

FRC Strategic Design

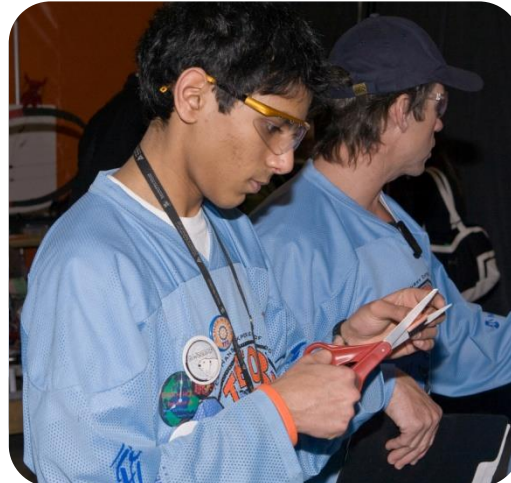
How to Decide Your Robot Design

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



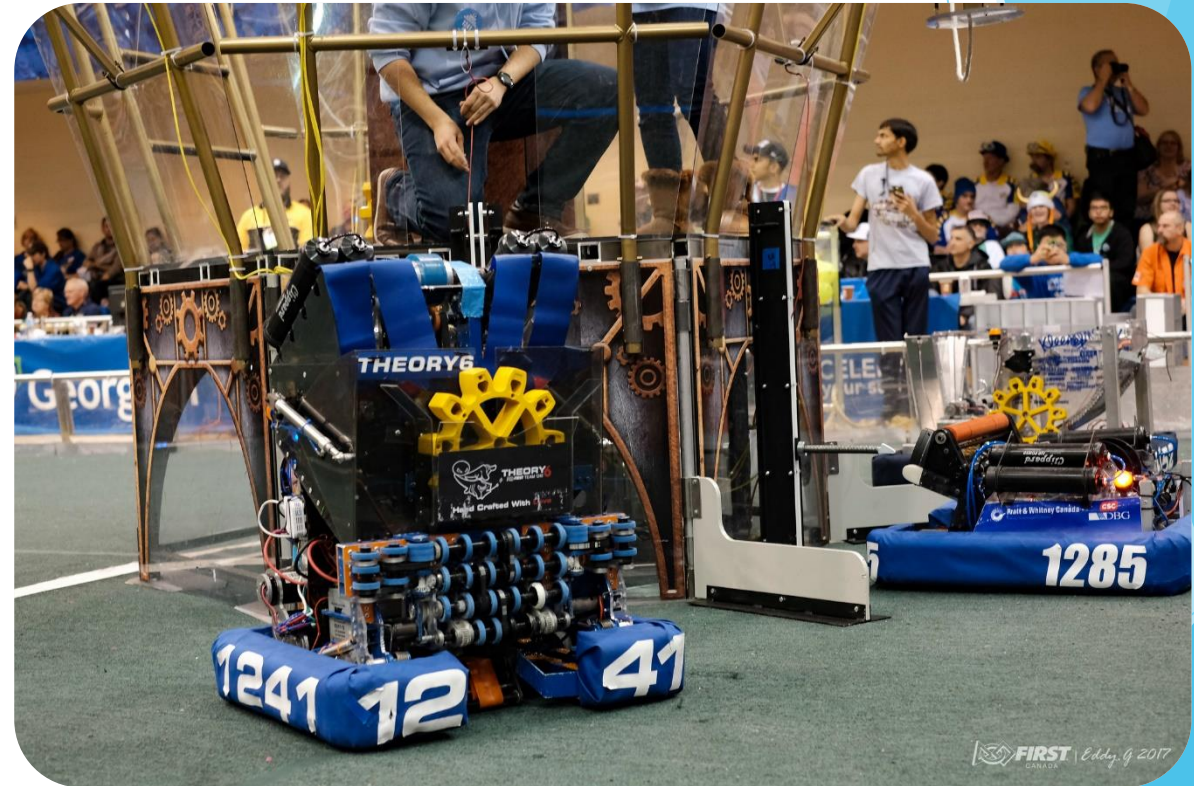
Max Guan

- ▶ Student at McMaster University
 - ▶ Bachelor of Engineering, Civil Engineering (2019)
- ▶ Joined FRC in 2013
 - ▶ Team 1241/1285
 - ▶ Student (2013-2014)
 - ▶ Lead Project Management Mentor
- ▶ Coach (2016-present)



Objectives

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



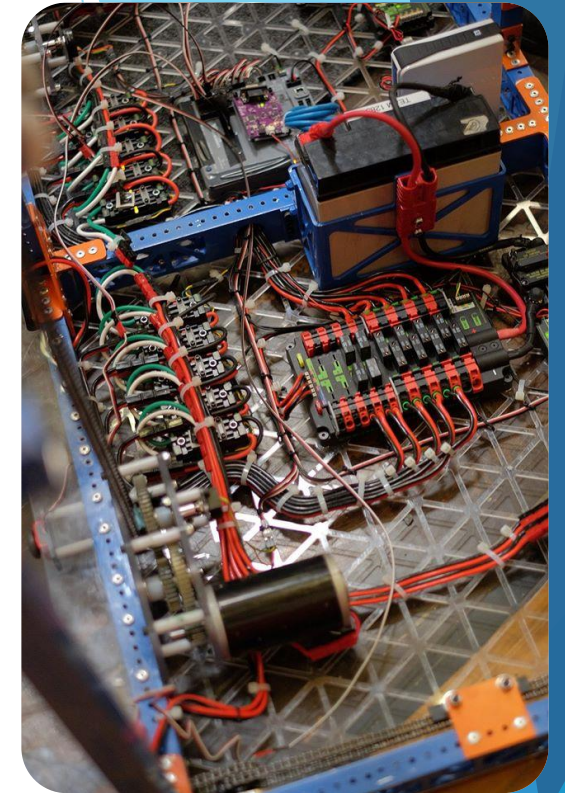
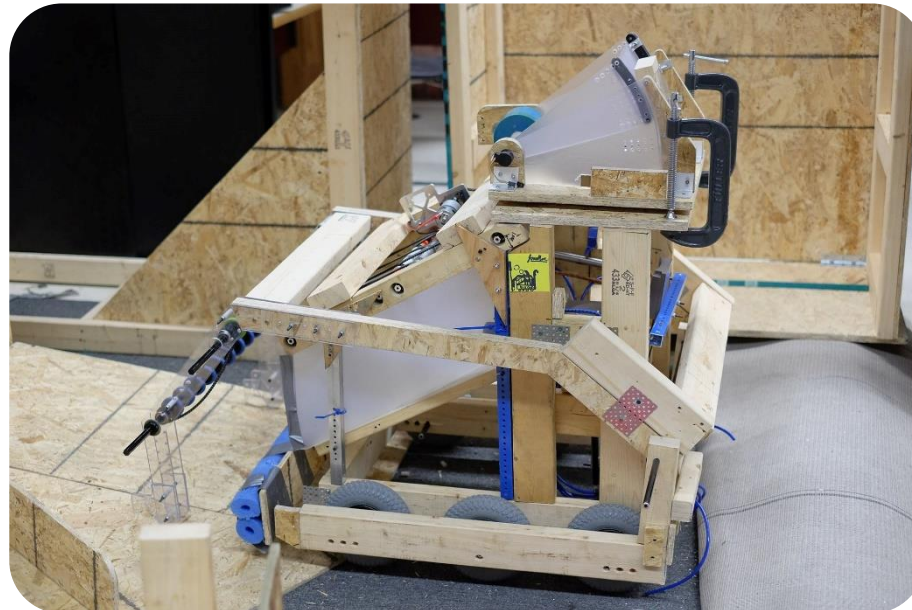
Tips For Designing

- ▶ 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 kickoff
 - ▶ In the past, we've held kickoff 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

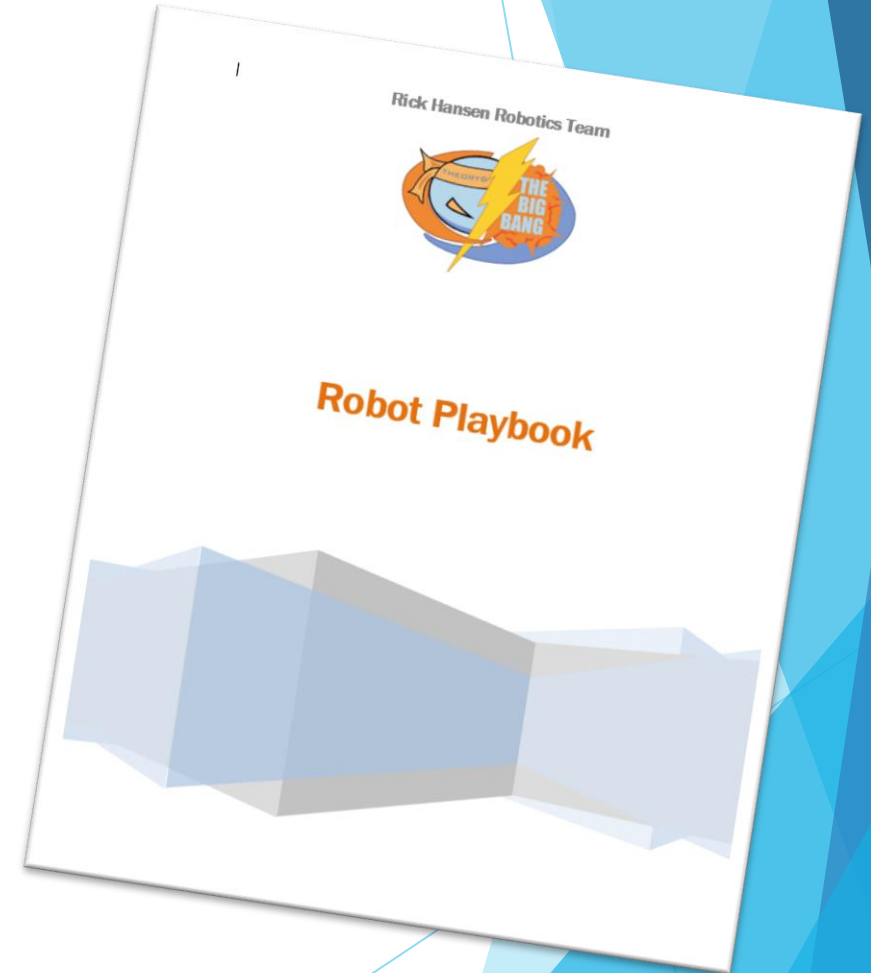
- ▶ 9:00am - Meet at location to discuss strategy/requirements list
 - ▶ Finalize the list of requirements
- ▶ 9:45am - Introduce mentors/leads for each section
 - ▶ Present strategy decisions from Saturday
- ▶ 10:30am - Discuss intake, tool, and end game design
 - ▶ Begin to collaborate designs
 - ▶ 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

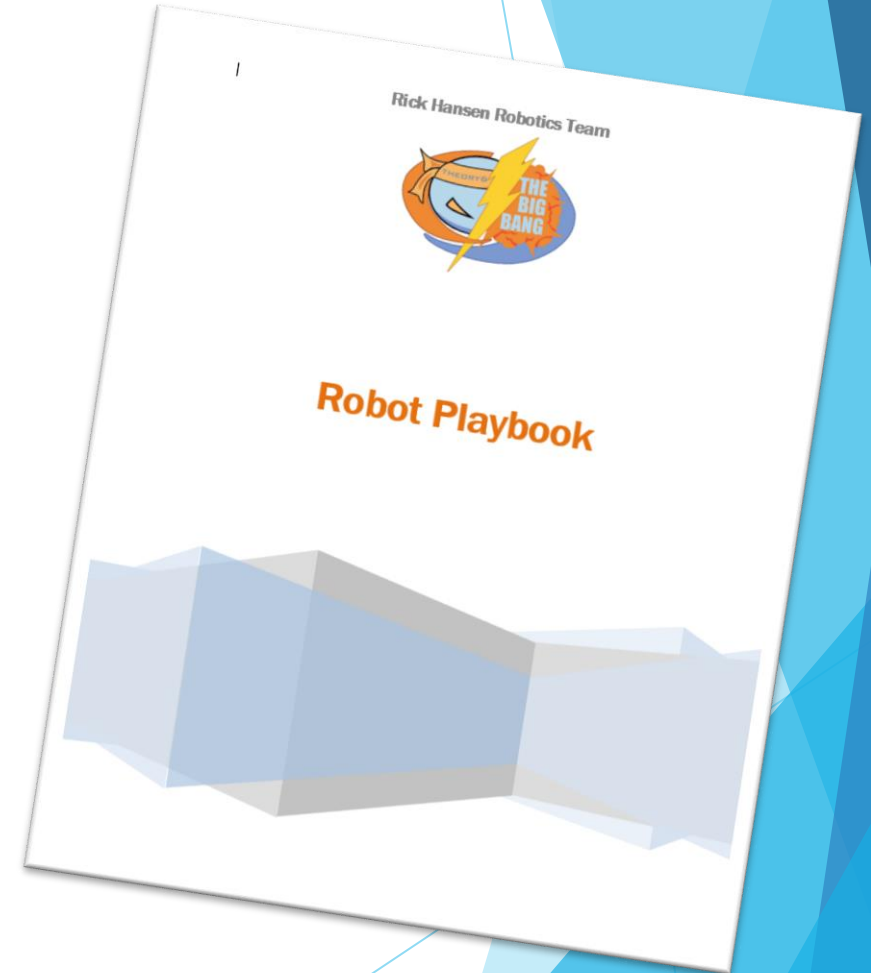
The Playbook

- ▶ 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.
- ▶ Available at:
<https://www.chiefdelphi.com/media/papers/3319>



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		Ranking Points
		AUTO	TELEOP	
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	-	-
	For every one (1) FUEL counted in the High Efficiency GOAL by T=0	+ 1 kPa	-	-
	For every nine (9) FUEL counted in the Low Efficiency GOAL by T=0	-	1	-
	For every three (3) FUEL counted in the High Efficiency GOAL by T=0	-	+ 1 kPa	-
	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

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)	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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)	<ul style="list-style-type: none"> • Niche • 1 RP point • No point cap • More protection • Higher tolerance • Flexible positions 	<ul style="list-style-type: none"> • Need 2 gear bots on alliance • Lower playoff bonus • Lower score output • Forced to pick up on floor • Ball variability
B/G/H (11)	<ul style="list-style-type: none"> • 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) 	<ul style="list-style-type: none"> • Complexity • Packaging • Tight deadlines • Resources limited and time to prototype • Weight allocation • Risk of failing

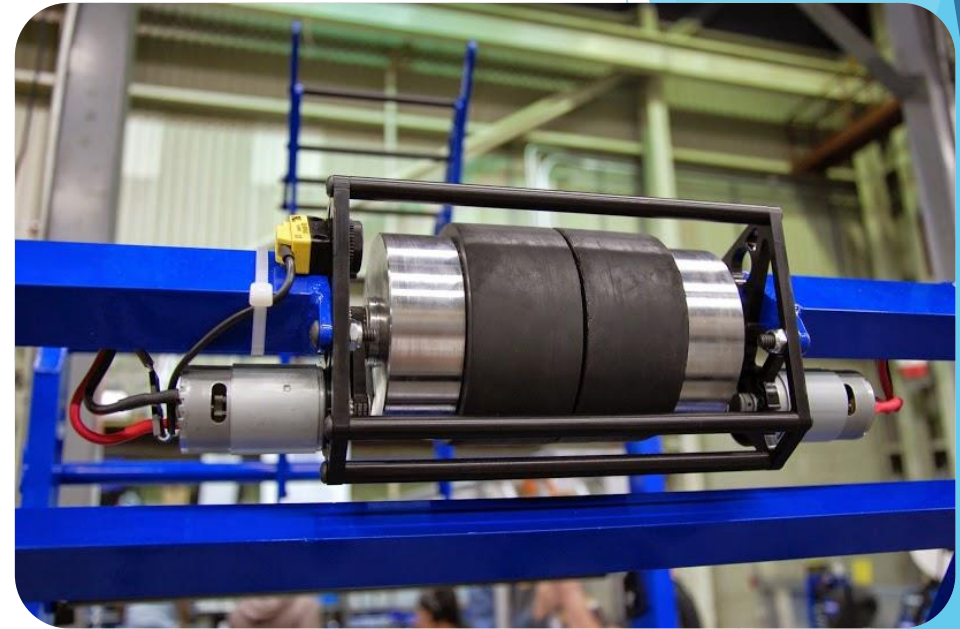
Mechanism Selection: Intake

- ▶ Roller Intake
 - ▶ “Touch and go” makes cycling faster
- ▶ “Chopstick” Intake
 - ▶ Harder to master controls
- ▶ Clamp Intake
 - ▶ Good for intaking game objects that need to stay in a certain orientation



Mechanism Selection: Ball Shooter

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



Mechanism Selection: Ball Shooter

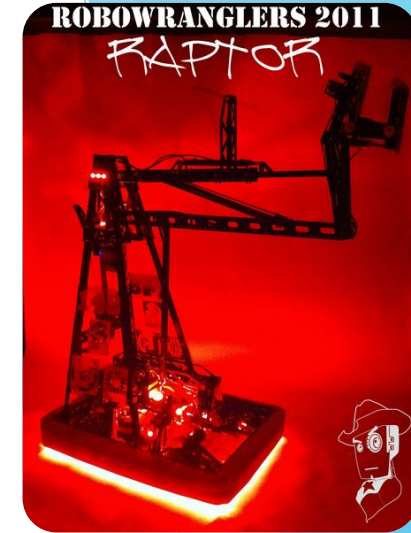
- ▶ Turret
 - ▶ Adds another level of complexity to design
 - ▶ Creates more strategic locations for shooting
- ▶ Vision Tracking
 - ▶ Adds a slight delay, but when implemented properly, increases success rate (2016 vs 2014)



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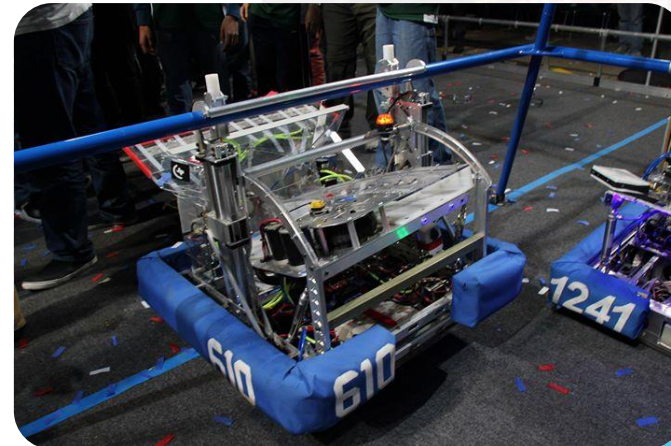
Mechanism Selection: Lift

- ▶ 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



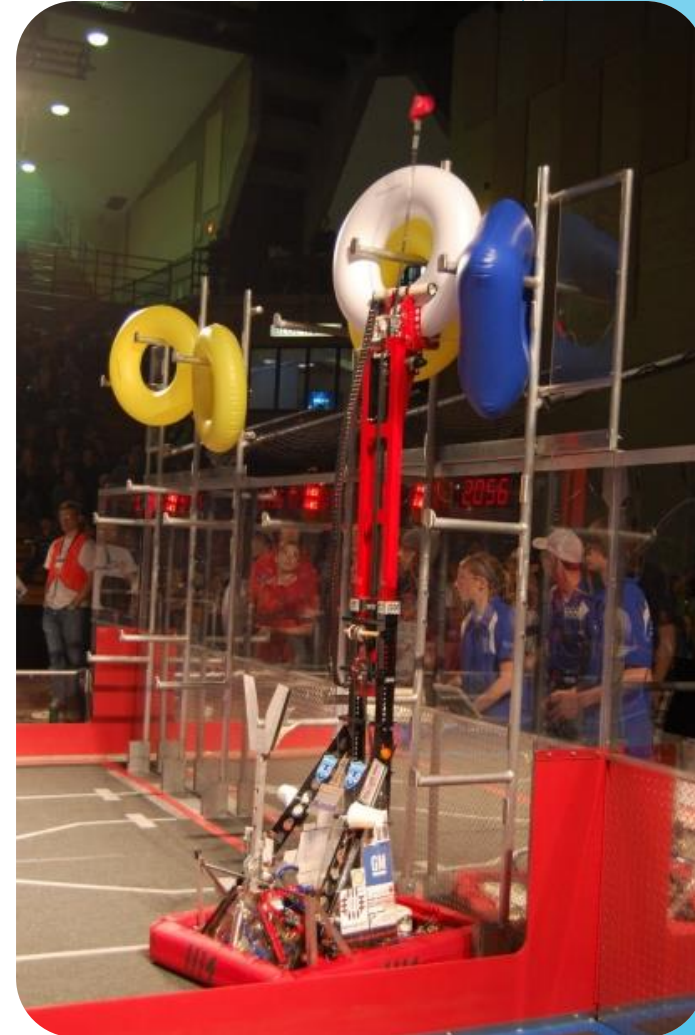
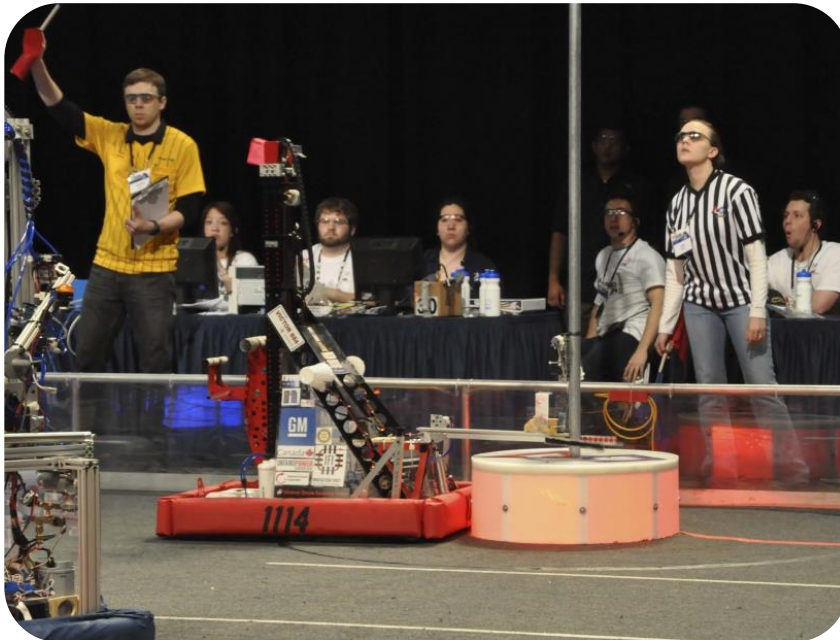
Mechanism Selection: Hanger/Climber

- ▶ Winch
 - ▶ Good for taller hangs/climbs, usually slower than pneumatic hangers
- ▶ 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 - 2013

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



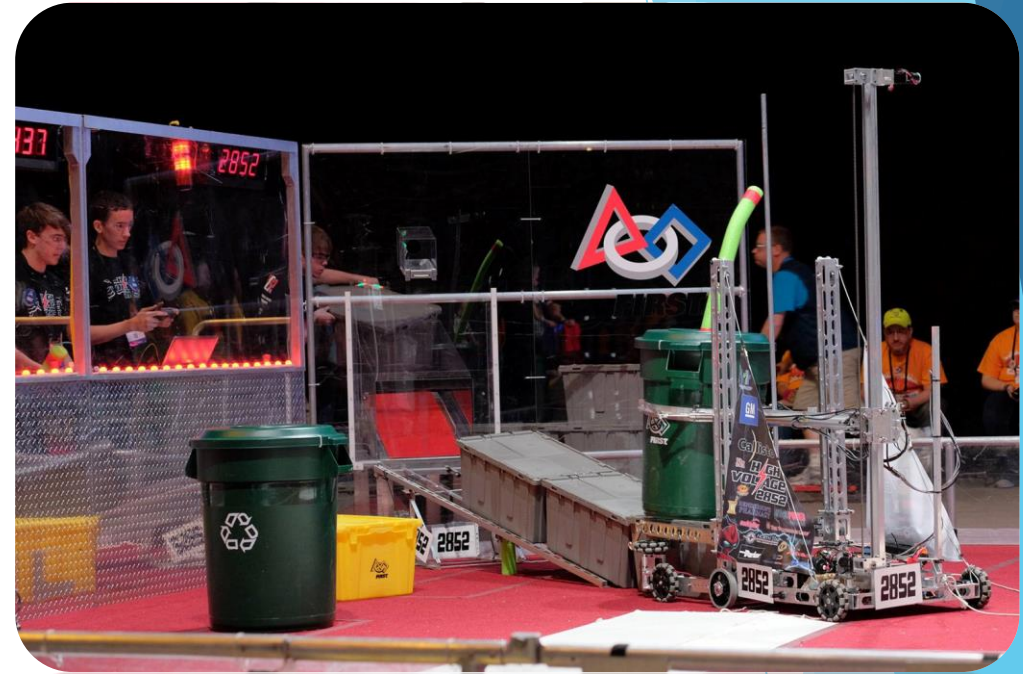
Winning Designs - 2014

- ▶ 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)



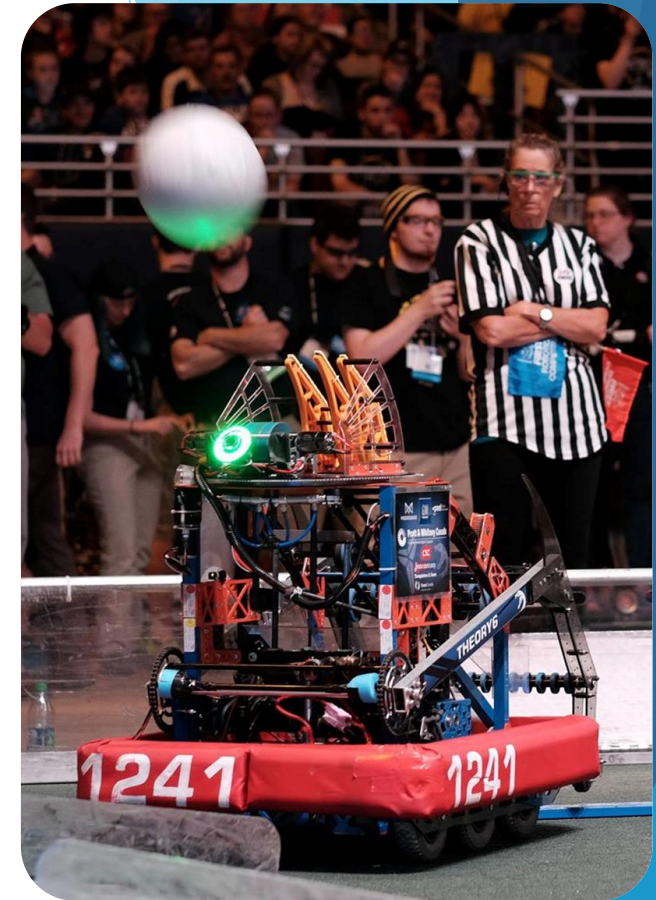
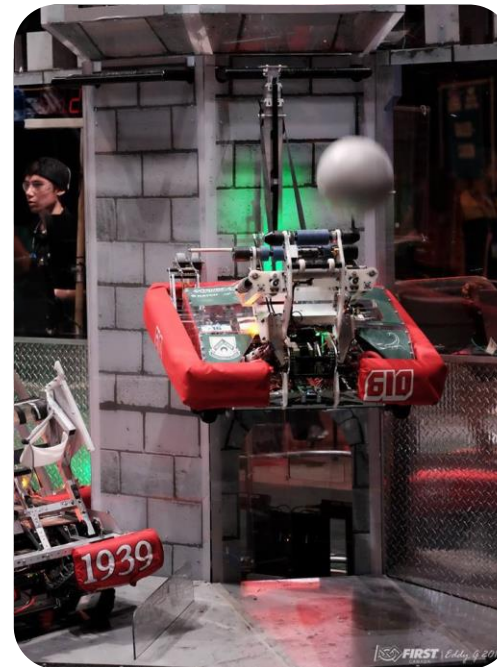
Winning Designs - 2015

- ▶ 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 40kPa early in the competition season



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Mock Kickoff



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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



Mock Kickoff - Game Manual

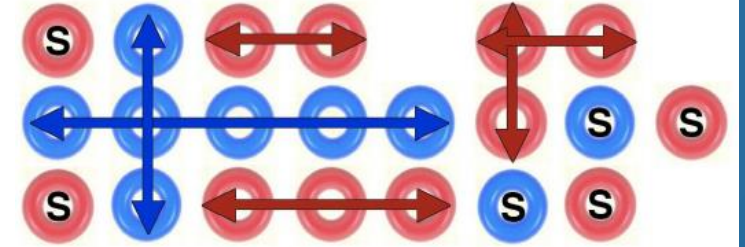
- ▶ Goal: Score consecutive ringers on the “spider”
 - ▶ Think of the spider like a 8x3 grid
 - ▶ Keepers - Cannot be removed, only placed during autonomous
 - ▶ Ringers - Cannot be removed
 - ▶ Spoilers - Can be removed, blocks ONLY ringers
- ▶ End Game:
 - ▶ Elevate robot off the field without the help of field elements

Mock Kickoff - Game Manual

OBJECTS (INNER/OUTER)	SCORED AS / RELATED RULE	OBJECTS (INNER/OUTER)	SCORED AS / RELATED RULE
	BLUE Rule <G11>		RED Rule <G11>
	BLUE Rule <G11>		RED Rule <G11>
	BLUE Rule <G13>		RED Rule <G13>
	NONE Rule <G16>		NONE Rule <G16>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G14>		RED Rule <G14>
	BLUE Rule <G15>		RED Rule <G15>
	BLUE Rule <G19>		RED Rule <G19>
	NONE Rule <G14>		NONE Rule <G14>
	NONE Rule <G15>		NONE Rule <G15>
	NONE Rule <G17>		NONE Rule <G17>
	NONE Rule <G14>		NONE Rule <G14>

<G54> SCORING - Total point values of SCORED ROWS are as follows:

- SINGLETON - 2 points
- ROW of 2 SCORED SPIDER LEGS - 4 points
- ROW of 3 SCORED SPIDER LEGS - 8 points
- ROW of 4 SCORED SPIDER LEGS - 16 points
- ROW of 5 SCORED SPIDER LEGS - 32 points
- ROW of 6 SCORED SPIDER LEGS - 64 points
- ROW of 7 SCORED SPIDER LEGS - 128 points
- ROW of 8 SCORED SPIDER LEGS - 256 points



Note: There is not an additional 2 points for each GAME PIECE in a ROW.

- Each ROBOT between 0 and 3.9 inches above floor level - 0 bonus points
- Each ROBOT between 4.0 and 11.9 inches above floor level - 15 bonus points
- Each ROBOT 12.0 inches or more above floor level - 30 bonus points

Mock Kickoff - List of Motions

- ▶ Tele-operated:
 - ▶ Driving
 - ▶ In all directions
 - ▶ Able to pivot (on a dime)
 - ▶ Intaking a tube
 - ▶ Lifting a tube
 - ▶ Scoring a tube
 - ▶ De-scoring and re-scoring a spoiler

Mock Kickoff - List of Motions

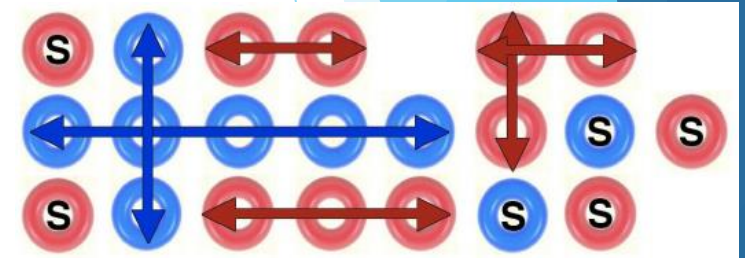
- ▶ Autonomous:
 - ▶ Vision tracking the spider
 - ▶ Scoring a keeper
 - ▶ Dropping a keeper
- ▶ End Game:
 - ▶ Elevating other robot(s) off the ground
 - ▶ Being elevated off the ground

Mock Kickoff - Scoring Analysis

OBJECTS (INNER/OUTER)	SCORED AS / RELATED RULE	OBJECTS (INNER/OUTER)	SCORED AS / RELATED RULE
	BLUE Rule <G11>		RED Rule <G11>
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	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G13>		RED Rule <G13>
	BLUE Rule <G14>		RED Rule <G14>
	BLUE Rule <G15>		RED Rule <G15>
	BLUE Rule <G19>		RED Rule <G19>
	NONE Rule <G14>		NONE Rule <G14>
	NONE Rule <G15>		NONE Rule <G15>
	NONE Rule <G17>		NONE Rule <G17>
	NONE Rule <G14>		NONE Rule <G14>

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Mock Kickoff - Scoring Analysis

- ▶ Each extra ringer in a row doubles the points
 - ▶ Use spoilers in the middle of a row for maximum point deduction
- ▶ A robot elevated LOW is approximately the score of a row of 4
- ▶ A robot elevated HIGH is approximately the score of a row of 5
- ▶ 18 Ringers (per alliance), 3 Keepers (per alliance), 4 Spoilers
 - ▶ Row of 8x2, row of 8x2, row of 5x1, row of 3x5, row of 2x3 = 596
 - ▶ Two robots elevated HIGH = 60
 - ▶ Maximum Score: 656
 - ▶ To achieve this, 3/3 autonomous must be successful, 18 ringers placed in tele-op and both HIGH elevations must be performed

Mock Kickoff - Scoring Analysis

- ▶ 18 Ringers (per alliance), 3 Keepers (per alliance), 4 Spoilers in total
 - ▶ Row of 8(x2), row of 5(x1), row of 3(x5), row of 2(x3) = 596
 - ▶ Two robots elevated HIGH = 60
 - ▶ Maximum Score: 656
 - ▶ To achieve this, 3/3 autonomous must be successful, 18 ringers placed in tele-op and both HIGH elevations must be performed
- ▶ Don't need to score the maximum!
 - ▶ If alliance 1 scores more rack points than the opponent, assuming no penalties and same end game points, alliance 1 will guarantee a win

Mock Kickoff - Strategic Goals

- ▶ Score long rows
- ▶ Defend your ringers
- ▶ Block opponent ringers from being used
- ▶ Use the spoiler or stop opponents from using it against you
- ▶ Use as little time to elevate as possible

Mock Kickoff - Needs and Wants

- ▶ Needs:

- ▶ Drive
- ▶ Score ringers anywhere on rack
- ▶ Be elevated HIGH
- ▶ Pick game elements off floor AND rack

- ▶ Wants:

- ▶ De-score spoilers
- ▶ Elevate two robots

Mock Kickoff - Mechanism Selection

- ▶ Tele-Operated:
 - ▶ Drive Train?
 - ▶ Claw or Roller intake?
 - ▶ Elevator or Arm?
- ▶ End Game:
 - ▶ Ramp or lift?
 - ▶ Pneumatic or winch?

Questions?



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Thanks for Coming!

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