



HYDROGEN HORIZONS

2023 FIRST Global Challenge: *Hydrogen Horizons* Game Manual

UPDATES

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1. INTRODUCTION

1.1. About *FIRST*® Global

FIRST® Global organizes a yearly international robotics challenge to ignite a passion for science, technology, engineering, and mathematics (STEM) among the more than two billion youths across the world. By bringing these future STEM leaders together in an engaging and collaborative competition that drives home the importance, excitement, and applicability of STEM education, *FIRST* Global inspires students to learn the skills they will need to make the discoveries their parents and grandparents would consider miracles, impossibilities, or just plain science fiction.

FIRST Global also strives to convince the various governments and organizations of the world to embrace science, technology, engineering, and mathematics (STEM) education, and to support it by investing in their young adults that will soon begin to make their marks in the world.

Themed around the greatest challenges facing our planet, including the [14 Grand Challenges for Engineering](#) identified by National Academy of Engineering, each year a different challenge takes center stage in an effort to foster understanding and cooperation among the youth of the world as they use their abilities to solve the world's problems.

Participation in *FIRST* Global is about more than just robots. As participants learn to find solutions to the world's greatest challenges – water, energy, security, medicine, food, climate, and education – they learn how to work with each other, trust each other, and become part of a truly global community.

More information about *FIRST* Global, including contact information and links to social media, can be found on the [FIRST Global](#) website.

1.2. The 2023 *FIRST* Global Challenge: *Hydrogen Horizons*

As our dependence on energy continues to grow, it becomes increasingly important to innovate the solutions that will ensure a cleaner and more equitable energy future around the world. Renewable energy comes from natural sources that are continually replenished, including the sun, wind, heat within the earth, and water. This year's theme calls on *FIRST* Global teams to reimagine the future of energy and create more sustainable ways to power our planet.

The 2023 *FIRST* Global Challenge focuses specifically on the role of hydrogen in the planet's renewable energy and reduced carbon future. Hydrogen-based energy technologies allow for enhanced methods of carrying and storing the energy generated from renewables.

1.3. Conventions and Updates

Key words that have a specific definition in *Hydrogen Horizons* are indicated in ALL CAPITAL LETTERS and are defined in the Glossary section of this document.

Comments highlighted in blue boxes provide details regarding warnings, cautions, and notes for a specific rule. Pay close attention to their content as they provide insight into the reasoning behind a rule and other helpful information.



Comments highlighted in grey boxes are educational and are intended to provide additional detail as to how elements of *Hydrogen Horizons* directly relate to real-life industry and applications.

Any modification to this game manual, including updates or clarifications, will be published in the Updates table on the cover page of this document. The most recent published version of this game manual is considered to be the official

version. Teams should visit the document periodically to ensure awareness of any changes. Documentation related to the game can be found at <https://first.global/frc/>.

1.4. Translations

The *Hydrogen Horizons* game manual is written in English and translated into other languages. In the event of any conflict between a translated version of the game manual and the English language version, the English version as published on the *FIRST* Global website (at <https://first.global/frc/>) is considered the correct and commanding version.

1.5. Question and Answer System

Teams can ask questions to clarify rules via the Official Rules subcategory on the *FIRST* Global Forum or by submitting them to support@first.global. Remember, only answers provided by *FIRST* Global are considered official clarification of rules.

There is a dedicated Question and Answer (Q&A) document to share commonly asked questions about the game and robot rules, and the official *FIRST* Global responses. The document is located at <https://first.global/frc/>. Answers posted to the Q&A document by *FIRST* Global are considered official clarification of rules, thus teams are encouraged to periodically review updates.

2. THE GAME

2.1. Game Description

Hydrogen Horizons is played on a 7 m by 7 m elevated platform. Six teams compete with their ROBOTS on the PLAYING FIELD during the 2 minutes and 30 seconds (2:30) of play, with each MATCH featuring a different randomized combination of teams.

The objective of *Hydrogen Horizons* is for two REGIONAL ALLIANCES, each composed of three teams, to PRODUCE HYDROGEN and OXYGEN by extracting atoms from the RESERVOIR, STORE the HYDROGEN and OXYGEN in the respective HYDROGEN TANK and OXYGEN ACCUMULATOR, TRANSPORT the HYDROGEN TANK to the OXYGEN ACCUMULATOR, and CONVERT the HYDROGEN into other useful forms of energy as it is combined with OXYGEN.

Near the end of the MATCH, the REGIONAL ALLIANCES combine into a single GLOBAL ALLIANCE and position their ROBOTS on the HYDROGEN HUB to demonstrate each nation's technical ability to use hydrogen as an energy carrier. GLOBAL ALLIANCES that have five or more ROBOTS able to demonstrate EXPERT PROFICIENCY shall receive additional points, known as a COOPERTITION® BONUS.

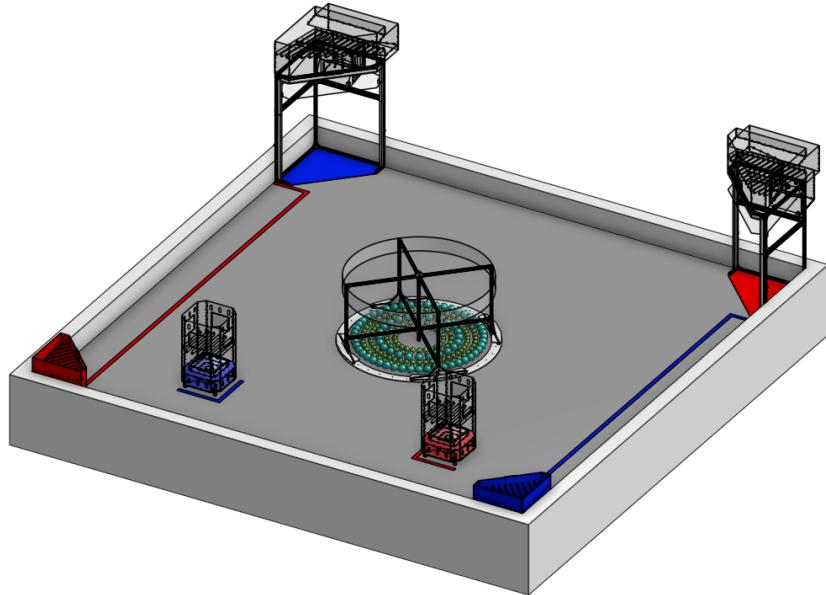


Figure 2-1: *Hydrogen Horizons* PLAYING FIELD

2.2. Playing Field

The PLAYING FIELD is a raised 7 m by 7 m platform bounded by the GUARDRAILS, a system of borders at least 30 cm tall surrounding the PLAYING FIELD perimeter. The PLAYING FIELD is inclusive of the HYDROGEN TANKS, OXYGEN ACCUMULATORS, ELECTROLYZERS, RESERVOIR, HYDROGEN HUB, and the inward facing surfaces of the GUARDRAILS. The PLAYING FIELD SURFACE is the horizontal surface bounded by the GUARDRAILS and covered with a low pile carpet similar to those found in many public or commercial buildings. Any low pile carpet may be used for practice, and will react in a similar way for game pieces and ROBOTS.

Red and blue ALLIANCE STATIONS, located on opposing sides of the PLAYING FIELD, are where the DRIVE TEAMS (DRIVERS, CAPTAINS, and HUMAN PLAYERS) stand during the MATCH. The team makeup of the REGIONAL ALLIANCES in each MATCH is randomly assigned during the 2023 FIRST Global Challenge in Singapore (referred to as the EVENT). The specific location for each DRIVE TEAM within the ALLIANCE STATIONS is determined by the REGIONAL ALLIANCE members. DRIVE TEAMS must remain within the boundaries of the ALLIANCE STATION, which is marked on the floor and extends outward 150 cm from the edge of the GUARDRAIL and wraps around the ELECTROLYZER.

The REGIONAL ZONES are parallel to the ALLIANCE STATIONS, extending 50 cm from the GUARDRAIL and marked with gaffer tape on the PLAYING FIELD SURFACE.

PLAYING FIELD drawings and CAD models can be found at <https://first.global/fgc/>.

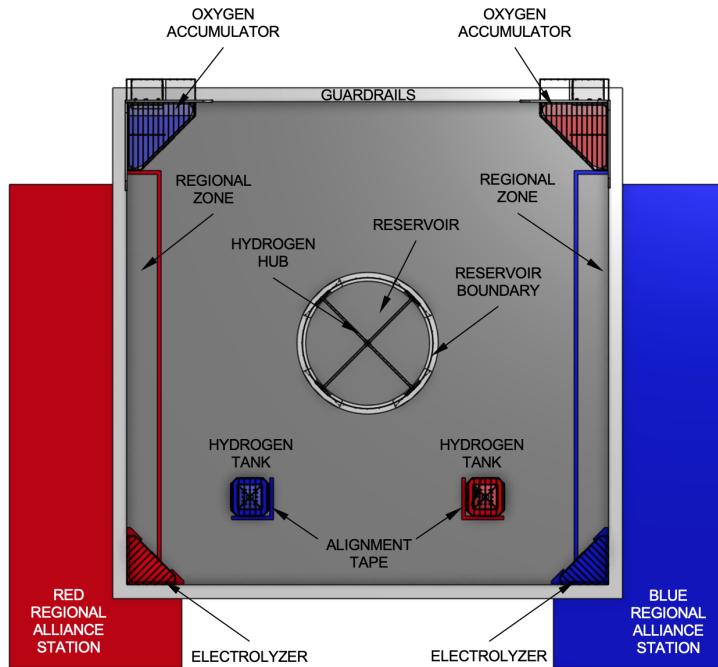


Figure 2-2: PLAYING FIELD Layout

The RESERVOIR, located in the center of the PLAYING FIELD, is a circular region bounded by the RESERVOIR BOUNDARY, which is made of textured high density polyethylene (HDPE). The RESERVOIR contains all game pieces (HYDROGEN and OXYGEN, representing water) at the start of the MATCH.

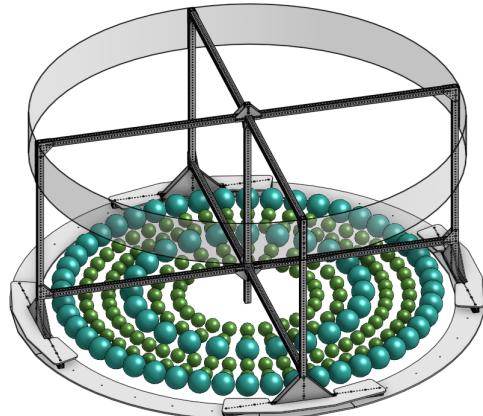


Figure 2-3: RESERVOIR

The HYDROGEN HUB is the square aluminum tubing structure above the RESERVOIR and the area enclosed by the vertical plane extending upward from the outer edge of the RESERVOIR BOUNDARY. At the top is a circular band of polycarbonate to ensure HYDROGEN TANKS don't enter the HYDROGEN HUB.

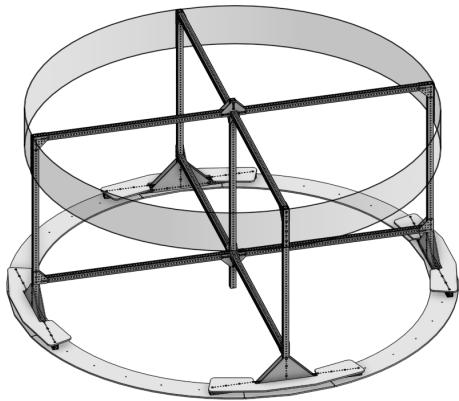


Figure 2-4: HYDROGEN HUB

Two mobile HYDROGEN TANKS, colored red and blue for each REGIONAL ALLIANCE, are pre-positioned for each MATCH at a location marked by ALIGNMENT TAPE on the PLAYING FIELD SURFACE. The square HYDROGEN TANKS are 100 cm tall and sit atop four caster wheels. Each HYDROGEN TANKS weighs approximately 13 kg and has slats midway that allow HYDROGEN to filter through to the bottom of the HYDROGEN TANK.

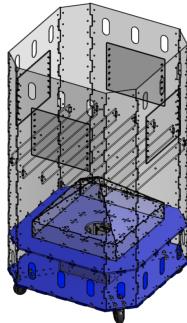


Figure 2-5: HYDROGEN TANK

Two OXYGEN ACCUMULATORS, colored red and blue for each REGIONAL ALLIANCE, are located at the corners of the PLAYING FIELD opposite to each REGIONAL ALLIANCE STATION. They are 200 cm tall and have slats approximately 15 cm from the top that allow HYDROGEN to filter through and return to the PLAYING FIELD SURFACE. OXYGEN stay on the upper portion and are stored in a bin with a hinged door located behind the OXYGEN ACCUMULATOR. The base of the OXYGEN ACCUMULATOR is an irregular pentagon on the PLAYING FIELD SURFACE made from HDPE and colored red or blue.

The NETTING is open-meshed material positioned behind the OXYGEN ACCUMULATOR to prevent game pieces from leaving the PLAYING FIELD, but not to act as a backstop or assist for STORING OXYGEN in the OXYGEN ACCUMULATOR. For that reason, no specifications are provided regarding the NETTING.

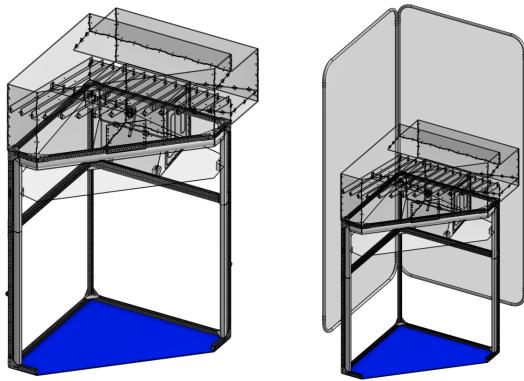


Figure 2-6: OXYGEN ACCUMULATOR and NETTING

Two ELECTROLYZERS, colored red and blue for each REGIONAL ALLIANCE, are located at the corners of the PLAYING FIELD adjacent to each REGIONAL ALLIANCE STATION. Each ELECTROLYZER is open on the top and has slats that allow HYDROGEN to filter through to the bottom section while the OXYGEN remains on top. There is an opening on the bottom of the ELECTROLYZER for HYDROGEN to return to the PLAYING FIELD SURFACE.

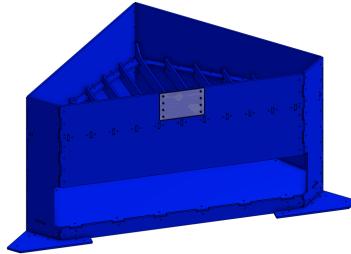


Figure 2-7: ELECTROLYZER

AprilTags are a system of visual tags that can be used by a ROBOT to determine its position on the PLAYING FIELD. AprilTags are located at the top center of each OXYGEN ACCUMULATOR, ELECTROLYZER, and the four sides of each HYDROGEN TANK. The AprilTag files can be [found here](#).

The CONVERSION BUTTON is an illuminated plastic button, approximately 76 mm in diameter, located in each ALLIANCE STATION. Once pressed, it causes OXYGEN in the OXYGEN ACCUMULATOR to be released from the bin located behind the OXYGEN ACCUMULATOR.

2.3. Game Pieces

Two types of game pieces are featured in *Hydrogen Horizons*, both made of closed-cell polyurethane foam and printed with the FIRST Global Logo.

Green HYDROGEN atoms have a diameter of 60 mm diameter and weigh an average of 20 grams each. A total of 144 HYDROGEN are located in the RESERVOIR at the start of the MATCH.

Blue OXYGEN atoms have a diameter of 100 mm and weigh an average of 62 grams each. A total of 72 OXYGEN are located in the RESERVOIR at the start of the MATCH.



Figure 2-8: HYDROGEN and OXYGEN Atoms

3. HOW TO PLAY AND SCORING

3.1. Overview

There are two components to each MATCH. During the REGIONAL ALLIANCE component (the first 2 minutes of the MATCH), teams work in groups of three, a REGIONAL ALLIANCE, to PRODUCE and STORE HYDROGEN AND OXYGEN, then TRANSPORT and CONVERT HYDROGEN into a different usable form. During the GLOBAL ALLIANCE component (the final 30 seconds of the MATCH) all six teams work together to demonstrate each nation's proficiency in hydrogen technologies.

The objective of *Hydrogen Horizons* is for two REGIONAL ALLIANCES, each composed of three teams, to PRODUCE HYDROGEN and OXYGEN by extracting atoms from the RESERVOIR, STORE the HYDROGEN and OXYGEN in the respective HYDROGEN TANK and OXYGEN ACCUMULATOR, TRANSPORT the HYDROGEN TANK to the OXYGEN ACCUMULATOR, and CONVERT the HYDROGEN into other useful forms of energy as it is combined with OXYGEN.



To ensure a more equitable energy future around the world, we need to transition from fossil fuels to alternative sources of energy that are clean, sustainable, affordable, accessible, and reliable. We also need to develop ways to more efficiently generate and use energy, and invest in enhanced methods for carrying and storing energy, including hydrogen-based technologies.

A horizon is defined as the limit of perception, ideas, knowledge, experience, or possibility in a particular field or activity. In *Hydrogen Horizons*, FIRST Global teams learn about reaching beyond our current limits to revolutionize the global energy system: hydrogen technologies.

3.2. Regional Alliance Component

REGIONAL ALLIANCES are made of three randomly assigned teams each, one designated red and the other blue. DRIVE TEAMS start the MATCH standing in their ALLIANCE STATION.



The technology development and investment needed to transition to a clean energy future starts with regional and national efforts, such as investment in research and development, new energy policy, establishing infrastructure, and creation of national hydrogen strategies. Building momentum in a nation is the first step.

The REGIONAL ALLIANCE component of each MATCH represents regional and intergovernmental partnerships that aim to build momentum towards the adoption of hydrogen technologies. This level of collaboration capitalizes on each nation's development of hydrogen production, storage,

transportation, processes, and infrastructure to develop further opportunities and expand regional impacts, thus sharing knowledge and experience for the benefit of all.

ROBOTS start the MATCH in the REGIONAL ZONE next to their corresponding ALLIANCE STATION, in contact with the GUARDRAIL. A total of 144 green HYDROGEN atoms and 72 blue OXYGEN atoms are randomly positioned in the central RESERVOIR in the form of water, or H₂O, prior to the start of the MATCH. Two HYDROGEN TANKS, colored red and blue for each REGIONAL ALLIANCE, are pre-positioned on the ALIGNMENT TAPE. The MATCH begins when the announcer says “go”.



Hydrogen is the most abundant element in the universe. On Earth, it is most commonly found bonded to other elements, primarily oxygen in the form of water, or H₂O. The two hydrogen atoms and one oxygen atom are held together by chemical bonds. The ability to create and release these chemical bonds makes hydrogen an ideal energy carrier.

As an energy carrier, rather than an energy source, hydrogen can store the energy applied to separate a water molecule until it is converted into a different form of energy. As such, hydrogen is a perfect complement to renewable energy, which can be cyclical and not constant (wind and solar) or difficult to store and transport from the source (hydro, geothermal, and ocean).

There are different color codes to describe the types of hydrogen, which are categorized depending on how it is produced.

- Green - Produced by electrolysis of water enabled by renewable energy (as seen in *Hydrogen Horizons!*)
- Blue, Black, Brown, Grey, and Turquoise - Produced from fossil fuels
- Pink, Purple, and Red - Produced by electrolysis of water using nuclear power
- Yellow - Produced using various types of grid electricity
- White - Naturally occurring

Based on weight, the energy content of hydrogen is higher than that of any fuel (about three times more than gasoline). However, based on volume, the opposite is true (gasoline has four times more energy content per volume than hydrogen).

There are four steps of the REGIONAL ALLIANCE component:

1. PRODUCE HYDROGEN and OXYGEN by extracting atoms from the RESERVOIR
2. STORE the HYDROGEN and OXYGEN in the respective HYDROGEN TANK and OXYGEN ACCUMULATOR
3. TRANSPORT the HYDROGEN TANK to the OXYGEN ACCUMULATOR
4. CONVERT the HYDROGEN into other useful forms of energy as it is combined with OXYGEN

Step 1: PRODUCE HYDROGEN and OXYGEN by extracting atoms from the RESERVOIR

For the first two minutes of the MATCH, each REGIONAL ALLIANCE works to extract water, represented by HYDROGEN and OXYGEN atoms, from the RESERVOIR or the PLAYING FIELD SURFACE. ROBOTS can perform the separation and atomic differentiation, or they can use the ELECTROLYZERS to sort the atoms by size. This produces separated HYDROGEN and OXYGEN atoms.



Water is made from two hydrogen atoms and one oxygen atom. Water molecules can be separated into their atomic components using a process called electrolysis. Electrolyzers have energy as an input and that energy breaks the bonds that hold the hydrogen and oxygen atoms together. The first law of thermodynamics, also known as the law of the conservation of energy, states that energy can neither be created nor destroyed - only converted from one form of energy to another. Since energy is applied to break chemical bonds, it is stored within the hydrogen

atoms.

Hydrogen Horizons focuses on green hydrogen, thus the energy put into the electrolyzer comes from renewable sources.

Step 2: STORE the HYDROGEN and OXYGEN in the respective HYDROGEN TANK and OXYGEN ACCUMULATOR

ROBOTS proceed to STORE HYDROGEN in their REGIONAL ALLIANCE'S mobile HYDROGEN TANK and OXYGEN in their OXYGEN ACCUMULATOR. REGIONAL ALLIANCES may reposition their HYDROGEN TANKS anywhere on the PLAYING FIELD SURFACE once the MATCH begins.

HYDROGEN can only be manipulated by ROBOTS, and only be STORED in the HYDROGEN TANK. It can be collected from the RESERVOIR or elsewhere on the PLAYING FIELD SURFACE, including the base of the ELECTROLYZER.

OXYGEN can be manipulated by ROBOTS or with assistance from HUMAN PLAYERS. ROBOTS can:

- Collect OXYGEN from the PLAYING FIELD SURFACE and directly STORE it in the OXYGEN ACCUMULATOR
- Deliver OXYGEN to an ELECTROLYZER for a HUMAN PLAYER, who can:
 - Place the OXYGEN into a ROBOT that is correctly positioned within the REGIONAL ZONE
 - Directly STORE the OXYGEN in the OXYGEN ACCUMULATOR by throwing it

OXYGEN can only be STORED in the OXYGEN ACCUMULATOR. NETTING is located behind each OXYGEN ACCUMULATOR to prevent OXYGEN from exiting the PLAYING FIELD, however teams will not be penalized if an OXYGEN atom makes contact with the NETTING before entering the OXYGEN ACCUMULATOR.

If an OXYGEN atom accidentally enters the HYDROGEN TANK, HUMAN PLAYERS may remove the stray atom only if the HYDROGEN TANK is positioned in the REGIONAL ZONE and in contact with the GUARDRAIL.



Hydrogen, as the smallest and lightest element, must be “manipulated” for storage to be efficient. It can be physically compressed as a gas in high-pressure tanks or as a liquid at cryogenic temperatures. It can also be stored on materials, such as metal hydrides or as a derivative such as ammonia.

In *Hydrogen Horizons*, HYDROGEN may only be stored in the HYDROGEN TANK by ROBOTS, representing that technology is required to overcome the challenge of storing hydrogen.

The quality of hydrogen can impact how well it is converted into other types of energy. The more pure the gas, the more efficient the conversion. As such, teams are allowed to purify their collected HYDROGEN atoms as needed by removing stray OXYGEN atoms from their HYDROGEN TANK .

Oxygen is easier and safer to store, thus can be manipulated by both ROBOTS and HUMAN PLAYERS.

Step 3: TRANSPORT the HYDROGEN TANK to the OXYGEN ACCUMULATOR

When each REGIONAL ALLIANCE decides their HYDROGEN TANK is sufficiently filled, they transport the HYDROGEN TANK to align it with the OXYGEN ACCUMULATOR.



Often, the location where hydrogen is produced differs from the location of conversion and end use. Infrastructure to support hydrogen transportation includes vehicles, ships, and

pipelines. There is currently infrastructure in place around the world for hydrogen transport, however increased demand for hydrogen as part of the global energy future will require investment, growth, and new methods of transport.

Transportation challenges include leakage, efficiency, purity, cost, and safety. These challenges are represented in the stability of the HYDROGEN TANKS, which are susceptible to tipping over if ROBOTS aren't careful!

Step 4: CONVERT the HYDROGEN into other useful forms of energy as it is combined with OXYGEN

Once the HYDROGEN has been transported, the energy it carries can be converted into a different usable form. At any time during the last 30 seconds of the MATCH, the HUMAN PLAYERS can press the CONVERSION BUTTON to initiate the conversion process, releasing the OXYGEN so that it may fall into the HYDROGEN TANK.

A CONVERSION MULTIPLIER is applied to the total sum of HYDROGEN and OXYGEN atoms in the HYDROGEN TANK at the end of the MATCH.

HYDROGEN TANK position at the end of the MATCH determines the CONVERSION MULTIPLIER earned:

- NO ALIGNMENT
 - HYDROGEN TANK is not aligned with the OXYGEN ACCUMULATOR and has not crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR
 - CONVERSION MULTIPLIER: 1.0
- PARTIAL ALIGNMENT (COMBUSTION)
 - HYDROGEN TANK has partially crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR
 - Must have some HYDROGEN atoms in the HYDROGEN TANK
 - CONVERSION MULTIPLIER: 1.2
- FULL ALIGNMENT (FUEL CELL)
 - HYDROGEN TANK has fully crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR
 - Must have some HYDROGEN atom in the HYDROGEN TANK
 - CONVERSION MULTIPLIER: 1.3

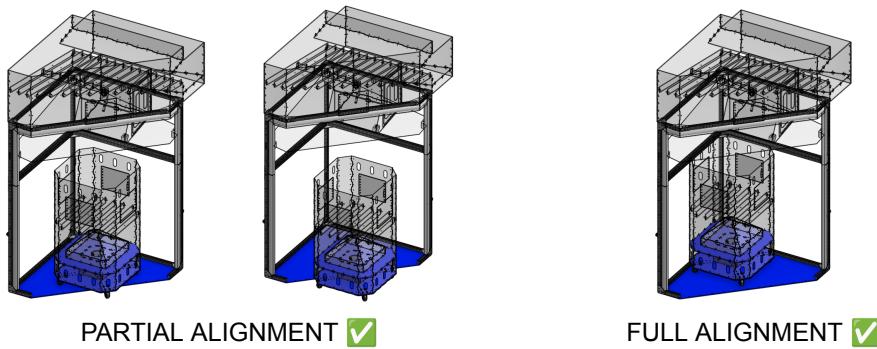


Figure 3-1: PARTIAL and FULL ALIGNMENT

A REGIONAL ALLIANCE earns HYDROGEN and OXYGEN points for the total sum of HYDROGEN and OXYGEN atoms in the HYDROGEN TANK at the end of the MATCH at a rate of 1 point per atom. HYDROGEN or OXYGEN atoms that remain in the OXYGEN ACCUMULATOR, on the ELECTROLYZER, or on the PLAYING FIELD SURFACE do not earn points.

OXYGEN may not be STORED in the HYDROGEN TANK or OXYGEN ACCUMULATOR once the CONVERSION BUTTON has been pressed. ROBOTS are allowed to continue STORING HYDROGEN until the end of the MATCH.



The energy carried by hydrogen can be converted into different usable forms of energy, with water as the only byproduct. In *Hydrogen Horizons*, teams can demonstrate different methods of conversion.

- In a fuel cell, hydrogen is recombined with oxygen in an electrochemical reaction to produce electrical energy, or electricity. If the HYDROGEN TANK is in FULL ALIGNMENT with the OXYGEN ACCUMULATOR, this represents a FUEL CELL and is the most efficient method of conversion. When a HUMAN PLAYER presses the CONVERSION BUTTON, all of the OXYGEN is released into the HYDROGEN TANK to support the reaction.
- Hydrogen can also be burned to produce thermal energy, or heat, however this method is less efficient than a fuel cell as it includes combustion heat losses. COMBUSTION is represented when the HYDROGEN TANK has PARTIAL ALIGNMENT with the OXYGEN ACCUMULATOR. When a HUMAN PLAYER presses the CONVERSION BUTTON, only some of the OXYGEN is released into the HYDROGEN TANK to support the reaction.
- If the HYDROGEN TANK has NO ALIGNMENT with the OXYGEN ACCUMULATOR, then the HYDROGEN inside remains unconverted and represents the unrealized potential as an energy carrier.

3.3. Global Alliance Component

During the final 30 seconds of the MATCH, the REGIONAL ALLIANCES combine into a single GLOBAL ALLIANCE and position their ROBOTS on the HYDROGEN HUB to demonstrate each nation's proficiency in hydrogen technologies.



Each nation and region works to develop their own hydrogen strategies, but the sharing of ideas turns it into a global movement. The GLOBAL ALLIANCE component of the MATCH represents a collaboration of all nations to advance hydrogen technologies and accelerate the transition to a clean and efficient energy system.

There are three different levels of PROFICIENCY that each ROBOT can demonstrate: DEVELOPING, INTERMEDIATE, and EXPERT.

DEVELOPING PROFICIENCY

- ROBOT is not positioned on the HYDROGEN HUB
- PROFICIENCY points per ROBOT: 0

INTERMEDIATE PROFICIENCY

- ROBOT fully supported by the RESERVOIR BOUNDARY or the PLAYING FIELD SURFACE within the RESERVOIR BOUNDARY (directly or indirectly)
- Must be entirely contained within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY
- PROFICIENCY points per ROBOT: 5

EXPERT PROFICIENCY

- ROBOT fully supported by the HYDROGEN HUB structure (directly or indirectly)
- Not required to be contained within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY
- PROFICIENCY points per ROBOT: 10

Each REGIONAL ALLIANCE earns the sum of PROFICIENCY points from all six ROBOTS.



The global energy system is a worldwide balance of energy supply (including the types of energy and amount of each supplied), and demand (how it is consumed across the world (how much consumed, how it is used, and efficiency of use). The HYDROGEN HUB in *Hydrogen Horizons* symbolizes each nation's technical ability to use hydrogen as an energy carrier, establish hydrogen hub networks of hydrogen producers, transporters, and users, and aid in the transition to an improved energy future.

As the GLOBAL ALLIANCE position their ROBOTS on the HYDROGEN HUB, they are demonstrating three levels of proficiency:

- EXPERT PROFICIENCY represents thorough knowledge and demonstration of hydrogen technologies locally, and a willingness to help other nations use hydrogen as an energy carrier
- INTERMEDIATE PROFICIENCY represents a solid understanding of hydrogen technologies and the ability to implement these technologies on a local scale
- DEVELOPING PROFICIENCY represents an understanding of hydrogen technology concepts and a willingness to build technical aptitude

3.4. Coopertition® Bonus

Coopertition® is displaying kindness and respect in the face of fierce competition. *Coopertition* is founded on the concept that teams can and should cooperate with each other even as they compete. *Coopertition* means competing always, but assisting and enabling others when you can.

GLOBAL ALLIANCES that have five or more ROBOTS able to demonstrate EXPERT PROFICIENCY shall receive additional points, known as a *COOPERTITION*® BONUS.

- Five ROBOTS demonstrating EXPERT PROFICIENCY = 15 *COOPERTITION* BONUS points
- Six ROBOTS demonstrating EXPERT PROFICIENCY = 30 *COOPERTITION* BONUS points



The planet as a whole benefits most when the majority of nations are proficient in hydrogen technologies.

3.5. Scoring Summary

Scoring is consistent through RANKING, PLAYOFF, and FINAL MATCHES. The following tables and equation summarize MATCH scoring rubric. A Google Sheets scoring calculator is available [here](#). Please make a copy of the calculator file to edit the values. All fractional scores round up to the nearest whole number.

Table 3-1: HYDROGEN and OXYGEN Points

Achievement	Point Value
Each HYDROGEN atom STORED in the HYDROGEN TANK at the end of the MATCH	1
Each OXYGEN atom STORED in the HYDROGEN TANK at the end of the MATCH	1

Table 3-2: CONVERSION MULTIPLIER

Achievement	Multiplier Value
NO ALIGNMENT: HYDROGEN TANK is not aligned with the OXYGEN ACCUMULATOR and has not crossed the vertical plane extending upward from the diagonal edge of the OXYGEN ACCUMULATOR base	1.0

PARTIAL ALIGNMENT (COMBUSTION): HYDROGEN TANK has partially crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR	1.2
FULL ALIGNMENT (FUEL CELL): HYDROGEN TANK has fully crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR	1.3

*Multiplier value applied to total HYDROGEN and OXYGEN points at the end of the MATCH

Table 3-3: PROFICIENCY Points

Achievement	Point Value
DEVELOPING: ROBOT is not positioned on the HYDROGEN HUB	0
INTERMEDIATE: ROBOT fully supported by the RESERVOIR BOUNDARY or the PLAYING FIELD SURFACE within the RESERVOIR BOUNDARY (directly or indirectly) and <u>entirely contained</u> within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY	5
EXPERT: ROBOT fully supported by the HYDROGEN HUB structure (directly or indirectly)	10

Table 3-4: COOPERTITION BONUS Points

Achievement	Point Value
Less than 5 ROBOTS demonstrating EXPERT PROFICIENCY	0
5 ROBOTS demonstrating EXPERT PROFICIENCY	15
6 ROBOTS demonstrating EXPERT PROFICIENCY	30

A REGIONAL ALLIANCE'S MATCH score is the sum of:

- HYDROGEN points plus OXYGEN points multiplied by the CONVERSION MULTIPLIER
- Plus PROFICIENCY points of all six ROBOTS
- Plus COOPERTITION BONUS points

$$\left[\left(\begin{array}{c} \text{HYDROGEN Points} \\ + \\ \text{OXYGEN Points} \end{array} \right) \times \text{CONVERSION MULTIPLIER} \right] + \left(\begin{array}{c} \text{ROBOT A PROFICIENCY Points} \\ + \\ \text{ROBOT B PROFICIENCY Points} \\ + \\ \text{ROBOT C PROFICIENCY Points} \\ + \\ \text{ROBOT D PROFICIENCY Points} \\ + \\ \text{ROBOT E PROFICIENCY Points} \\ + \\ \text{ROBOT F PROFICIENCY Points} \end{array} \right) + \text{COOPERTITION BONUS} = \text{MATCH Score}$$

The REGIONAL ALLIANCE with the highest MATCH score wins!

4. GENERAL MATCH AND GAME-SPECIFIC RULES

4.1. Overview

This section details the rules and violations associated with MATCH play and the game specifically.

4.2. Violations

The consequences for violating rules are defined below.

TABLE 4-1: VIOLATIONS

Violation Consequence	Details
YELLOW CARD	An official warning issued to a team for breaking a rule. Additional YELLOW CARDS may be elevated to a RED CARD at the judgment of the HEAD REFEREE, depending on the severity and frequency of the offense.
YELLOW CARD + FOUL	An official warning plus penalty assessed to a team for breaking a rule. YELLOW CARD + FOUL issued to teams during the MATCH come with a 10% point penalty off the MATCH score, which will be awarded to the opposing REGIONAL ALLIANCE. Additional YELLOW CARD + FOULS may be elevated to a RED CARD at the judgment of the HEAD REFEREE, depending on the severity and frequency of the offense.
RED CARD	An official penalty assessed to a team for repeatedly breaking a rule, breaking multiple rules, or egregious actions. Generally, a YELLOW CARD is given before a RED CARD, but it is at the HEAD REFEREE'S judgment to issue a RED CARD based on the severity of the offense. When a team is issued a RED CARD, they will receive 0 points for that specific MATCH.
DISQUALIFIED	A team is no longer allowed to participate in any aspect of the EVENT.
ROBOT disabled for MATCH	The offending ROBOT is disabled by the HEAD REFEREE during MATCH and will no longer be in play. The team with the disabled ROBOT will still earn points for the MATCH.
ROBOT not allowed to compete	The offending ROBOT is not allowed to participate in the MATCH, and the team receives no points for that MATCH.
Must be corrected before MATCH can start	The problem must be corrected before the MATCH can start, otherwise the ROBOT is not allowed to compete in the MATCH.

4.3. General Match Rules

- M01** **Teams must play the game as written.** These rules are written in a simple manner to make them as accessible as possible. Attempts to gain competitive advantage by employing an unintended method of play violates the rules and does not meet the spirit of FIRST Global.

Violation Consequence: YELLOW CARD, YELLOW CARD + FOUL, or RED CARD depending on severity of offense.

- M02** **Each DRIVE TEAM may consist of up to four student team members.** The maximum allowed DRIVE TEAM members are two DRIVERS, one CAPTAIN and one HUMAN PLAYER. The minimum required DRIVE TEAM members are one HUMAN PLAYER, who should show up for MATCHES even if the ROBOT is not functioning (see **M04**). The DRIVE TEAM, identified by wearable buttons, are the only team members allowed at the PLAYING FIELD and to set up the ROBOT.

Violation Consequence: Must be corrected before MATCH can start.

- M03 DRIVE TEAMS should show up to the MATCH ready to play.** DRIVE TEAMS should show up to MATCHES ready to play, with all their equipment in a condition that will not delay the start of the MATCH. MATCHES are expected to start promptly. DRIVE TEAMS are not permitted to make repairs or perform complicated set-up or adjustments at the PLAYING FIELD.

Violation Consequence: RED CARD.

- M04 DRIVE TEAMS must send at least one HUMAN PLAYER to their scheduled MATCHES.** If a ROBOT is unable to participate in the MATCH, at least one HUMAN PLAYER representative must show up to the MATCH. MATCHES will not be delayed to wait for a missing team.

Violation Consequence: RED CARD.

MATCH schedules are subject to change and may be running ahead or behind the listed times. Teams are expected to actively monitor which MATCHES are currently playing to ensure they arrive at their scheduled MATCHES on time.

- M05 ROBOTS must display their REGIONAL ALLIANCE and national flags.** At all times during the tournament, ROBOTS should display their national flag, which will be provided by FIRST Global at the EVENT. During MATCHES, ROBOTS must display the correct REGIONAL ALLIANCE color (red or blue). REGIONAL ALLIANCE colors will be distributed at the EVENT.

Violation Consequence: Must be corrected before MATCH can start.

- M06 DRIVE TEAMS must start and stop the ROBOT at the right time.** ROBOTS should start the MATCH stationary and in compliance with the starting rules stated in **G02** and **G03**. Controllers can be held by the DRIVE TEAM with the ROBOT program in the Init state, but the ROBOTS cannot move until “go” in the countdown “three, two, one, go!” ROBOTS should stop moving promptly when the MATCH timer reaches zero (0:00) by stopping the program on their REV Robotics Driver Hub.

Violation Consequence: YELLOW CARD.

DRIVE TEAMS should maintain an awareness of the MATCH timer, as operating the ROBOT after the MATCH timer has reached zero (0:00) can cause a team to be given a YELLOW CARD. Any points earned by a ROBOT after the MATCH ends will not be counted towards the final score.

- M07 DRIVE TEAMS must remain in their assigned ALLIANCE STATIONS throughout the MATCH.**

Violation Consequence: YELLOW CARD.

- M08 Outside communication with the DRIVE TEAM is prohibited during the MATCH.** Members of the DRIVE TEAM are expected to only communicate with other DRIVE TEAMS in their MATCH.

Violation Consequence: YELLOW CARD.

Communication with spotters in spectator areas or via wireless communication means is not allowed. This rule applies only to strategic or coordinated coaching communication from anyone outside of the DRIVE TEAM and does not apply to general cheering or support.

- M09 DRIVE TEAMS should not contact anything inside of the PLAYING FIELD until LEDs on the OXYGEN ACCUMULATOR indicate that it is safe to do so.** DRIVE TEAMS should not reach into the PLAYING FIELD

or contact the HYDROGEN, OXYGEN, or ROBOTS, either directly or by using an object, unless the LEDs on the OXYGEN ACCUMULATOR are green and indicate that the PLAYING FIELD is safe to enter. This rule applies both before and after the MATCH, and in all situations except those covered by **M11, G13, and G14**.

Violation Consequence: **YELLOW CARD.**

M10 **DRIVE TEAMS must not directly interact with ROBOTS during the MATCH.** The DRIVE TEAM is prohibited from touching ROBOTS, either directly or by using objects at any time, with the exception of **M11**.

Violation Consequence: **YELLOW CARD.**

M11 **After the MATCH has started, if a ROBOT has not moved, DRIVE TEAMS may handle their respective ROBOT within the first 30 seconds of the MATCH.** DRIVE TEAMS and specifically designated FIRST Global Field Support staff can attempt the following corrections to get their ROBOT playing in the MATCH.

- A. Turn the ROBOT on or off.
- B. Plug in the battery.
- C. Fix loose wire connections.

Once the ROBOT has moved under its own power, the ROBOT may not be touched by any humans until the MATCH has ended. DRIVE TEAMS should not touch other ROBOTS, HYDROGEN, OXYGEN, or any part of the PLAYING FIELD while attempting repair on their immobile ROBOT, as that contact would be considered a violation of **M09** and/or **M10**.

Violation Consequence: **ROBOT disabled for MATCH.**

M12 **ROBOTS must not intentionally damage, tip over, or disable other ROBOTS.** Strategies which are aimed at damaging, tipping, or disabling other ROBOTS are not in the spirit of FIRST Global and are not allowed. Teams are responsible for the actions of their ROBOTS at all times. Driving recklessly is not an excuse for tipping or damaging another ROBOT. Teams are also responsible for building a robust ROBOT which will not easily tip or become entangled due to minor contact.

Violation Consequence: **YELLOW CARD + FOUL.**

Accidental tipping and ENTANGLEMENT may occur and are a part of normal game play, however intentional or egregious violations as determined by the HEAD REFEREE may result in a RED CARD. Repeat offenses may result in a team being DISQUALIFIED from the remainder of the EVENT.

M13 **ROBOTS must stay on the PLAYING FIELD.** If a ROBOT goes completely out of bounds or appears to have a high likelihood of violating **M14** due to actions outside of the PLAYING FIELD, it will be disabled by the HEAD REFEREE for the rest of the MATCH. This is not intended to penalize ROBOTS for having mechanisms which inadvertently and inconsequentially cross the GUARDRAIL by a small amount during normal game play.

Violation Consequence: **ROBOT disabled for MATCH.**

M14 **ROBOTS must not be dangerous or damage the PLAYING FIELD, HYDROGEN, OXYGEN, other ROBOTS, or humans.** ROBOTS should not damage the PLAYING FIELD, HYDROGEN, OXYGEN, other ROBOTS, or pose a safety risk to team members, volunteers, or spectators. If the HEAD REFEREE determines a ROBOT is in violation of this rule, or that a ROBOT has a high likelihood of violating this rule, the ROBOT may be disabled for the MATCH and must be re-inspected before subsequent MATCHES.

Violation Consequence: **ROBOT disabled for MATCH.**

ROBOTS must not have sharp edges which could cut someone or damage the PLAYING FIELD, HYDROGEN, or OXYGEN. DRIVE TEAMS should pay close attention to the interaction of their ROBOTS with the HYDROGEN, OXYGEN, and the PLAYING FIELD. Large abrasions, holes, or other damage to the HYDROGEN, OXYGEN, or PLAYING FIELD elements violate this rule.

- M15** **ROBOTS may not grab, grapple, grasp, attach to, hang from, or otherwise be supported by any part of the PLAYING FIELD unless otherwise explicitly permitted.** Other than the HYDROGEN HUB structure, ROBOTS should not be designed to attach to any part of the PLAYING FIELD, including the GUARDRAILS, OXYGEN ACCUMULATOR, NETTING, ELECTROLYZER, or the circular band of polycarbonate surrounding the upper edge of the HYDROGEN HUB.

Violation Consequence: **YELLOW CARD.**

This rule is intended to prevent ROBOTS from damaging the PLAYING FIELD, either intentionally or unintentionally.

- M16** **Strategies aimed at causing an opponent to violate a rule are not allowed.** If a team forces an opponent to violate a rule, the penalty that would typically be assigned to the opponent will instead be assigned to the REGIONAL ALLIANCE of the team that forced the violation.

Violation Consequence: **YELLOW CARD + FOUL.**

- M17** **Scores are final and there are no replays.** All of the volunteers at FIRST Global work hard to provide a fair and consistent game experience for all teams, but occasionally mistakes may be made. How teams deal with adversity will say as much about their character as how they deal with success. Teams should avoid situations which could be rule violations and make their scoring actions clear to avoid misunderstandings.

If teams have questions about rules or rulings, there is a designated area near the PLAYING FIELD where the DRIVE TEAM can wait for the HEAD REFEREE or REV Robotics and discuss the concern. This discussion is meant to help the team understand the reason behind the rule or ruling, not for the team to argue for changes to the rule or ruling.

- M18** **Teams should behave as a representative of a whole nation on a global stage.** All teams are expected to behave in a respectful and professional manner when interacting with other FIRST Global teams, volunteers, spectators, and staff during the EVENT. Student and adult team members are held to the same standard, and teams may be DISQUALIFIED from the FIRST Global Challenge for uncivil or egregious behavior.

Violation Consequence: **YELLOW CARD, YELLOW CARD + FOUL, RED CARD, or DISQUALIFIED depending on severity of offense.**

FIRST Global is a truly international competition and thus the cultural customs and expectations of other teams may be different from participants' home nations. Please be aware of this fact and approach interactions with good intent and positive expectations.

4.4. Game-Specific Rules

- G01** **Hydrogen Horizons is intended to be a scoring game.** ROBOT actions, intentional or not, which only serve to prevent the opposing REGIONAL ALLIANCE from scoring or which are outside the intent of fair and productive game play are not allowed. These actions include but are not limited to:

A. Interfering with the opposing REGIONAL ALLIANCE'S scoring at any time during the MATCH.

- B. Preventing the free movement of one or more of the opposing REGIONAL ALLIANCE'S ROBOTS by blockading, trapping, or pinning (as determined by the HEAD REFEREE).

Violation Consequence: **YELLOW CARD + FOUL.**

G02 **ROBOTS must start the MATCH within a 50 cm x 50 cm x 50 cm volume.** Before the MATCH can start, all ROBOTS on the PLAYING FIELD must meet this requirement. The national flags and REGIONAL ALLIANCE colors (as defined in **M05**) are allowed to exceed this volume constraint.

- A. If the problem can be corrected quickly, the HEAD REFEREE will invite a DRIVE TEAM member to fix the situation for the offending ROBOT.
- B. If the problem cannot be corrected quickly, the offending ROBOT will be removed from the PLAYING FIELD and the MATCH will start without the offending ROBOT.

ROBOTS may extend beyond this size after the MATCH begins, but teams should pay attention to **M12** and **G01**. ROBOTS that expand must be able to do so independently and cannot have detachable parts (see **R04**).

Violation Consequence: **Must be corrected before the MATCH can start.**

G03 **ROBOTS must start each MATCH in the REGIONAL ZONE next to their corresponding ALLIANCE STATION and in contact with the GUARDRAIL.** Some part of the ROBOT must be in contact with the GUARDRAIL. No other part of the ROBOT may be in contact with any other part of the PLAYING FIELD, or any other ROBOT.

Violation Consequence: **Must be corrected before MATCH can start.**

G04 **FIRST Global reserves the right to adjust the quantity of HYDROGEN and OXYGEN for the RANKING, PLAYOFF, and FINAL MATCHES.**

G05 **ROBOTS may hold an unlimited number of HYDROGEN and OXYGEN at any time during the MATCH.**

G06 **HUMAN PLAYERS may only have in their possession a maximum of two OXYGEN at any time.** This includes all actions, from retrieving OXYGEN from the ELECTROLYZER to placing it in a ROBOT, removing it from a HYDROGEN TANK, or STORING it in the OXYGEN ACCUMULATOR.

Violation Consequence: **YELLOW CARD + FOUL.**

G07 **Damaged HYDROGEN and OXYGEN will not be counted towards the MATCH score.** HYDROGEN and OXYGEN that are damaged or deformed during the MATCH will not be added to a REGIONAL ALLIANCE'S MATCH score.

Violation Consequence: **YELLOW CARD, YELLOW CARD + FOUL, or RED CARD depending on severity of offense.**

G08 **HYDROGEN and OXYGEN must remain on the PLAYING FIELD.** HYDROGEN and OXYGEN are to remain on the PLAYING FIELD or be in the process of being STORED in the GOALS.

HYDROGEN and OXYGEN ejected from the PLAYING FIELD will be reintroduced into the PLAYING FIELD SURFACE by FIRST Global Field Support staff when safe to do so. There is no guarantee that the HYDROGEN and OXYGEN will be reintroduced during the MATCH.

G09 **Each team may pre-designate only one HUMAN PLAYER for each MATCH.** The DRIVE TEAM member acting as HUMAN PLAYER must remain in this role through the duration of the MATCH. Team members may not substitute roles. HUMAN PLAYERS will be provided with an identifier to designate their role.

Violation Consequence: YELLOW CARD + FOUL.

- G10 HYDROGEN may only be touched, manipulated, and STORED by a ROBOT.** HUMAN PLAYERS are not allowed to handle HYDROGEN.

Violation Consequence: YELLOW CARD + FOUL.

- G11 OXYGEN may be touched, manipulated, and STORED by a ROBOT or a HUMAN PLAYER.** The pre-designated HUMAN PLAYERS, as defined in **G09**, are the only DRIVE TEAM members allowed to handle OXYGEN.

Violation Consequence: YELLOW CARD + FOUL.

- G12 REGIONAL ALLIANCES may reposition their HYDROGEN TANKS anywhere on the PLAYING FIELD SURFACE once the MATCH begins.** HYDROGEN TANKS may be moved from their initial position, marked by ALIGNMENT TAPE.

- G13 HUMAN PLAYERS may retrieve OXYGEN from the top of the ELECTROLYZERS.** OXYGEN may only be retrieved by HUMAN PLAYERS from the top surface of the ELECTROLYZERS, and not from ROBOTS or any other part of the PLAYING FIELD, with the exception of **G15**.

Violation Consequence: YELLOW CARD + FOUL.

If HYDROGEN or OXYGEN become wedged or stuck on the slats at the top of the ELECTROLYZER, HUMAN PLAYERS may carefully release the atoms, provided they do not reach through the slats to do so.

- G14 HUMAN PLAYERS can load OXYGEN in a ROBOT only if the ROBOT is in the REGIONAL ZONE and in contact with the GUARDRAIL.** OXYGEN must be loaded in a ROBOT that is in the REGIONAL ZONE and in contact with the GUARDRAIL, which is the same as the MATCH starting position described in **G03**.

Violation Consequence: RED CARD.

Per **M10**, HUMAN PLAYERS may not contact the ROBOT while loading OXYGEN.

- G15 HUMAN PLAYERS may remove OXYGEN accidentally STORED in the HYDROGEN TANKS.** Any OXYGEN atoms that accidentally deflect into the HYDROGEN TANKS can be removed by a HUMAN PLAYER only if the HYDROGEN TANK is positioned in the REGIONAL ZONE and in contact with the GUARDRAIL.

Violation Consequence: RED CARD.

- G16 HUMAN PLAYERS and ROBOTS may not intentionally launch HYDROGEN or OXYGEN at any ROBOT or human, or outside the PLAYING FIELD.**

Violation Consequence: RED CARD.

- G17 OXYGEN that contacts the NETTING before entering the OXYGEN ACCUMULATOR will not incur a penalty.** The intended purpose of the NETTING is to prevent game pieces from leaving the PLAYING FIELD, but not to act as a backstop or assist for STORING OXYGEN in the OXYGEN ACCUMULATOR. However, teams will not be penalized if an OXYGEN atom makes contact with the NETTING before entering the OXYGEN ACCUMULATOR.

- G18** **The CONVERSION BUTTON may only be pressed during the last 30 seconds of the MATCH and only by the HUMAN PLAYERS.** Only once the MATCH timer reads 0:30 may HUMAN PLAYERS press the CONVERSION BUTTON; not allowed to push earlier than that.
- Violation Consequence: RED CARD.
- G19** **HYDROGEN or OXYGEN not fully contained in the HYDROGEN TANK at the end of the MATCH will not be counted towards the MATCH score.** HYDROGEN and OXYGEN atoms must be fully inside the HYDROGEN TANK.
- G20** **OXYGEN may not be STORED in the HYDROGEN TANK or OXYGEN ACCUMULATOR once the CONVERSION BUTTON has been pressed.** Neither ROBOTS nor HUMAN PLAYERS can continue to STORE OXYGEN after the CONVERSION BUTTON has been pressed.
- Violation Consequence: YELLOW CARD + FOUL*
- ROBOTS are allowed to continue STORING HYDROGEN until the end of the MATCH.
- G21** **ROBOTS must meet all conditions to earn the INTERMEDIATE and EXPERT PROFICIENCY points.**
Specifically:
- To earn points for INTERMEDIATE PROFICIENCY, the ROBOT must be fully supported by the RESERVOIR BOUNDARY or the PLAYING FIELD SURFACE within the RESERVOIR BOUNDARY (directly or indirectly) and be entirely contained within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY.
 - To earn points for EXPERT PROFICIENCY, the ROBOT must be fully supported by the HYDROGEN HUB structure (directly or indirectly), however it is not required to be contained within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY.
- A ROBOT that is “fully supported indirectly” means the full weight of the ROBOT is supported by the HYDROGEN HUB structure, even if the ROBOT is not in direct contact with the HYDROGEN HUB structure itself. For example, if a ROBOT’S weight is transferred to the HYDROGEN HUB structure through direct contact with another ROBOT’S mechanism.
- G22** **Real-time scores displayed on the scoreboard are not official and are for in-MATCH reference use only.** Official MATCH scores will be validated after the MATCH ends.
- G23** **Scores are calculated when all ROBOTS, HYDROGEN, OXYGEN, and HYDROGEN TANKS come to rest at the end of the MATCH.** A 5-second period after the end of the MATCH (when the MATCH timer displays 0:00) will be used to establish the resting status of the ROBOTS, HYDROGEN, and OXYGEN, HYDROGEN TANKS, and the CONVERSION MULTIPLIER values earned. Teams should try to make scoring clear and unambiguous, particularly when positioning their ROBOTS on the HYDROGEN HUB.

5. THE ROBOT

5.1. Overview

This section outlines the rules and requirements for the design and construction of a 2023 FIRST Global ROBOT. FIRST Global ROBOTS are teleoperated and designed and built by student team members to compete in the *Hydrogen Horizons* game. REV Robotics supplies the 2023 FIRST Global REV Robotics Kit of Parts from which teams will build their ROBOTS. Spare or replacement parts, as well as additional information about materials contained in the 2023

FIRST Global REV Robotics Kit of Parts, can be found on the [REV Robotics](#) website. Robot build guides, technical resources, and CAD files of the components included in the 2023 *FIRST* Global REV Robotics Kit of Parts can be found at <https://first.global/fgc/robot-kit/>.

5.2. Robot Design and Construction Rules

- R01** **Each *FIRST* Global team can only enter one robot in the competition.** Changes and modifications can be made to the robot throughout the event, but there can only be one robot per team.
- R02** **ROBOTS must function in imperfect situations.** The PLAYING FIELD and placement of elements making up the PLAYING FIELD may vary by up to ± 25 mm except if specifically noted in the [2023 FGC Playing Field Drawings](#). ROBOT designs should be robust enough to work even if the PLAYING FIELD, HYDROGEN, or OXYGEN are not perfectly sized or have a slightly different texture.
- R03** **ROBOTS must be designed to start each MATCH within a 50 cm x 50 cm x 50 cm volume.** See **G02**.
- R04** **ROBOTS should remain in one piece on the PLAYING FIELD.** ROBOTS may not intentionally detach parts on the PLAYING FIELD during the MATCH.
- Violation Consequence:* YELLOW CARD, RED CARD, or ROBOT disabled for MATCH depending on severity of offense.
- R05** **ROBOTS should be designed to permit easy removal of HYDROGEN and OXYGEN without requiring the ROBOT to be powered.**
- R06** **Each ROBOT must pass an initial inspection before being allowed to play in any RANKING or PLAYOFF MATCH.**
- If a HEAD REFEREE or INSPECTOR determines that a ROBOT is in violation of any rules, the team may be issued a RED CARD for the current MATCH (if they are playing) and will be required to pass a re-inspection before competing in their next MATCH.
 - ROBOTS may be re-inspected at any time.
 - If a team makes major modifications to their ROBOT, re-inspection is required.

Violation Consequence: ROBOT not allowed to compete or RED CARD depending on severity of offense.

- R07** **ROBOTS must be constructed from only the quantity and type of components included in the 2023 *FIRST* Global REV Robotics Kit of Parts unless otherwise explicitly allowed.** Each team will receive one 2023 *FIRST* Global REV Robotics Kit of Parts composed of two components: one tote containing a FTC Starter Kit V3 and one tote containing *FIRST* Global-Specific Components.

The official list of allowable components is identified in the combined [2023 FGC Bill of Materials](#), with the following exceptions:

- Tools (5.5 mm nut driver, 5.5 mm combination wrench, #25 chain tool, and allen wrench kit)
- Control System (battery charger and Etpark Wired Controller for PS4)
- FTC Starter Kit Guide and Bill of Materials
- 2023 *FIRST* Global Challenge game pieces (OXYGEN and HYDROGEN)
- Caster wheels for prototyping HYDROGEN TANK
- Plastic storage bins/totes
- Cardboard shipping boxes
- Plastic and foam packaging materials

Violation Consequence: ROBOT not allowed to compete.

R08 **ROBOTS may only be constructed using official REV Robotics products from the 2023 FIRST Global REV Robotics Kit of Parts.** Unless otherwise specified in **R09**, no substitutions are allowed.

Violation Consequence: ROBOT not allowed to compete.

Teams may purchase additional parts for prototyping or as spares, but extra components cannot be used to increase the quantity included on the final ROBOT. This rule is intended to help keep the level of competition equal for all teams.

R09 **ROBOTS may also be constructed using the following additional “non-REV Robotics” parts:**

- A. Any commercially available M3 screws (up to 50 mm long) and any commercially available nuts and/or washers that are the same sizes as those included in the 2023 FIRST Global REV Robotics Kit of Parts. These additional parts are to be used as replacements and cannot be used to increase the quantity included on the final ROBOT.
- B. Additional zip ties or cable ties. Must be functionally equivalent to REV Robotics zip ties in all ways (for example, cannot be longer, stronger, or stiffer).
- C. Lubricants used only in small amounts to reduce friction within the ROBOT. Lubricants must not contaminate the PLAYING FIELD, HYDROGEN, OXYGEN, or other ROBOTS. Use of lubricants is limited to:
 - i. Non-aerosol grease used in extreme moderation only on the internal gearing of motors or servos as needed after a gearing repair.
 - ii. Bicycle chain lubricant for repairing rusty roller chain, provided it is used sparingly and excess amounts are wiped off.
- D. Small amounts of tape or heat-shrink tubing used solely for:
 - i. Labeling wires, motors, or sensors.
 - ii. Securing wire connections.
 - iii. Note that tape, glue, or other adhesives are not allowed for purposes other than those listed above/not allowed for assembling the robot.

Violation Consequence: ROBOT not allowed to compete.

R09 **Not all items included in the 2023 FIRST Global REV Robotics Kit of Parts may be modified.** Motors or servos may not be modified in any way. Modifications to wires which are to be used with electronic components are not allowed, except when those modifications return the wires to their original condition as provided by REV Robotics. Modifications to any electronic component are not allowed. Cutting mechanical components such as extrusion, brackets, screws, chain, hook and loop, and cords is allowed.

Violation Consequence: ROBOT not allowed to compete.

Teams are encouraged to cut and customize items included in the 2023 FIRST Global REV Robotics Kit of Parts as allowed to make the best ROBOT design they can. Since teams only receive limited materials in the 2023 FIRST Global REV Robotics Kit of Parts and replacements will not be provided, it is important to think before you cut!

Replacing gears or restoring the condition of motor gearboxes is allowed if approved by FIRST Global or REV Robotics.

R10 **ROBOTS may use only one control system.** This means one Control Hub, one Expansion Hub, and one 12-Volt battery.

Violation Consequence: ROBOT not allowed to compete.

- R11 Not all designs that meet all other rules are legal.** The following design features are not allowed:
- Those which could potentially damage the PLAYING FIELD.
 - Those which could potentially damage the HYDROGEN and OXYGEN.
 - Those which pose an unnecessary risk of ENTANGLEMENT.
- Violation Consequence: ROBOT not allowed to compete.*
- R12 There is no minimum or maximum weight restriction on the ROBOT.**
- R13 ROBOTS may include personalization and decoration provided it does not affect or enhance the performance of the ROBOT.** For example, sponsor logos, flags, and artwork. Paint is allowed provided that it does not change the properties of the material it is being applied to (such as changing the coefficient of friction). These will be reviewed as part of the inspection process identified in **R06**.
- Violation Consequence: ROBOT not allowed to compete.*
- R14 ROBOT software must meet the minimum version requirement.** The Robot Controller app running on the Control Hub must be version 8.2.X, and the Driver Station app running on the Driver Hub must be version 8.2.X. For instructions on checking which software versions you have and performing the updates, [install the REV Hardware Client](#) and see [Updating the Control Hub's Robot Controller Application](#) and [Updating the Driver Hub's Driver Station Application](#).
- Violation Consequence: ROBOT not allowed to compete.*

Teams should program their ROBOTS using Blocks or OnBot Java. While it is possible to use Android Studio, FIRST Global and REV Robotics do not recommend using it for the EVENT. Support will not be available to teams that do not program in Blocks or OnBot Java.

6. THE TOURNAMENT STRUCTURE

6.1. Overview

The 2023 FIRST Global Challenge is played in a tournament format, consisting of three types of MATCHES. RANKING MATCHES provide each team with the opportunity to compete with its ROBOT on the PLAYING FIELD to earn points that will help determine their rank amongst the total participating teams. PLAYOFF MATCHES follow the RANKING MATCHES to determine which teams advance to the FINAL MATCHES. FINAL MATCHES determine the FIRST Global Winning Alliance.

6.2. Practice Matches

Each team will have the opportunity to play in an unscored PRACTICE MATCH at the EVENT. PRACTICE MATCHES are held before the start of RANKING MATCHES to allow teams to test their ROBOTS. Practice fields are available throughout the duration of the EVENT for teams to continue testing their ROBOTS.

6.3. Ranking Matches

Each team will play a set number of RANKING MATCHES based on the time allowed in the schedule. RANKING MATCH assignments and schedules will be generated once ROBOTS have been inspected. Teams will earn points based on their REGIONAL ALLIANCE'S performance during RANKING MATCHES, and the points will determine which teams advance to the PLAYOFF MATCHES.

Each team is ranked based on the average of the sum of their best MATCH scores. Each team's single lowest-scoring MATCH will not be included in total ranking consideration.

If a team is issued a RED CARD for any RANKING MATCH, that team receives 0 points for the MATCH. All other teams on the REGIONAL ALLIANCE receive the MATCH points.

If one or more teams are tied for a ranking position at the conclusion of RANKING MATCHES, the next factor for determining which teams advance to the PLAYOFF MATCHES is the highest single RANKING MATCH score from the team's RANKING MATCHES. The team with the highest single RANKING MATCH score advances.

If there continues to be a tie between one or more teams after ranking position and the highest single RANKING MATCH score from the team's RANKING MATCHES has been considered, the next factor for determining which teams advance to the PLAYOFF MATCHES is total HYDROGEN plus OXYGEN points. The team with the highest cumulative HYDROGEN plus OXYGEN points from all RANKING MATCHES advances.

6.4. Alliance Selection

TOURNAMENT ALLIANCES for the PLAYOFF MATCHES and FINAL MATCHES are selected following the conclusion of RANKING MATCHES, and do not change for the remainder of the EVENT.

A total of 32 teams compete in PLAYOFF MATCHES, divided into eight four-team TOURNAMENT ALLIANCES. At the conclusion of RANKING MATCHES, the top 24 teams will be automatically placed into eight TOURNAMENT ALLIANCES based on their rank and according to Table 6-1. Each of the eight TOURNAMENT ALLIANCES is led by one of the top-ranked eight teams as determined at the conclusion of the RANKING MATCHES. An additional eight teams will be selected via a random draw from the remaining pool of teams to fill the fourth slot on each TOURNAMENT ALLIANCE.

The random draw is selected from the remaining teams (ranked #25 and below) and is independent of team rank.

Table 6-1: TOURNAMENT ALLIANCES

TOURNAMENT ALLIANCE	Team Rankings at the Conclusion of RANKING MATCHES				
1	#1 Ranked Team	#9 Ranked Team	#24 Ranked Team	Random Draw	
2	#2 Ranked Team	#10 Ranked Team	#23 Ranked Team	Random Draw	
3	#3 Ranked Team	#11 Ranked Team	#22 Ranked Team	Random Draw	
4	#4 Ranked Team	#12 Ranked Team	#21 Ranked Team	Random Draw	
5	#5 Ranked Team	#13 Ranked Team	#20 Ranked Team	Random Draw	
6	#6 Ranked Team	#14 Ranked Team	#19 Ranked Team	Random Draw	
7	#7 Ranked Team	#15 Ranked Team	#18 Ranked Team	Random Draw	
8	#8 Ranked Team	#16 Ranked Team	#17 Ranked Team	Random Draw	

Only three of the four TOURNAMENT ALLIANCE teams will compete in each PLAYOFF and FINAL MATCH. The TOURNAMENT ALLIANCE teams determine which ROBOTS will participate in each MATCH.

Four teams per TOURNAMENT ALLIANCE allows for teams to make strategic choices as to which ROBOT plays each MATCH, while allowing for more teams to participate in the PLAYOFF and FINAL MATCHES. All teams on the TOURNAMENT ALLIANCE are treated equally and will all share in any

awards that the team receives.

6.5. Playoff Matches

The PLAYOFF MATCHES are structured as a tournament consisting of sixteen MATCHES. HYDROGEN points, OXYGEN points, CONVERSION MULTIPLIER, PROFICIENCY points, and COOPERTITON BONUS points remain unchanged from RANKING MATCHES. Each of the eight TOURNAMENT ALLIANCES will play four MATCHES according to Table 6-2.

Table 6-2: PLAYOFF MATCH Structure

MATCH Number	Competing TOURNAMENT ALLIANCES	
MATCH 1	TOURNAMENT ALLIANCE 4	TOURNAMENT ALLIANCE 7
MATCH 2	TOURNAMENT ALLIANCE 5	TOURNAMENT ALLIANCE 6
MATCH 3	TOURNAMENT ALLIANCE 3	TOURNAMENT ALLIANCE 8
MATCH 4	TOURNAMENT ALLIANCE 1	TOURNAMENT ALLIANCE 2
MATCH 5	TOURNAMENT ALLIANCE 5	TOURNAMENT ALLIANCE 4
MATCH 6	TOURNAMENT ALLIANCE 3	TOURNAMENT ALLIANCE 6
MATCH 7	TOURNAMENT ALLIANCE 2	TOURNAMENT ALLIANCE 7
MATCH 8	TOURNAMENT ALLIANCE 1	TOURNAMENT ALLIANCE 8
MATCH 9	TOURNAMENT ALLIANCE 3	TOURNAMENT ALLIANCE 4
MATCH 10	TOURNAMENT ALLIANCE 2	TOURNAMENT ALLIANCE 5
MATCH 11	TOURNAMENT ALLIANCE 1	TOURNAMENT ALLIANCE 6
MATCH 12	TOURNAMENT ALLIANCE 7	TOURNAMENT ALLIANCE 8
MATCH 13	TOURNAMENT ALLIANCE 2	TOURNAMENT ALLIANCE 3
MATCH 14	TOURNAMENT ALLIANCE 1	TOURNAMENT ALLIANCE 4
MATCH 15	TOURNAMENT ALLIANCE 5	TOURNAMENT ALLIANCE 8
MATCH 16	TOURNAMENT ALLIANCE 6	TOURNAMENT ALLIANCE 7

The eight TOURNAMENT ALLIANCES are each ranked based on the sum of the four scores from each PLAYOFF MATCH. The top three ranked TOURNAMENT ALLIANCES advance to the FINAL MATCHES.

6.6. Final Matches

The FINAL MATCHES consist of three MATCHES. Each of the top three ranked TOURNAMENT ALLIANCES from the PLAYOFF MATCHES will play two MATCHES, one against each of the other two TOURNAMENT ALLIANCES, according to Table 6-3.

Table 6-3: FINAL MATCH Structure

MATCH Number	Competing TOURNAMENT ALLIANCES	
MATCH 1	#1 Ranked TOURNAMENT ALLIANCE	#3 Ranked TOURNAMENT ALLIANCE
MATCH 2	#3 Ranked TOURNAMENT ALLIANCE	#2 Ranked TOURNAMENT ALLIANCE
MATCH 3	#2 Ranked TOURNAMENT ALLIANCE	#1 Ranked TOURNAMENT ALLIANCE

The three TOURNAMENT ALLIANCES are each ranked based on the sum of the two scores from each FINAL MATCH. The top ranked TOURNAMENT ALLIANCE is declared the *FIRST* Global Winning Alliance.

6.7. Tournament Rules

- T01** **All four teams in a TOURNAMENT ALLIANCE must participate in a minimum of one PLAYOFF MATCH.** If a TOURNAMENT ALLIANCE'S teams do not come to an agreement on which teams will play in each MATCH, a random selection will be made by *FIRST* Global.
- T02** **Tournament rules apply to all four teams on each TOURNAMENT ALLIANCE in the PLAYOFF and FINAL MATCHES.**
- T03** ***FIRST* Global reserves the right to modify the pairing of teams based on situational considerations at the EVENT after the final rankings are determined.** In the event that these pairings must change, every effort will be made to ensure changes have minimal impact on the TOURNAMENT ALLIANCE average strength by keeping changes within three ranking positions. Teams will be notified of these changes prior to the TOURNAMENT ALLIANCE pairing announcements.

7. SKILLS CHALLENGE

To be announced.

8. GLOSSARY

Key Word	Definition
ALIGNMENT TAPE	Tape on the PLAYING FIELD SURFACE that designates the starting position of the HYDROGEN TANKS.
ALLIANCE STATION	The locations on opposing sides of the PLAYING FIELD where DRIVE TEAMS stand during the MATCH.
CAPTAIN	A student team member on the DRIVE TEAM. The CAPTAIN'S primary responsibility is to monitor MATCH play and advise the DRIVERS and HUMAN PLAYERS. The CAPTAIN also coordinates strategy with other GLOBAL and REGIONAL ALLIANCE members. There is no explicit rule that the CAPTAIN cannot hold or touch the controls. Each DRIVE TEAM may have one CAPTAIN.
COMBUSTION	See PARTIAL ALIGNMENT.
CONVERSION BUTTON	The CONVERSION BUTTON is an illuminated plastic button, approximately 76 mm in diameter, located in each ALLIANCE STATION.
CONVERSION MULTIPLIER	A multiplier applied to the total sum of HYDROGEN and OXYGEN atoms in the HYDROGEN TANK at the end of the MATCH.
CONVERT	The process of changing the STORED HYDROGEN into different usable forms of energy using a FUEL CELL or COMBUSTION.
COOPERTITION BONUS	Additional points awarded to a GLOBAL ALLIANCE for five or more ROBOTS able to demonstrate EXPERT PROFICIENCY.

DEVELOPING PROFICIENCY	A ROBOT that is not positioned on the HYDROGEN HUB during the GLOBAL ALLIANCE component of the MATCH.
DISQUALIFIED	A team is no longer allowed to participate in any aspect of the EVENT.
DRIVE TEAM	Up to four student team members who fulfill the roles of DRIVERS, CAPTAIN, and HUMAN PLAYER for a given MATCH.
DRIVER	A student team member on the DRIVE TEAM. The DRIVER operates the team's ROBOT during the MATCH. Each DRIVE TEAM may have up to two DRIVERS.
ELECTROLYZER	A structure located in the corner of the PLAYING FIELD that separates HYDROGEN and OXYGEN atoms by size.
ENTANGLEMENT	When two or more ROBOTS become interconnected on the PLAYING FIELD during the course of the MATCH.
EVENT	The 2023 <i>FIRST</i> Global Challenge taking place in Singapore.
EXPERT PROFICIENCY	A ROBOT that is fully supported by the HYDROGEN HUB structure (directly or indirectly) during the GLOBAL ALLIANCE component of the MATCH.
FINAL MATCHES	The third and final set of official EVENT MATCHES. FINAL MATCHES determine the <i>FIRST</i> Global Winning Alliance.
FOUL	An official penalty assessed to a team for breaking a rule. A FOUL issued to teams during the MATCH comes with a 10% point penalty off the MATCH score, which will be awarded to the opposing REGIONAL ALLIANCE.
FUEL CELL	See FULL ALIGNMENT.
FULL ALIGNMENT (FUEL CELL)	HYDROGEN TANK has fully crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR.
GLOBAL ALLIANCE	A cooperative of six <i>FIRST</i> Global teams that work together during the final 30 seconds (0:30) of the MATCH to position their ROBOTS on the HYDROGEN HUB in order to earn PROFICIENCY points and COOPERTITION BONUS points.
GUARDRAIL	A system of borders at least 30 cm tall surrounding the PLAYING FIELD perimeter to contain HYDROGEN and OXYGEN and prevent ROBOTS from inadvertently leaving the PLAYING FIELD.
HEAD REFEREE	An official assigned by <i>FIRST</i> Global to enforce the rules of the game.
HUMAN PLAYER	A student team member on the DRIVE TEAM that interacts with OXYGEN and the COMPRESSOR BUTTON during the MATCH. Each DRIVE TEAM may have one HUMAN PLAYER.
HYDROGEN	Green closed-cell polyurethane foam balls with a diameter of 60 mm. HYDROGEN are STORED in the HYDROGEN TANKS.
HYDROGEN HUB	The square aluminum tubing structure above the RESERVOIR and the area enclosed by the vertical plane extending upward from the outer edge of the RESERVOIR BOUNDARY. At the top is a circular band of polycarbonate to ensure HYDROGEN TANKS don't enter the HYDROGEN HUB.
HYDROGEN TANK	A square, mobile structure mounted on caster wheels where HYDROGEN is STORED.
INSPECTOR	An official assigned by <i>FIRST</i> Global to assess the legality of a ROBOT.

INTERMEDIATE PROFICIENCY	A ROBOT that fully supported by the RESERVOIR BOUNDARY or the PLAYING FIELD SURFACE within the RESERVOIR BOUNDARY (directly or indirectly) and is entirely contained within the vertical plane extending upward from the outer diameter of the RESERVOIR BOUNDARY during the GLOBAL ALLIANCE component of the MATCH.
MATCH	The 2 minutes and 30 seconds (2:30) of gameplay where the DRIVE TEAM operates their ROBOT on the PLAYING FIELD. The MATCH begins when the announcer says “go” and the MATCH timer starts to count down from 2:30. The MATCH ends when the MATCH timer reaches zero (0:00).
NETTING	Open-meshed material positioned behind the OXYGEN ACCUMULATOR to prevent game pieces from leaving the PLAYING FIELD, but not to act as a backstop or assist for STORING OXYGEN in the OXYGEN ACCUMULATOR.
NO ALIGNMENT	HYDROGEN TANK is not aligned with the OXYGEN ACCUMULATOR and has not crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR.
OXYGEN	Blue closed-cell polyurethane foam balls with a diameter of 100 mm. OXYGEN are STORED in the OXYGEN ACCUMULATORS.
OXYGEN ACCUMULATOR	A structure located in the corner of the PLAYING FIELD where OXYGEN is STORED. The base is an irregular pentagon on the PLAYING FIELD SURFACE made from HDPE.
PARTIAL ALIGNMENT (COMBUSTION)	HYDROGEN TANK has partially crossed the vertical plane extending upward from the diagonal edge of the base of the OXYGEN ACCUMULATOR.
PLAYING FIELD	A raised 7 m by 7 m platform bounded by the GUARDRAILS and inclusive of the HYDROGEN TANKS, OXYGEN ACCUMULATORS, ELECTROLYZERS, RESERVOIR, and the HYDROGEN HUB.
PLAYING FIELD SURFACE	The horizontal surface of the PLAYING FIELD, bounded by the GUARDRAILS and covered with a low pile carpet.
PLAYOFF MATCHES	The second set of official EVENT MATCHES. PLAYOFF MATCHES determine which TOURNAMENT ALLIANCES advance to the FINAL MATCHES.
PRODUCE	The process of extracting water, represented by HYDROGEN and OXYGEN atoms, from the RESERVOIR or the PLAYING FIELD SURFACE to separate the HYDROGEN and OXYGEN atoms.
PROFICIENCY	Six teams working together in a GLOBAL ALLIANCE to position their ROBOTS on the HYDROGEN HUB to demonstrate each nation’s proficiency in hydrogen technologies.
RANKING MATCHES	The first set of official EVENT MATCHES. RANKING MATCHES determine which teams advance to the PLAYOFF MATCHES.
RED CARD	An official penalty assessed to a team for repeatedly breaking a rule, breaking multiple rules, or egregious actions. Generally, a YELLOW CARD is given before a RED CARD, but it is at the HEAD REFEREE’S judgment to issue a RED CARD based on the severity of the offense. When a team is issued a RED CARD, they will receive 0 points for that specific MATCH.
REGIONAL ALLIANCE	A cooperative of three FIRST Global teams that work together to PRODUCE and STORE HYDROGEN AND OXYGEN, then TRANSPORT and CONVERT HYDROGEN into a different usable form during the first 2 minutes of the MATCH.
REGIONAL ZONE	The area on the PLAYING FIELD parallel to the ALLIANCE STATIONS, extending 50 cm from the GUARDRAIL and marked with gaffer tape on the PLAYING FIELD SURFACE.

RESERVOIR	A circular region located in the center of the PLAYING FIELD and bounded by the RESERVOIR BOUNDARY. The RESERVOIR contains all game pieces (HYDROGEN and OXYGEN, representing water) at the start of the MATCH.
RESERVOIR BOUNDARY	A circular structure made from HDPE that contains the HYDROGEN and OXYGEN atoms at the start of the MATCH.
ROBOT	Any single electromechanical mechanism or device created from the 2023 <i>FIRST</i> Global REV Robotics Kit of Parts for the 2023 <i>FIRST</i> Global Challenge and operated by DRIVE TEAMS in MATCHES.
RUN	The timed series of actions performed by a ROBOT participating in the SKILLS CHALLENGE.
STORE	The process of putting HYDROGEN into the HYDROGEN TANK and OXYGEN into the OXYGEN ACCUMULATOR.
TOURNAMENT ALLIANCE	A cooperative of up to four <i>FIRST</i> Global teams that work together during the PLAYOFF MATCHES and FINAL MATCHES and do not change for the remainder of the EVENT.
TRANSPORT	The process of moving the HYDROGEN TANK and aligning it with the OXYGEN ACCUMULATOR.
YELLOW CARD	An official warning issued to a team for breaking a rule. Additional YELLOW CARDS may be elevated to a RED CARD at the judgment of the HEAD REFEREE, depending on the severity and frequency of the offense.