

FRC Strategic Design

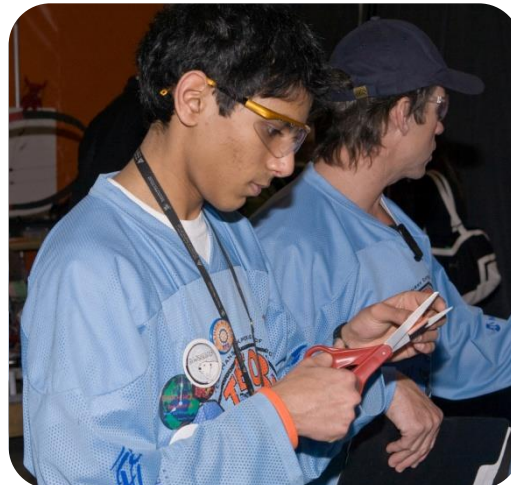
How to Decide Your Robot Design

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



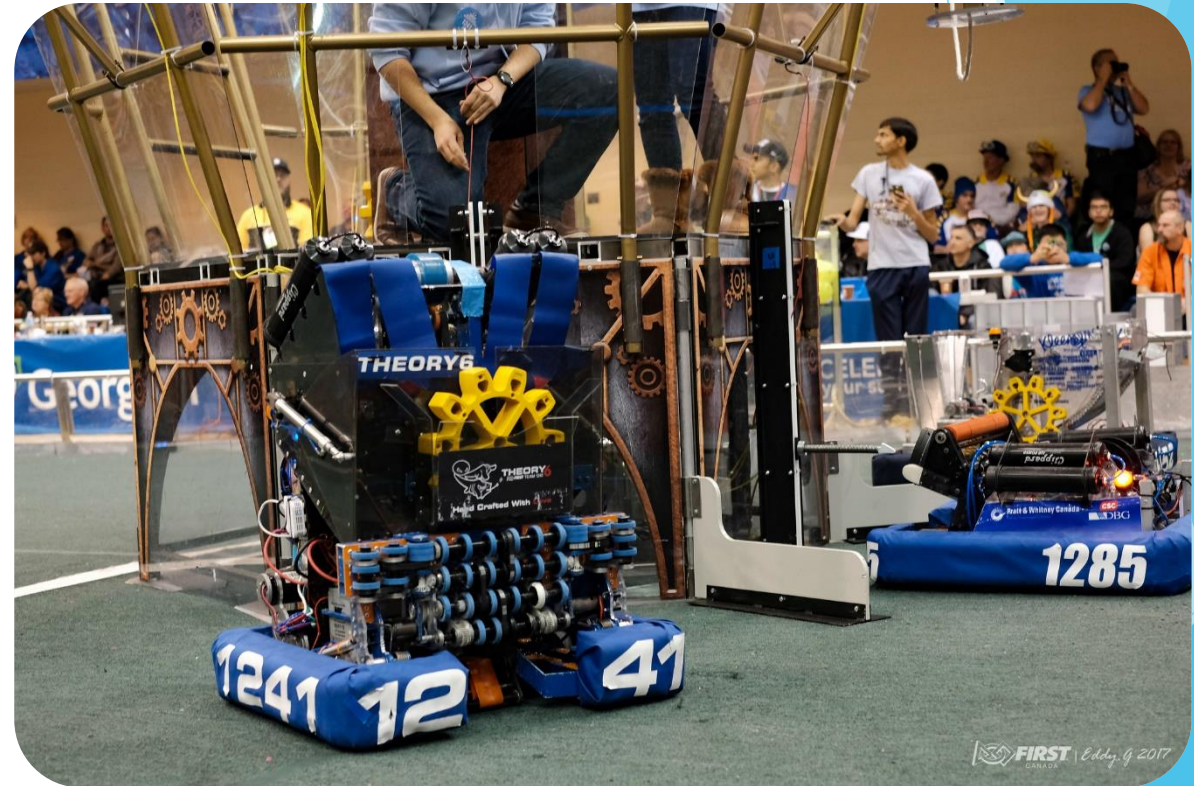
Shaqeeb Momen

- ▶ Student at McMaster University
 - ▶ Bachelor of Engineering and Management, Mechatronics Engineering (2023)
- ▶ Joined FRC in 2014
 - ▶ Team 1241/1285
 - ▶ Student (2014-2017)
- ▶ Gypsum Technologies
 - ▶ Mechanical Specialist Intern



Objectives

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



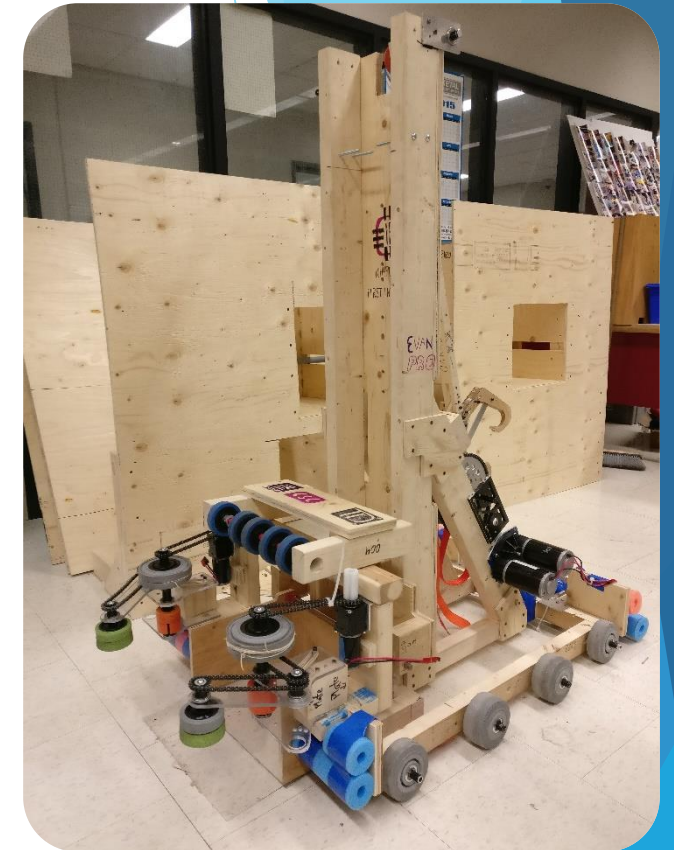
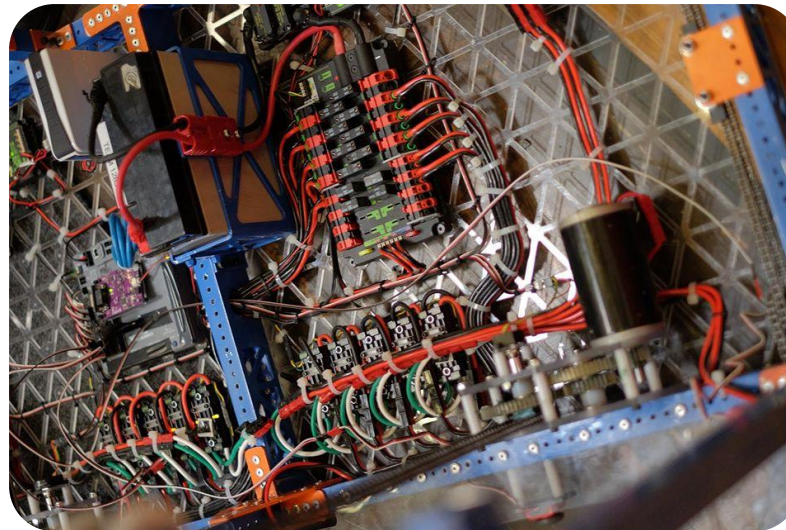
Tips For Designing

- ▶ 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, and choosing early
- ▶ 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
- ▶ 4:00pm - Movements and preferences
 - ▶ Determine all movements/tasks that your robot will complete
 - ▶ Outline the possible robot roles and identify the specific role that would be most successful given the resources of the team
 - ▶ Separate tasks into their respective subsystems

Kickoff Schedule - Sunday

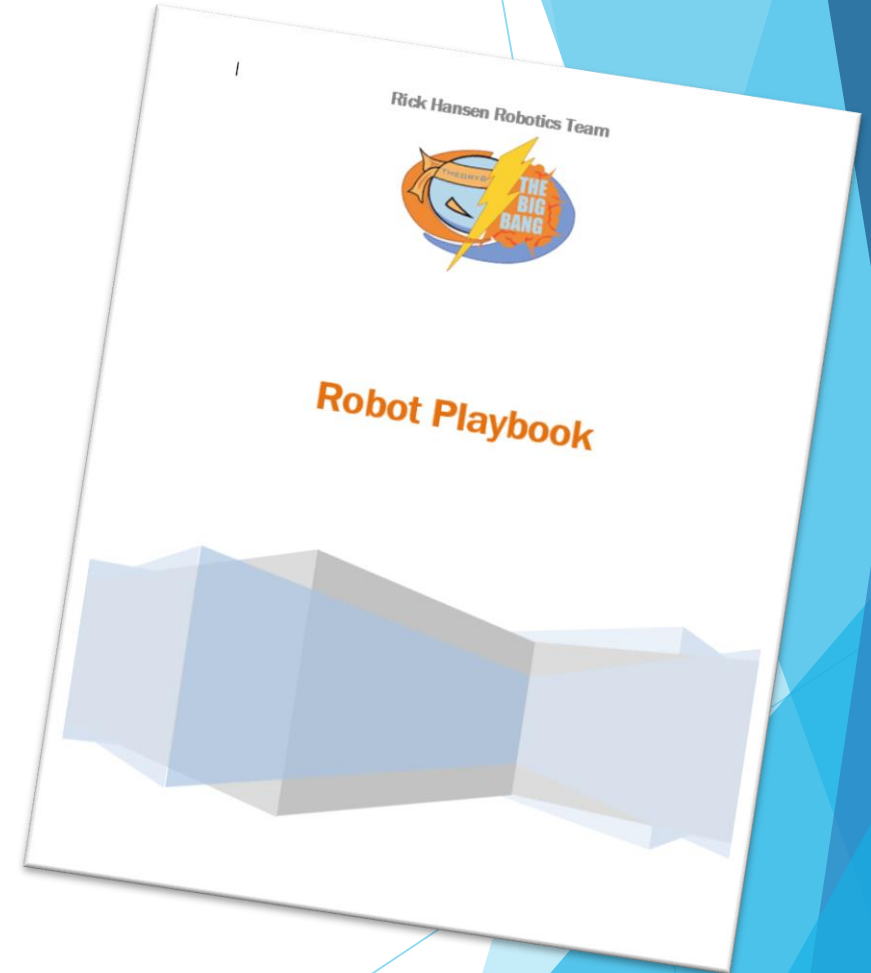
- ▶ 9:00am - Meet at location to discuss strategy/requirements list
 - ▶ Finalize the list of requirements
- ▶ 9:45am - Introduce Mentors/Leads for each section
 - ▶ Present strategy decisions from Saturday
- ▶ 10:30am - Discuss intake, tool, and end game design
 - ▶ Each Design must meet the requirements determined on Saturday
 - ▶ 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 studies
 - ▶ Detailed drivetrain design begins

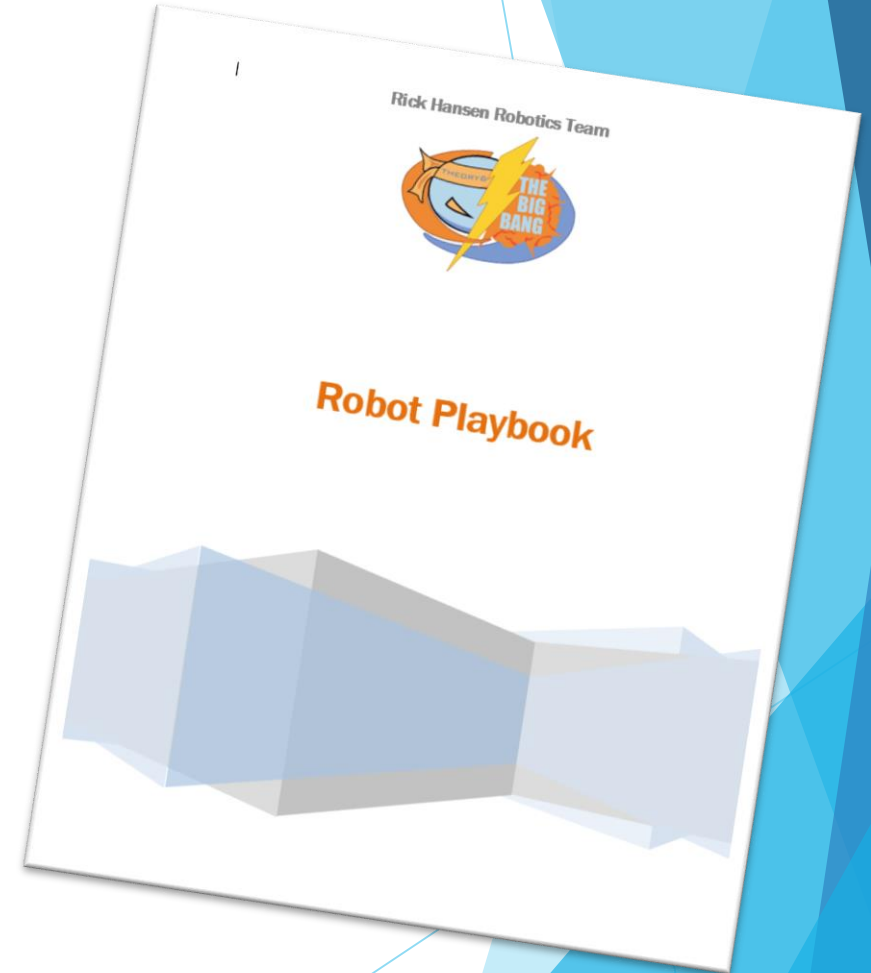
The Playbook

- ▶ 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.
- ▶ https://docs.wixstatic.com/ugd/0470e2_a5c58513b8d1446490efecfc1156e422.pdf



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
- ▶ 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
- ▶ ****This is becoming increasingly difficult, so we mean find methods that guarantee you scoring more than your opponent.

Scoring Breakdown

- ▶ List all possible ways of scoring in autonomous, tele-op and endgame
- ▶ Determine Maximum Score
- ▶ 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	-	-
	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	-	-
Pressure accumulation	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)

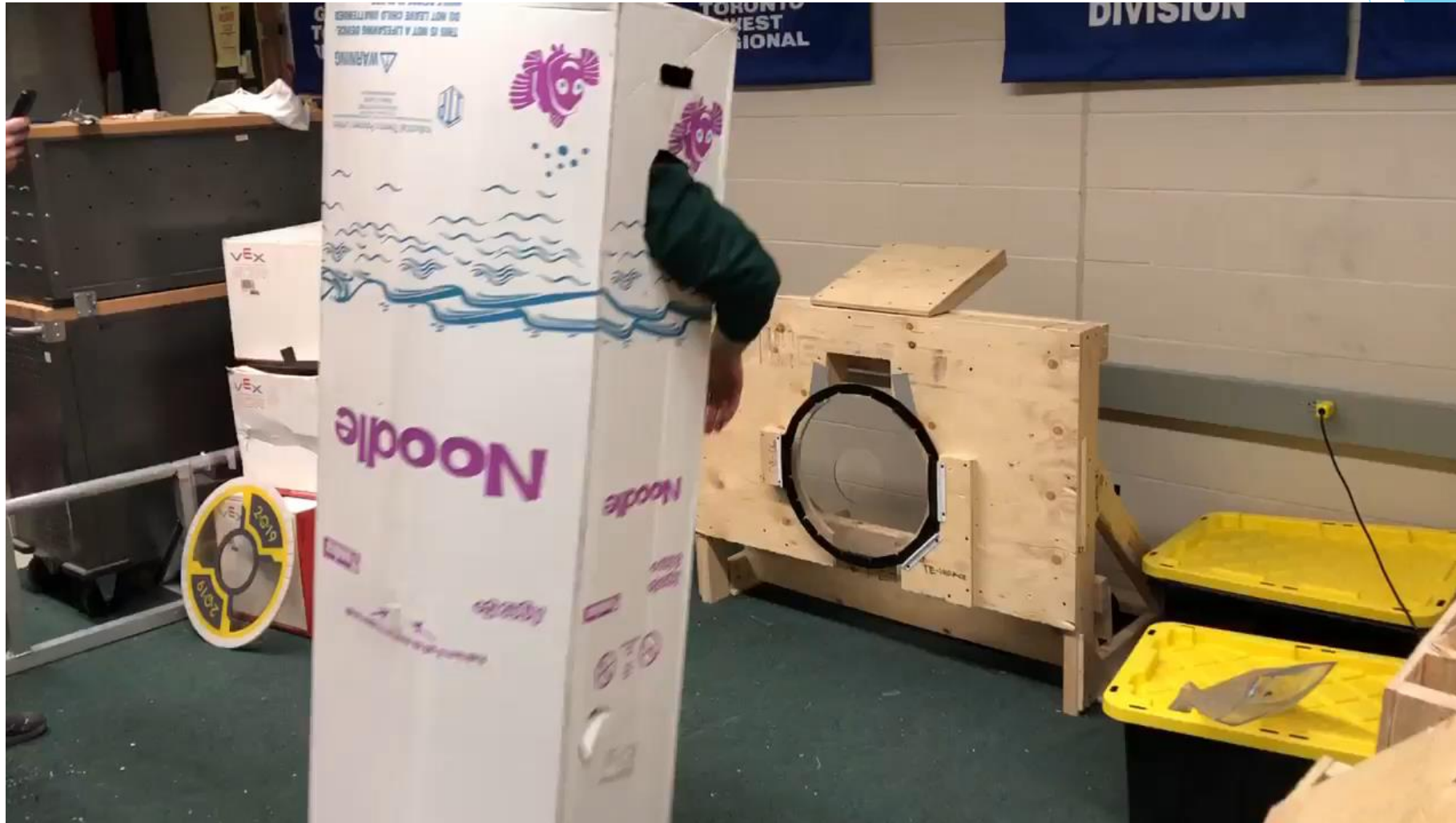
Movements and Preferences

- ▶ List all possible robot movements
 - ▶ Crossing x defence, stacking totes x high, etc.
- ▶ Determine robot roles and select which one you prefer
- ▶ Outline role specific benchmarks to be successful at that role
 - ▶ Able to solo x rotors, able to win the minibot race
- ▶ 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

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

Movements and Preferences



Movements and Preferences



Movement and Preferences

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., 2019 1619, 2767, 254 suction cup Level 3 climb
 - ▶ 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

Subsystem Categories

- ▶ Most (if not all) robots in FRC can be broken down into 4 (or less) main subsystems by tasks
 - ▶ 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.



Mechanism Selection: 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**



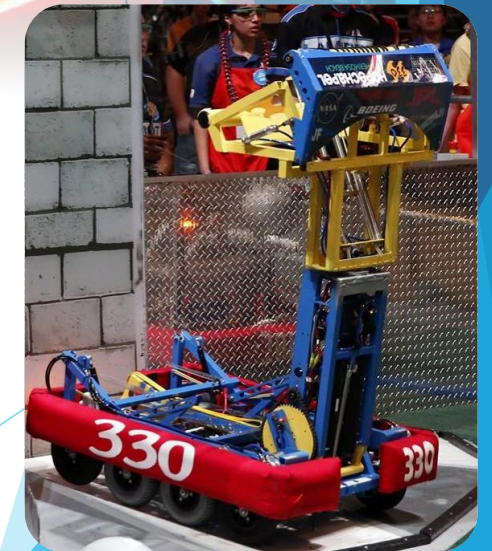
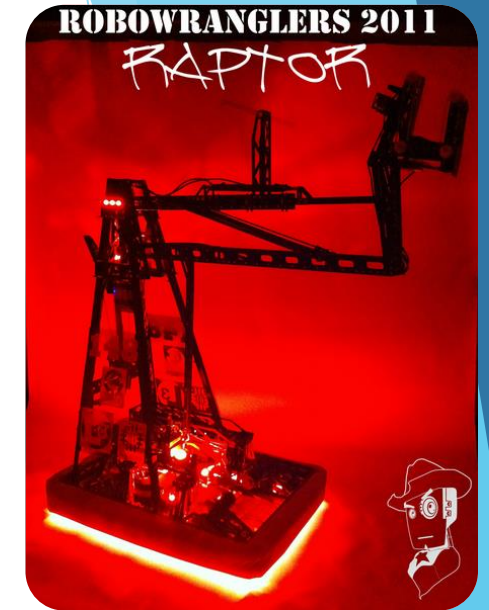
Mechanism Selection: Shooter

- ▶ 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 or can be expensive to do quickly



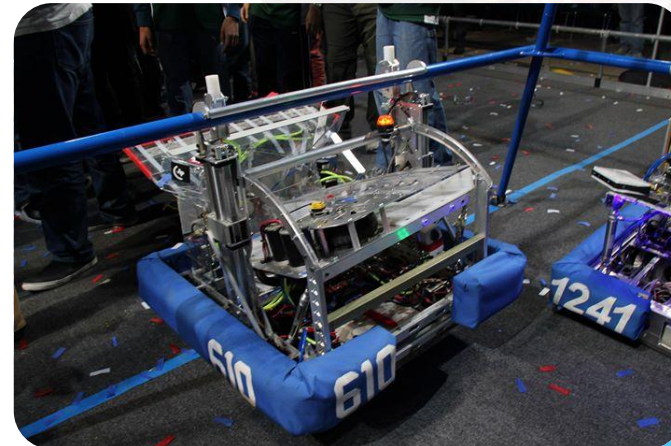
Mechanism Selection: Lift

- ▶ 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
 - ▶ Requires great attention to detail



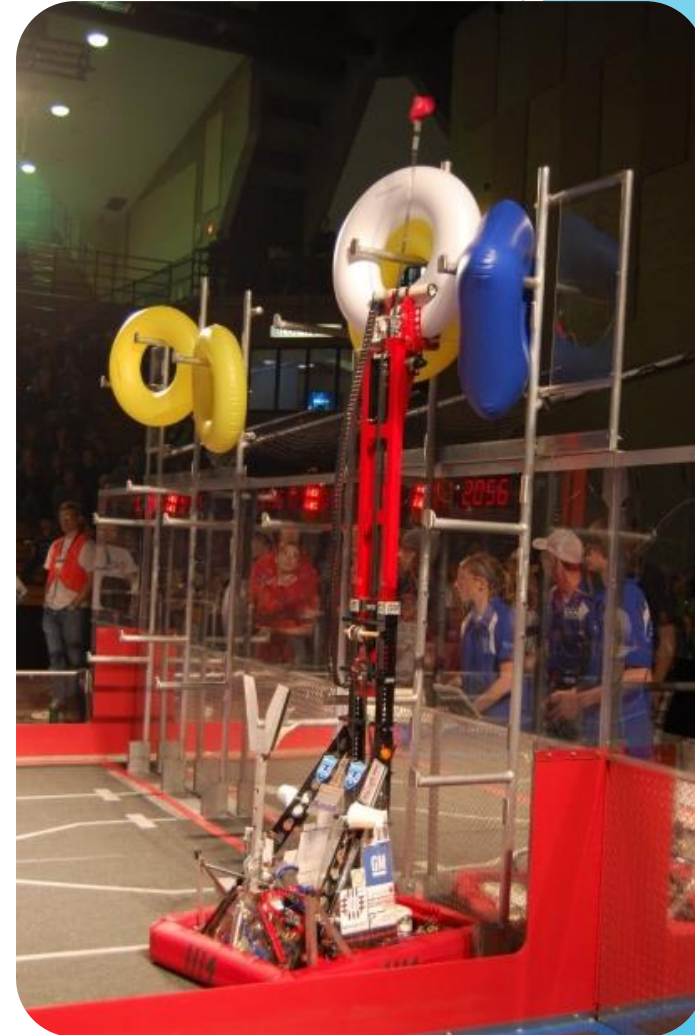
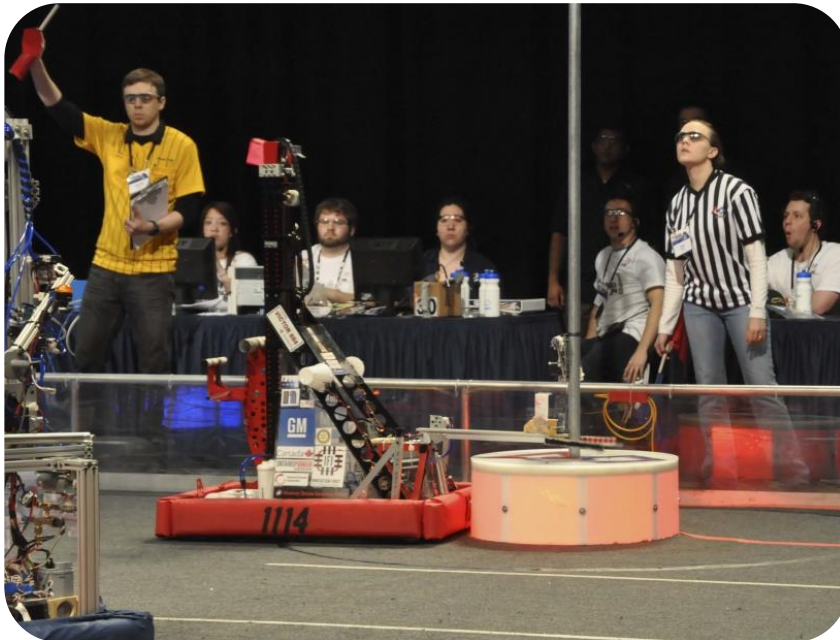
Mechanism Selection: Hanger/Climber

- ▶ 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 - 2017

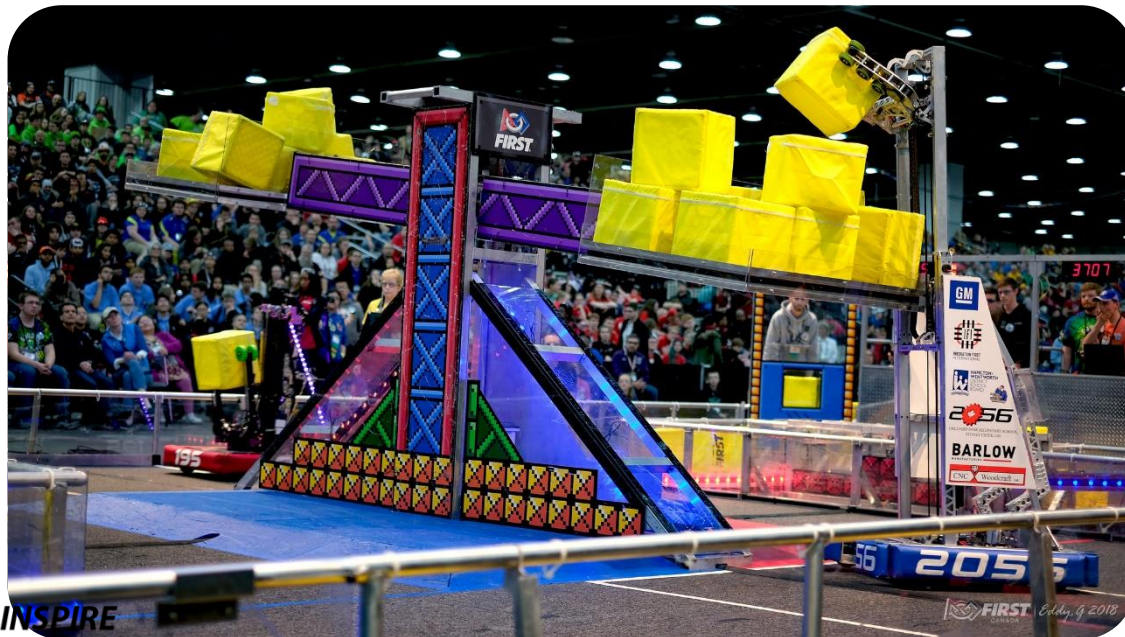
- ▶ 4 Rotor Offence and Defence
 - ▶ Defending the 4th rotor meant a point swing of over 100
- ▶ Key Autonomous: Hopper Auto
 - ▶ 3x value for fuel was essential to achieving 40rp early in the competition season



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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: 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: Breach opponents defenses (outerworks), Score boulders into opponents tower, and capture it.
- ▶ Boulders are obtained from 2 locations
 - ▶ Secret Passage - Located at your alliance wall station
 - ▶ Floor - Some boulders are located at the centre of the field before match starts, missed boulders can also be picked up
- ▶ Protected Zones: Secret Passage, and if you are contacting the outerworks
- ▶ End Game:
 - ▶ Capture the opponents tower once it is damaged by being on the batter or climbing the rung with bumpers a certain height above the floor
 - ▶ Points are awarded for capturing, and elevating

Mock Kickoff - Game Manual

Figure 2-2: Zones & Markings

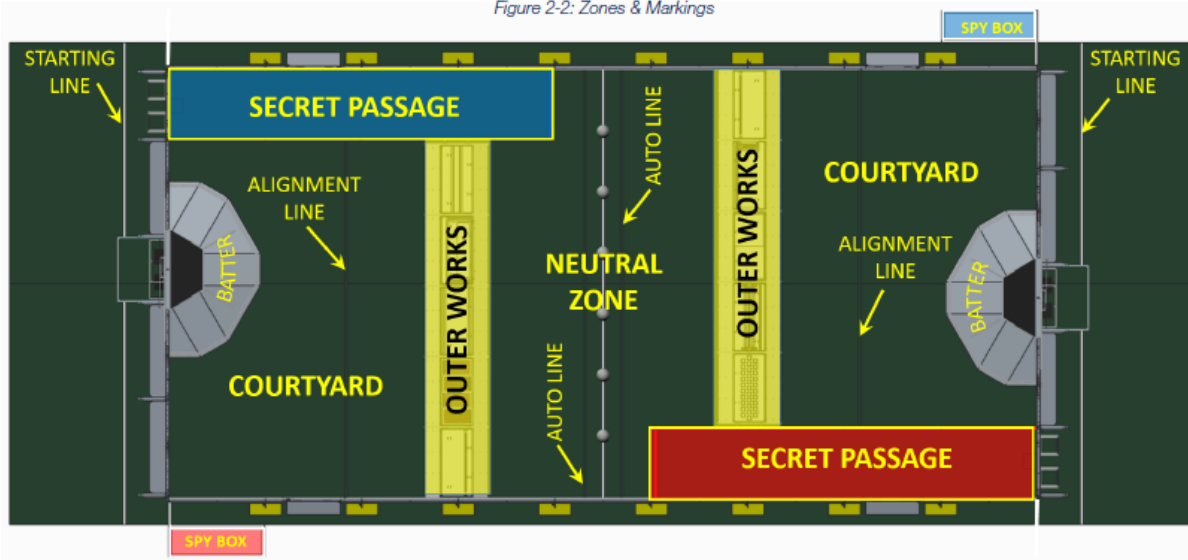
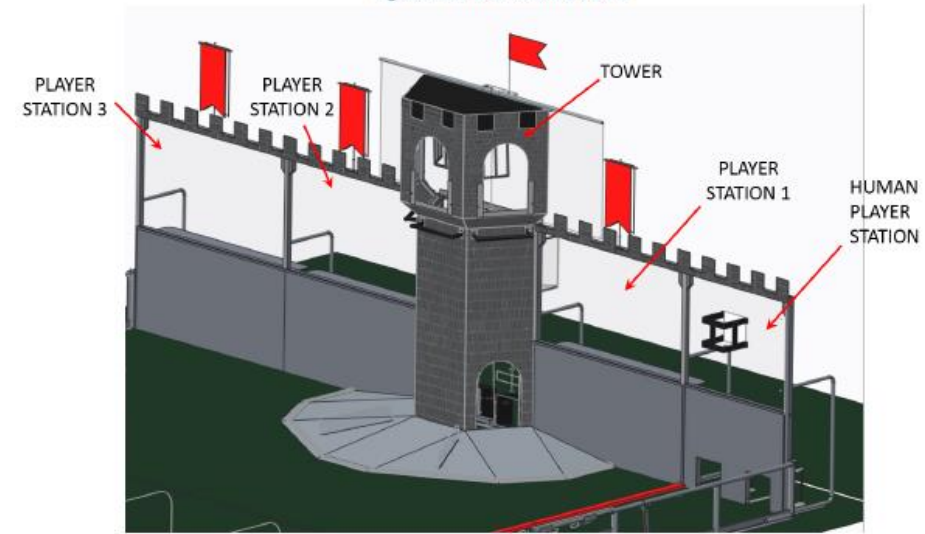


Figure 2-23: Red CASTLE WALL

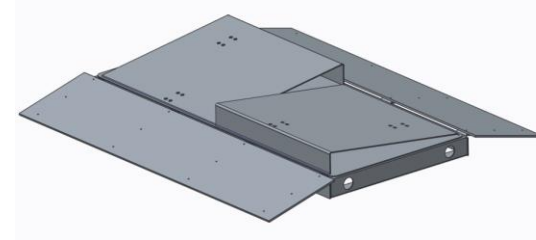
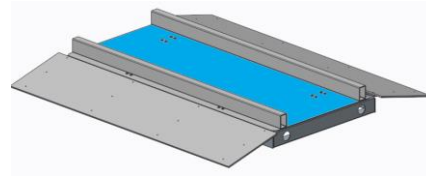
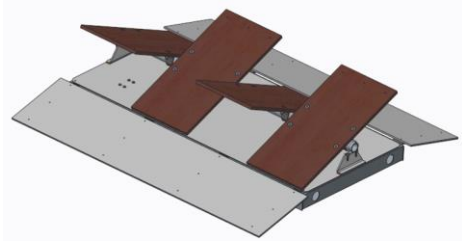


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Breach	-	-	1 RP	20
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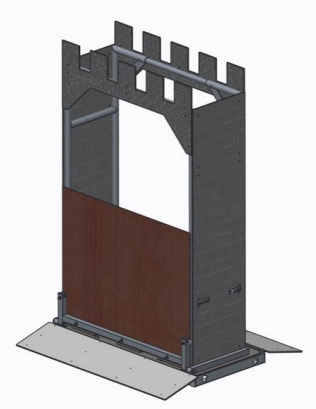
Mock Kickoff - Game Manual



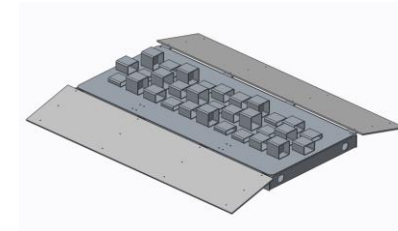
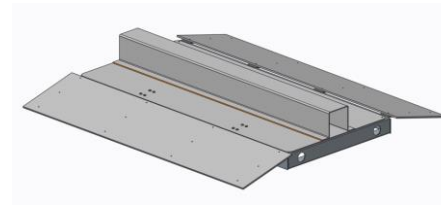
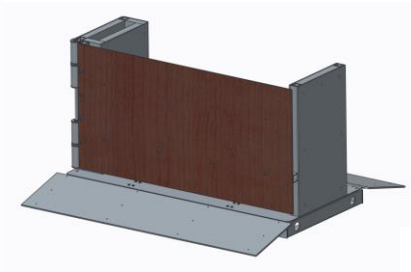
Category A



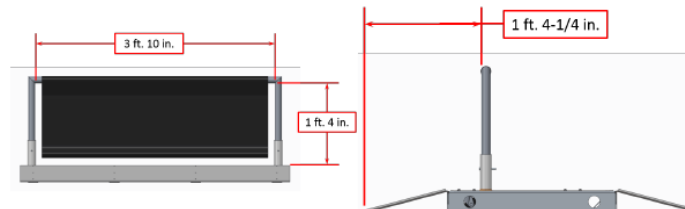
Category B



Category C



Category D



Low Bar

Mock Kickoff - List of Motions

- ▶ Tele-operated:
 - ▶ Driving
 - ▶ In all directions (categories A, B, C, D, Low Bar)
 - ▶ Able to pivot (on a dime)
 - ▶ Intaking a boulder from floor
 - ▶ Obtaining boulder from feeder station
 - ▶ Scoring a boulder(which goal? And from where on the field?) -> 8 boulders causes tower to be damaged and able to be captured
 - ▶ Crossing defenses (A, B, C, D, Low Bar) -> 80% defenses causes Breach = 1RP

Mock Kickoff - List of Motions

- ▶ Autonomous:
 - ▶ Crossing a defense (A, B, C, D, Low Bar)
 - ▶ Vision tracking goal
 - ▶ Scoring a boulder
 - ▶ Picking up boulder
- ▶ End Game:
 - ▶ Challenging the castle (getting onto batter = 5pts)
 - ▶ Scaling the castle rung (15pts)

Mock Kickoff - Scoring Analysis



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Mock Kickoff - Scoring Analysis (2013)

- ▶ 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
 - ▶ $45 \text{ discs} \times 3\text{pts} + 6 \text{ discs} \times 5 = 165$
 - ▶ 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

- ▶ Cross defenses A, B, D, Low Bar
- ▶ Traverse secret passage
- ▶ Score in high goal (10pts during Autonomous, 5 points during Teleop) from outerworks and from courtyard
- ▶ Score in low goal (5pts during Autonomous, 1 point during Teleop)
- ▶ Camera tracking for scoring
- ▶ Obtain boulder from floor
- ▶ Climb onto rung during endgame

Mock Kickoff - Subsystem Roles

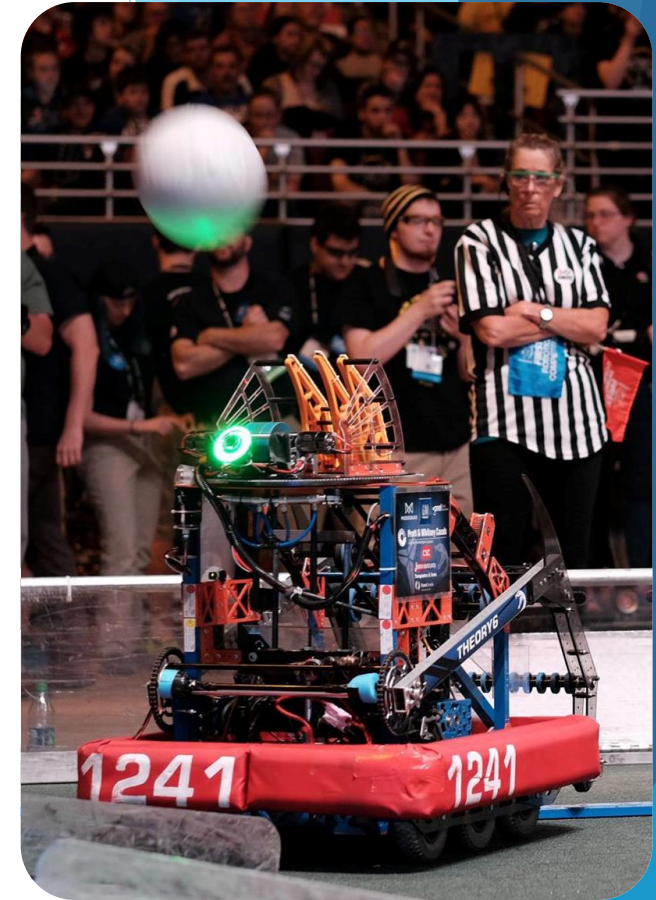
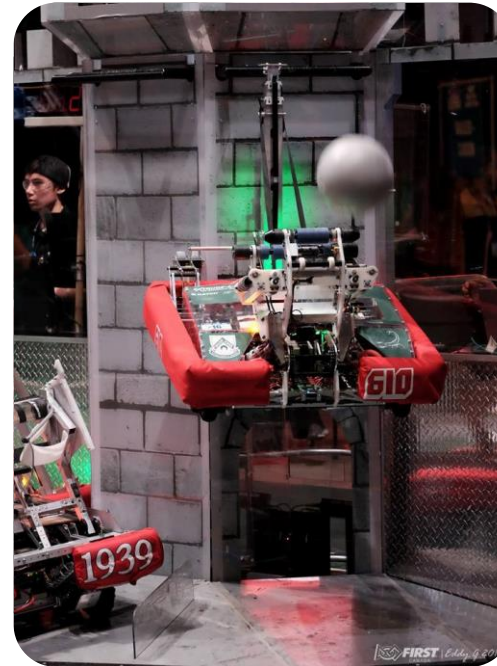
- ▶ Assign your all your needs to the general subsystems (you may not need all of them)
 - ▶ Drive
 - ▶ Intake
 - ▶ Tool
 - ▶ Endgame

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? Catapult vs Flywheel
- ▶ End Game:
 - ▶ Climb on the rungs?
 - ▶ Pneumatic or winch?

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



Winning Designs



Mock Kickoff - Waterloo Regional 2016



Questions?



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Thanks for Coming!

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