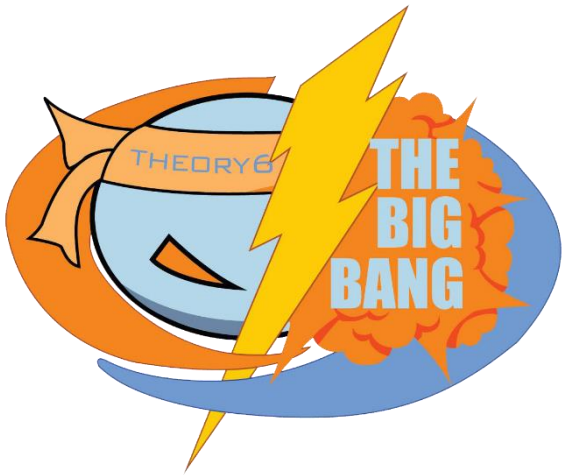
FRC Strategic Design

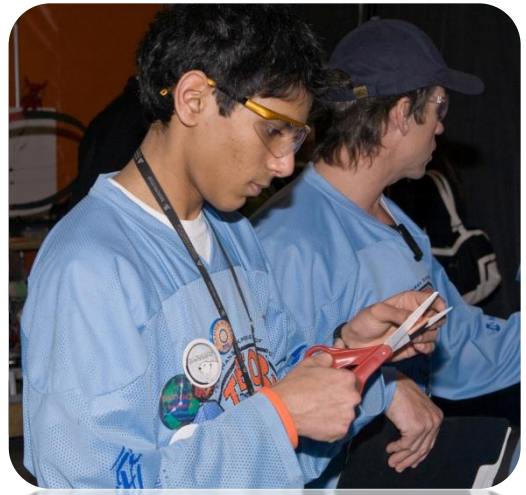
How to Decide Your Robot Design

Team 1241/1285



Malavya Shah

- Graduate of University of Waterloo
  - Bachelor of Applied Science, Mech. Eng. (2014)
- Joined FRC in 2007
  - Team 1241/1285
  - Student (2007-2009)
  - Lead Engineering Mentor
- Gypsum Technologies
  - Mechanical Specialist Engineer

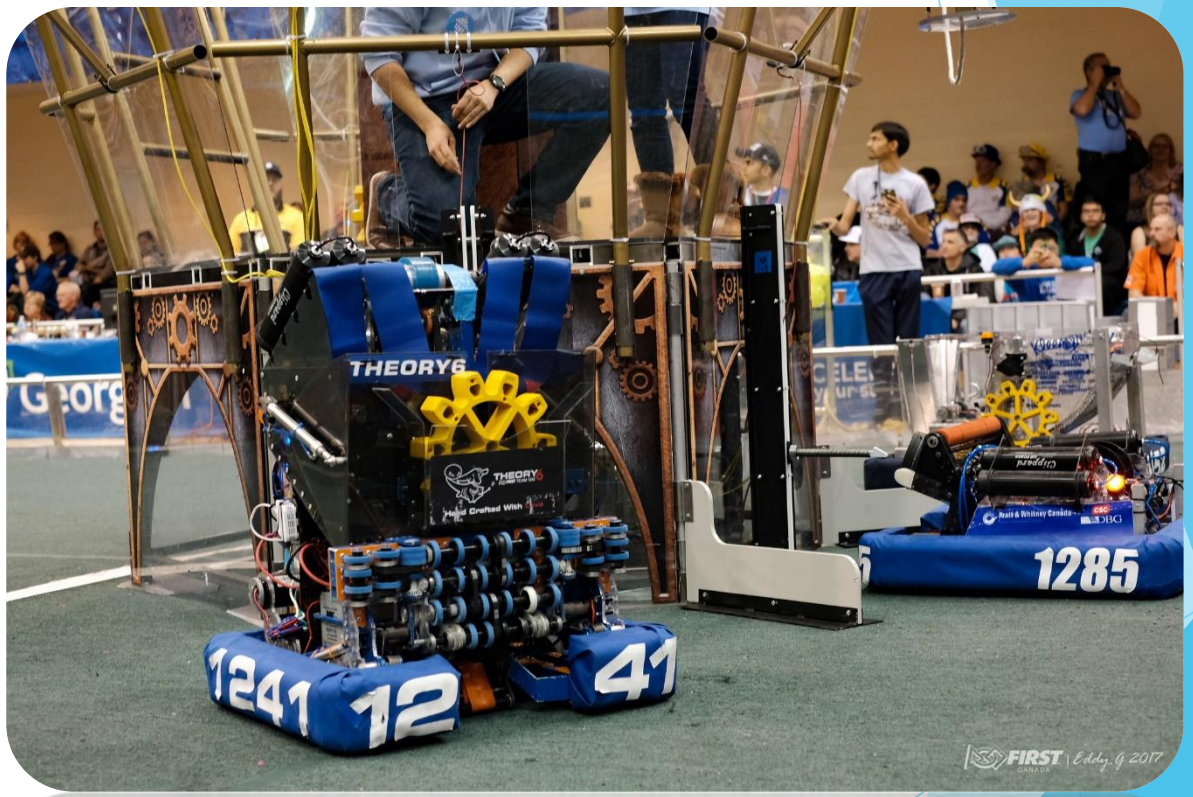


Shaqeeb Momen

- Student at McMaster University
  - Bachelor of Engineering and Management, Mechatronics Engineering (2022)
- Joined FRC in 2014
  - Team 1241/1285
  - Student (2014-2017)
- Current Role
  - Design Mentor 1285 (2018 to present)

Objectives

- The Importance of Strategic Design
- Kickoff (and How 1241/1285 Does It)
- Game analysis
- Strategic Mechanism Selection
- Winning Designs
- Mock Kickoff

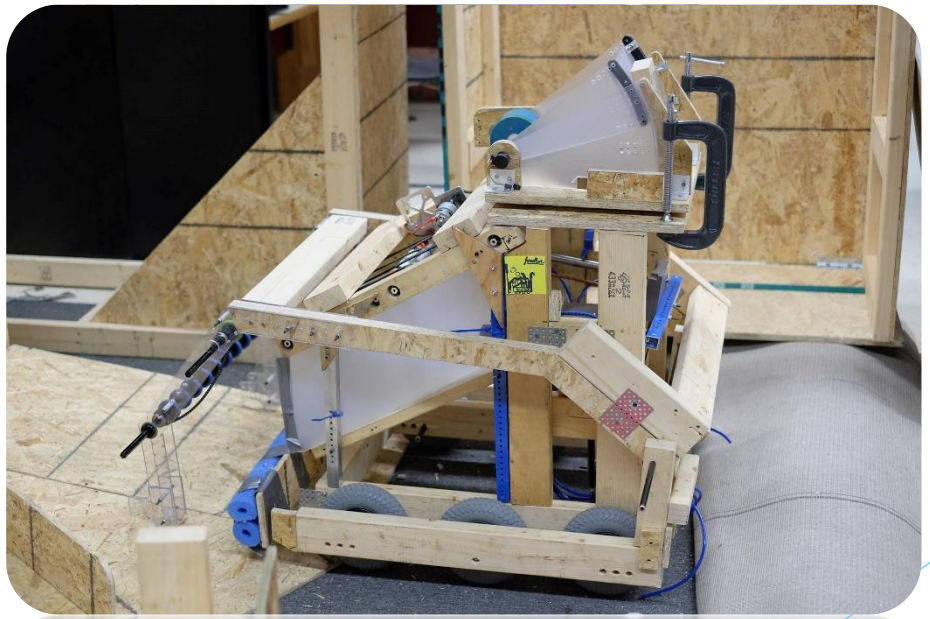


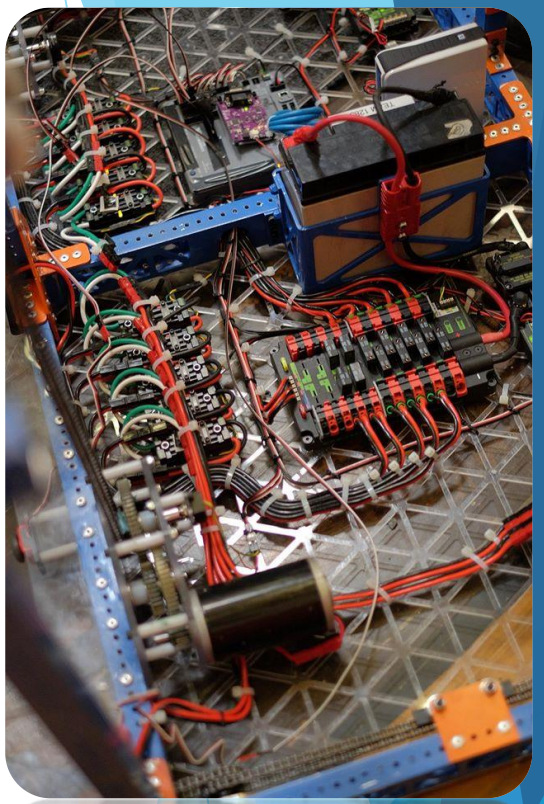
Tips For Designing

- There is no right answer for an FRC game!
- Keep things simple
- Pay attention to orientation of game piece
- Possess game piece easily and quickly (touch and go)
- Try and take off load on motors when using arms
- Use sensors wherever possible
- Prove your designs through prototyping, not assumptions
- Pay attention to your team's skill level and resources

Your Fate Lies In Kickoff

- The decisions made during kickoff can dictate the rest of the design period
- Things to decide during kickoff:
  - Drive chassis
  - Strategic capabilities
  - Mechanisms to prototype





Kickoff Schedule - Saturday

- 9:30am – Gather to watch Kick-Off
  - In the past, we've held Kick-Off at a library/auditorium
- 12:00pm – Lunch
  - During this time, students and mentors can begin to read the game manual or continue watching field videos
- 12:45pm – Divide into 4 or 5 groups, each led by a mentor
  - Read game manual thoroughly
  - Read rules out loud, writing down any questions about the game

Kickoff Schedule - Saturday

- 2:30pm – Detailed scoring analysis and strategy
  - Break scoring into autonomous, tele-op, and endgame
- 4:00pm – Movements and preferences
  - Outline the possible robot roles and identify the specific role that would be most successful given the resources of the team
- 8:00pm – Wrap up

Kickoff Schedule - Sunday

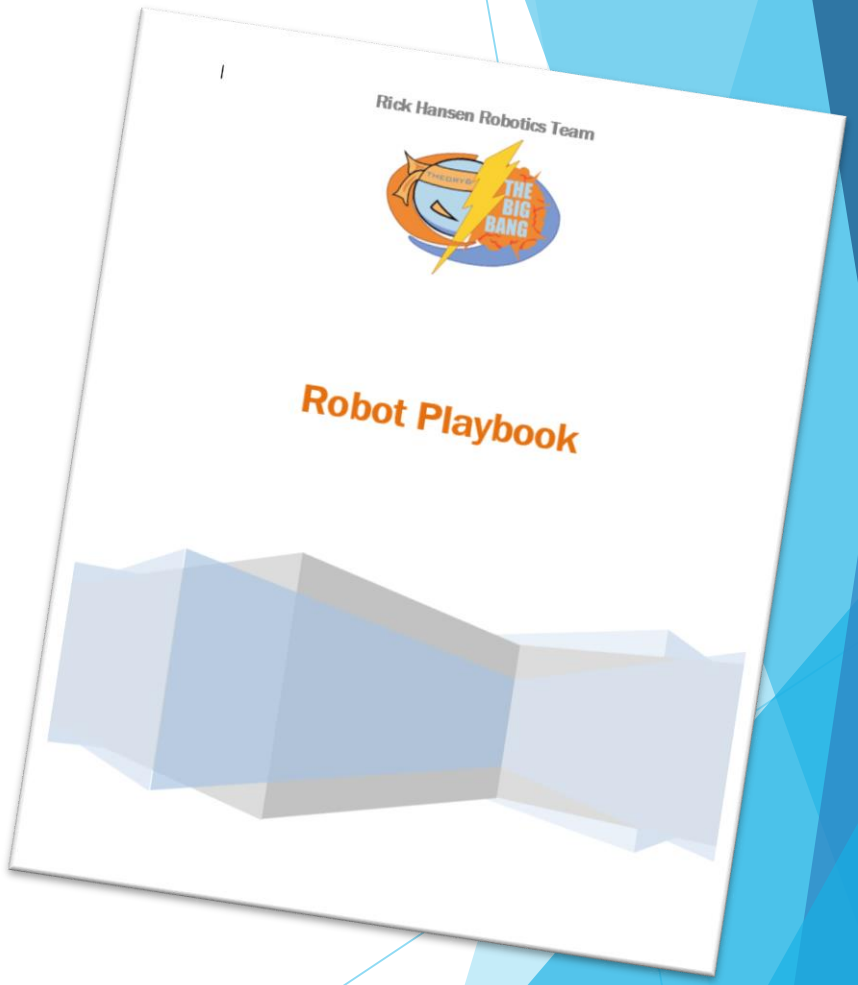
- 9:00am – Meet at location to discuss strategy/requirements list
  - Finalize the list of requirements
- 9:45am – Introduce Mentors/Leads for each section
  - Present strategy decisions from Saturday
- 10:30am – Discuss intake, tool, and end game design
  - Begin to collaborate designs
  - Drivetrain should be selected by this point (must have a good reason for non-WCD)
- 12:30pm – Lunch

Kickoff Schedule - Sunday

- 1:00pm – Discuss presented designs, rank and select
  - Accounting the advantages and disadvantages, two designs should be selected for each subsystem to be prototyped
- 2:30pm – Detailed decisions and plan of action week 1
  - Set prototype variables for each proof of concept
- 4:00pm – Lead mentors and key lead students begin preliminary geometric and parametric studies
  - Detailed drivetrain design begins

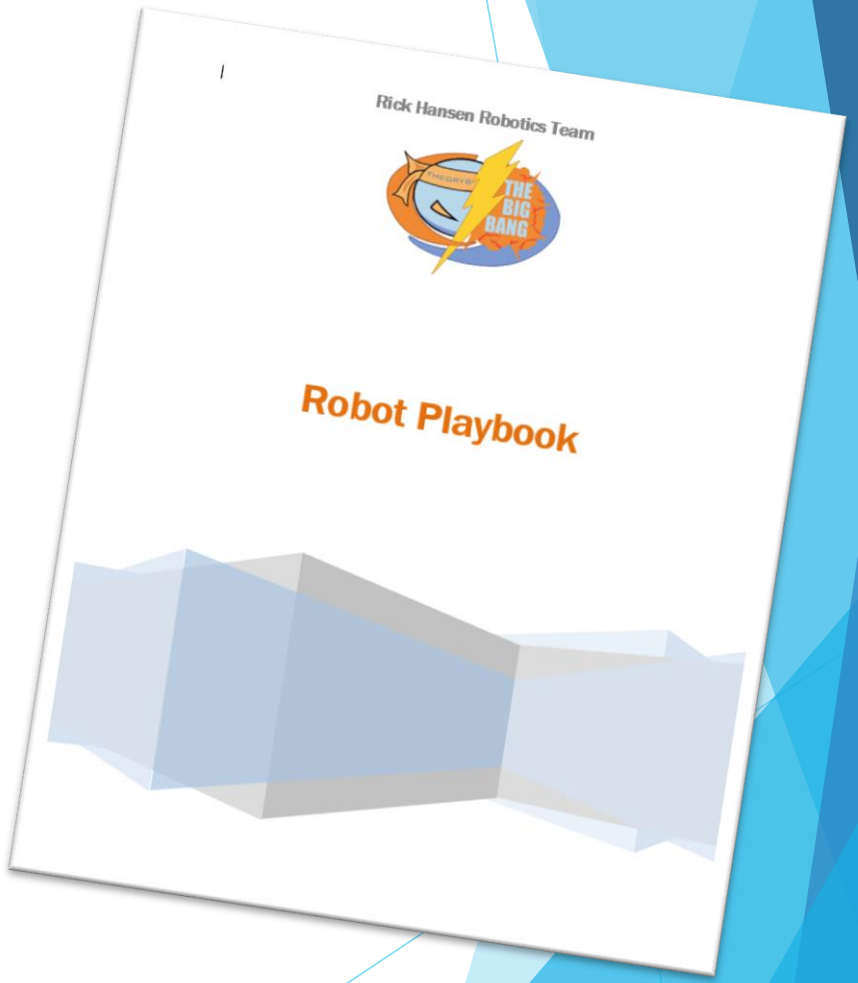
The Playbook

- Started with Team 1241, later adapted by 1285
- The “bible” of strategic design
- The Dos and Don’ts for a robotics team
  - Team specific, but is public for other teams to refer to
- Usually print out multiple copies to use during Kickoff



The Playbook

- Contains information passed on through build seasons
  - Mechanism selection
  - Historic performance of certain mechanisms
  - Design tips
  - Etc.



Reading the Game Manual

- Find important “loopholes” that can change your design strategy
  - E.g., 2011 1114’s Chokehold strategy
  - E.g., 2015 Ramps and tethered robots
  - E.g., 2016 Outerworks shot
- Important details can change mechanism selection
  - E.g., 2017 Custom rope
- Important for drivers and coaches to understand for practice
  - E.g., 2014 G40 – Human player reaching into the field of play

Scoring Breakdown

- List all possible ways of scoring
- Calculate time/resources required for each scoring motion
- Optimize time/resources with maximum points
- Note the importance of endgame/autonomous points!

Point Values

Action	Auto	Teleop	Qual	Playoff
Reaching defense	2	-	-	-
Crossing undamaged defence	10	5	-	-
Boulder in Low Goal	5	2	-	-
Boulder in High Goal	10	5	-	-
Challenge (per robot)	-	5	-	-
Scale (per robot)	-	15	-	-
Breach	-	-	1 RP	20
Capture	-	-	1 RP	25

Action	Criteria	MATCH Points AUTO	MATCH Points TELEOP	Ranking Points
AUTO mobility	For each ROBOT that breaks the BASE LINE vertical plane with their BUMPER by T=0	5		
Pressure accumulation	For every three (3) FUEL counted in the Low Efficiency GOAL by T=0	1 + 1 kPa	-	-
	For every one (1) FUEL counted in the High Efficiency GOAL by T=0			
	For every nine (9) FUEL counted in the Low Efficiency GOAL by T=0	-	1 + 1 kPa	
	For every three (3) FUEL counted in the High Efficiency GOAL by T=0			
	If ALLIANCE exceeds a threshold pressure of 40 kPa		20 (Playoffs only)	1 (Quals only)
ROTOR engagement	For each ROTOR turning by period's T=0	60	40	-
	If all four (4) ROTORS turning by T=0		100 (Playoffs only)	1 (Quals only)
Ready for Takeoff	For each TOUCHPAD triggered by a ROBOT at T=0		50	-
Win	ALLIANCE's final score exceeds their opponents'		-	2 (Quals only)
Tie	ALLIANCE's final score equals their opponents'			1 (Quals only)

Needs, Wants, Goals

- List all goals for a successful design
  - Able to solo x rotors, able to win the minibot race
- List all possible robot movements
  - Crossing x defence, stacking totes x high, etc.
- Categorize into needs and wants
  - Needs are absolutely necessary for a successful robot design
  - Wants are planned to be integrated into the design, but will be the first to be removed if resources run out

Autonomous and Endgame

- Autonomous and endgame mechanisms are sometimes unique mechanisms and one of the sacrifices made for robot design
  - E.g., 2014 254's 3 ball auto (no catcher)
  - E.g., 2016 1241's no hang endgame (sacrificed for more offence)
  - E.g., 2017 1241's auto gear holder
- Consider how the effort-reward ratio of these actions and how important they are to your strategy
  - Always work within the resource limitations of your team to help cut down

Decision Making

- Methods of decision making
  - Decision matrix: taking pros and cons and giving numerical values
  - Linear optimization: finding the upper bound of constraints to maximize scoring output

PROS/CONS BETWEEN GEAR, BALL, HANG

	PROS	CONS
G/H (6)	• 25% increase compared to next best • Less complex • Consistent, less mechanisms • Bigger bonus in playoffs • Easier for driver • Good strategy for districts • Easy to fix • Higher chance to go undefeated	• Capped score • Caps at 2 RP • Need help offensively • No offense after gears are finished • Need jack-of-all-trades for alliance • Need airship finished before all else • Less market value
B/H (0)	• Niche • 1 RP point • No point cap • More protection • Higher tolerance • Flexible positions	• Need 2 gear bots on alliance • Lower playoff bonus • Lower score output • Forced to pick up on floor • Ball variability
B/G/H **(11)**	• Higher scoring potential • Adaptability/versatility • Marketing easy • Always something to do • Flexible during match • Top tier team • Strategic complexity (quals vs elims, RP vs points)	• Complexity • Packaging • Tight deadlines • Resources limited and time to prototype • Weight allocation • Risk of failing

Robot Generalization

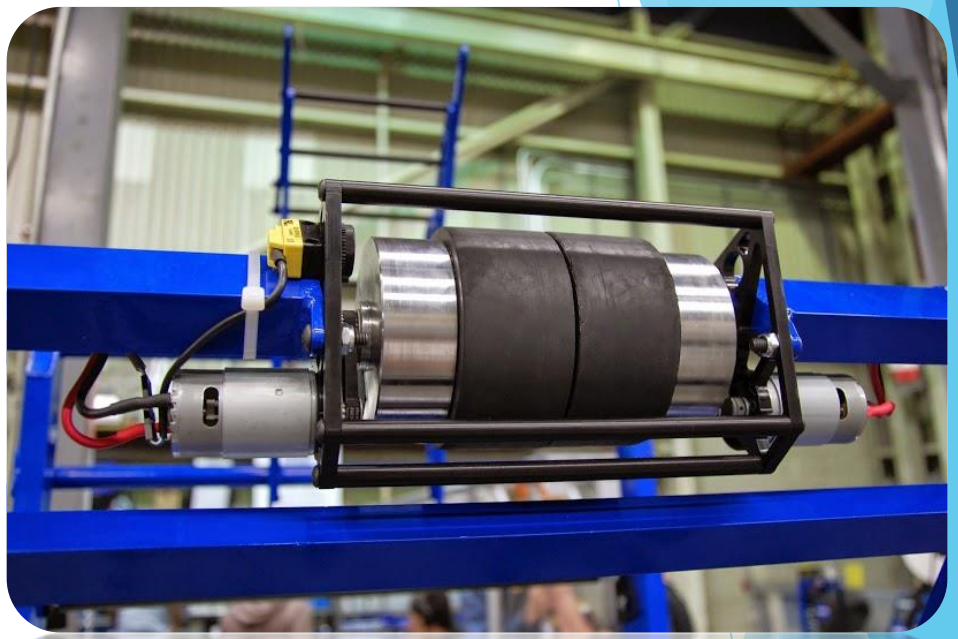
- Most (if not all) robots in FRC can be broken down into 4 (or less) main subsystems
  - Drivetrain: normally responsible for traversing the field and any obstacles or defence.
  - Intake: used for obtaining possession/ejecting of game pieces.
  - Tool: main mechanism(s) for scoring points/manipulating game objects (can vary heavily).
  - Endgame: mechanism(s) used for scoring points during the final portion of the match the, “Endgame” period.

Mechanism Selection: Intake

- "Touch & Go"
  - Aim for intakes to give possession of the game piece as soon as they come into contact.
  - This will require you to always have some set of active rollers/wheels to contact the game piece.
  - Ideally the linear speed of your intake is faster than your drive.
- Gripping
  - Apply some pressure with elastic/pneumatic methods to keep object secure
    - Clamps,Claws usually do the trick.
    - Sensors are always nice.

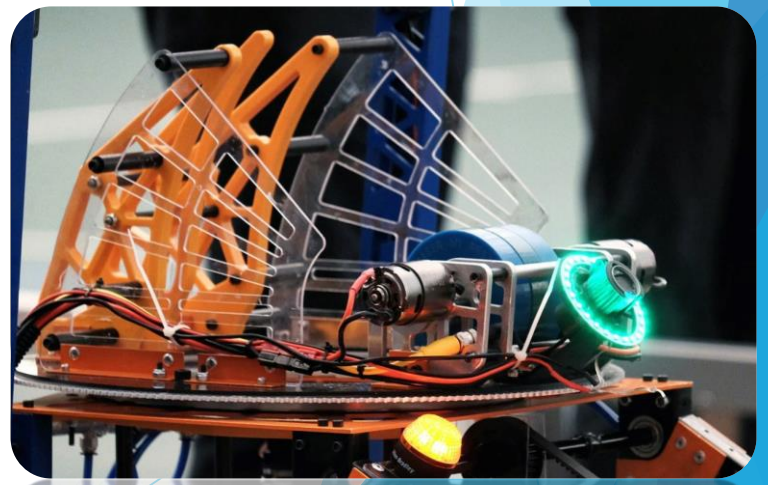
Mechanism Selection: Ball Shooter

- Catapult/Elastic Launcher
  - Can store the most potential energy
  - Needs to reset after each shot
  - Difficulty: **MEDIUM**
- Flywheel
  - Good for rapid/high volume shooting consistently
  - Difficulty: **HARD**
- Piston/Pneumatic Launcher
  - Usually the weakest and least efficient shooter style
  - Good for compact design
  - Difficulty: **EASY-ISH**



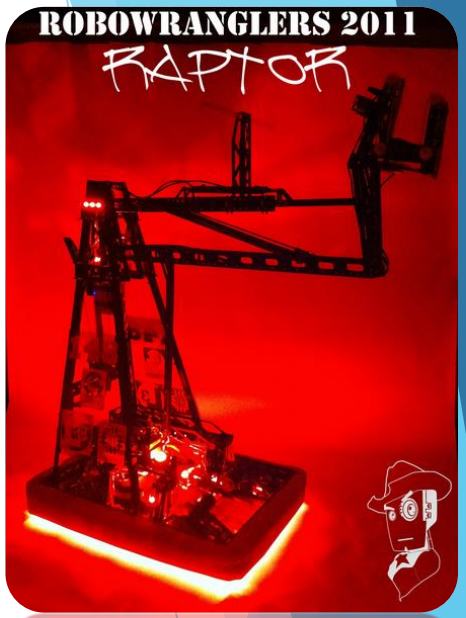
Mechanism Selection: Ball Shooter

- Turret
  - Adds another level of complexity to design
  - Creates more strategic locations for shooting
- Vision Tracking
  - Adds a slight delay, but when implemented properly, increases success rate(2016 vs 2014)
  - Add a dampener for camera to avoid shaking.
  - Requires large amount of time for testing by programmers



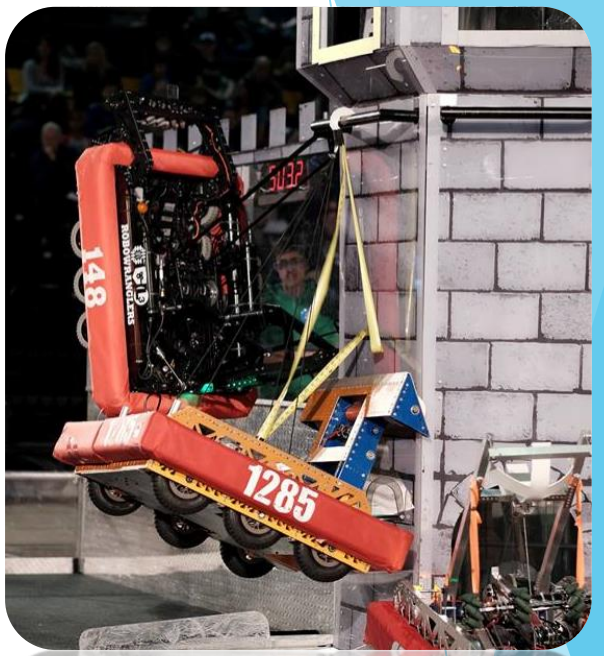
Mechanism Selection: Lift

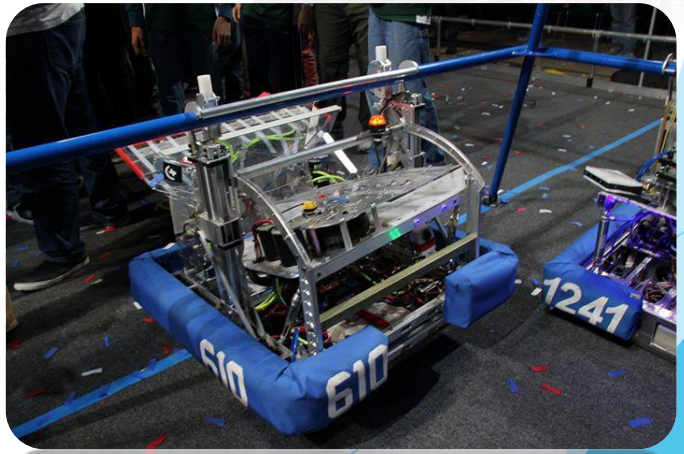
- Simple Bar Linkage
  - Good for rotating game piece or mechanism with lifting arm
- 4 or 6 Bar Linkage
  - Good for keeping game piece in same orientation during lifting
  - Arm swing may not be desirable for placing game pieces
- Elevator
  - Straight vertical lift makes design more simple



Mechanism Selection: Hanger/Climber

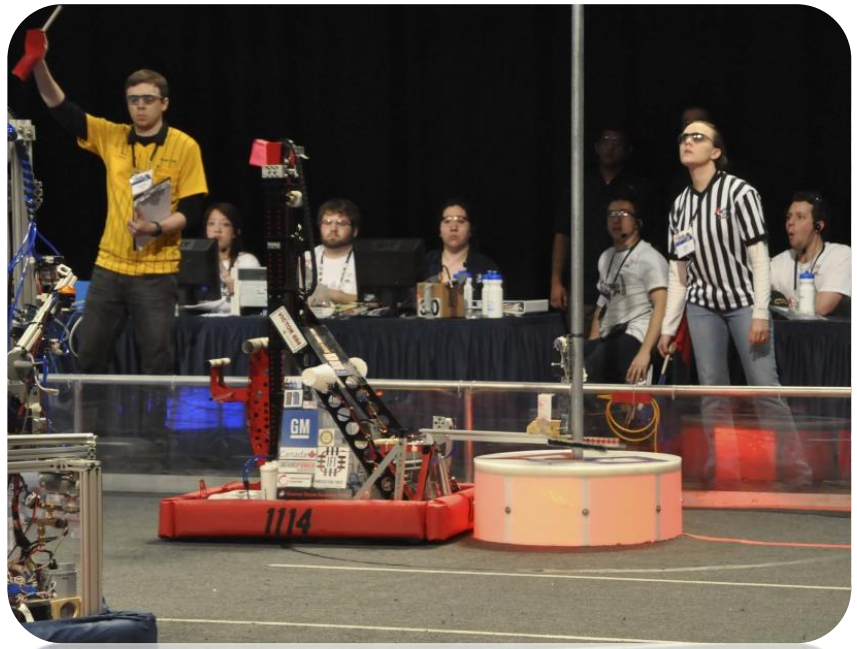
- Winch
  - Good for taller hangs/climbs, usually slower than pneumatic hangers
  - Ratcheting mechanism can help reduce load on motors
- Piston/Pneumatic
  - Good for short distance hangs
  - Can add constant force springs to reduce the required pneumatic force

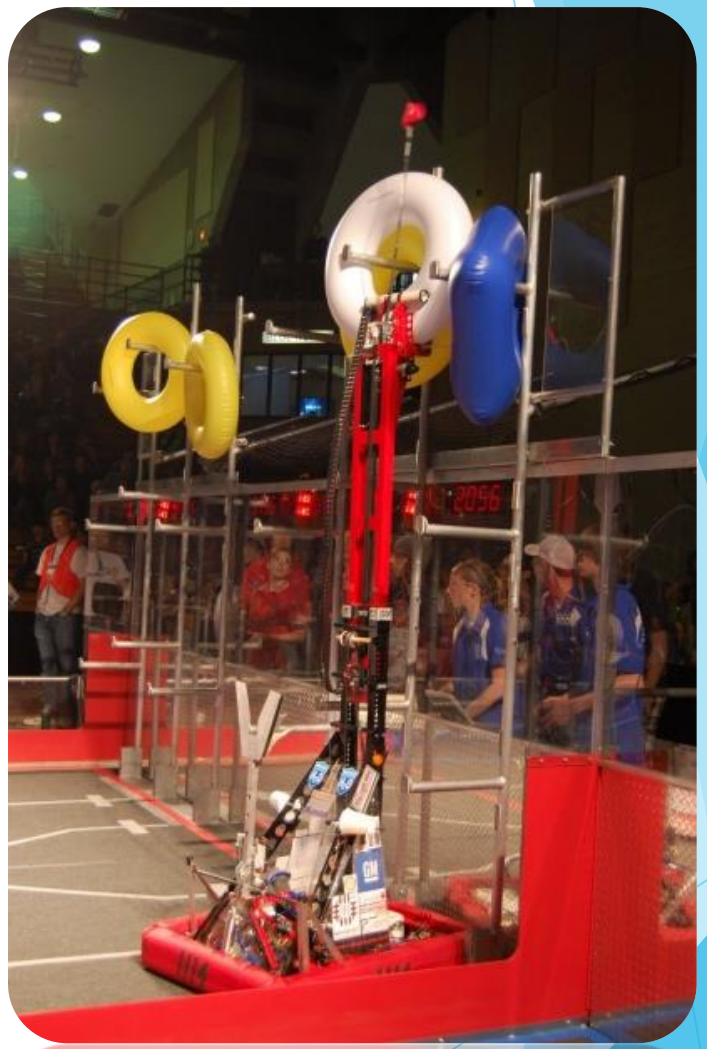




Winning Designs - 2011

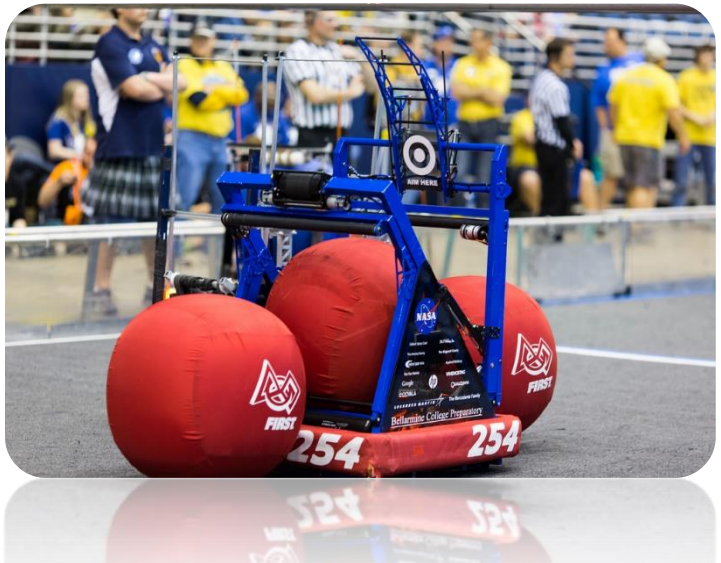
- 1114 - Simbotics
  - Chokehold strategy
- Key Endgame: Minibot Race





Winning Designs - 2014

- 254 – The Cheesy Poofs
  - 3 Ball Hot Autonomous
  - Multiple shots: fender, fender + robot
  - High shooter exit point
- Key Autonomous: Multiple Hot High Goals (254, 33)

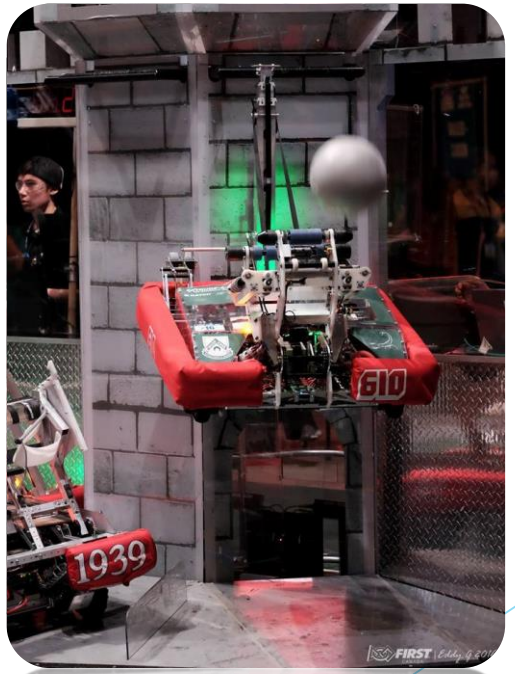


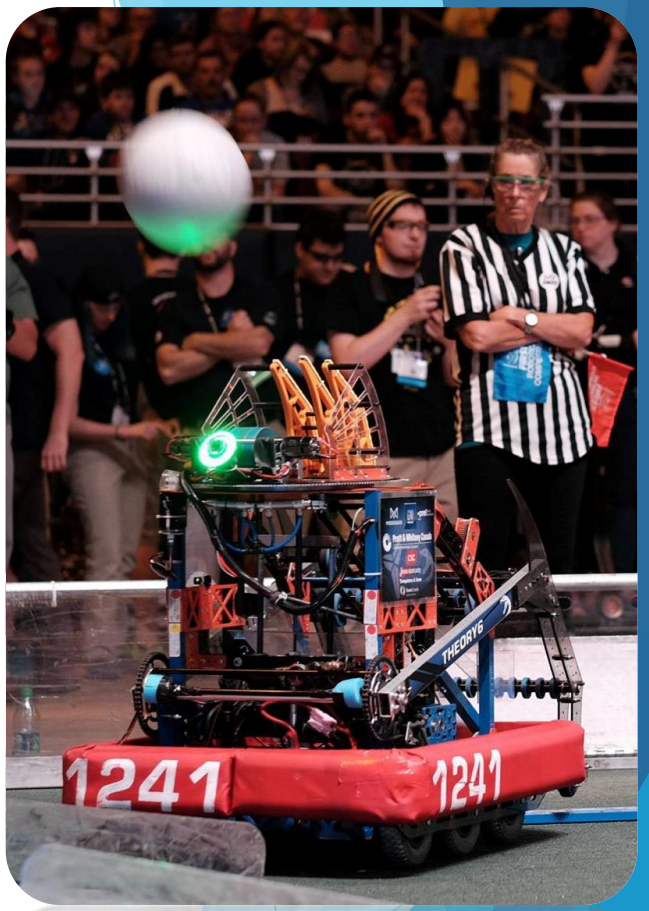
Winning Designs - 2015

- Ramp robots
  - Increased stacking speed
  - Human player can prepare totes instead of waiting for robot
- Tethered Robots – 4039, 148
  - Increased stacking speed
- Key Autonomous: Can Grabbing
  - Reduced opponents' maximum potential score

Winning Designs - 2016

- Outerworks shot
  - Opponents could not touch your robot while defending your shot
- Ball stealing (1241)
  - Reduces cycle time and helps damage the castle
- Key Endgame: Hanging Shot (610, 330)



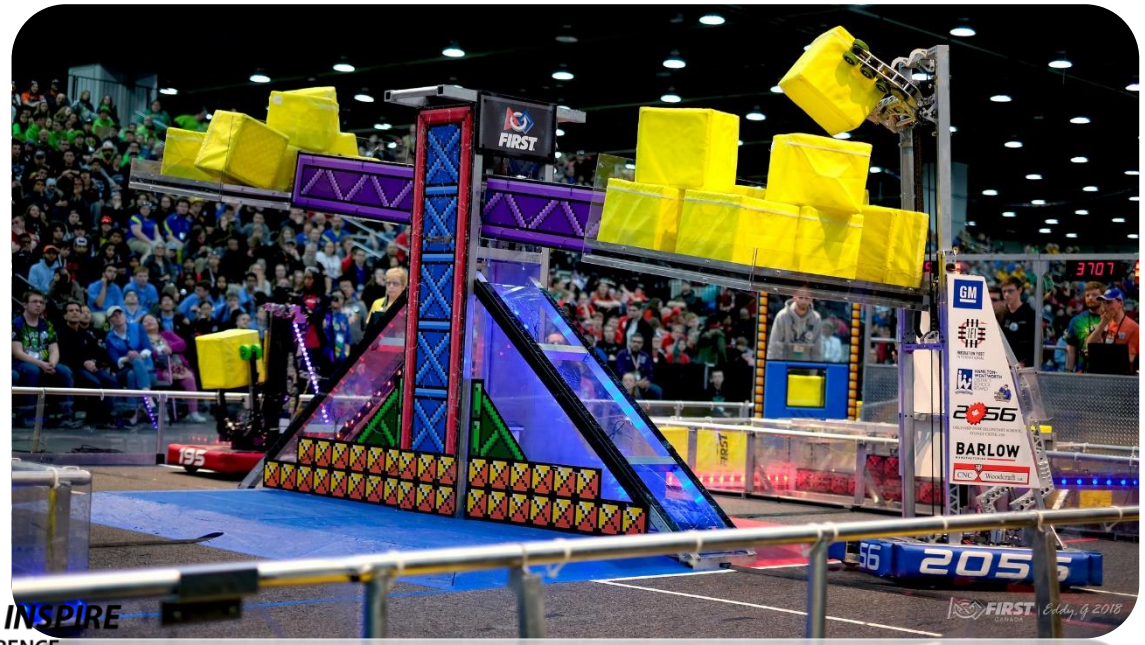


Winning Designs - 2017

- 4 Rotor Offence and Defence
  - Defending the 4th rotor meant a point swing of over 100
- Key Autonomous: Hopper Auto
  - 3x value for fuel was essential to achieving 40rp early in the competition season

Winning Designs - 2018

- Cube scoring on moving/losing scale (195)
  - Having ability to drop cubes on moving/losing scale cleanly meant higher stacks.
- Key Autonomous: 3-4 cubes scored on Scale (254)
  - 2x value for ownership. It also gives a head start for tele-operated period where opponents have to try and score 2 cubes to regain ownership.



Mock Kickoff

Mock Kickoff: Schedule

- Game Animation
- Game Manual
- List of Motions
- Scoring Analysis
- Strategic Goals
- Needs and Wants
- Mechanism Selection

- World Championships!

Mock Kickoff – Game Animation

https://www.youtube.com/watch?v=itHNW2OFr4Y

Mock Kickoff – Game Manual

- Goal: Score discs into the appropriate goals (3 goals at opposite driver station)
- Discs are obtained from 2 locations
  - Feeder Station – Located at your alliance wall station
  - Floor – Some discs are located here before match starts, missed discs can also be picked up
  - Protected Zones: Feeder Station, and if you are contacting the Pyramid
- End Game:
  - Elevate robot off the field and climb the pyramid
  - Points are awarded for each level of elevation

Mock Kickoff – Game Manual

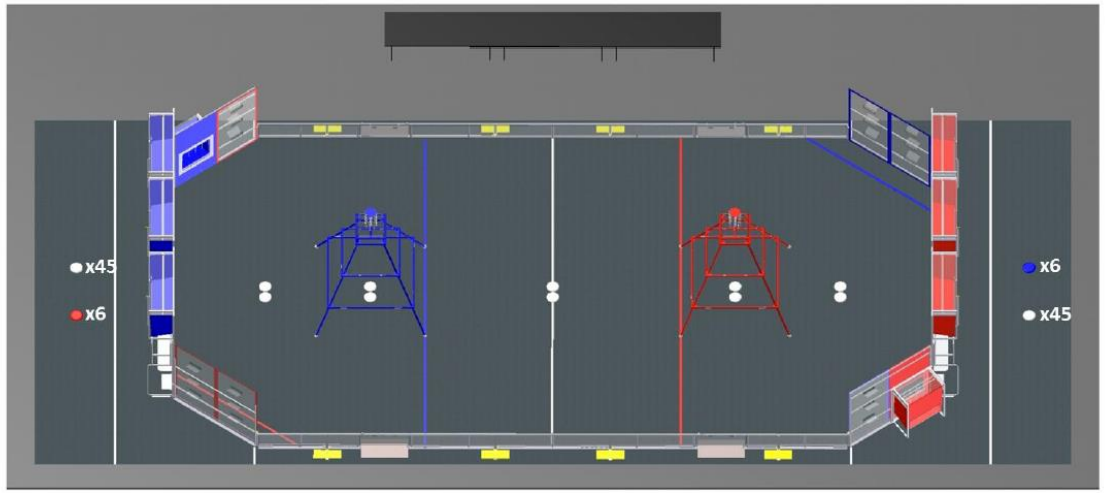
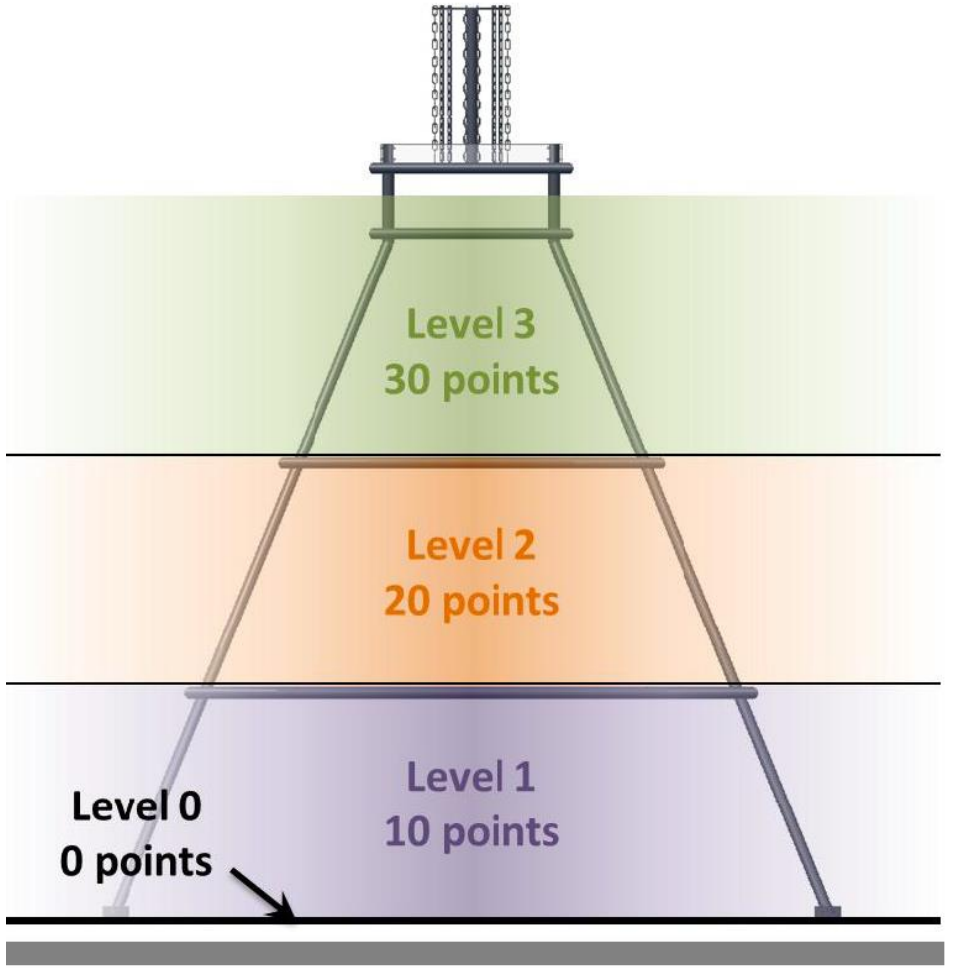


Figure 3-1: Starting Locations for DISCS

	AUTO	TELEOP
LOW GOAL	2	1
MIDDLE GOAL	4	2
HIGH GOAL	6	3
PYRAMID GOAL	N/A	5



Mock Kickoff – List of Motions

- Tele-operated:
  - Driving
    - In all directions
    - Able to pivot (on a dime)
  - Intaking a disc from floor
  - Obtaining disc from feeder station
  - Storing Discs (up to 4 at once)
  - Scoring a disc (which goal? And from where on the field?)
  - Scoring coloured discs on the pyramid (5pts per disc)

Mock Kickoff – List of Motions

- Autonomous:
  - Vision tracking goal
  - Scoring a disc
  - Picking up discs
- End Game:
  - Climbing the pyramid (10pt, 20pt, 30pt)

Mock Kickoff – Scoring Analysis

Mock Kickoff – Scoring Analysis

- Each disc in high goal is worth 3 pts in high goal (each cycle of 4 worth 12 pts)
- A robot elevated Level 1 is approximately the score of 1 cycle
- A robot elevated HIGH is approximately the score of 3 cycles
- 45 white discs (per alliance), 6 coloured discs (per alliance)
  - Autonomous (3 discs x 3 robots) + 6 accessible on floor = 90pts
  - 45 discs x 3pts + 6 discs x 5 = 165
  - Three robots elevated level 3 = 90
  - Maximum Score: 345
  - To achieve this, all discs have to be scored high, 3 robots must climb to level 3, and 6 discs scored on top of pyramid.

Mock Kickoff – Strategic Goals

- Score in high goal (3pts per disc)
- Obtain disc from feeder station
- Obtain disc from floor
- Block opponent from scoring
- Climb to level 1, 2, 3
- Score discs on top of pyramid

Mock Kickoff – Needs and Wants

- Needs:
  - Drive around the field, not get stuck on top of discs
  - Score discs in the high goal
  - Be elevated level 1
  - Pick game elements off floor and feeder station

- Wants:
  - Score on top of pyramid
  - Elevate to level 3

Mock Kickoff – Subsystem Roles

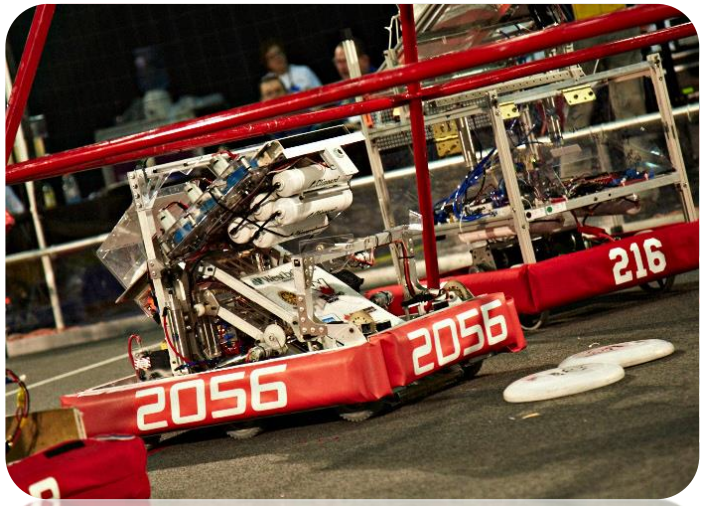
- Assign your all your needs to the general subsystems (you may not need all of them)
  - Drive
  - Intake
  - Tool
  - Endgame

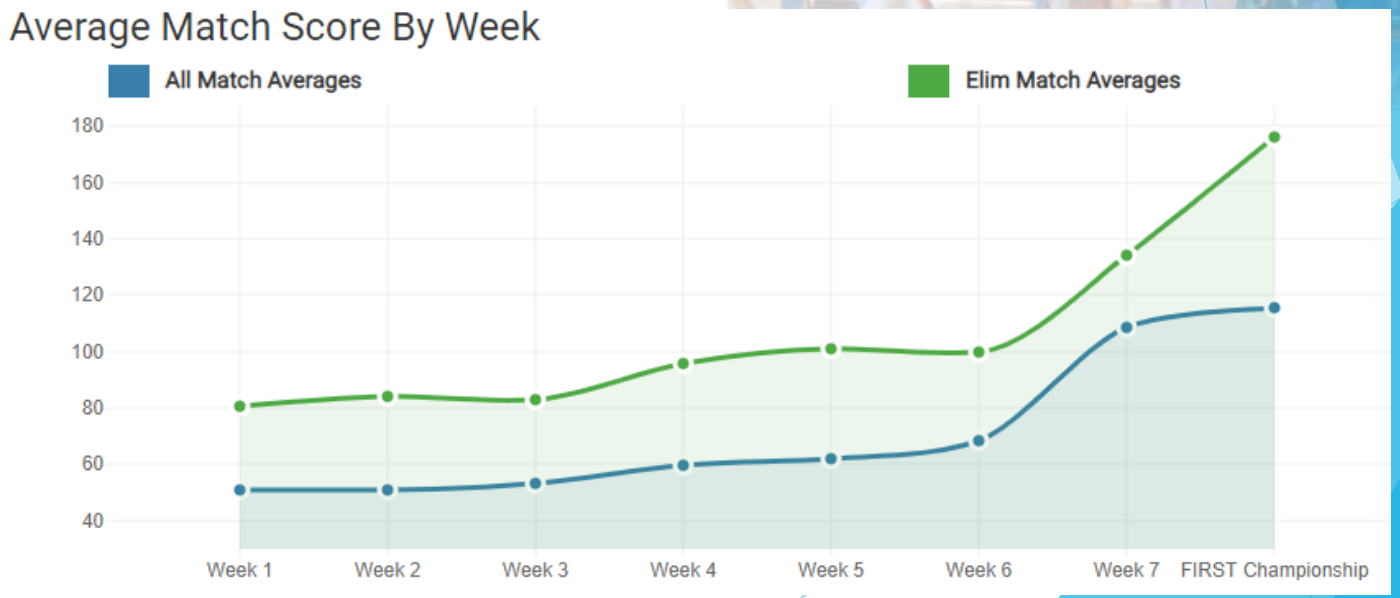
Mock Kickoff – Mechanism Selection

- Pick a mechanism that will best fit the task you assigned to each subsystem *(adding minor tweaks to achieve your goals is common)*
- Tele-Operated:
  - Drive Train Type?
  - Claw, clamp, roller, shovel intake?
  - Scoring mechanism?
- End Game:
  - Climb on the rungs vs corners?
  - Pneumatic or winch?

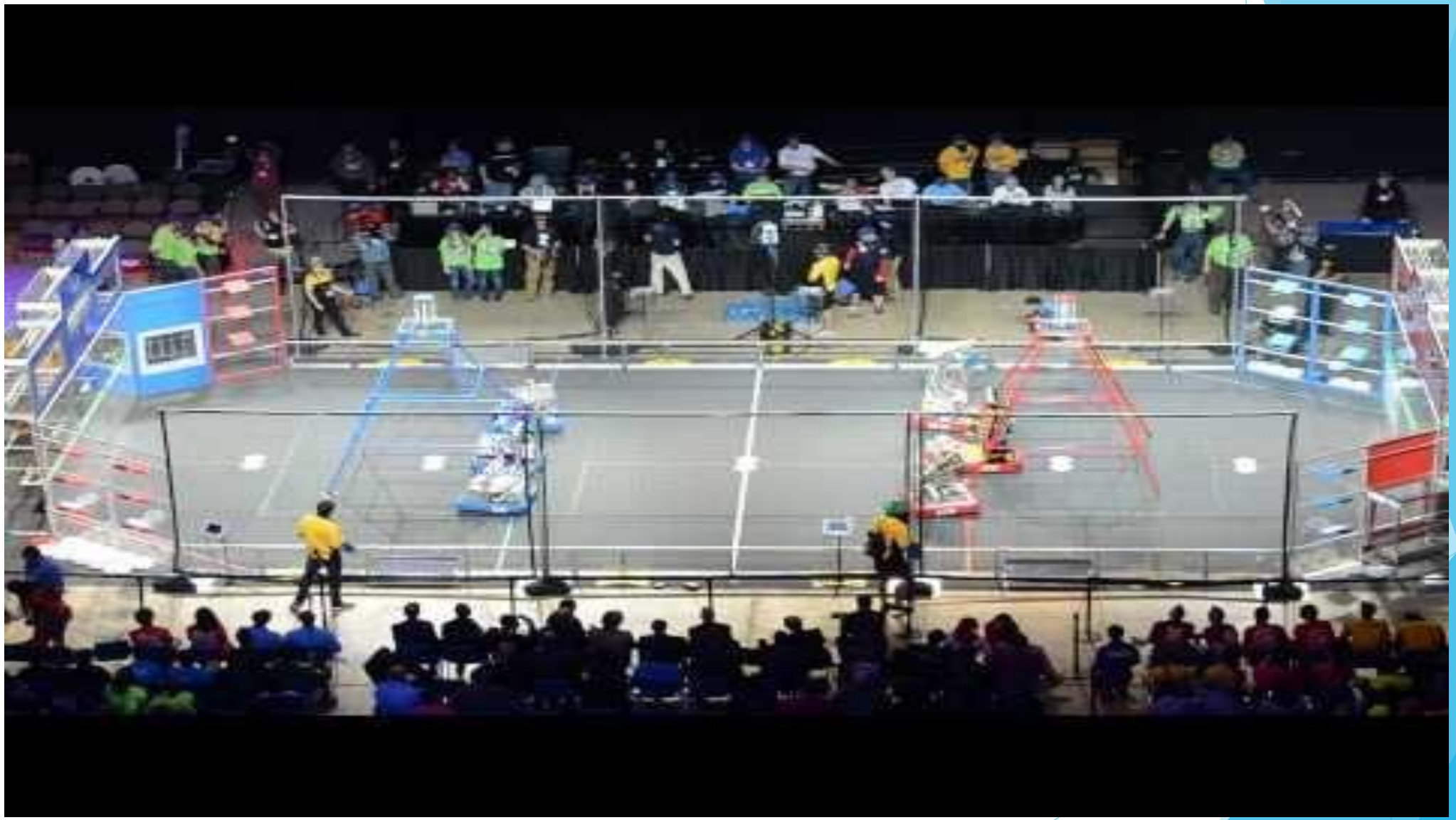
Winning Designs - 2013

- 1114 - Simbotics
  - 50 point hang
- Key Autonomous: 7 Disk Auto (2056)
- Key Endgame: 50 Point Hang (1114)





Mock Kickoff – World Championships



Amazing Designs

Amazing Designs

Questions?

Girls In STEM Olympics

https://www.theory6.ca/girls-in-stem-olympics

Thanks for Coming!

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