- **Objectives:** Design a prototype robot to construct a CPU over the course of three fabrication stages. These three stages are: collect large numbers of transistors to make Gates (chips), once enough gates are created, make integrated circuits from many gates (IC's), and build a CPU out of the assembled components.

- **The Game Field:** Field consists of four quadrants (red, green, yellow, and blue) arranged in a 24' x 24' square. Each quadrant is 12' x 12'. There are four main areas in each quadrant: robot area, gate fabrication, IC fabrication, and CPU fabrication. 24" x 24" driver area in corner in between IC fabrication and gate fabrication area. Figure 1.1

- **Gate Fabrication Piece Overview: T**he transistor container is a 7/8" wooden dowel 12 inches in length with the bottom half painted red. There are 15 per quadrant and six containers per quadrant are fitted with a Poka-yoke (2" washer on top which in the competition was changed to be 1.5"). The Poke-yoke containers are positioned on the front row of the transistor container storage.

- **Gate Fabrication Area Overview:** The lower and upper gate assembly lines for AND, OR, and NOT is composed of a 48" x 24" x 14" two-level frame. The lower receptacle consists of nine 3" PVC pipes, 6" in length and perpendicular to the ground. The upper-level receptacles consist of twelve 2"PVC pipes, 6" in length. The NAND assembly line frame is 24" x 24" x 7" made with 2" x 2" wood. The receptacles consist of three 3" PVC pipes 6" in length with a 30° incline. Transistor container storage consists of 2" x 4" x 48" lumber containing fifteen 1" drilled holes in a staggered pattern, five centered in front of each of the AND, OR, and NOT areas. Figure 1.2

- **Gate Fabrication:** The gate fabrication area consists of the transistor container storage and three assembly lines for placement of transistor containers (lower gate assembly line, upper gate assembly line, and the NAND gate assembly line). The transistor container (the wooden stick): all transistor containers are upside down and to use all transistors inside (not same as points), the red end needs to be poking up or out. Lower gate assembly: the lower gate assembly line has three receptacles for building the gates: and, or, and not. A single transistor container (the painted wooden stick) loaded paint side up in one of the receptacles provides 48 transistors, while one improperly loaded upside down provides only 24. In the upper gate assembly (top four receptacles), a properly loaded transistor container (red sticking out) provides 96 transistors, while an improperly loaded one provides 48. The NAND gate assembly line is only for manufacturing NAND gates and a properly loaded transistor container (painted side up) provides 96 while in improper one provides 48.

- **Gate Inventory:** At the end of the match, Gates will be placed in inventory based on number of transistors loaded to each receptacle. AND, OR, and NOT gates require 24 each while NAND require 16.

- **Gate Scoring:** AND, OR, and NOT gates manufactured are worth 10 points each and NAND gates are 8.

- **IC Fabrication Piece Overview:** There are four standard clothes hangers per quadrant for the AND (blue), OR (white), and NOT (red) gates. There are eight black clothes hangers for the NAND gate. Hangers are positioned within the gate container storage in the following order from left to right: one red, one white, one blue, and two black. This pattern is repeated four times and the hangers are oriented with the hook away from the tower (towards CPU fabrication) with the point facing the ground.

- **IC Fabrication Area Overview:** The tower consists of four 4" x 4" x 48" wooden posts and each one has its corresponding name stenciled onto it with the top edge 9 inches below the top of the post. Beginning

with the tower closest to the spotter, the order is MUX, Adder, Decoder, and D-Latch. The tower base is 1" x 6" x 61.5" to connect each tower. The tower kicker is 2" x 4" x 25.75" with 45° angle supporting each tower. The lower and upper assembly-line pegs are constructed from ½ inch PVC pipe. The lower assembly peg is 32 inches above the base and 4 inches in length parallel to the ground and a PVC cap is on the exposed end. The upper is centered on top of the post extending upwards 1 ½ inches with a PVC 90° elbow, attaching the 8 inch peg with an end cap to the rest of the post. The gate container storage is a 6' x 6" wooden platform four inches from and parallel to the floor with 4" x .25" slots that are cut 2 inches apart.

- **IC Fabrication:** The IC fabrication area consists of four assembly towers: MUX, Adder, Decoder, and D-Latch. Each tower, when loaded with the correct combination of gates, will fabricate its designated type of IC. Multiple gate combinations may be placed on the same tower during a single match. The lower assembly line is configured to operate at normal speed and loading the correct combination of gates will produce a maximum of one IC per combination and only if the appropriate amount of inventory exists. The upper assembly-line operates at double speed and loading the correct combination of gates results in a maximum of two ICs per gate combination. However, each tower can only operate as fast as the slowest assembly-line in use, so if any are loaded onto the bottom assembly-line, the upper assembly-line will operate at normal speed instead of double speed.

- **IC Inventory:** MUX configurations: 2 AND (blue) + 1 OR (white) + 1 NOT (red), or simply 3 NAND (black). Adder configurations: 1 AND (blue) + 1 OR (white) + 1 NOT (red), or 2 NAND (black). Decoder configurations: 1 AND (blue) + 1 NOT (red), or 2 NAND (black). D-Latch configurations: 1 AND (blue) + 1 OR (white) + 1 NOT (red), or 1 NAND (black).

- **IC Scoring:** Each MUX manufatured is worth 80 points, Adders are worth 60, Decoders are worth 40, and D-Latches are worth 60.

- **CPU Fabrication Piece Overview:** Components are made with ¾" aluminum coated foam with a 1" x 2" wooden handle attached with screws. The MUX is a trapezoid approximately 7.5" x 4.5" there is one available in each field quadrant (looks like the right half of a capitol A). The Adder is a trapezoid 7.5" x 4.5" and there is one available in each quadrant (looks like the left half of a capital A). The Decoder is a 5.5" x 7.5" rectangle and there are two of them available in each field quadrant. The D-Latch is a 5.5" x 3.5" rectangle with seven available in each quadrant.

- **CPU Fabrication Area Overview:** Assembly area is a 48" x 48" plywood frame with four 2" x 4" legs of various lengths creating a surface with a 30° incline in the center. The front edge of the frame is 15 inches from the floor. There is a raised painted wooden template dividing the core processor area and memory module for scoring pieces. Component storage is made of two wooden platforms parallel to and resting on the floor, approximately 12 inches to the left and right of the front center support post of the CPU assembly area.

- **CPU Fabrication and Inventory:** Two sub areas are core processor and memory module and both use IC's fabricated in Stage 2. Only one component for each space and only if they are in inventory. The pieces are considered properly placed if fully inside the scoring receptacle and flush with the bottom surface. The core processor (area on the left) requires three registers, an instruction decoder, and an ALU. Registers are created properly by placing a D-Latch within any designated register receptacle, the decoder is created by properly placing a decoder within the instruction decoder receptacle, and the ALU

requires placing of both a MUX and an Adder in the receptacle. Core processor ICs may be placed over multiple matches. The memory module area on the right side is capable of fabricating both and 8-bit and 32-bit memory modules. For an 8-bit, properly place one D-Latch within any designated memory unit receptacle. For a 32-bit, place four D-Latches in the memory area and one decoder within the address decoder receptacle all within the same match. Any amount of D-Latches without a properly placed address decoder will count as an 8-bit and be put in inventory as one, and the same is if there are fewer than the required decoders for the 32-bit. To complete the CPU, these components must be fabricated: 3 registers, one instruction decoder, one ALU, and one (8/32-bit) memory module. Figure 1.3

- **CPU Fabrication Scoring:** Every Register installed is worth 90 points, Instruction Decoders are 60, every MUX installed in ALU is 120, every adder installed in ALU is 90, a complete 8-bit memory module is 90, a 32-bit memory module is 420, a 8-bit completed CPU is worth 512, and a 32-bit CPU completed is worth 1,024 points.

- **Robot Trolley Overview:** The entire trolley assembly is operated by the spotter and used to position the robot. It is rotated about a pivot point for movement between fabrication areas. The three major parts are: the robot attachment platform which is a 23" x 15.75" plywood base with a four wheeled skates on which the robot must mount with clamps in the safe mounting area, the guide rails are 9' x 12" x 4" (LxWxH) with the plywood base and is screwed onto the Lazy Susan whose pivot point is 3 ½ feet from each side the field, the pulley system has a drive pulley with 25 gallon bucket lids screwed to the back with two 4" flanges as spacers, and the drive pulley and crank are positioned on a 36 inch tower with the crank approximately 30 inches above the ground (the guide pulleys of the 2 inch casters are located on the tower and guide rails). The trolley safety arc is located at the opposite end of the trolley from the spotter with the trolley wheels running along it. The spotter box is a portion of the robot trolley area roughly defined as a 7' square with a 2' indention at the pivot assembly. Figure 1.4

- **Inventory System:** Components fabricated in each stage are inventoried by the scoring software. Inventories are calculated at the end of the match in the following order: stage I, stage II, and then stage III (inventory can be consumed in same match in which it is fabricated). For stage II or stage III components to be fabricated, the appropriate quantity of required components must exist in inventory and are then consumed to create the new components. No components are deducted from inventory if fabrication fails due to insufficient inventory. Fabrication within stage II and III will be in the following order of priority: stage II priority (MUX>Adder> Decoder> D-Latch) and stage III priorities are: 1. Instruction Decoder> Address Decoder 2. Register> Memory Unit 3. 32-bit CPU> 8-bit CPU.

- **Scoring:** A cumilitive inventory is maintained during gameplay and is separate from scoring. Scores are detirmined at the end of the match and scores for each match are added to the previous match to create a cummulaive score. Fabrication is based on the positions of game pieces at the end of the match and any game piece in contact with the robot/robot trolley at the end of the match does not count. In the event of a tie, the winner is the one with the highest notebook score (if the notebooks are tied, flipping a quarter will determine the winner). A 5S bonus is awarded at the end of the match (but not finalized until the end of the round) when no game pieces have been removed from play and any pieces touching the floor are touching the robot. Calculated with: (# of 5S's / #of matches completed) X (10%) X (cumulative score) and will be rounded to nearest integer.

- **Restrictions and Considerations:** Game pieces must be in the correct scoring location at the end of the match to score points or count towards inventory, game pieces will not earn points or be at inventory at the

end of the game if they are in contact with any part of the robot or any part that detached from it during the match, game pieces on the factory floor may be recovered if the robot is capable of doing so, and game pieces touching the floor outside the boundary are considered out of play. The robot must remain mounted to the platform for the entire match and if the robot loses contact with the platform, it must remain idle for the remainder of the match and previously placed game pieces will be considered eligible. No game piece or robot part may be dropped or placed within the robot trolley assembly and will result in an emergency 20 second shutdown of operations (penalty) while a referee removes it from the robot trolley assembly and places it out of play (causes automatic forfeiture of 5S bonus for match). If an item lies along the wheel path on the trolley safety arc, it cannot be run over; you can pick it up with the robot, Leave it and move the trolley in the other direction, or ask the referee to remove it in exchange for a 20 second penalty. The spotter may only interact with the external areas of the main crank assembly tower any other interaction will cause a 20 second penalty and failure to comply with penalty may result in complete match disqualification.

- **Game Operations:** Each match is three minutes long and played with four teams if possible. Each team may only have two members on the field per match (driver and spotter). Matches have a 30 second set up at the beginning and prior to the setup period; Teams shall wait at the spotter area until signaled and then will attach the robot and move it into starting position. The robot attachment platform must be within the starting position indicator, but the robot trolley may be in any position at the start of the match. If the team is unsuccessful in the first 30 seconds to set the robot, they may continue to attach the robot in return for 20 second penalty (and if they're still attaching a poster the match, another 20 second penalty will be applied). Drivers must rotate match to match while spotters are left to the team's discretion. There are four phases of competition: the seeding round (round robin competition with eight matches for each team with the top seven teams advancing to the semi final round), the wildcard match (One match between the four teams with the highest BEST notebook design score and that has already ranked in the top seven. No previous match scores/inventory will be included in this round or added to any other portion of the competition. Also, all prerequisite inventory restrictions from stage II and III are lifted so fabrication can be accomplished at any stage.), the semi final round (Round robin competition with each team participating in three matches with the top four advancing to finals. Before participating, the scores are reset to zero and the inventory is set to one MUX, to D-Latches, one Decoder, and three AND/OR/NOT Gates.), and the final round consists of the top four teams from the semi finals participating in three final matches with the scores being reset and the inventory being reset to the same as the semi finals. Final-round ranking is based on cumulative scores from the three matches.

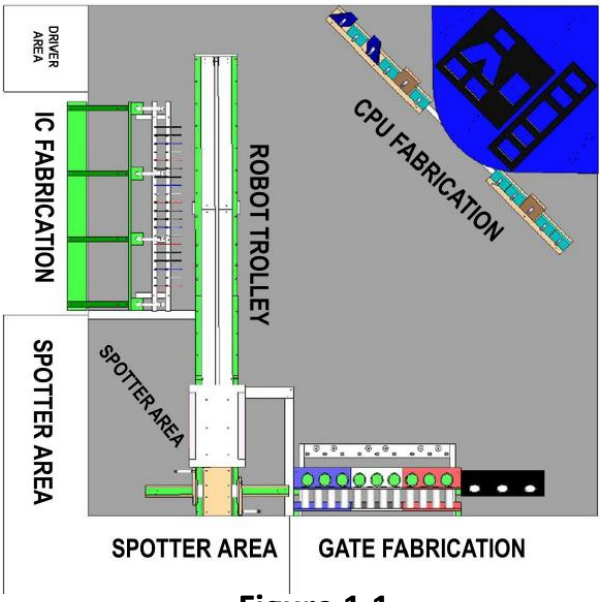

Figure 1.1

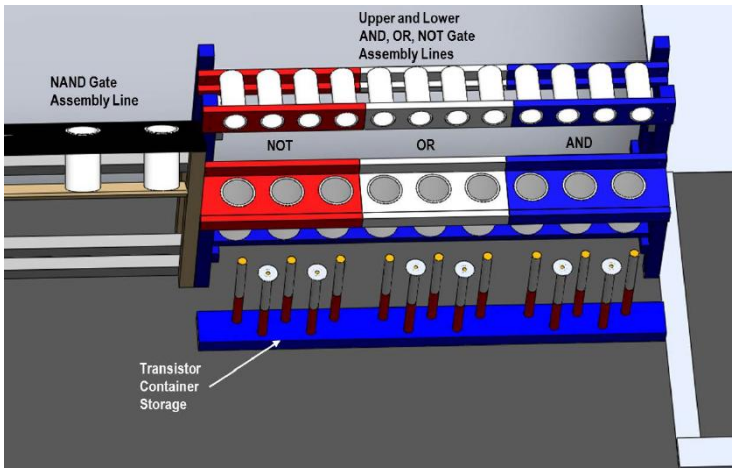

Figure 1.2

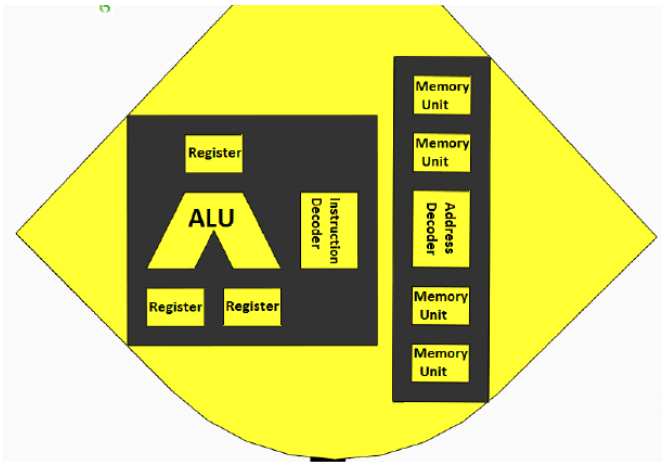

Figure 1.3

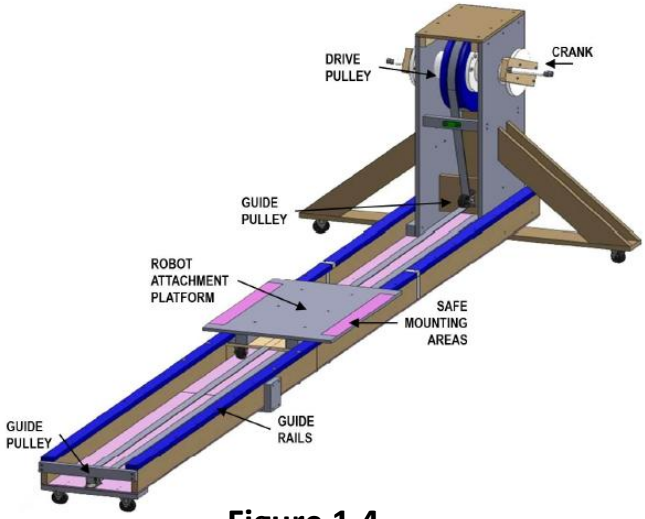

Figure 1.4