *FIRST* to enforce the rules of INFINITE RECHARGE
RENDEZVOUS POINT	a 5 ft. 6¾ in. (~170 cm) wide, 12 ft. 6¾ in. (~383 cm) deep, infinitely tall volume formed by the ALLIANCE colored BOUNDARIES and the black BOUNDARY pair that divides the Red and the Blue BOUNDARIES.
ROBOT	an electromechanical assembly built by the *FIRST* Robotics Competition team to play the current season's game and includes all the basic systems required to be an active participant in the game –power, communications, control, BUMPERS, and movement about the field.
ROTATION CONTROL	Rotate CONTROL PANEL at least three (3) (but no more than five (5)) complete revolutions in the same direction.
RP	a Ranking Point
RS	the Ranking Score
RSL	a ROBOT Signal Light
RUNG	a 1¼ in. schedule 40 aluminum pipe (1.66 in. (~4 cm) outer diameter) with two (2) exposed 4 ft. 7⅝ in. (~141 cm) long sections.
SECTOR	A 26 ft. 11¼ in. (~821 cm) wide by 10 ft. 2 in. (~310 cm) deep infinitely tall volume formed by an ALLIANCE'S ALLIANCE WALL, guardrail, and INITIATION LINE. The SECTOR includes the INITIATION LINE.
SHIELD GENERATOR	a 14 ft. 1½ in. (~431 cm) wide, 15 ft. ¾ in. (~459 cm) deep, and 9 ft. 6½ in. (~291 cm) tall structure located in the center of the field, oriented at a 22.5 degree angle relative to the guardrails.

Term	Definition
SIGNAL LEVEL	circuits which draw ≤1A continuous and have a source incapable of delivering >1A, including but not limited to roboRIO non-PWM outputs, CAN signals, PCM Solenoid outputs, VRM 500mA outputs and Arduino outputs
STARTING CONFIGURATION	the physical configuration in which a ROBOT starts a MATCH
STARTING LINE	a white tape line spanning the width of the carpet and located 2 ft. 4 in. (~71 cm) from the back of the PLAYER STATION 2 diamond plate panel to the near edge of the tape.
SURROGATE	a team randomly assigned by the FIELD Management System to play an extra Qualification MATCH
TARGET ZONE	a 4 ft. (~122 cm) wide, 2 ft. 6 in. (~76 cm) deep infinitely tall volume with a triangular base bounded by the POWER PORT and ALLIANCE colored tape.
TECH FOUL	a credit of fifteen (15) points toward the opponent's MATCH score
TECHNICIAN	a precollege student member of the DRIVE TEAM who is a resource for ROBOT troubleshooting, setup, and removal from the FIELD
TELEOP	The second phase of each MATCH is called the Teleoperated Period (TELEOP) and consists of the remaining two minutes and fifteen seconds (2:15).
TIMEOUT	a period of up to six (6) minutes between MATCHES which is used to pause Playoff MATCH progression
TRENCH	a 3 ft. ½ in. (~93 cm) tall, 4 ft. 8 in. (~142 cm) wide, and 3 ft. 5½ in. (~105 cm) deep structure that forms a 4 ft. 4 in. (~132 cm) wide, 2 ft. 4 in. (~71 cm) tall, and 2 ft. 6 in. (~76 cm) deep tunnel.
TRENCH RUN	a 4 ft. 7 ½ in. (~141 cm) wide, 18 ft. (~549 cm) deep, infinitely tall volume that is bounded by the guardrail, the edge of the TRENCH vertical support closest to the center of the FIELD, and ALLIANCE colored tape.
VENDOR	a legitimate business source for COTS items that satisfies all the criteria listed in the Robot Construction Rules' Overview section.
VRM	a Voltage Regulator Module
YELLOW CARD	a warning issued by the Head REFEREE for egregious ROBOT or team member behavior or rule violations. A subsequent YELLOW CARD within the same tournament phase results in a RED CARD