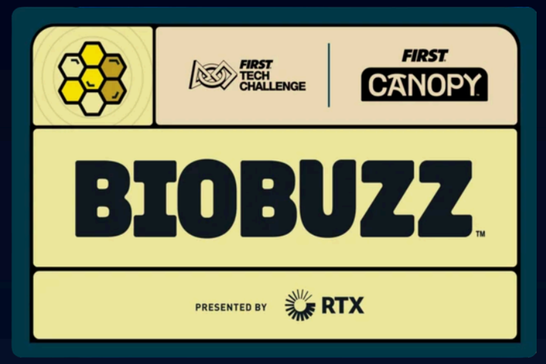


FIRST TECH CHALLENGE

ROBOTICS ENGINEERING & DESIGN

Neil Benjamin and Jason Zhu

Engineering Co-Leads
Grizzly Tech #23929

9/1/26

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1 Mechanical Design Fundamentals

2 Overview of FTC

3 Chassis/Drivetrain

4 Motors/Servos

5 Subsystems

6 Custom Machining

7 Control System

8 Conclusion

MECHANICAL DESIGN FUNDAMENTALS



ENGINEERING DESIGN PROCESS

Definition: Identify exactly the problem you are trying to solve

Research: Build off of existing ideas, approaches, and products

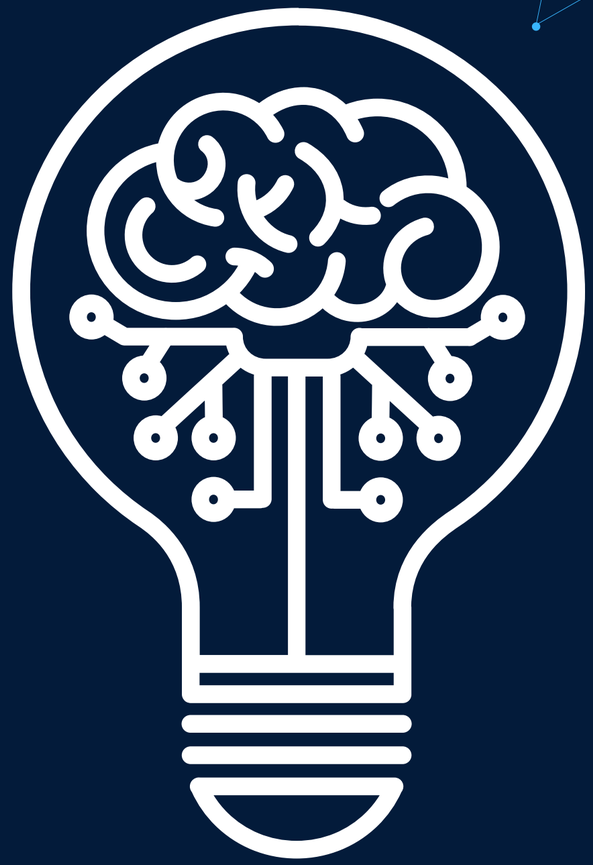
Conceptualization: think of as many solutions as you can

Realization: Determine which idea is the “best”, and why

Build: Prototype and develop your solution

Test: Experiment with your product and evaluate its performance

Iterate: Make improvements. rinse and repeat



KEY STRATEGIC PRINCIPLES

1. **WEIGHT DISTRIBUTION**
2. **STABILITY + BALANCE**
3. **MODULARITY**
4. **PRECISION + ALIGNMENT**
5. **ACCESSIBILITY**
6. **TONS OF TESTING + ITERATION**



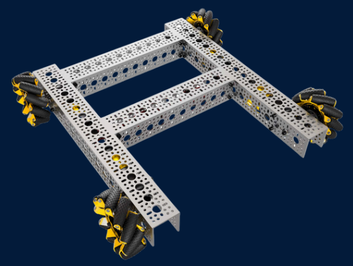
DISCUSSION

WHY IS DESIGN STRATEGY SO IMPORTANT IN ROBOTICS?

DISCUSSION

WHAT ARE THE STEPS OF THE ENGINEERING DESIGN PROCESS?

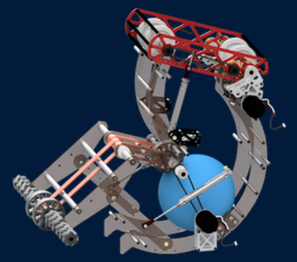
OVERVIEW OF FTC ROBOT SYSTEM



Chassis/Drivetrain



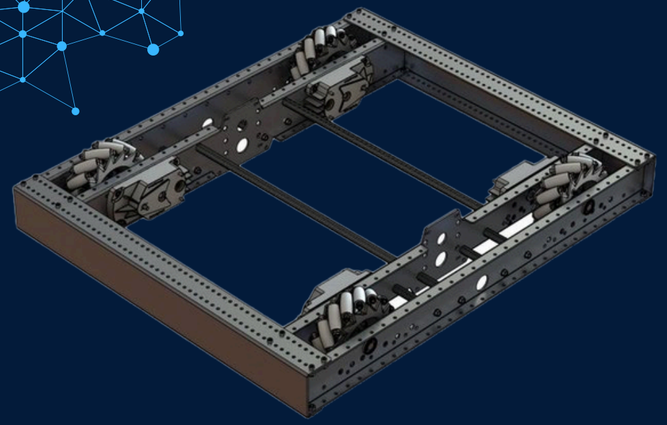
Motors/Servos

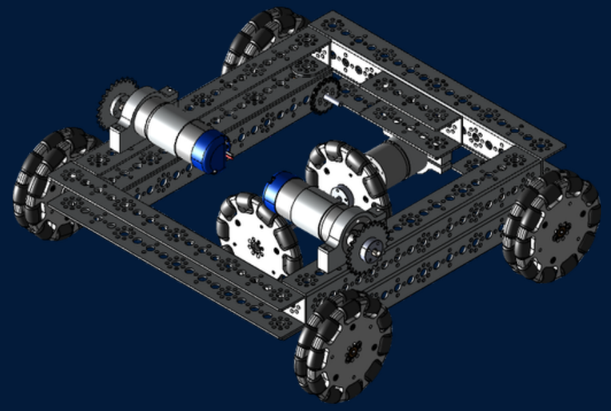


Subsystems

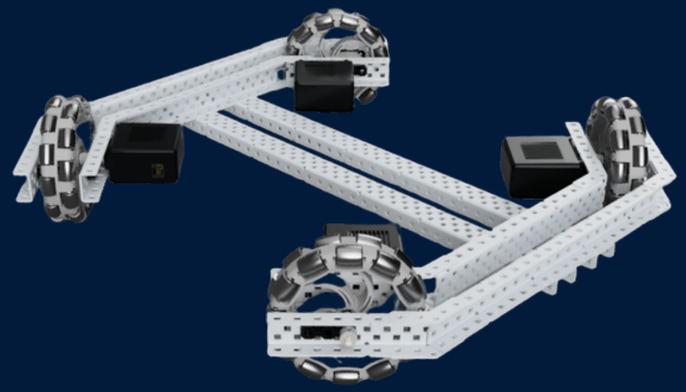


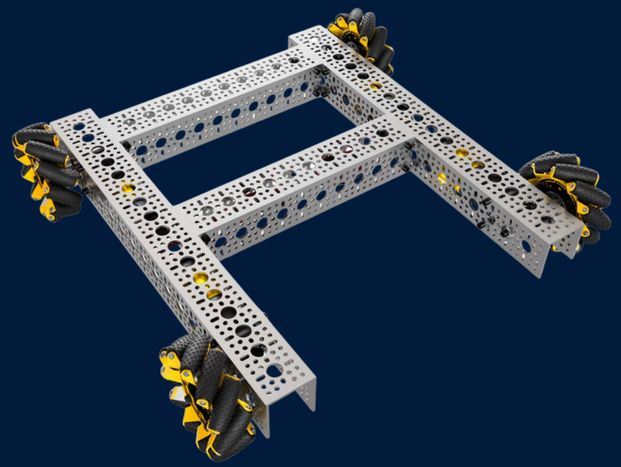
Control System





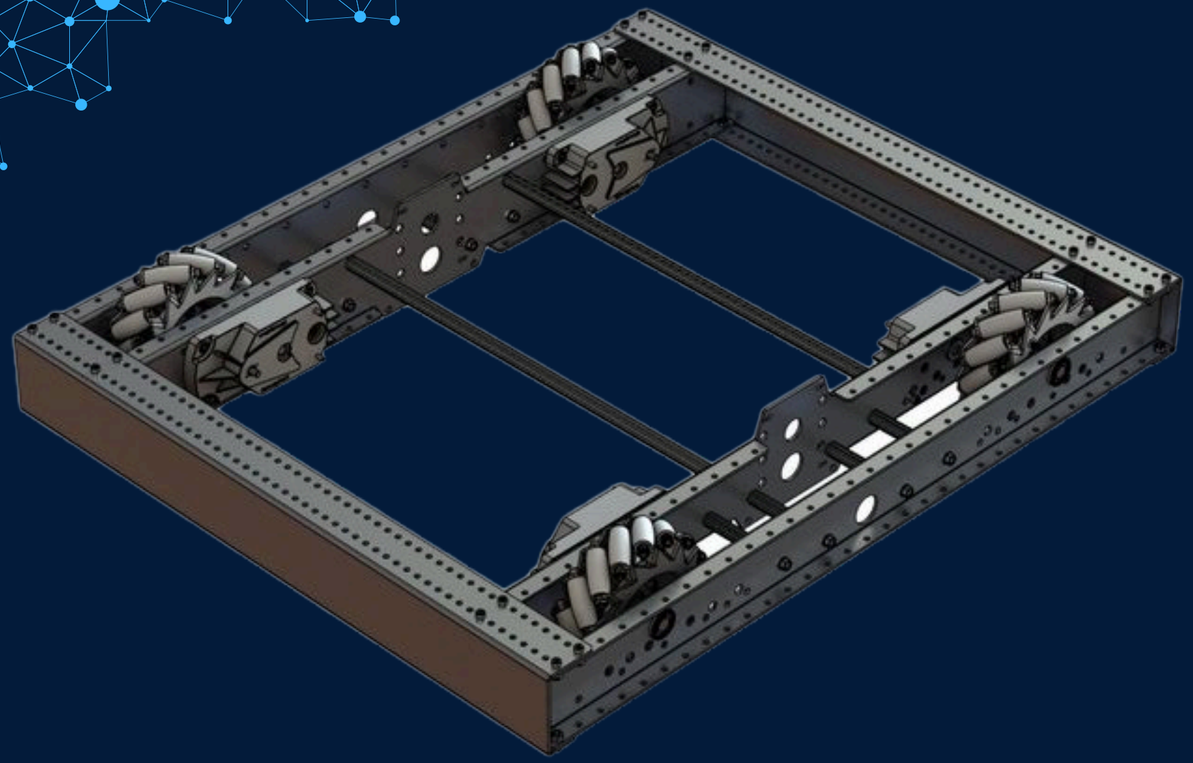
CHASSIS/ DRIVETRAIN





- Base/Fundamental for the robot
- Usually consists of 4-6 wheels
- Facilitates movement of robot & Crucial for the function of the robot
- If the drivetrain doesn’t work, the robot won’t work!

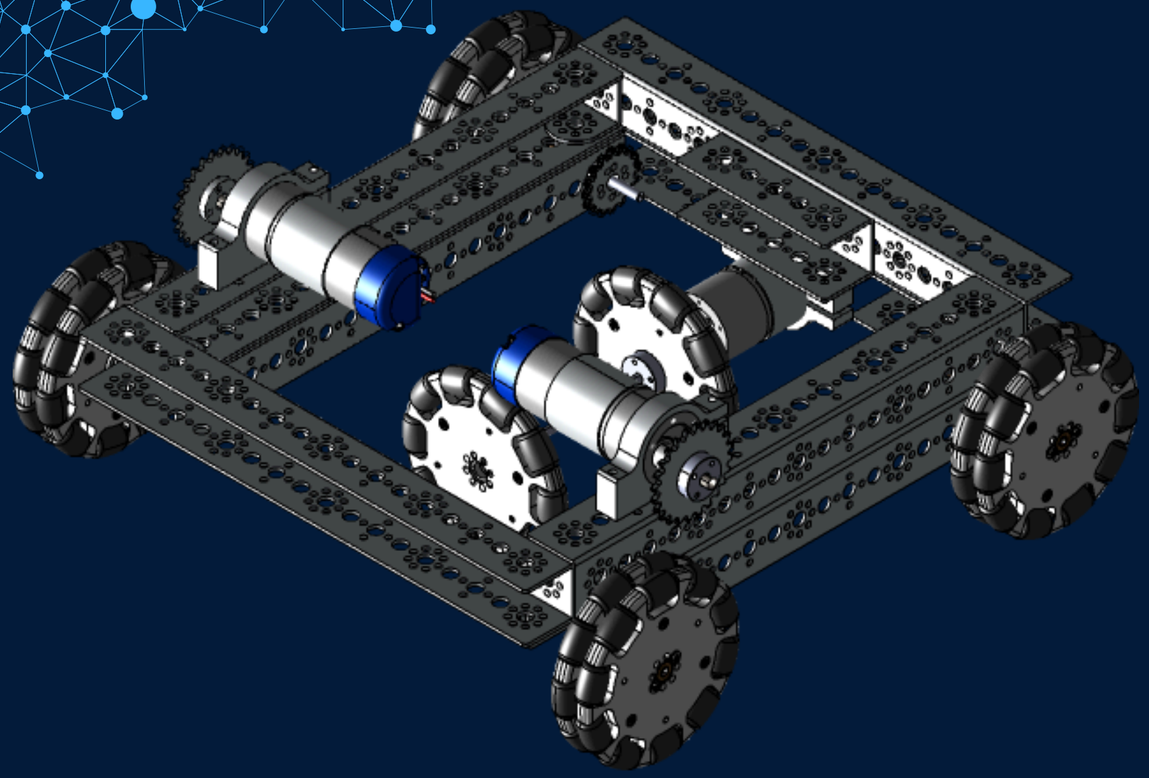
TANK DRIVE



- Typically uses traction wheels
- To turn:
  - Turn left and right wheels in opposite directions
  - Turn one side faster than the other

Pros	Cons
Good acceleration	Poor manuverability
Prioritize Traction	Cannot move sideways
Great defense	Less powerful

H-DRIVE



- Holonomic Drivetrain
- Uses all Omni wheels
- Relies on “strafer wheels” perpendicular to forward/backward wheels to acheive strafing

Pros	Cons
Combines Tank + Holonomic advantages	Strafing is slightly less effective than Mecanum
Great Manuverability	Complex suspension occasionally needed
Good traction + speed	

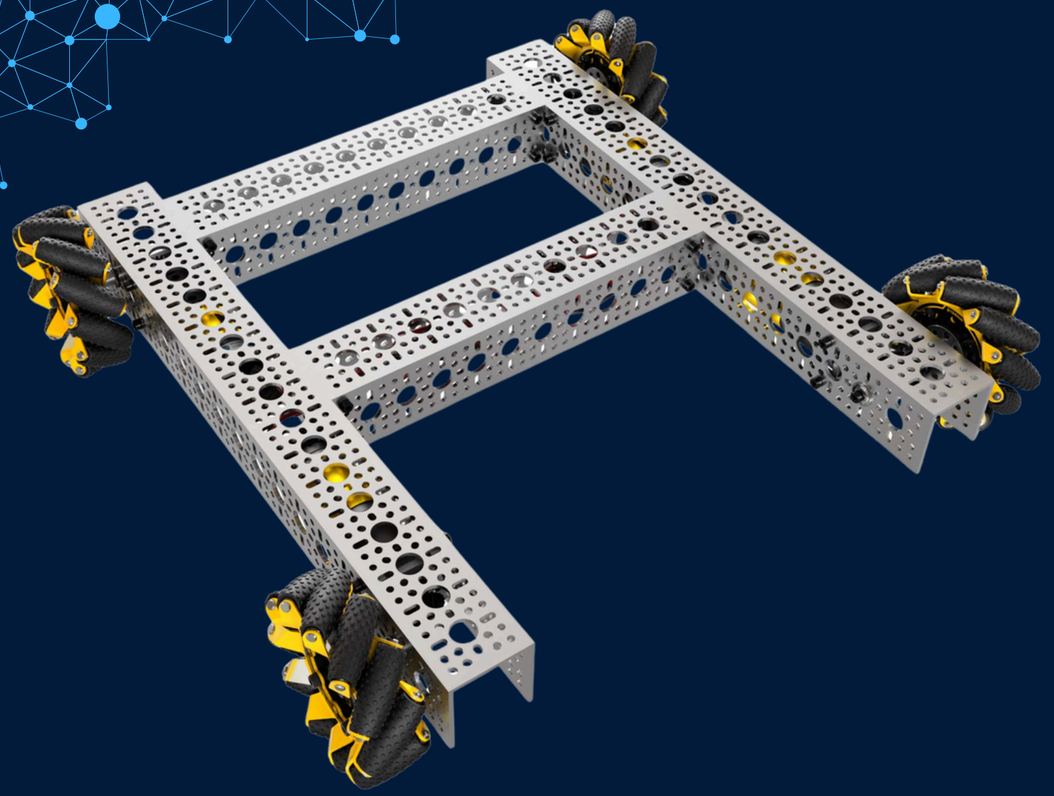


X-DRIVE

Pros	Cons
Good manuverability	Pushed around easily
Good acceleration	Awkward / Difficult packaging
Good traction + speed	

- 4 omni wheels mounted at 45 degree angle
- X-Drive Bot’s strafe + forward speed are equivalent

MECANUM



- 4 Wheel drive
- Mecanum wheels consist of 45 degree rubber rollers
- Running diagonal motors will allow it to strafe

Pros	Cons
Great manuverability	Drift/Slippage
Versatile Drivetrain	Able to be pushed around in defense
Good acceleration, can reach top speeds	Wheels must be powered independently

TRADEOFFS

Wheel size:

- Larger Wheels → more speed, less torque
- Smaller Wheels → more torque, less speed
- Choose based upon game field and obstacles

Wheel Type:

- Traction Wheels - high grip, resulting in good pushing power
- Omni wheels - smoother turning, less traction
- Mecanum wheels - full omnidirectional movement, but reduced pushing power

Gear Ratios:

- High Gear Ratios: more torque, less speed
- Low Gear Ratios: less torque, high speed
- Match ratio to robot weight and task demand

MOTORS/SERVOS

Crucial for moving parts on the robot
Powers wheels & parts of the subsystem

Motors

- Best for running heavy subsystems (e.g: active intake)
- Continuous 360 degree rotation
- Different RPM (Rotations Per Min) adapt to specific scenarios
- Faster motor = less torque
- Slower motor = more torque

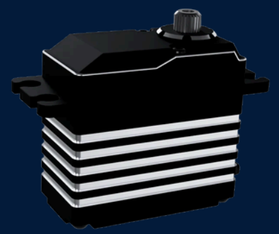




Servos

- Limited range (usually 180-270 degrees)
- Can be continuous rotation
- Best for precise movement (e.g: arms, gates)
- Torque and speed depend on power

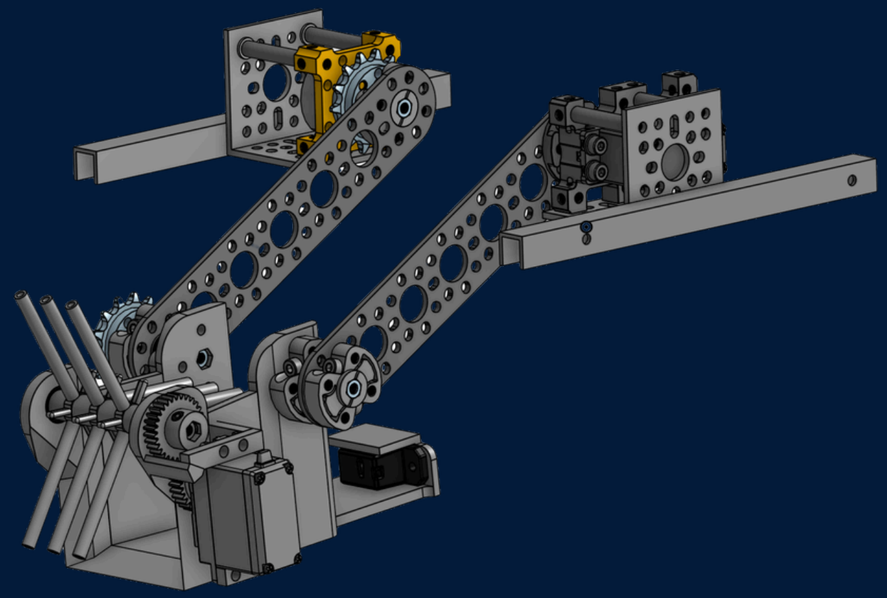




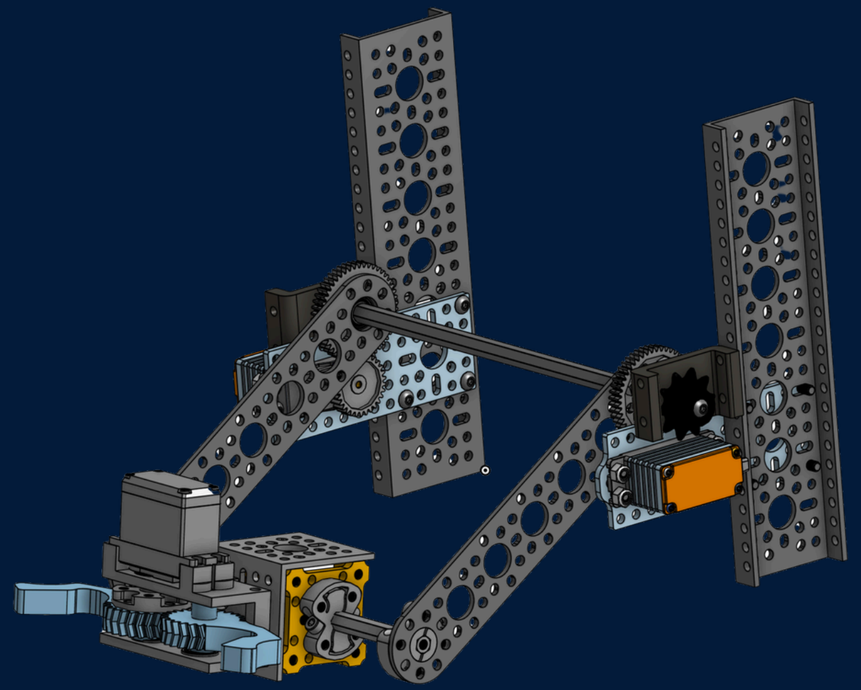
SUBSYSTEMS

Crucial for playing the game
(mechanisms to score points)

Intake



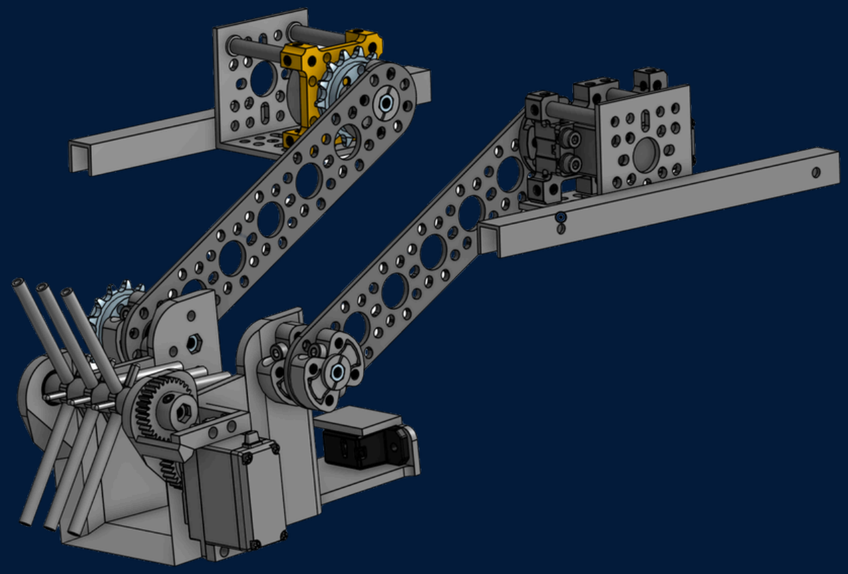
Outtake

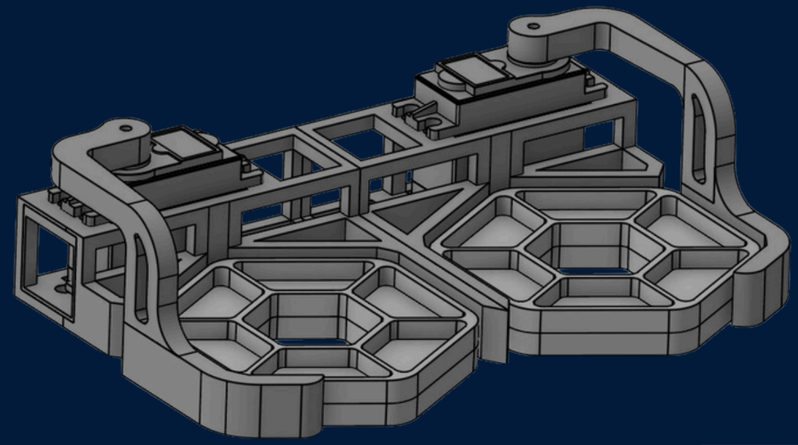


INTAKE

- Crucial for obtaining objects from the ground
- First stage of scoring process
- Effiiency here affects the robot performance most!

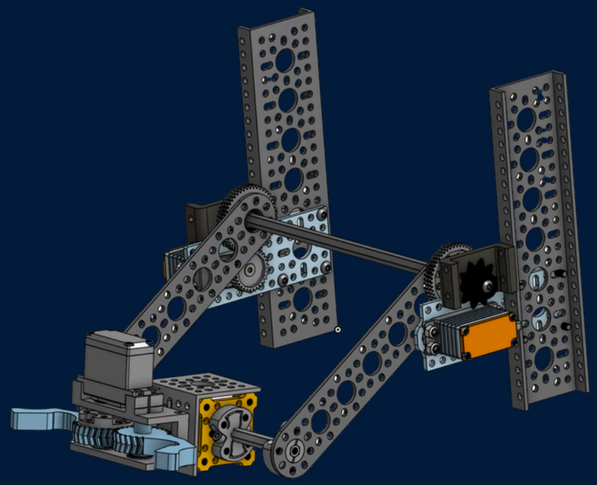
Passive Intake	Active Intake
Uses no motors	Uses forms of wheels to suck the object in
Relies on contact of game element	Excel at picking up large pieces
Claws/grabbers, sloped funnels, etc.	Can pick up multiple elements



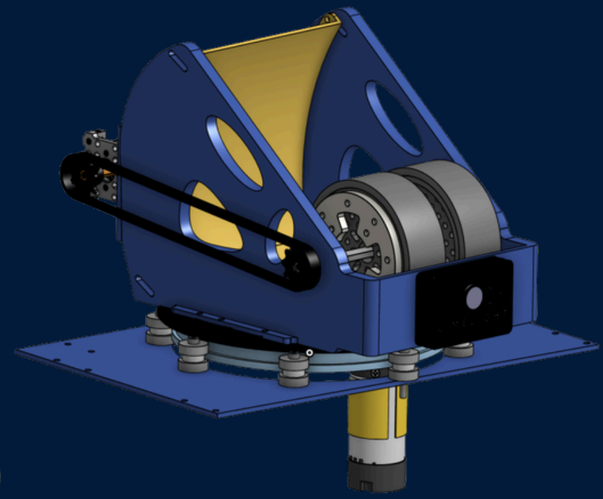




OUTTAKE/TRANSFER



- To transfer the game element to a next stage of scoring
- Direct transfers, flip up transfers, conveyor transfers, etc.



- Direct Hand-Off (Active-to-Active): The intake directly places the game piece into the outtake mechanism (like a claw or bucket) without dropping it
  - Requires precise sensor integration and alignment, but offers high reliability

- Flip-Up / Pivoting Transfers: The intake pivots back or tilts upward to gravity-feed or eject the game element directly into the elevator or scoring assembly



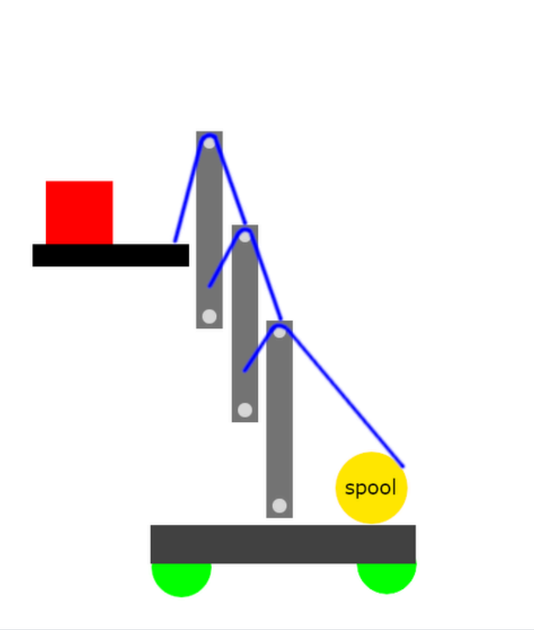
- Conveyor & Ramp Transfers: Driven by compliant wheels, surgical tubing, or continuous belts to channel game elements upward from ground level into a scoring bin or launcher



LINEAR EXTENSION

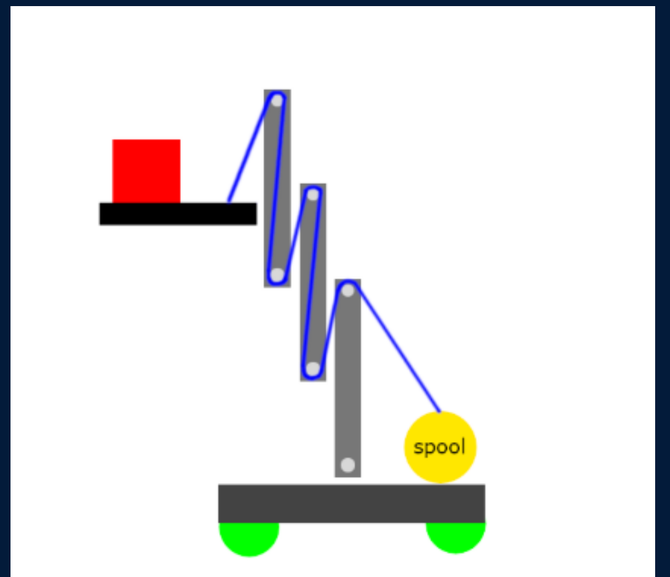
Horizontal or vertical extension

- Reaching for:
  - Game element
  - Scoring area
- String driven / Belt driven slides
- Continuous stringing
  - Easy to set up and requires less motor force
  - Slow due to all stages moving one at a time
- Cascade Stringing
  - More complex stringing
  - Faster extension, more efficiency
  - Places more strain on string/belt, harder to set up
- Retraction:
  - Return string + spring system retracts slides (string-driven)
  - Continuous (no secondary string on belt-driven)



CASCADE

CONTINUOUS





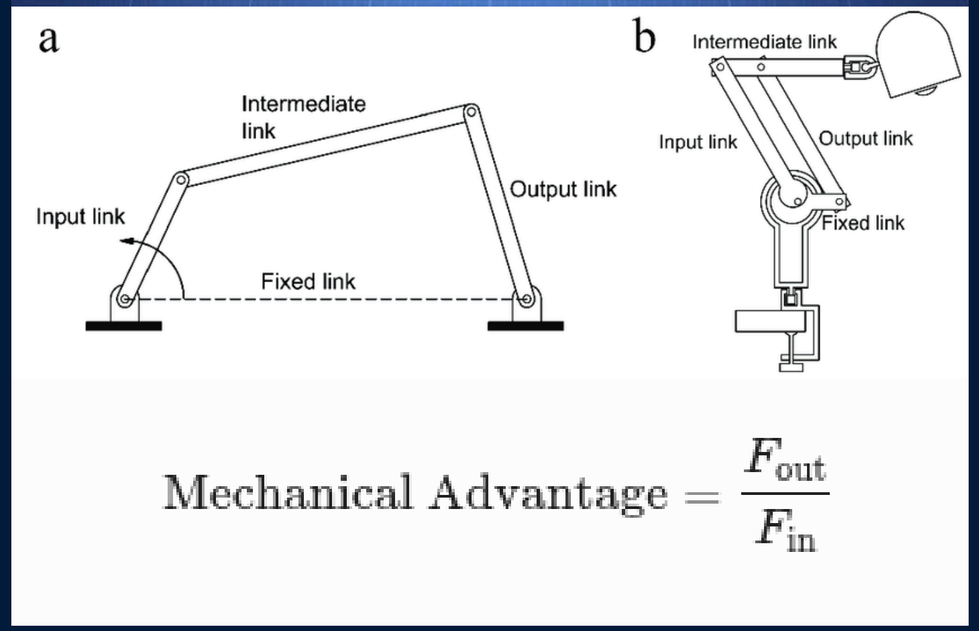
LINKAGES

- Four-Bar Linkage: Keeps the end-effector (claw/intake) parallel to the ground or at a fixed angle throughout the entire motion profile
- Virtual Four-Bar (V4B): Uses belts, chains, or sprockets across a pivot joint to mimic a standard four-bar motion, saving significant weight and mechanical space
- Scissors Linkage: Uses crisscrossed links to achieve long linear expansion, though rarely preferred in FTC due to stability issues and slop.

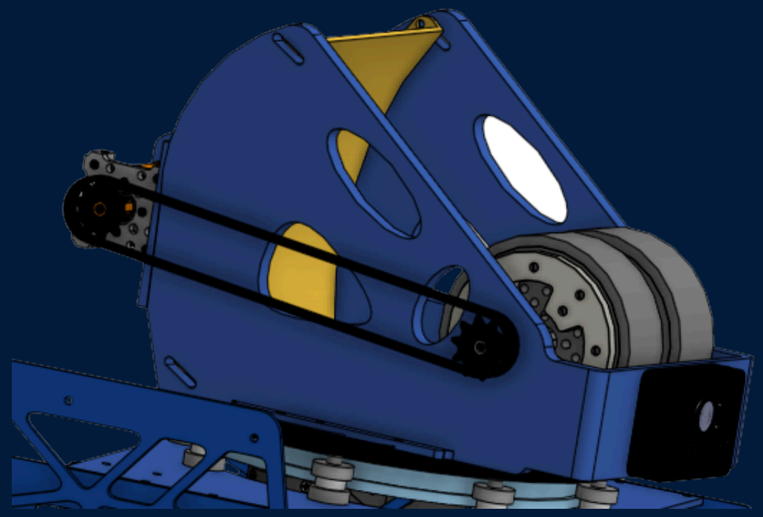
Key Advantages in FTC

- Speed & Simplicity
- Custom Motion Curves
- Altering mechanical advantage





POWER TRANSMISSION



- Efficient way to transfer rotational energy from motors to mechanisms (best when having to deal with spacial constraints)

Direct Drive: Directly mounting end effector/mechanism onto the shaft of motor or servo

- Simple but can wear gearboxes easily over time

Gears: Transmitting rotational force through interlocking teeth of two gears

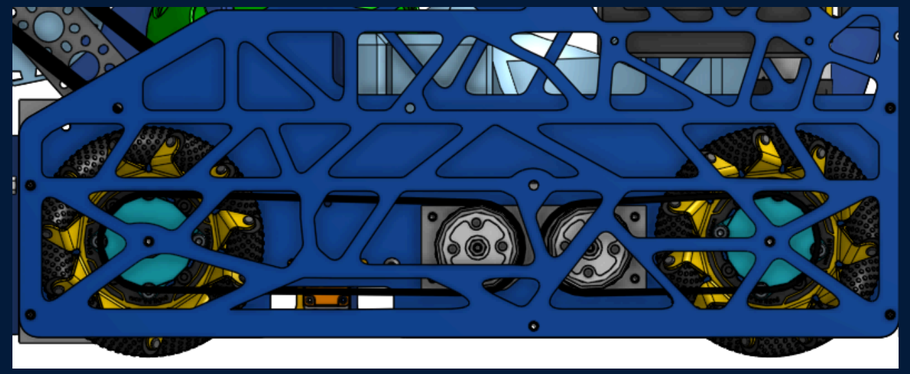
- Compactness + speed/torque reductions but must be precise

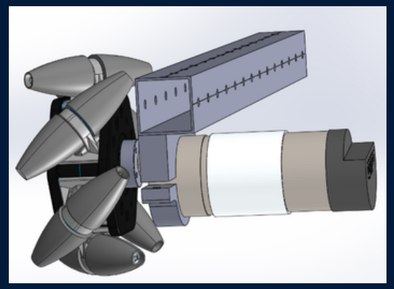
Chains & Sprockets: Using interconnected links driven by toothed wheels

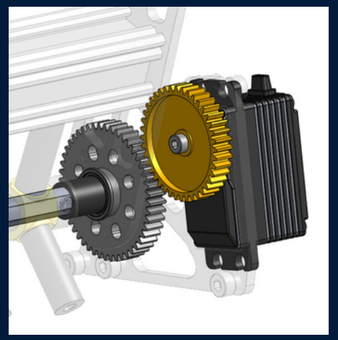
- Best for high torque applications, easily customizable length, can cover distance

Timing Belts & Pulleys: Similar to chain & sprocket;

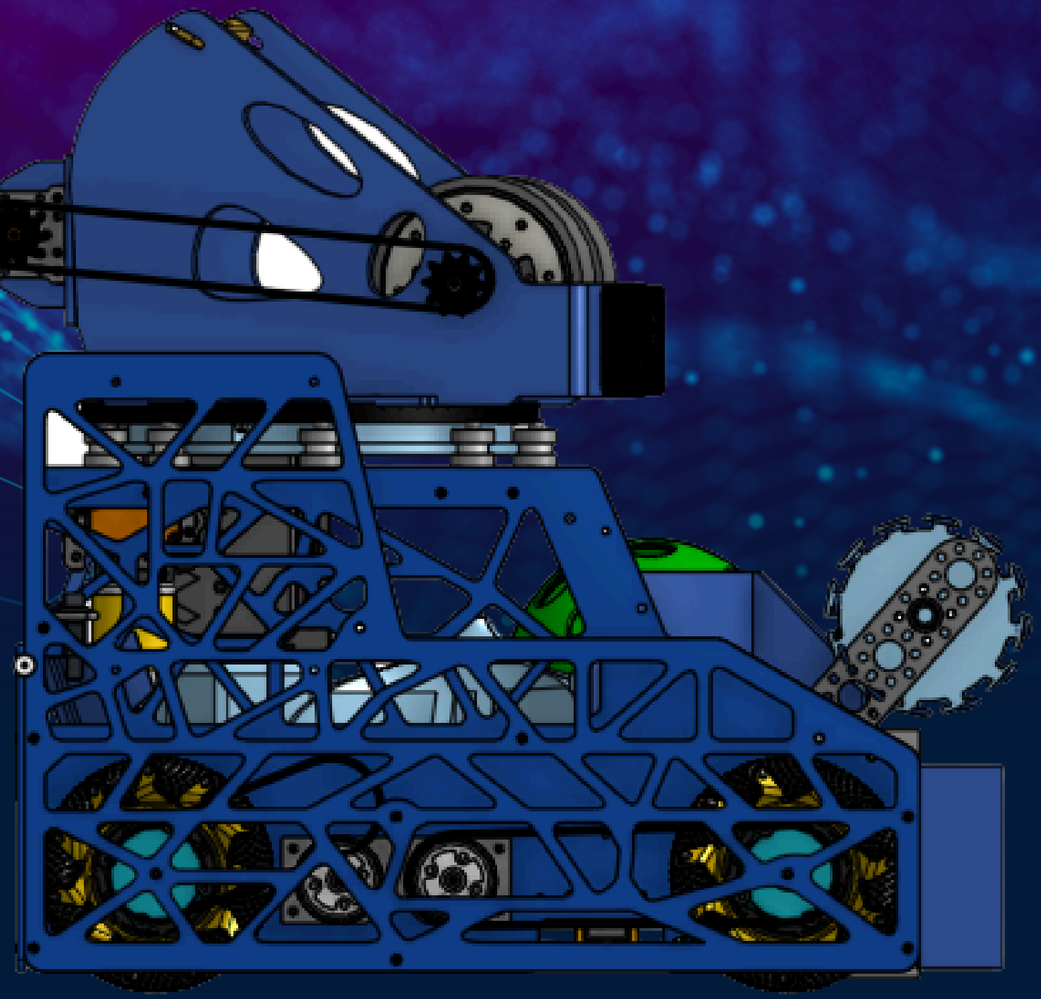
- Great for drivetrains, high speed intake rollers, linear motion











- 3D Printing: CAD First, then can print using .stl file
- Laser Cutting / Waterjet cutting
- Made out of Aluminum, Steel, Carbon Fiber, etc.
- CNC Machining
- Good for custom drivetrains, custom subsystems

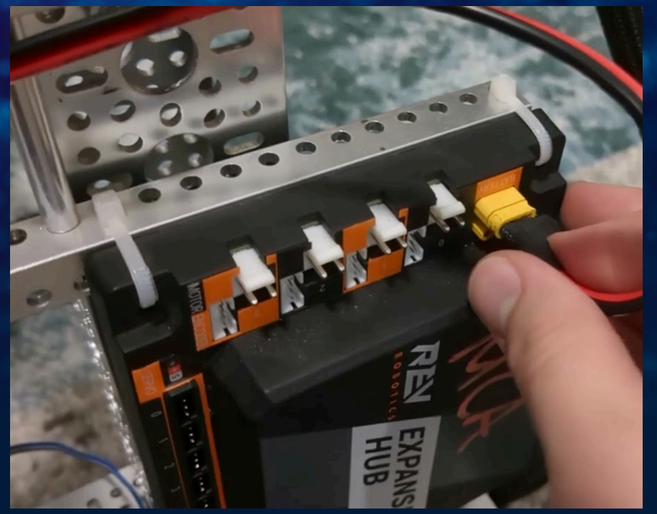
CUSTOM MACHINING

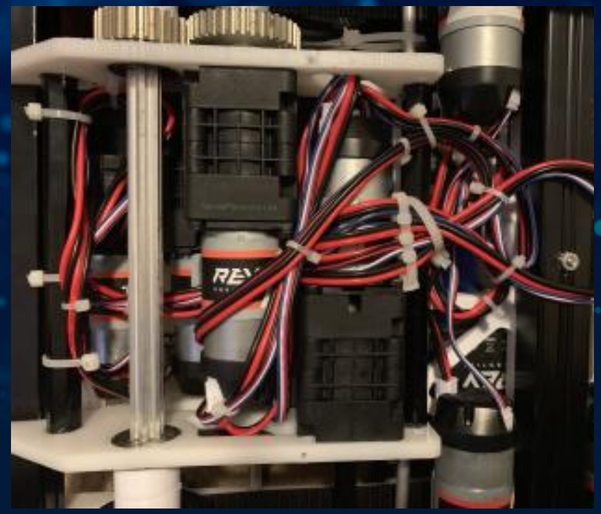


DISCUSSION

WHAT ARE SOME TYPES OF CUSTOM MACHINING?

CONTROL SYSTEM



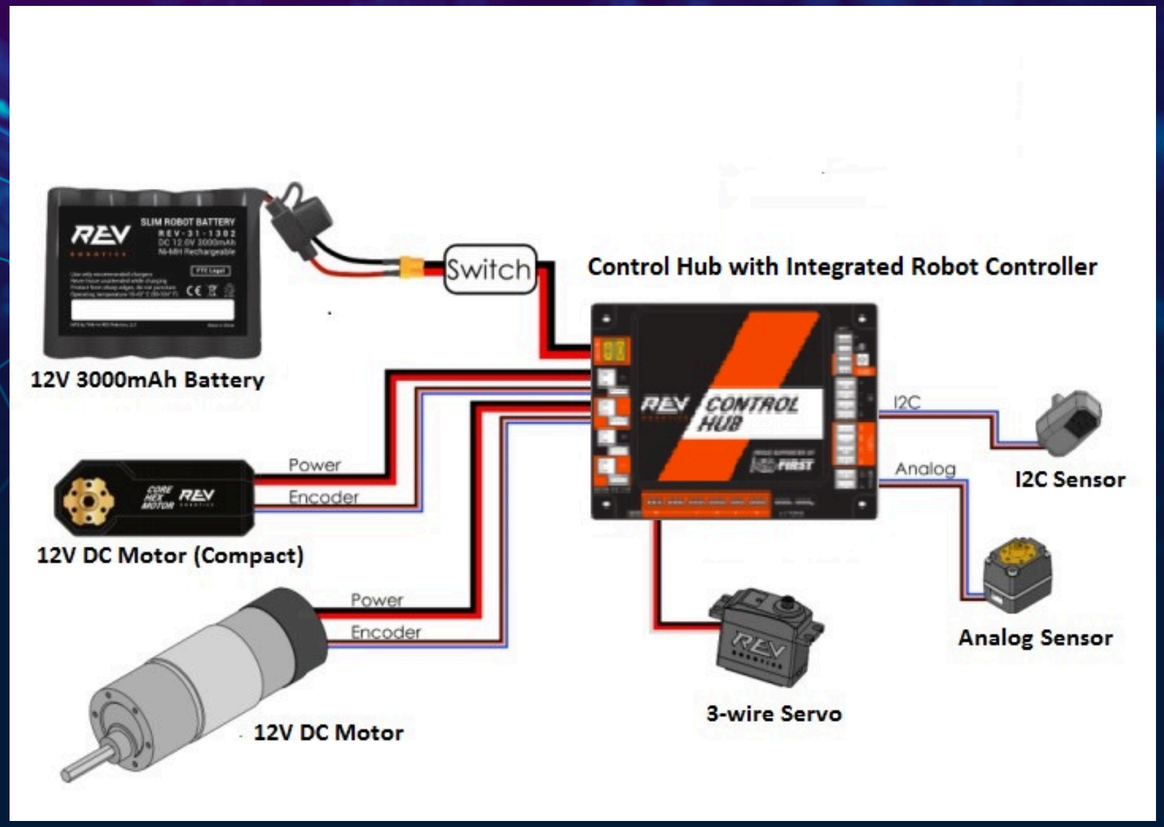


Electronics

- Hubs for code deployment
- Odometry pods

Wiring

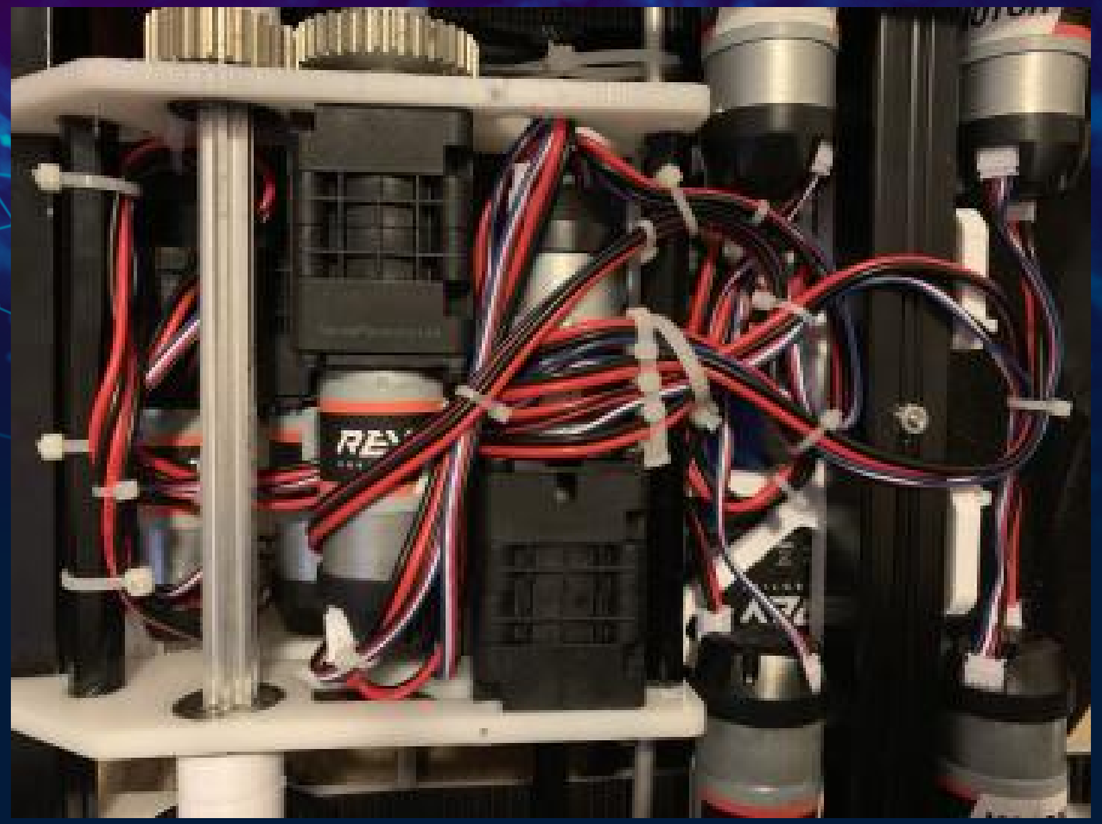
- Power, Data, Motion Execution
- Wire management



- Control Hub + Expansion Hub for powering robot
- Driver hub for managing robot operations
- Up to 8 motors and 10 servos
- Odometry pods for localization, tracking, etc for autonomous
- Color sensors
- Distance sensors
- Infrared sensors
- LED lights

ELECTRONICS





WIRING

- Main power cables
- Battery + battery cable adapter
- Data/Communication wiring
- Servo wiring
- Motor wiring
- Encoder cables (for both odo pod + motor)
- Cable Management: Sleeves, Coils, etc.

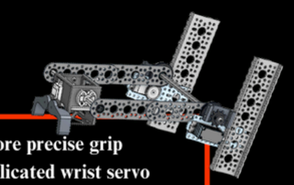


2024-2025 Season

Mechanical Design

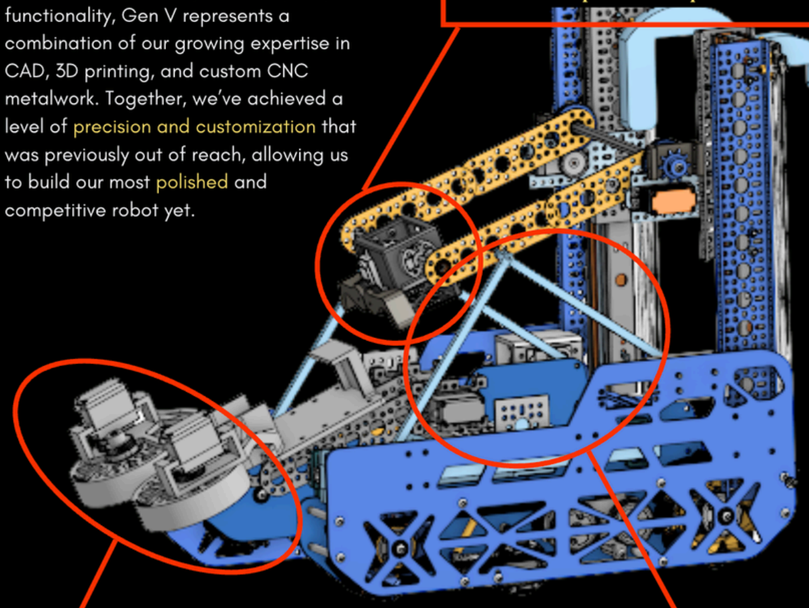
GENERATION V

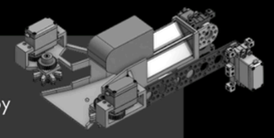
This was our 5th iteration of our design. We refined our linear slide system with a smoother extension mechanism, optimized the intake and outtake systems, and increasing scoring efficiency. Beyond functionality, Gen V represents a combination of our growing expertise in CAD, 3D printing, and custom CNC metalwork. Together, we've achieved a level of precision and customization that was previously out of reach, allowing us to build our most polished and competitive robot yet.



Outtake V5

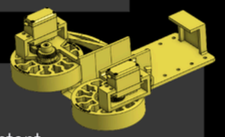
- **Smaller and more precise grip**
- **Removed complicated wrist servo**
- **One servo powering claw via gears**
- **5:8 Gear ratio on arm for optimized balance of speed and torque**





Intake V3 Complications:

- Surgical tubing not grippy
- Too slow/Not smooth
- Blocks sometimes enter sideways



V5 Solution:

- Gecko wheels
- Faster and more consistent
- More block contact prevents slippage

Linkage V5

- **Much more reliable intake extendo (Servo powered)**
- **Holds position easily and completely removes string and greatly reduces chances of failure**
- **Much faster transfer than previous intake slides powered by motors**
- **Built with interconnected Lego technic pieces**

Mechanical Design

GENERATION I

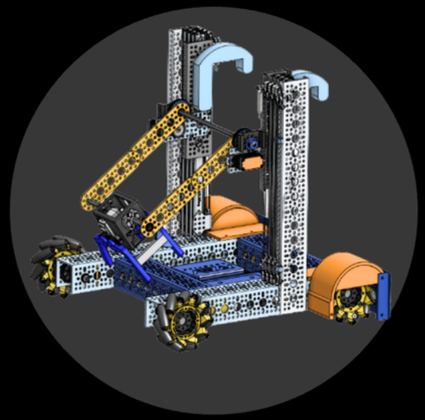
- One claw and arm
- Modified last year's Centerstage robot
- 4 Wheel Mecanum drive
- Hooks on rear end of slides

Pros:

- Temporary robot meant to be simple to use and build
- Fast and durable
- Capable of L2 Hang and high bucket

Cons:

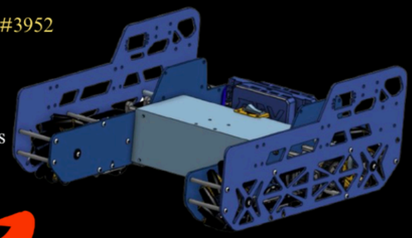
- Bad grip on samples
- Could not score specimen
- Unreliable slides

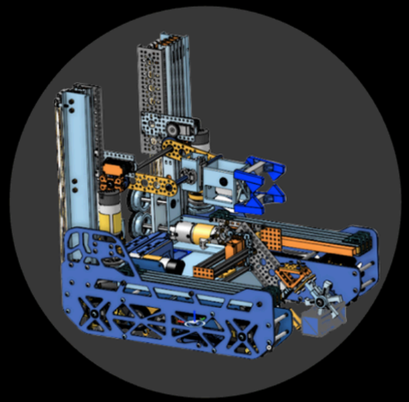


GENERATION III

New Additions:

- Custom machined drivetrain thanks to FRC team #3952
- Intake
  - Active intake using TPU Roller
  - Switched to a continuous rotation servo
  - Pivoting outtake using two Axon Max+ Servos
- Outtake
  - Wrist servo for specimen
  - Geared claw powered by one servo
  - Chunky claw design





Pros:

- Pivots efficiently
- Mecanum Drive allows for flawless strafing and traveling

Cons:

- String frequently loses tension on slides
- Tight interior space to work with due to interior linear slides
  - Tedious maintenance
- Slides were not synced all the time
- Can only pick up samples in one way

Grizzly Tech #23929

WEBSITE



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THANK YOU!

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