The Engineering Excellence Award, sponsored by Delphi, is presented to a competing team demonstrating engineering elegance through design, wiring methods, material selection, programming techniques and unique machine attributes.

DELPHI

TEAM 67

MAKING MULTIPURPOSE INTO A MANTRA

HOW FOCUSSING ON UTILITY AND SIMPLICITY RESULTS IN A WORLD CLASS ROBOT.

Team 67 is comprised of students from Milford High School, Lakeland High School, and the International Academy West in southeastern Michigan. Their mentors hail from the General Motors Proving Ground and the Huron Valley school district.

Their mission is as simply stated as their robot was designed:

The mission of the HOT Team is to inspire students' interest in science and technology by designing, building, and winning with the world's best robot. Their goals are to design a robot that executes strategies required to win the FRC Championship, while building for durability, reliability, and quality.

Initial Concepts: Starting Simple

HOT’s focus on simplicity started at the design phase. Mentors and students created a list of all the possible robot functions for Rebound Rumble.

The team decided that scoring in hybrid mode would be the most important aspect of the game. In addition, they decided that they needed to be able to collect and score the balls from the center bridge and score those in autonomous mode as well.

The team’s next highest priority was the ability to balance on both the cooperative and alliance ramps, and to move across the ramps easily.

Surprisingly, their least important priority was to score baskets in teleoperated mode.

Balls

1. Score in top hoop
2. Score in middle hoop
3. Score in bottom hoop
4. Score in autonomous
5. Catch balls from human player slot
6. Pick up balls from floor
7. Pick up balls from ramp
8. Catch balls from other robots
9. Shoot and collect at the same time
10. Shoot balls from robot at multiple angles
11. Make shots that are close
12. Shoot Balls from a long way away
13. Ball release above 60 inches

Ramps

1. Balance on ramps
2. Balance on ramps with partner
3. Help 2 other robots balance
4. Orient on ramps

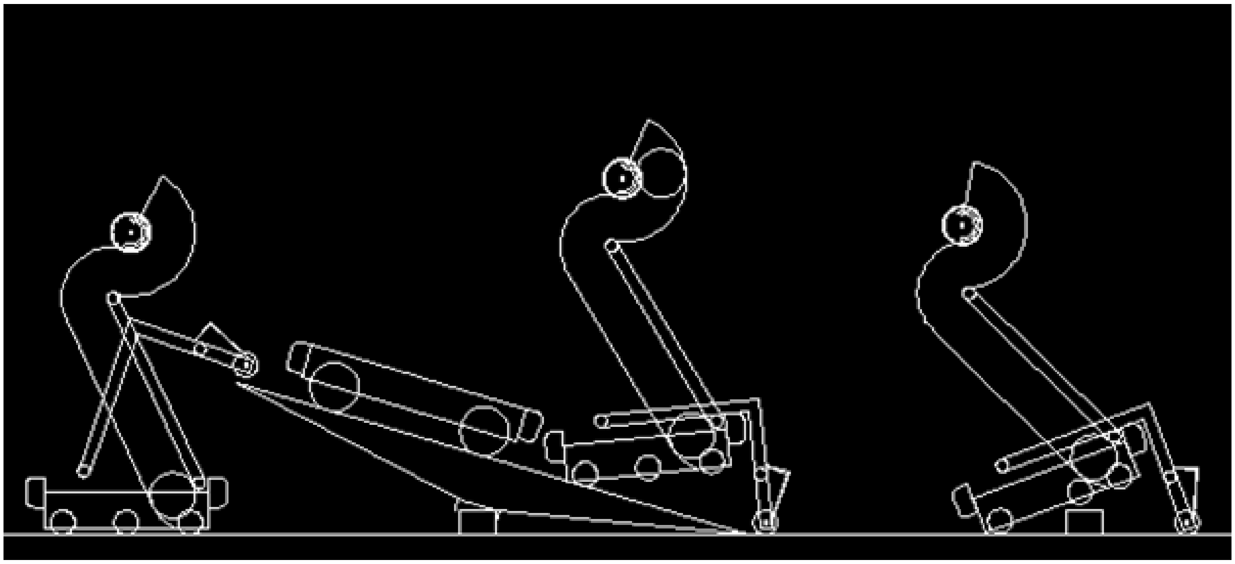
Team 67 Started with a comprehensive list of robot functions for this year’s game.

Team 67 narrowed their list into a few key robot objectives.

Score in Hybrid
- Score in Top Basket
- Collect and Score balls from middle ramp
  - Tip level ramp
- Pickup balls from the floor
- Camera Aim

Balance on Coop and Alliance Ramps
- Balance 1, 2, or 3 robots
- Traverse ramp

Teleoperated Ball Scoring
- Score quickly and accurately



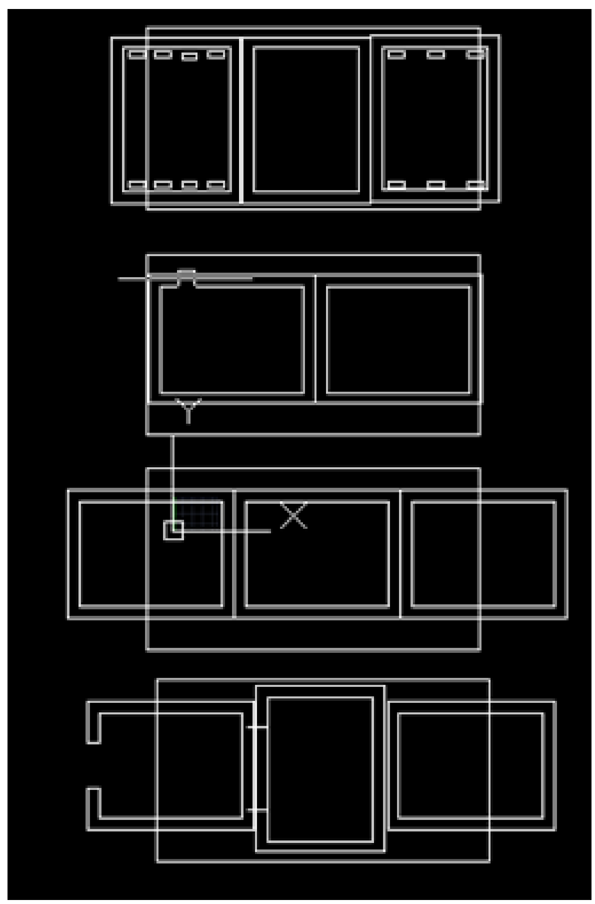
Initial utility arm sketches show a basic arm that could raise and lower the bridge and help the robot balance.

Next, the team started sketching out balancing patterns on the ramp, and discussing bridge lowering methods. From their sketches it was clear that it would be much easier to balance three wide robots than any other configuration. Three long robots appeared to be nearly impossible.

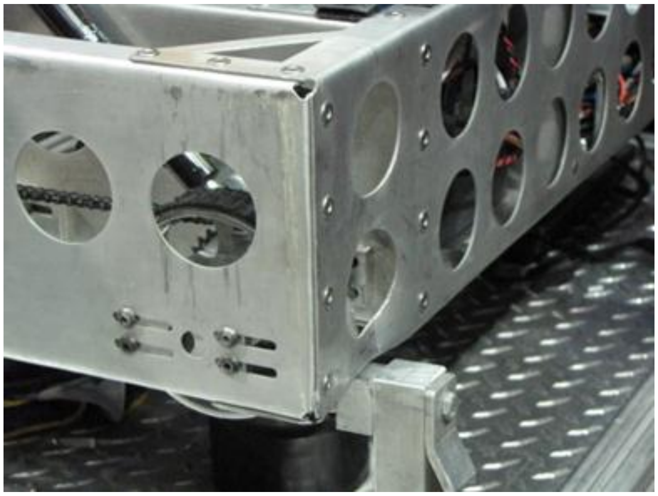
HOT also began working on sketches of a utility arm. Initial concept sketches had a simple arm that could lower the bridge, help the robot balance, and help the robot travel over the bump.

Based on their early sketches, they settled on an initial robot concept. The robot would have a wide drive base, a single wheeled shooter, and a utility arm.

It quickly became apparent that 3 wide robots would have a far better chance of balancing on the bridge.



Team 67's shooter concept was taken from the 2006 design of team 25.



Driving Towards Success

The team started out with the same basic drivetrain they've used since 2008. They used a water jet to cut out pieces of 1/16" 5052 aluminum. The structure was bent then riveted together.

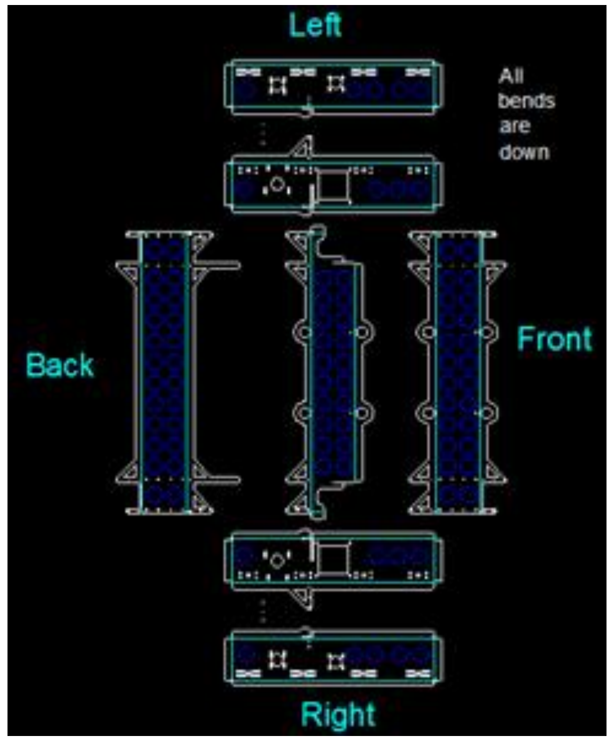
The finished chassis weighed 8 pounds. Special care went into making sure that slots were in the proper places for the gear box mounting and axles to allow adjustment.

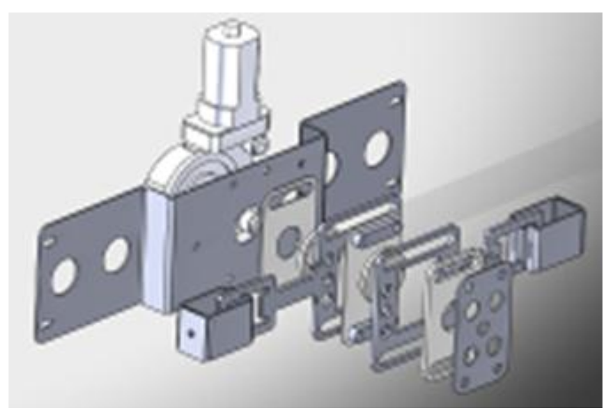
HOT's members decided that top speed would not be as important as maneuverability. They used an AndyMark Supershifter gearbox, with two CIM Motors per side. The output shaft had a 22 tooth sprocket driving a 32 tooth sprocket attached to the middle wheel. With four inch wheels their drivetrain had a 10.67:1 gear ratio for high torque, and a 4.18:1 gear ratio for high speed. This gave their robot a top speed of approximately 15 feet per second.

Team 67 designed a shifter that eschewed the use of pneumatics to save weight. The design used a cam to push and pull the shift mechanisms into place. Springs were incorporated into the arms to prevent the cam from dead-heading the shifting mechanism on either transmission.

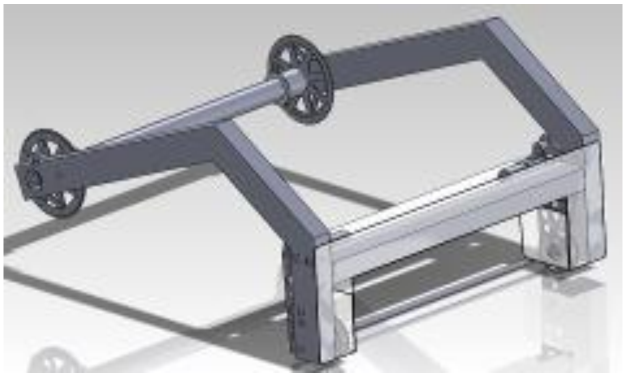
67's lightweight chassis was cut on a water jet, then bent and fastened with rivets.

Initial utility arm sketches show a basic arm that could raise and lower the bridge and help the robot balance.





The team used a cam-driven shifting mechanism for their two speed transmissions.



HOT's arm was designed with contact in mind. The rectangular tubing used was thicker than most teams' chassis.

Utility Arm Motor Calculations		
RPM	**Gearing**	**Torque (ft-lb)**
19300	RS-550 Free Speed	0.37
742	26:1 Banebot Gearbox	9.62
159	4.67:1 CIMple Box	44.93
25	100:16 Chain & Sprocket Reduction	280.78
2.35	Seconds for 1 Rev	
0.59	Seconds for 1/4 Rev	
	Torque available w/2 -RS550	561.57
	Estimate of Torque w/ 4 gearing changes @ 90% eff	368.44
	Torque needed to lift robot	163
	Safety Factor	2.26

The team used a cam-driven shifting mechanism for their two speed transmissions.

Getting an Arm Up on the Competition

The initial geometry of arm was constrained by the bumper height, the starting configuration of the robot, and a rule created by the game design committee that stated the arm could never extend more than 14 inches beyond the robot.

In addition, the arm had to be able to lift the robot front end to traverse the barrier, and balance a bridge with three robots on it. As a result, the team used an extremely high gear ratio and powerful motors. With a final gear ratio of around 759:1, the arm had 368 foot-lbs of torque.

The arm was designed out of 2 inch x 3 inch aluminum tubing that was welded together. Two Banebot RS-550 motors drove the arm. The final arm design allowed it to push downwards with 138 lbs of force. Gas struts were designed to help hold the arm at the ball pickup position without use of the motors and to help lift it back to the rest position after balancing the bridge.

When the robot approached the bridge, the arm was used to push down on the floor to lift the front end over the bump. This coupled with the high torque drivetrain made moving across the center barrier of the field effortless.

The multipurpose arm was designed with enough torque to balance the bridge with three robots on it.

The arm allowed the team to push down the ramp and collect balls at the same time.

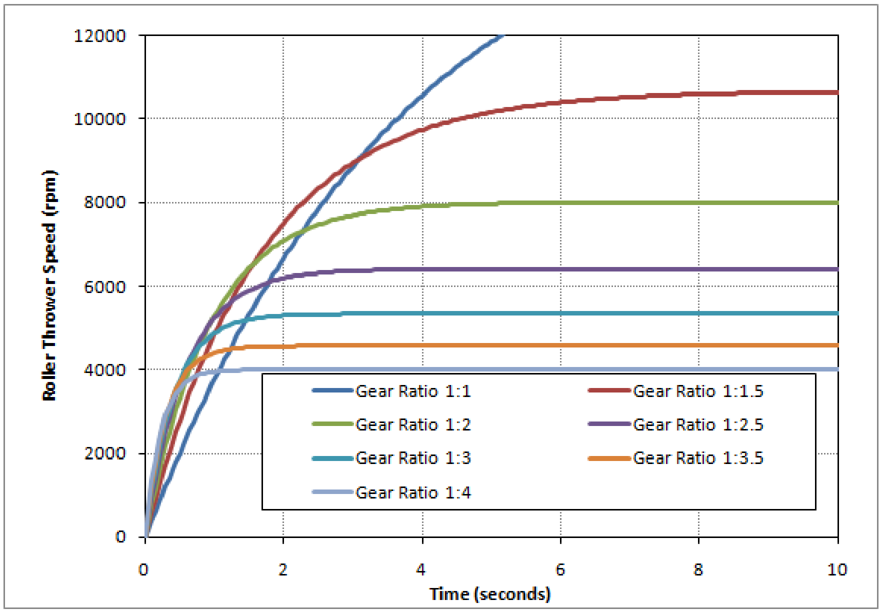
The arm was also the team's ball pickup mechanism.

Aside from acting as a balancing mechanism, the arm was also used to lower the bridge. This allowed the team to drive onto the bridge during teleoperated and acquire additional balls to score.

To acquire the balls, however, the utility arm also served as a ball pickup mechanism. The team designed a roller system that pulled the balls in. A bar across the bottom of the arm served to support the underside of the ball. The balls were pinched between the upper roller and bottom bar, then lifted to the ball hopper.

Using the arm as an intake allowed the team to utilize the full width of the robot to acquire balls. Rules constrained the size of an opening that teams could make in their front bumpers to 22 inches. HOT's design allowed them to utilize the entire 38 inch width of the robot.

A roller on top with a bar on the bottom made the arm capable of picking up balls and dropping them into the team's ball hopper.



An analysis of rotational inertia created this shooter speed over time graph. This allowed the team to minimize their spin up time while maximizing their range.

The "Key" to Consistency

The team decided that their first course of action in designing a shooter should be to look back, rather than forward. They researched previous years' games to determine what type of shooter was consistent and produced the backspin that they wanted for a repeatable shot.

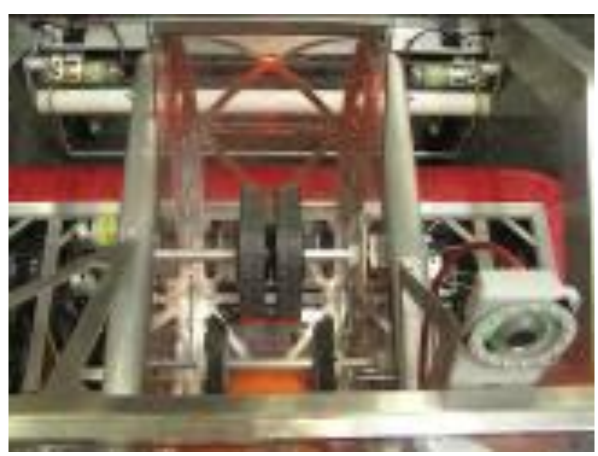
They decided that a single wheeled shooter would provide the best combination of accuracy and backspin. Next, they prototyped a single wheel shooter and started experimenting with shots at different locations on the floor.

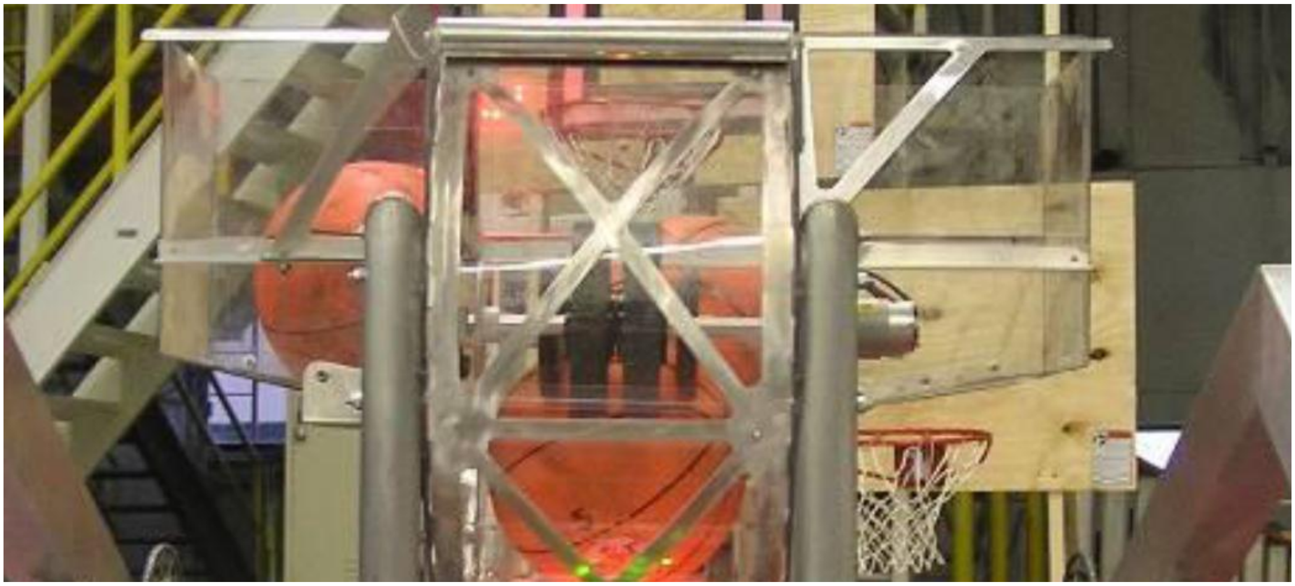
Two kit-of-part wheels powered by dual AndyMark 9015 motors and a custom gearbox provided an 8000 RPM free speed.

HOT practiced shooting from the fender, the key, and everywhere else on the field with their prototype. Game rules came into play while the team worked with their shooter design. It was illegal for teams to contact other robots in the key. That provided protection for robots in the key.

For shooting from the key to be worthwhile, the team needed to prove that it was possible to hit approximately 90% of their shots. The prototype shooter, with an angle of 45 degrees and 2 inches of ball compression at 4000 RPM came very close to that.

A smooth ball channel that was tightly integrated to the chassis for rigidity provided a consistent firing platform.





The chute structure was reinforced by large tubes on either side. The hopper could handle 3 balls at the same time.

The team's ball hopper was designed to be as wide as their utility arm. When the utility arm raises and dumps the balls in, then center ball and the one on the right are allowed to fall into the shooter feeder chute. The ball on the left is held back by a roller to prevent jamming.

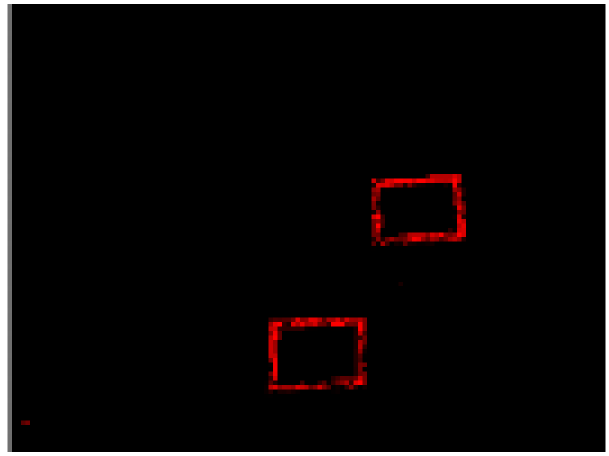
The team's feeder system is also designed to improve the accuracy of the shooter. HOT's members realized that centering the ball as it entered the shooter was important. That led to the custom made feeder wheels with bevels that forced each ball into the middle of the chute. In addition, they found that how the ball entry into the shooter was critical. They made the chute leading to their shooter on a downward angle, so that when the ball was released by the centering rollers, gravity caused the ball to roll into the shooter.

Finally, they realized the entire structure had to be rigid to shoot consistently. They welded large tubes on either side of their shooter, giving it enough structure so that it would not deform when balls were passing through.

Two wheels wrapped in rubber meter the incoming balls into the shooter.

A roller in the ball hopper prevents both side-balls from trying to roll in at the same time and jamming.

An LED light around the camera lens illuminates the target. Reflective tape on the backboard reflects the same color back.



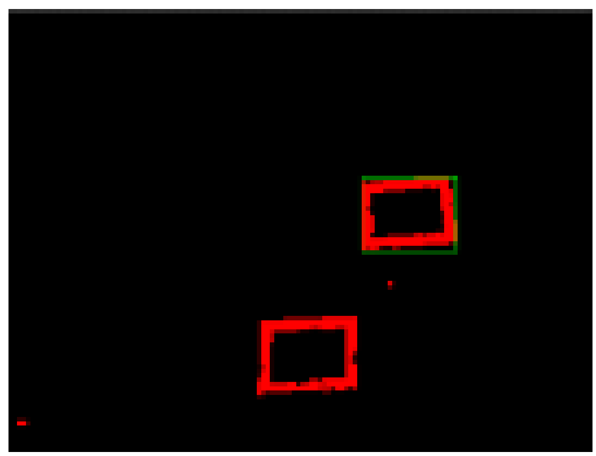
First, the picture is filtered for the specific color the team is looking for.

Hot also incorporated automatic aiming in their robot. Their camera aiming allowed the team to aim and fire at the press of a single button.

An LED light ring was used to shine light at the retro-reflective tape located above the basket. The robot's program then filtered for the color the team was looking for, then checked for appropriate geometry on the remaining shapes. Finally, it located the target and determined how far from center the target was.

The robot used that data to turn the robot so that it was facing directly toward the target. Encoders were used on the drivetrain to provide feedback on how far the robot had turned.

Next, the program finds objects that conform to certain geometry, and highlights them.



An encoder (the black object on the right) is used to measure how far the drivetrain has moved. In this case, the encoder is in a two speed transmission.

The End Game

Despite the other systems on HOT's robot, the key to their success was their focus on combining functions into a single simple device. Team 67's multipurpose arm was a feat of engineering, but the lesson was one that any FRC team can execute.