BEST 2013
Gatekeeper
Game Specific Rules

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Version 1.05
August 15, 2013

1.0 Introduction / Game Premise

As the world of electronics grows larger and larger, the internal components continue to grow smaller and smaller. Transistors, gates, registers, memory, decoders - all working together making electronics simple yet complex. We all agree, future economies will depend on us building the BEST robots and cutting-edge technology.

The BEST Robotics motto has always been "no robot left behind". One challenge remains: Squeaky, the original BEST robot needs serious upgrades to become Squeaky 2.0.

Almost all of the components for Squeaky's upgrade have been secured through generous BEST sponsors, but one component is still missing: the BEST CPU (Central Processing Unit). Squeaky 2.0 will require the newest and fastest CPU on the market.

BEST Robotics will be interviewing corporations in 42 days to award the contract to upgrade Squeaky. BEST Robotics will base the award on efficiency of each company's production line (robot performance), engineering notebook, marketing strategy, exhibit booth, and sportsmanship.

Please read in detail the specifics on how to create a BEST CPU. Apply logic and critical thinking skills to determine the number of transistors and types of gates needed to be successful. As the "Gatekeeper", we look forward to seeing you in 42 days to determine which corporation is the BEST of the BEST! Good Luck!

2.0 Objectives

Design a prototype robot to construct a CPU over the course of three fabrication stages.
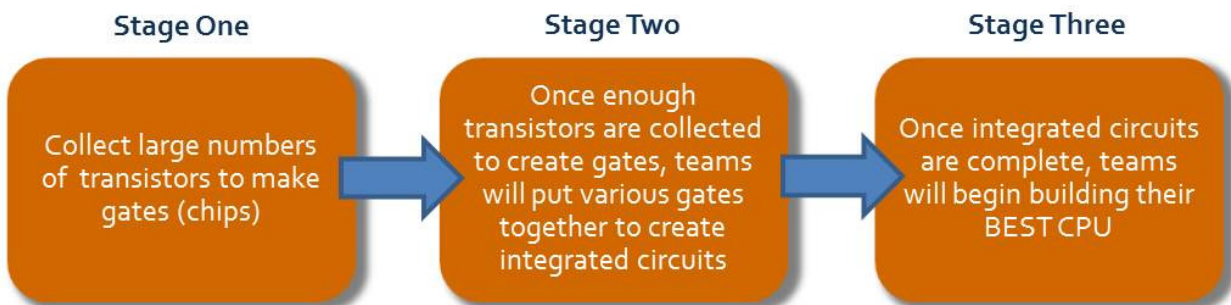

Figure 1: Game Stage Progress

2.1 Stage 1: Gate Fabrication

Collect transistors and place them into designated receptacles within the Gate Fabrication area to be converted into the desired logic gates. Transistors may be converted into the following logic gates: AND, OR, NOT, and NAND.

2.2 Stage 2: Integrated Circuit (IC) Fabrication

Collect logic gates and place them in the proper combinations within the IC Fabrication area to be converted into the desired integrated circuits, or "ICs".

Logic gates may be converted into the following ICs: Multiplexers (MUX), Adders, Decoders, and Data Latches (D-Latch).

2.3   Stage 3: CPU Fabrication

Place ICs within the CPU Fabrication area to be converted into the components necessary for a CPU. ICs may be converted into the following CPU components: Registers, Arithmetic Logic Units (ALUs), Instruction Decoders, Memory Units and Address Decoders.

3.0   Game Field Description

The Gatekeeper Game Field consists of four quadrants (red, green, yellow, and blue) arranged in a 24' x 24' square. Each quadrant is approximately 12'x12' square.
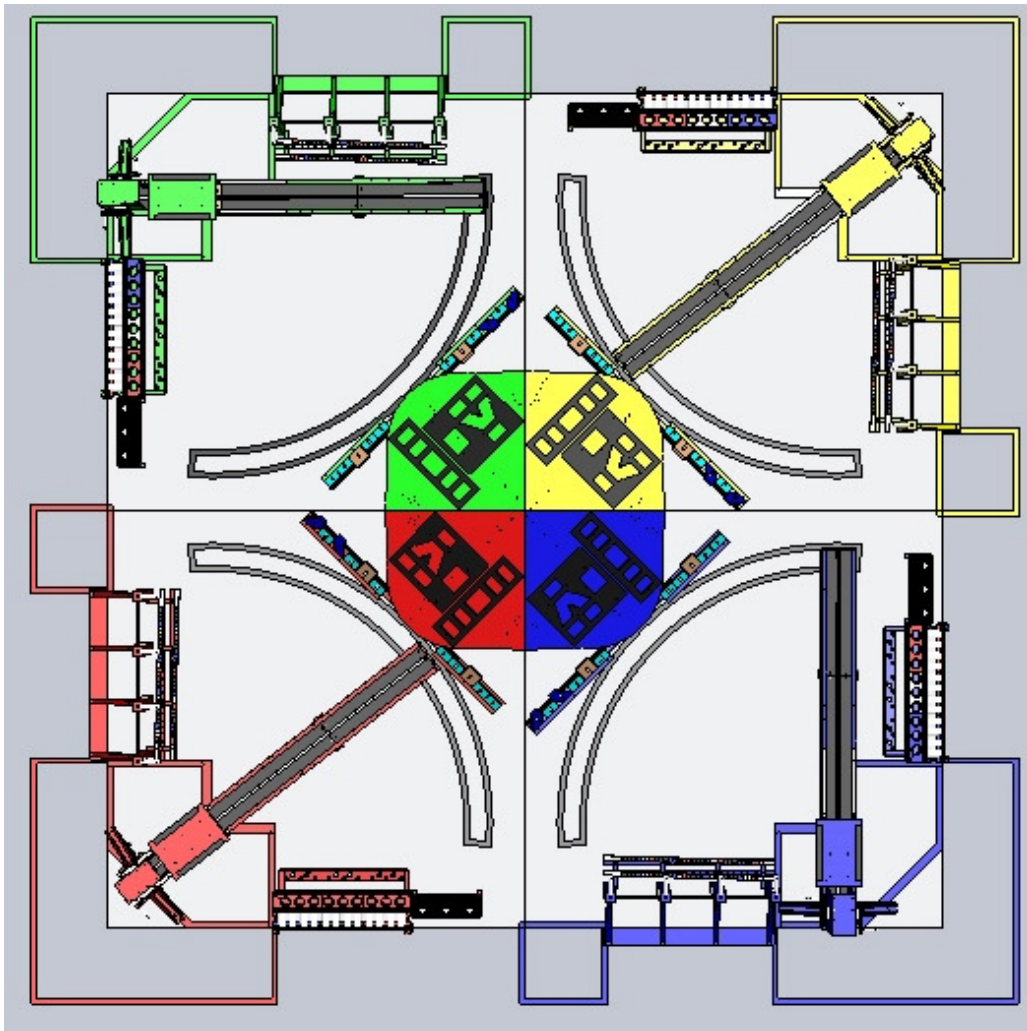
See the field drawings for full dimensions.

Figure 2: Field Overview (All quadrants)

Each quadrant consists of four main areas: Robot Trolley, Gate Fabrication, IC Fabrication and CPU Fabrication. Additionally, the 24" x 24" driver box is located on the edge of the quadrant adjacent to the IC Fabrication area. The spotter area is located on the corner of the quadrant between Gate Fabrication and IC Fabrication.

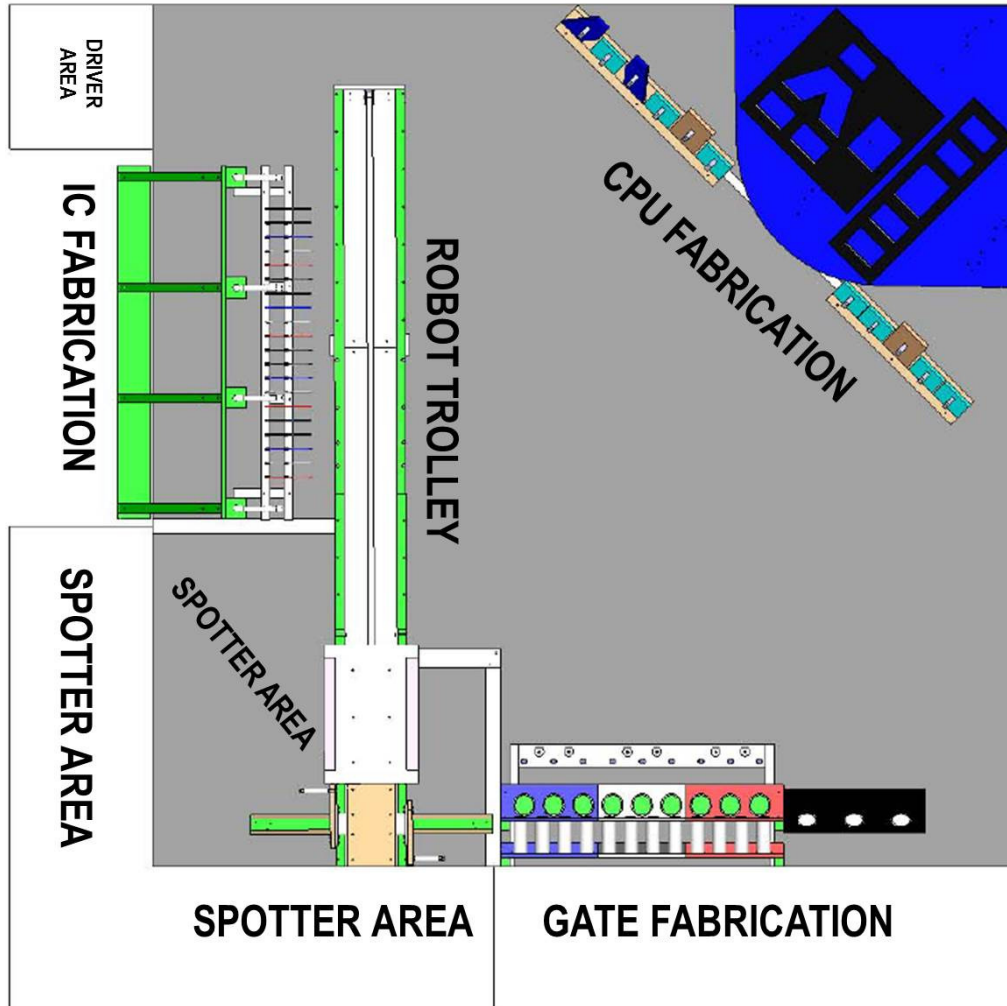There is one team per quadrant during a match.

Figure 3: Game Quadrant

3.1   Gate Fabrication Area Overview

3.1.a   Lower and Upper Gate Assembly Lines for AND, OR and NOT gates
- 48" x 24" x 14", two-level frame
- Lower Level Receptacles: 9 each 3" PVC pipe 6" length perpendicular to ground
- Upper Level Receptacles: 12 each 2" PVC pipe 6" length and parallel to ground
- Frame is painted three distinct colors (listed closest to furthest from the spotter): blue (AND), white (OR) and red (NOT) to distinguish gate fabrication areas.

3.1.b   NAND Gate Assembly Line
- 24" x 24" x 7" frame made with 2" x 2" wood
- Receptacles: 3 each 3" PVC pipe 6" length 30° incline
- Frame is painted black.

3.1.c   Transistor Container Storage
- 2" x 4" x 48" lumber containing 15 1" holes drilled in a staggered pattern, 5 each centered in front of the AND, OR, and NOT areas.
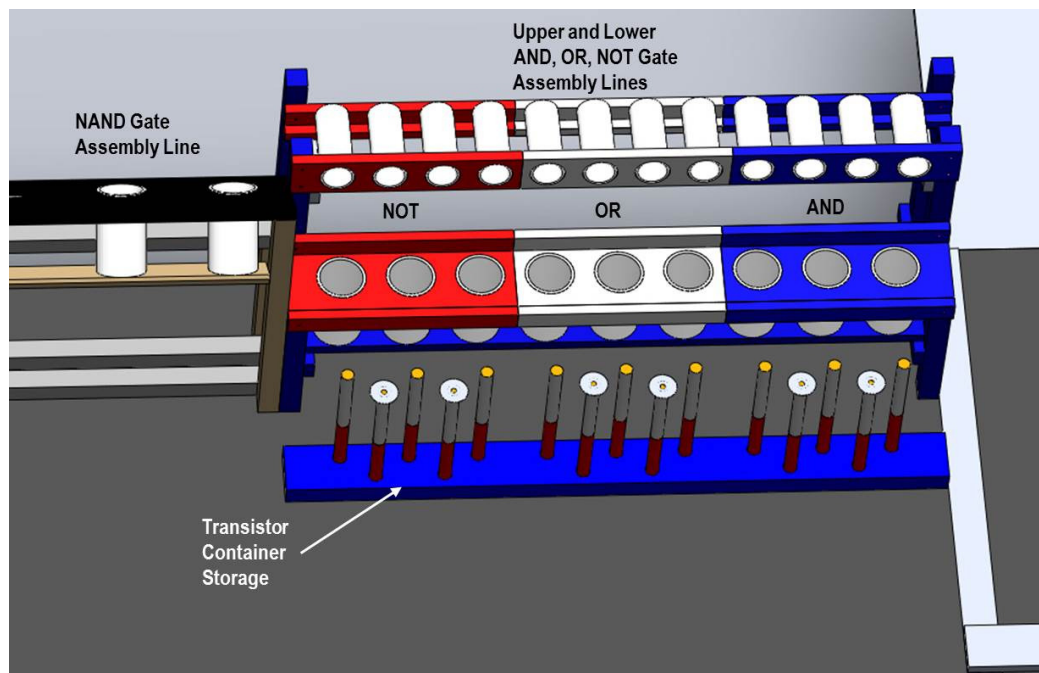

Figure 4: Gate Fabrication Area

3.2   IC Fabrication Area Overview

3.2.a   Tower
4 each 4" x 4" x 48" wooden post. Each tower shall be identified with the corresponding component name stenciled on each side with the top edge 9" below the top of post. Beginning with the tower closest to the spotter the order is: MUX, Adder, Decoder and D-Latch.

3.2.b   Tower Base
1" x 6" x 61 ½" connecting each tower.

3.2.c   Tower Kicker
2" x 4" x 25 ¾" with 45° angles supporting each tower.

3.2.d   Assembly Line Peg
Both the Lower and the Upper Assembly line peg are constructed from ½" PVC pipe.
- Lower Assembly Peg
32" above base 4" in length parallel to ground. PVC cap on exposed end.
- Upper Assembly Peg
Centered on top of post extending upwards is a ½" PVC 90° elbow joining an 8" peg with an end cap. The peg will be oriented to be parallel to the Lower Assembly Peg at the beginning of a match. The entire peg can rotate freely about the piece inserted into the post.

3.2.e   Gate Container Storage
6' x 6" wooden platform 4" from and parallel to floor. 4"x 1/4 " slots cut 2" apart.

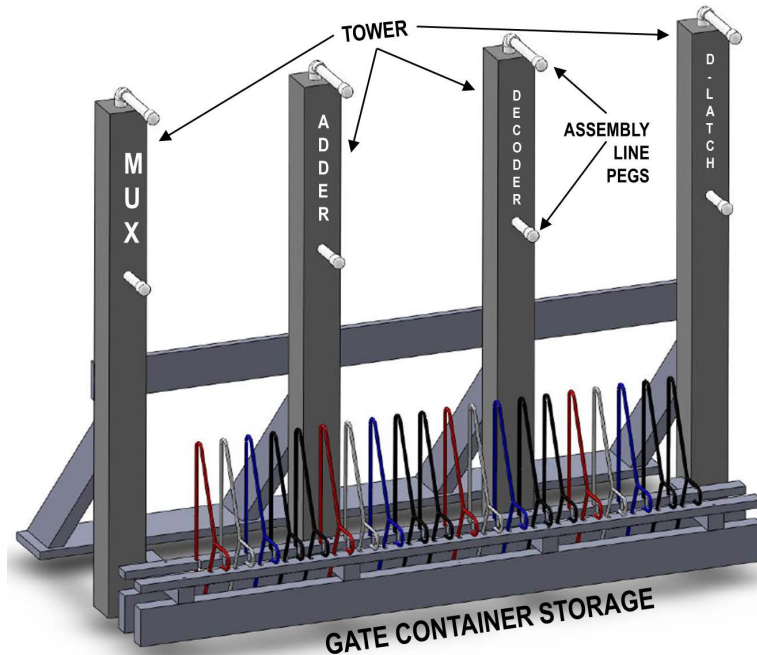

Figure 5: IC Fabrication Area

3.3   CPU Fabrication Area Overview

3.3.a   CPU Assembly Area
48" x 48" plywood frame with four 2" x 4" legs of various lengths create a surface with a 30° incline. The center, front edge of the frame is 15" from the floor. There is a raised painted wooden template divided into the core processor area and memory module area for scoring pieces.

3.3.b   Component Storage
Two (2) wooden platforms parallel to and resting on the floor, positioned approximately 12" to the left and right of the front center support post of the CPU assembly area.
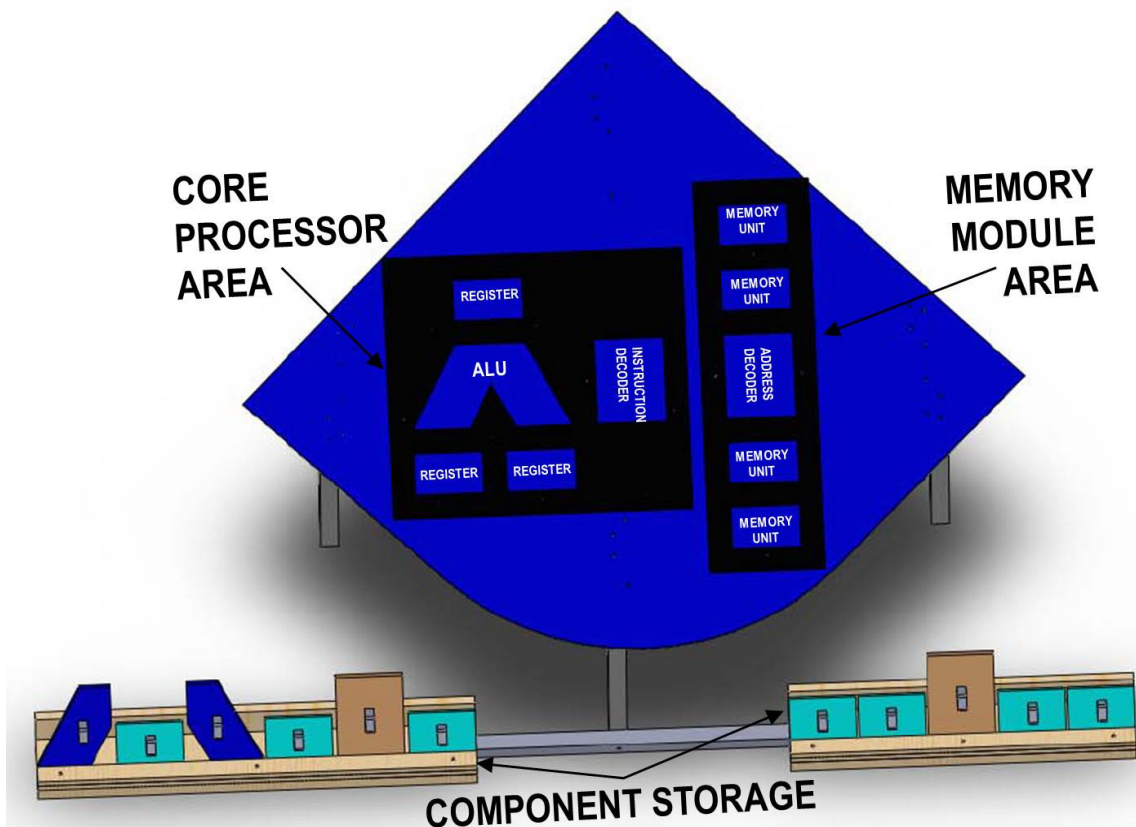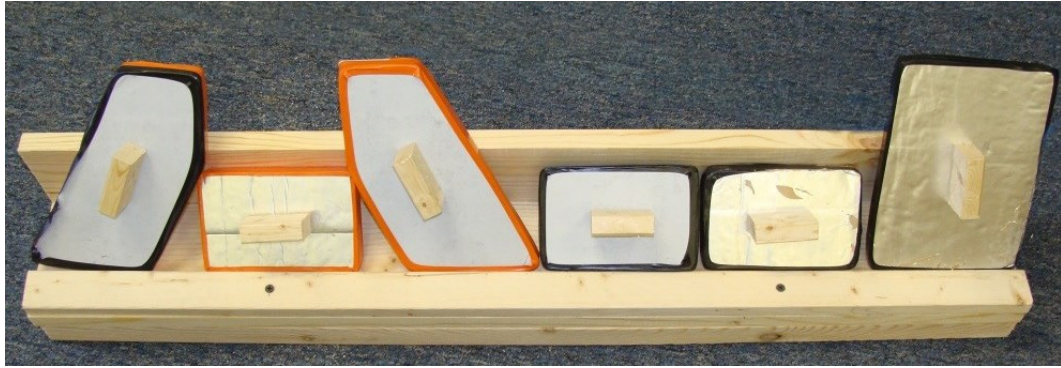

Figure 6: CPU Fabrication Area Overview

Figure 7: Component Storage Starting Positions (Left Side)
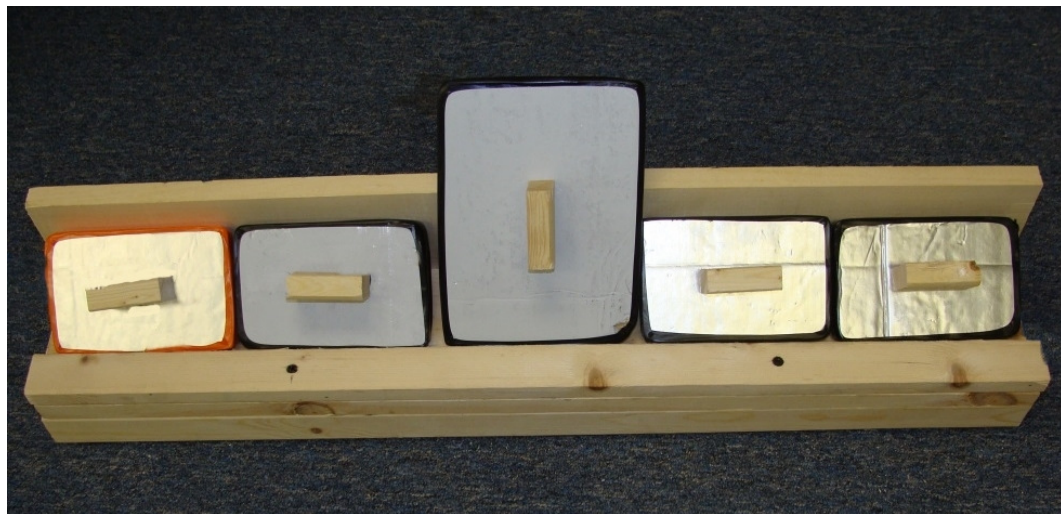
Figure 8: Component Storage Starting Positions (Right Side)

3.4   Robot Trolley Overview

3.4.a   Robot Trolley Assembly
The entire trolley assembly is operated by the spotter and is used to position the robot. The trolley is rotated about its pivot point for movement between fabrication areas. The Robot Trolley Assembly consists of three integral parts: robot attachment platform, guide rails and pulley system.

3.4.b   Robot Attachment Platform
The Robot Attachment Platform is a 23" x 15.75" plywood base with a four-wheel skate on which the robot must mount with clamps in the safe mounting areas. The skate rides on the trolley inside of the Trolley Guide Rails on 2" casters and is attached to a Habasit® drive belt.

3.4.c   Guide Rails
The Guide Rails are 9' in length x 12" width and 4" height with a plywood base. The guide rail assembly is screwed to the Lazy Susan whose pivot point is 3½' from each side of the field. The guide rail assembly has four 2" caster wheels.

3.4.d   Pulley System
The Pulley System has a drive pulley consisting of two 5 gallon bucket lids screwed back to back with two 4" flanges as spacers. The drive pulley and crank are positioned on a 36" tower. The crank is approximately 30" above the ground. Guide Pulleys of 2" casters are located in the tower and guide rails.

3.4.e   Trolley Safety Arc
The Trolley Safety Arc is located at the opposite end of the trolley from the spotter. The trolley wheels run along the trolley safety arc. Gaffer's tape delineates this path.

3.4.f   Spotter Box
The spotter box is a portion of the robot trolley area. The spotter area is roughly defined as a 7' square with a 2' square indention at the trolley pivot assembly.
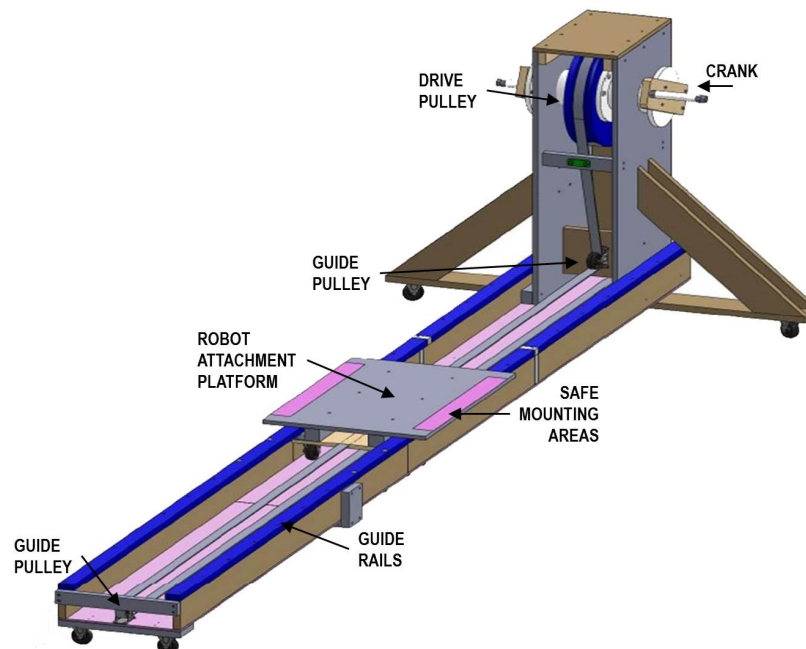
Figure 9: Robot Trolley Assembly

4.0   Game Piece Description

There is an independent set of game pieces for each quadrant. Each fabrication area has a unique set of game pieces to be used for the respective area.

4.1   Gate Fabrication Piece Overview

4.1.a   Transistor Container
A 7/8" wooden dowel 12" in length with half (6") painted. There are 15 per quadrant. Six (6) containers per quadrant are fitted with a Poka-yoke top, represented by a 2" washer, to assist with loading.
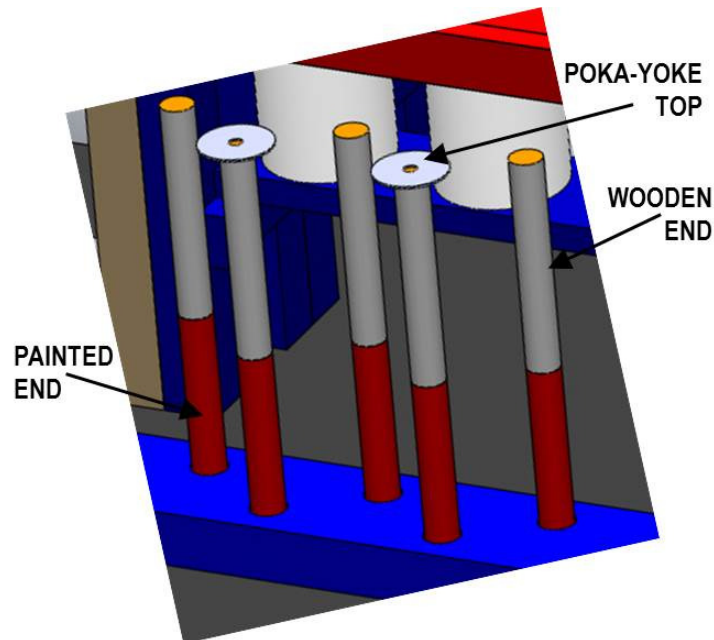

Figure 10: Transistor Container (Dowel)

4.1.b   Starting Position
The Poka-yoke containers are positioned on the front row (as viewed from the interior of the quadrant) of the Transistor Container Storage.
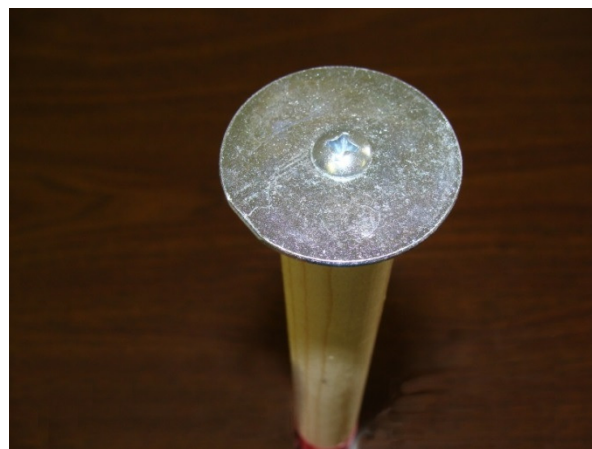
Figure 11: Transistor Container with Poka-yoke

4.2   IC Fabrication Piece Overview

4.2.a   AND Gates
Four (4) standard (adult) blue plastic tubular clothes hangers per quadrant.

4.2.b   OR Gates
Four (4) standard (adult) white plastic tubular clothes hangers per quadrant.

4.2.c   NOT Gates
Four (4) standard (adult) red plastic tubular clothes hangers per quadrant.

4.2.d   NAND Gates
Eight (8) standard (adult) black plastic tubular clothes hangers per quadrant.
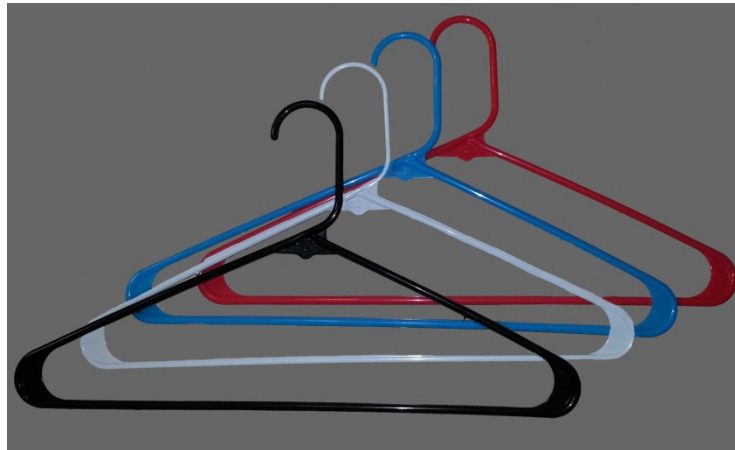
Figure 12: IC Fabrication Piece

4.2.e   Starting Position
The hangers are positioned within the Gate Container Storage in the following order from left to right when viewed from inside the quadrant: one (1) red, one (1) white, one (1) blue, and two (2) black. This pattern is repeated four (4) times. At the beginning of a match, hangers are oriented hook away from the tower with the open area of the hook facing down.
See Figure 5 for details

4.3   CPU Fabrication Piece Overview

The components are made from 3/4" thick R-max aluminum-coated insulating foam with a 1"x 2" wooden handle attached with screws. The components match the geometry of the template within the CPU Fabrication area.

4.3.a   MUX
Represented by approximately 7 ½" x 4 ½" trapezoid
There is one MUX available in each field quadrant.

4.3.b   Adder
Represented by approximately 7 ½" x 4 ½" trapezoid
There is one Adder available in each field quadrant.

4.3.c   Decoder
Represented by 5 ½" x 7 ½" rectangle
There are two Decoders available in each field quadrant.

4.3.d   D-Latch
Represented by 5 ½" x 3 ½" rectangle
There are seven D-Latches available in each field quadrant.
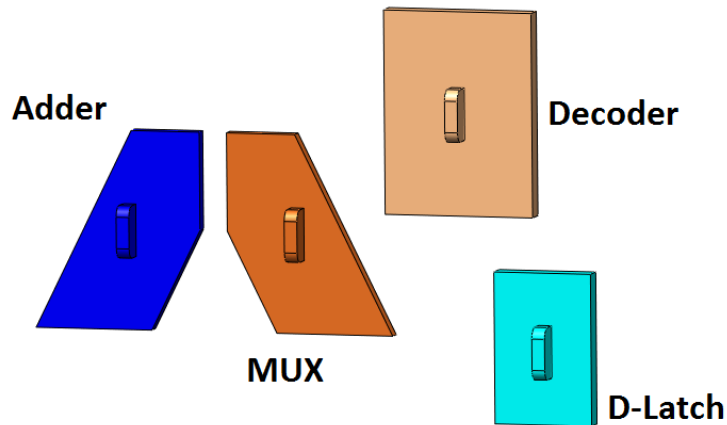
Figure 13: CPU Fabrication Piece Overview

5.0   Gameplay

5.1   Inventory System

Gatekeeper utilizes an inventory system that is independent from scoring values. Components that are fabricated in each stage are placed in the team's inventory. This inventory is not represented physically, but is instead maintained by the BEST scoring software.

Inventory is calculated at the end of the match in the following order: Stage 1, Stage 2, and then Stage 3. This means that inventory can be consumed in the same match in which it is fabricated.

For a component from Stage 2 or Stage 3 to be fabricated, the appropriate quantity of required components must exist in inventory and are consumed to create the new component. No components are deducted from inventory if fabrication fails due to insufficient inventory or if a game piece is not in a valid scoring receptacle at the end of a match.

Fabrication within Stage 2 and Stage 3 will be attempted in the following order of priority:

- Stage 2 Priority
    ♦ MUX > Adder > Decoder > D-Latch
- Stage 3 Priority
    ♦ Instruction Decoder > Address Decoder
    ♦ Register > Memory Unit
    ♦ 32-bit CPU > 8-bit CPU

For example, a team has 1 AND gate, 1 OR gate, and 1 NOT gate in inventory. At the end of the next match they attempt to fabricate both a D-Latch and an Adder. Based on the priority listed above, 1 AND gate, 1 OR gate, and 1 NOT gate are consumed from inventory and one Adder would be placed into inventory.

Hubs will provide a display for viewing team inventory, but it is highly recommended that teams track their own inventory.

5.2   Gate Fabrication

The Gate Fabrication area consists of the Transistor Container Storage and three assembly lines for placement of transistor containers: the Lower Gate Assembly Line, the Upper Gate Assembly Line, and the NAND Gate Assembly Line.

5.2.a   Transistor Container
Due to a mistake by the inventory delivery system, all of the transistor containers were delivered upside down (painted side down) to Transistor Container Storage. They may still be used while upside down, but the Gate Fabrication area is only able to use ½ of the container. For all of the transistors in a container to be used during fabrication, the container must be rotated so it is right-side up (painted side up or out). Any transistor container may be used on any of the assembly lines. A transistor container holds 96 transistors.

5.2.b   Lower Gate Assembly
The Lower Gate Assembly Line consists of three receptacles designated for building each of the following gates: AND (blue), OR (white), and NOT (red). This line is experiencing problems and is running at half efficiency. A transistor container properly loaded (painted side up) into one of the receptacles provides 48 transistors. A transistor container improperly loaded (painted side down) into one of the receptacles provides 24 transistors.

5.2.c   Upper Gate Assembly
The Upper Gate Assembly Line consists of four receptacles designated for building each of the following gates: AND (blue), OR (white) and NOT (red). A transistor container properly loaded (painted side out) into one of the receptacles provides the full 96 transistors. A transistor container improperly loaded (painted side in) into one of the receptacles provides only 48 transistors.

5.2.d   NAND Gate Assembly
The NAND Gate Assembly Line is only used for manufacturing NAND gates (black). A transistor container properly loaded (painted side up) into one of the receptacles provides 96 transistors. A transistor container improperly loaded (painted side down) into one of the receptacles provides 48 transistors.

5.2.e   Gate Fabrication
At the end of the match, gates will be placed into inventory based on the number of transistors loaded into each of the receptacles. The number of transistors required to create a specific type of gate is listed in Table 1 below.

Table 1: Transistors Per Gate

Gate Type	Transistors Required Per Gate
AND	24
OR	24
NOT	24
NAND	16

5.3   IC Fabrication

The IC Fabrication Area consists of four assembly towers. There is one tower configured to fabricate each of the four IC types: MUX, Adder, Decoder and D-Latch.

5.3.a   Towers
When loaded with the correct combination of gates, each tower will fabricate its designated type of IC. Multiple gate combinations may be placed on the same tower during a single match. Each tower contains two assembly lines, represented by PVC pegs, which are configured to operate at a different speed.

5.3.b   Lower Assembly Line
The Lower Assembly Line is configured to operate at normal speed. Loading the correct combination of gates onto this assembly line results in a maximum of one IC per gate combination, if and only if the appropriate amount of inventory exists.

5.3.c   Upper Assembly Line
The Upper Assembly Line is configured to operate at double speed.
Loading the correct combination of gates onto this assembly line results in
a maximum of two ICs per gate combination, if and only if the appropriate
amount of inventory exists

Table 2: IC Fabrication

IC Type	Possible Gate Configuration
MUX	2 AND + 1 OR + 1 NOT
	3 NAND
Adder	1 AND + 1 OR + 1 NOT
	2 NAND
Decoder	1 AND + 1 NOT
	2 NAND
D-Latch	1 AND + 1 OR + 1 NOT
	1 NAND

Each tower can only operate as fast as the slowest assembly line in use. For
example, loading two gates onto the Upper Assembly Line and one on the Lower
Assembly line will result in the tower running at normal speed, not at double
speed.

The gates may be placed on to the Assembly Line Peg in any orientation, and
must be contacting and supported completely by the peg, i.e. gates may not be
daisy-chained, and no portion of the gate may be supported by the Tower.
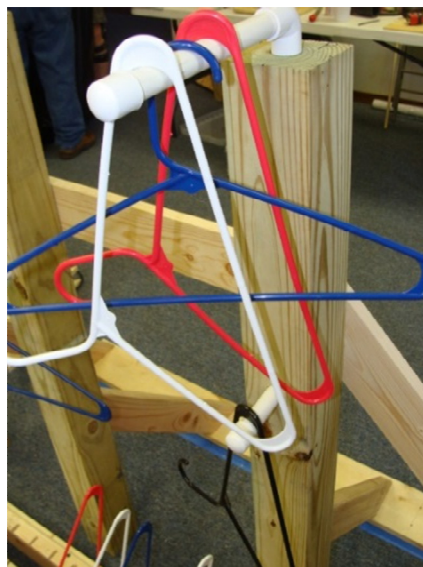
Figure 14: Gate (Hanger) Orientation

5.4   CPU Fabrication

The CPU Fabrication Area consists of two sub-areas: the core processor (left) and memory module (right). Both areas use ICs fabricated in Stage 2. Only one (1) component may be placed in any designated receptacle. ICs may only be used for fabrication if they exist within inventory. Stage 3 game pieces are considered properly placed if they are fully inside the designated scoring receptacle and flush with the bottom surface.
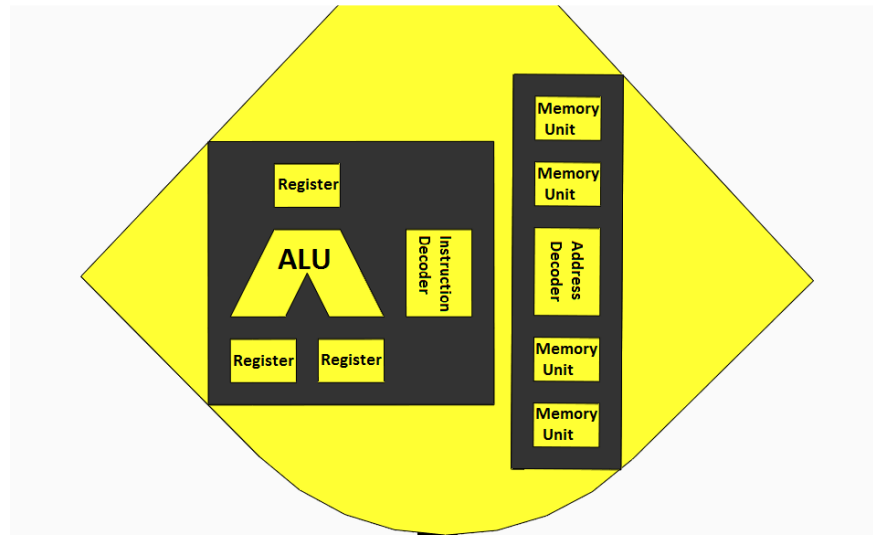
Figure 15: CPU Fabrication Area

5.4.a   Core Processor Area
The Core Processor Area, on the left, requires three Registers, an Instruction Decoder, and an ALU. Registers are created by properly placing a D-Latch within any designated Register receptacle. The Instruction Decoder is created by properly placing a Decoder within the designated Instruction Decoder receptacle. The ALU requires placing of both a MUX and an Adder in their designated receptacle. Core processor ICs may be placed over multiple matches.

For example, a team places two (2) Registers, one (1) MUX, and one (1) Instruction Decoder in a match. The next match they place one (1) Register and one (1) Adder. At the end of the second match, they would be awarded one (1) ALU (MUX + Adder) and would have three (3) Registers, one (1) ALU and one (1) Instruction Decoder in inventory to be used towards fabricating a CPU.

5.4.b   Memory Module Area
The Memory Module Area, on the right, is capable of fabricating two types of memory modules: an 8-bit Memory Module and a 32-bit Memory Module. To fabricate an 8-bit Memory Module requires properly placing

one D-Latch within any designated Memory Unit receptacle. To fabricate a 32-bit memory module requires properly placing four D-Latches within the designated Memory Unit receptacles and properly placing one Decoder within the designated Address Decoder receptacle **within the same match**.

If more than one D-Latch is properly placed within the designated Memory Unit receptacles but no Decoder is properly placed in the Address Decoder receptacle, a single 8-bit Memory Module will be fabricated and placed into inventory if the proper prerequisite inventory exists.

If a Decoder is properly placed within the designated Address Decoder receptacle but between one (1) and three (3) D-Latches are properly placed within the designated Memory Unit receptacle, a single 8-bit Memory Module will be fabricated and placed into inventory if the proper prerequisite inventory exists.

Any inventory placed which is not consumed in the fabrication of a CPU is neither removed from inventory nor awarded points.

5.4.c   To complete a CPU, the following components must be fabricated:
- Three (3) Registers
- One (1) Instruction Decoder
- One (1) ALU
- One (1) Memory Module (8-bit or 32-bit)

The type of CPU that is fabricated is determined by the highest-bit Memory Module available in inventory.

5.5   Robot Trolley Operation

5.5.a   Robot Mounting Base
The robot must be built with a base such that it can easily mount to a 23"x16"x½" plywood mounting base using four (4) 2"-wide binder clips with 1" capacity. Mounting clips may be positioned by the team in the designated safe mounting areas, but at least one clip must be attached in each of the safe mounting areas. Prior to mounting, the robot must remain balanced, unaided, atop the mounting base.
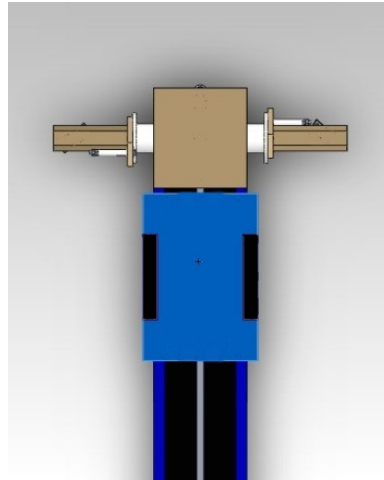
Figure 16: Designated Safe Mounting Areas (Black)

6.0   Scoring

A cumulative inventory is maintained during gameplay and is separate from the total score. Game pieces have different scoring values based on how they are used during fabrication of the CPU. Scores are determined at the end of each match. The score for each match is added to the previous match to create a cumulative score.

6.1   Gate Fabrication Scoring

General note: Transistors do not score individual points and are not accumulated. Any unused transistors within a transistor container are wasted.

AND Gates Manufactured	=	10 Points Each
OR Gates Manufactured	=	10 Points Each
NOT Gates Manufactured	=	10 Points Each
NAND Gates Manufactured	=	8 Points Each

6.2   IC Fabrication Scoring

MUX Manufactured	=	80 Points Each
Adders Manufactured	=	60 Points Each
Decoders Manufactured	=	40 Points Each
D-Latches Manufactured	=	60 Points Each

6.3   CPU Fabrication Scoring

Register Installed	=	90 Points Each
Instruction Decoder Installed	=	60 Points
MUX Installed in ALU	=	120 Points
Adder Installed in ALU	=	90 Points
8-Bit Memory Module Completed	=	90 Points
32-Bit Memory Module Completed	=	420 Points
8-Bit CPU Completed	=	512 Points
32-Bit CPU Completed	=	1024 Points

6.4   Match Scoring / Calculations

Fabrication is completed based on the positions of game pieces at the end of the match. Any game piece still in contact with the robot or robot trolley at the end of the match does not count.

6.5   Tie-Breaker

In the event of a tie, the winner will be the team with the highest notebook score. If the notebook scores are also tied, the winner will be determined by flipping a standard U.S. Quarter. The tie-breaker is only invoked if there is a tie at the end of a round.

6.6   5S Bonus

A 5S Bonus is awarded at the completion of each match for maintaining a clean and safe work environment. The 5S Bonus (5S) is calculated at the end of each match, but is not finalized until the end of the round. The 5S Bonus will be awarded at the end of a match, if no game pieces have been removed from play, and any game pieces in contact with the floor are also in contact with the robot. The maximum 5S per round is 10% of the scored amount. The total 5S is calculated using the following formula:

$$\frac{(number\ of\ 5Ss)}{(number\ of\ matches\ completed)} \times (10\%) \times (cumulative\ score)$$

Example: A team that keeps a clean and safe quadrant during 6 out of 8 matches will result in a 7.5% bonus being applied to its score at the end of the round.

All 5S Bonus values will be rounded down to the nearest integer.

Note: Although the running 5S will be displayed after each match as part of the score, it will not be finalized until all matches in a round are complete; therefore, a team's bonus may fluctuate if it fails to maintain a clean and safe quadrant in successive matches.

7.0   Restrictions and Considerations

- Game pieces must be in the correct scoring location at the end of the match to score points or count toward inventory.
- Game pieces will not earn points or be added to the team inventory at the end of the match if they are in contact with any part of the team's robot or any part detached from the robot during the match.
- Game pieces dropped onto the factory floor may be recovered by the robot if the robot is capable of doing so.
- Game pieces that touch the floor outside the boundary of the quadrant are considered Out of Play.

7.1 Robot Mounting Considerations

The robot must remain mounted to the Robot Attachment Platform for the entirety of the match. If the robot loses contact with the Robot Attachment Platform, the robot must remain idle for the remainder of the match. Any previously placed game pieces will be considered eligible.

7.2 Trolley Guide Restrictions

It is imperative nothing hinders the operation of the Robot Trolley Assembly. No game piece or robot parts may be placed or dropped within the Robot Trolley Assembly. Any items dropped within the Robot Trolley Assembly results in an emergency 20-second shutdown of operations (penalty) while a safety technician (field referee) removes it from the Robot Trolley Assembly and places it out of play. This results in an automatic forfeiture of the 5S Bonus for that match.

Neither the Robot Trolley Assembly nor the robot may be moved or manipulated during a shutdown. Failure to comply with the shutdown restrictions may result in a complete shutdown (match disqualification) if the referee determines the offense to be intentional.

7.3 Trolley Safety Arc Restrictions

The Trolley Safety Arc is located at the opposite end of the trolley from the spotter. The trolley wheels run along the Trolley Safety Arc. If an item obstructs the wheel path, it cannot be run over. There are three options available for the team to choose from:
- Pick up or move the item with the robot
- Leave the item and move the trolley in the opposite direction,
- Ask the safety technician (field referee) to remove the item from play and accept a 20-second shutdown of operations (penalty).

7.4 Trolley Operator (Spotter) Restrictions

Once the match begins, the trolley operator (spotter) may only interact with the external areas of the main crank assembly tower. Interaction with the trolley in other areas, such as the outrigger supports, trolley guide rails, or internal mechanisms, or contact with any other portion of the playing field will result in an emergency 20-second shutdown of operations (penalty). Failure to comply with the shutdown restrictions may result in a complete shutdown (match disqualification) if the referee determines the offense to be intentional.

The spotter is not required to maintain contact with the trolley and is allowed to freely move about the designated spotter area, as long as no other rules are violated when doing so.

8.0   Game Operations

8.1   Match Protocol

Each match shall be three minutes long and is played with four teams if possible. The scoring software will assign teams to a match and will determine the team's quadrant. A team shall have only two (2) members on the field per match, one (1) driver and one (1) spotter.

Each match will have a 30 second setup period. Prior to the beginning of the match, teams shall wait at the spotter area until the beginning of the setup period. Once signaled, teams will have the duration of the setup period to attach their robot to the Robot Attachment Platform. After the robot is attached, the Robot Attachment Platform must be positioned behind the Robot Attachment Platform starting position indicator. The Robot Trolley assembly may be in any position at the start of the match.

If a team has not successfully attached their robot by the end of the setup period, they may continue to attach the robot; this results in an emergency 20-second shutdown of operations (penalty) applied at the beginning of the match. If a team continues to attach their robot once the match has begun, the 20 second penalty will be applied once the team is ready to begin gameplay.

8.2   Driver and Spotter Rotation

Drivers must rotate from match to match. Spotter rotation is left to the team's discretion. Please refer to the Generic Game Rules.

8.3   Competition Protocol

The competition consists of four phases – a seeding round, wild card match, semi-final round, and a final round. Refer to the Generic Games Rules for more detail.

8.3.a   The Seeding Round
The Seeding Round consists of round robin competition with eight matches (or fewer depending on local hub discretion) for each team. The top seven teams ranked by cumulative score advance to the semi-final round.

8.3.b   The Wild Card Match
The Wild Card Match consists of one match between the four teams with the highest BEST design notebook score that are not already ranked in the top seven teams from the seeding round. No previous match scores or inventory will be included. No score or inventory from this phase will be added to any other portion of the competition.
During the Wild Card match, all prerequisite inventory restrictions for Stage 2 and Stage 3 are lifted and fabrication can be accomplished at any stage.

The winner of the wild card match is the team with the highest score accumulated, including bonus, and moves on to the semi-final round.

8.3.c   The Semi-Final Round
The Semi-Final round consists of round robin competition with each team participating in three matches. Before the semi-final phase, scores are reset to zero and the inventory is set to the following:
- 1 MUX, 2 D-Latch, 1 Decoder
- 3 AND gates, 3 OR gates, 3 NOT gates

The semi-final round ranking is based on cumulative scores from the three matches. Gameplay is the same as previously described for the seeding round. The top four ranking teams advance to the final round.

8.3.d   The Final Round
The final round consists of the top four teams from the semi-final round participating in three final matches. Before the final round, scores are reset to zero and the inventory is set to the following:
- 1 MUX, 2 D-Latch, 1 Decoder
- 3 AND gates, 3 OR gates, 3 NOT gates

The final round ranking is based on cumulative scores from the three matches. Gameplay is the same as previously described for the seeding round. The winner is the team with the most points accumulated during the final matches.

9.0   Terminology

32-bit CPU: A CPU that can process numbers up to 32 bits in length.

32-bit Memory Module: A memory module that stores data in 32-bit chunks.

5S: An organizational method designed to maintain workplace efficiency. The five S's are Sort, Set in order, Shine, Standardize, and Sustain (maintain).

8-bit CPU: A CPU that can process numbers up to 8 bits in length.

8-bit Memory Module: A Memory module that stores data in 8-bit chunks.

Adders: A logic circuit that adds two binary numbers and outputs the result.

Address Decoder: A decoder which takes an address number and selects the appropriate data line for that address.

AND Gate: A logic device which generates a logic 1 only if all of its inputs are 1.

Arithmetic Logic Unit (ALU): The part of a CPU that performs general math operations.

Bit: A single binary digit, can be either a 0 or 1.

Core processor: See CPU.

Central Processing Unit (CPU): The part of a computer that performs the arithmetic, logic, and control functions.

Data Latches (D-Latch): A latch that stores whatever value is on its data line when the clock is toggled.

Decoder: A device which undoes encoding so that the original information in a signal or group of signals can be retrieved ALTERNATIVELY a circuit that converts a numerical binary input into a a single output.

Gate (Logic Gate): A circuit that converts digital input signal(s) into an output signal based on a logical operation.

Instruction Decoder: A decoder which takes an instruction as an input and "programs" the CPU to perform the operation (e.g. setting the ALU mode for subtract, add, multiply, or divide).

Integrated Circuit (IC): The placement of numerous transistors and circuits onto a silicon chip.

Memory Unit: A group of registers used to store data.

Memory: The part of a computing device where data and instructions are stored.

Multiplexer (MUX): A device that selects one of several input signals and forwards the selected input into a single line.

NAND Gate: Stands for NOT-AND. Gives an inverted output of AND logic.

NOT Gate: A logic device whose output is always opposite the input.

OR Gate: A logic device which generates a logic 1 if any one of its two or more inputs are 1.

Poka-yoke: Any mechanism in manufacturing that helps an equipment operator.

Register: A group of latches used to store data.

Transistor: A small electronic semiconductor device having at least three electrical contacts, used in a circuit as an amplifier or a switch.

10.0   Revision History

This section is not part of the Game Specific Rules, but is provided to aid in determining changes to this document.

Rev	Date	Impact	Summary of Changes
1.05	August	Minor	Fix minor errors
1.04	August	Minor	Kickoff Distribution; Change color in overall field image
1.03	July	Minor	Hub Distribution
1.02	June	Minor	Added Example Round
1.0	March	Minor	Prototype Game Development

11.0   Appendix: Example Round

Match 1 -   **Goal: Build up Gate inventory**
Robot Placed:
Stage 1
> NAND   - 1 Non-painted, 1 Painted
> AND   - 1 Upper/Painted
> OR   - 1 Lower/Non-painted
> NOT   - 1 Lower/Painted

Resulting Inventory
> NAND - 9   OR   - 1
> AND   - 4   NOT   - 2

5S Bonus? Yes
Match Score: 142 Points
Cumulative Score: 142 Points * (100% + (10% * 1/1)) = 156

Match 2 -   **Goal: Use Existing Gates to Make ICs**
Placed:
Stage 2
> MUX Tower   - 2 AND, 1 OR, 1 NOT (On Lower Peg)
> Adder Tower   - 1 AND, 1 OR, 1 NOT (On Lower Peg)
> Decoder Tower   - 1 AND, 1 NOT (On Upper Peg)
> D-Latch Tower   - 4 NAND (On Lower Peg)

Resulting Inventory
> MUX   - 1
> Adder   - 0 (Only 1 OR gate in inventory, used to make MUX)
> Decoder   - 1 (Placed on upper, but only inventory to make 1)
> D-Latch   - 4
> NAND   - 5 (4 used for D-Latch)
> AND   - 1 (2 used for MUX, 1 used for Decoder)
>   NOTE: No inventory used by failed Adder or Decoder
> OR   - 0 (1 used for MUX)
> NOT   - 0 (1 used for MUX, 1 used for Decoder)

5S Bonus? Yes
Match Score: 360
Cumulative Score: (142 + 360) * (100% + (10% * 2/2)) = 552

Match 3 -   **Goal: Build a missing Adder, start CPU**
Placed:
Stage 2
> Adder Tower   - 2 NAND (On Lower)
Stage 3
> Register   - 2

                Adder   - 1
                Instr Decoder   - 1

Resulting Inventory
                Instr Decoder   - 1
                ALU (Adder)   - 1 (The Adder created this round is immediately used)
                Register   - 2
                MUX   - 1
                Adder   - 0 (An Adder was created, but was consumed for the ALU component)
                Decoder   - 0
                D-Latch   - 2
                NAND   - 3
                AND   - 1
                OR   - 0
                NOT   - 0

5S Bonus? No
Match Score: 390
Cumulative Score: (142 + 360 + 390) * (100% + (10% * 2/3)) = 951   (10% * 2/3 = 6.66%)

Match 4 -   **Goal: Finish 8-Bit CPU**
Placed:
Stage 3
                Register   - 1
                Memory Unit   - 1
                MUX   - 1

Resulting Inventory:
                CPU (8-Bit)   - 1
                Memory Unit   - 0 (Used to make CPU)
                Instr Decoder   - 0 (Used to make CPU)
                ALU (Adder)   - 0 (Used to make CPU)
                ALU (Mux)   - 0 (Used to make CPU)
                Register   - 0 (Used to make CPU)
                Mux   - 0
                Adder   - 0
                Decoder   - 0
                D-Latch   - 0
                NAND   - 3
                AND   - 1
                OR   - 0
                NOT   - 0

5S Bonus? Yes
Match Score: 812
Cumulative Score: (142 + 360 + 390 + 812) * (100% + (10% * 3/4)) = 1831