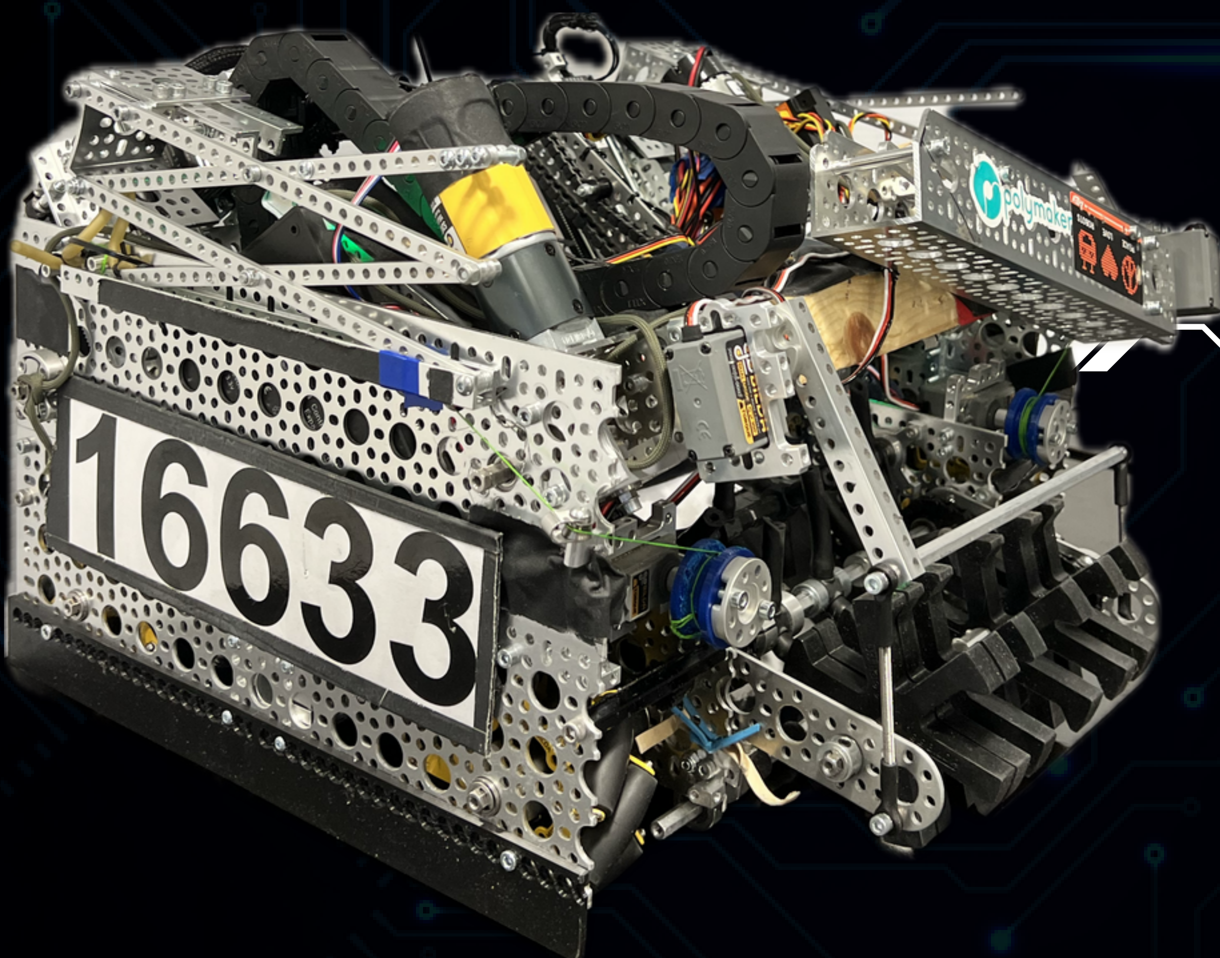
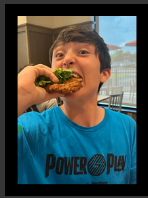
BOTS IN BLACK 16633



PORTFOLIO

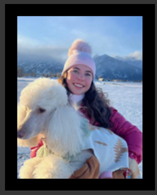
MEET THE TEAM



ALESSIO
CAPTAIN

BARBARA
OUTREACH LEAD

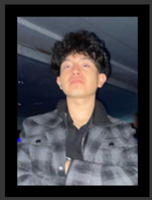
JACK
OUTREACH



AUDREY
OUTREACH

WILLIAM
DESIGN LEAD

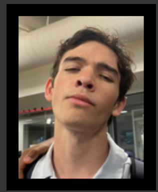
HARRISON
DESIGN



KEVIN
DESIGN

WHIT
DESIGN

COLE
SOFTWARE LEAD



RUSSELL
SOFTWARE

ACQUIRING MENTORS

MR. TANGKA

MR. MICHAUD

MR. KAGIKA

Mentor Acquisition:

- Welcomed new mentor *Mr. Tangka*, Georgia Tech student in *industrial and product design.*
- Engaged *Mr. Tangka* for help with refining **robot** and **brand** design and aesthetics.

Existing Mentor Collaboration:

- Leveraged expertise of *Mr. Michaud* and *Mr. Kagika* on designated math days.
- Applied mathematical lessons to develop *algorithms* for **vision** and **robot motion**

$$mag\,(x,z) = \left(\sum_{r=1}^{d} |x_r - z_r|^p \right)^{1/p}$$

Minkowski Distance

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt}$$

PID control loop

Impact:

- Combined mentorship enriched our team's technical skills and enhanced the overall design and functionality of our robot.

TEAM 16633

Our Team & Team Values

We are the Bots in Black, team 16633 from Marist School in Atlanta, Georgia. As a third-year FTC team, our mission is to:

Break Barriers, **I**nnovate, **B**uild Community

MEMBER DEVELOPMENT | SUSTAINABILITY

STEM PIPELINE

FUNDRAISING

We are grateful to be funded by **Marist School**. To help us reach our ambitious team goals this year, we maintained old sponsors and acquired new funding from:

- **VRTX 3D** and **SendCutSend** allowed us to create a custom, ball-based R&D drivetrain.
- **Under Armour** allowed us to create team shirts
- **GoBilda, REV Robotics, and Accenture** funded specialized robot parts like our odometry encoders

On the **Bots in Black**, we've cultivated a robust *STEM pipeline* to foster member development **in and outside of our team**. This year, we proudly welcomed three talented rookies, leveraging efficient team organization and tools like *Microsoft Planner* to build their skills and facilitate their **contribution to our success**.

Our **long-term sustainability goals** include:

- Creating 100% member retention, as we have lost 6 members over 5 years as a team
- Bringing in 1+ fresh faces **every year**
- Practicing leadership and organization skills with rookies

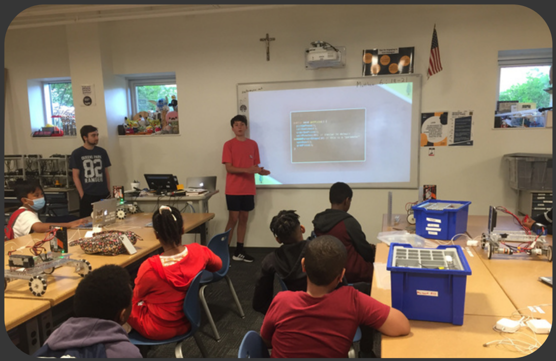
Our focus goes beyond internal growth; the Bots in Black actively contribute engineering, computer science, design, and marketing expertise in our community that has benefited our team along with other teams in FIRST Programs. Examples:

- Kevin, a REACH for Excellence graduate *(see pg. 3)*, whom we once tutored in a summer program, is now a vital builder and designer for our team.
- Cason, a 6th grader from Troop 74 where we did our robotics merit badge clinic (see pg. 4) is now a proud member of Team 14101.

OUTREACH

REACH FOR EXCELLENCE

- The Reach for Excellence program inspires students to excel in all aspects of their lives.
- It goes beyond traditional classrooms, encouraging exploration of passions and participation in extracurricular activities.
- Over the past three summers, Bots in Black scholars collaborated with Reach for Excellence.
- They taught computer science and robotics classes five days a week, simulating FTC-style competitions and engineering.
- The scholars leverage their First experience to ensure students are familiar with CS principles and tools for the engineering design process.



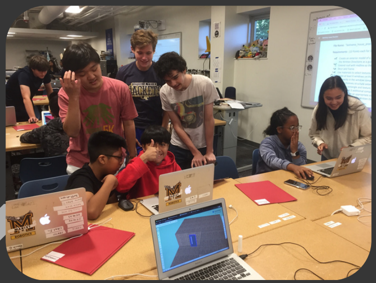
ALESSIO TEACHES JAVA METHODS TO 6TH GRADE

RUSSELL HELPS SOLEE & JADEN

SUMMER 2021:
BIB VOLUNTEERED AT REACH, SUPPORTING MIDDLE SCHOOL STUDENTS IN STEM
COMBINED HOURS: 185

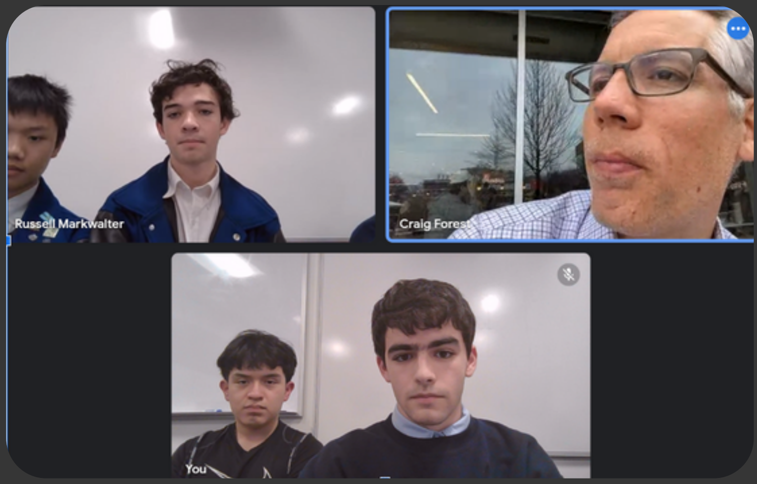
SUMMER 2022:
BIB STRENGTHENS STUDENT CONNECTIONS WHILE ENHANCING STEM COMMUNICATION AND EDUCATION SKILLS
COMBINED HOURS: 210

SUMMER 2023:
OUR ORIGINAL REACH GROUP GRADUATES WITH ENGINEERING EXPERTISE, AND A NEW COHORT BEGINS THE PROGRAM
COMBINED HOURS: 510



DR. FOREST | BSA MERIT BADGE | AAH!

- Team members met with a bioengineering professor at Georgia Tech to discuss successful strategies for problem-solving
- Dr. Forest emphasized clear communication in the design process, as well as flexibility in ideas.



- Bots in Black hosted a workshop with Boy Scout Troop 74 from Atlanta for them to get their robotics merit badges.
- The meeting married the principles of FIRST with the goals of the Boy Scouts of America to promote STEM in the community.

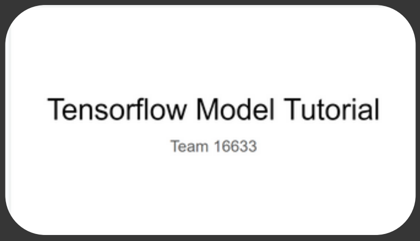
- BIB continues their work with the American Assimilation Helpline in 2023
- We worked tutoring python coding and math to kids about move or who have recently moved into the United States, expanding our knowledge of stem education while spreading stem to wider audiences

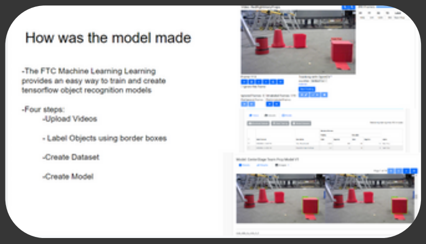
OUTREACH

KICKOFF | VISION SHARING | FIELD CENTRIC

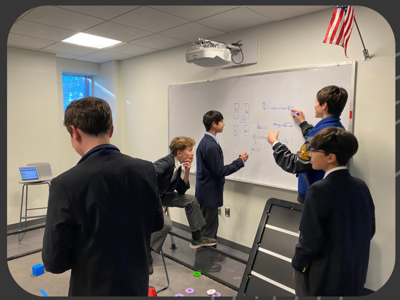
Marist hosted the Georgia FTC Kickoff this year and our team helped set up and host an April Tag workshop at this event. members from our team helped prepare robots to be used at the workshop and help guide the attending teams through the process of setting up the code and testing out the april tag vision

Once the game was released we quickly trained a tensorflow algorithm, developed a team prop standard, and created presentations and guides to help teams implement this vision code . We followed up on this resource throughout the year with updates, and improvements also publishing an Open CV solution with a more reliable consistency. All of the Marist teams use this vision code and many other teams in the Atlanta-League have adopted it as well.

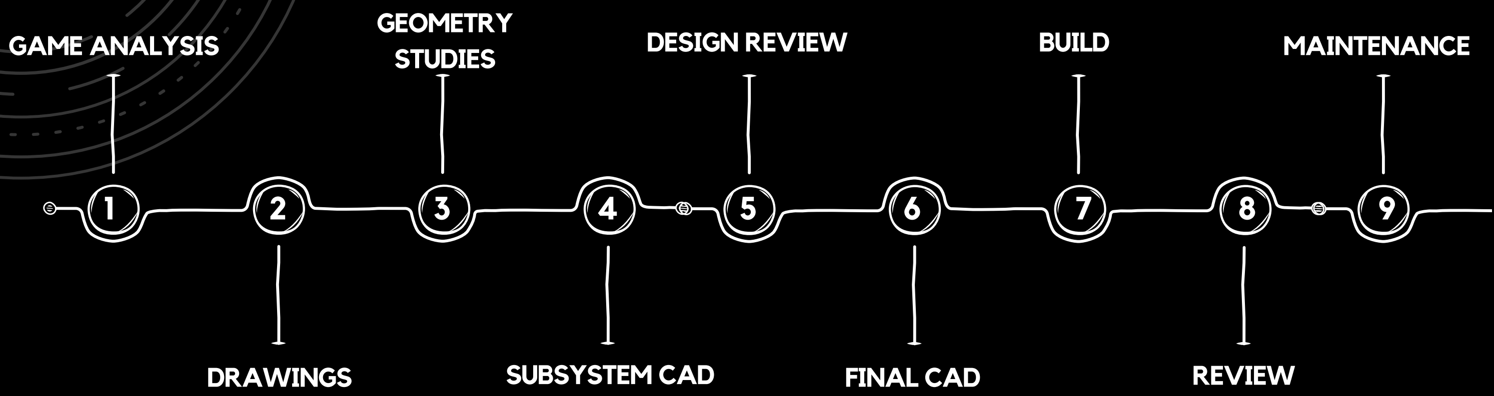




We helped team 18557 implement fieldcentric drive code for their robot and have drafted a modification to the MaristBaseRobot code for the following school year which adds fieldcentric functionality. We also plan on hosting a fieldcentric workshop for the Atlanta-Marist League teams which make it to states.

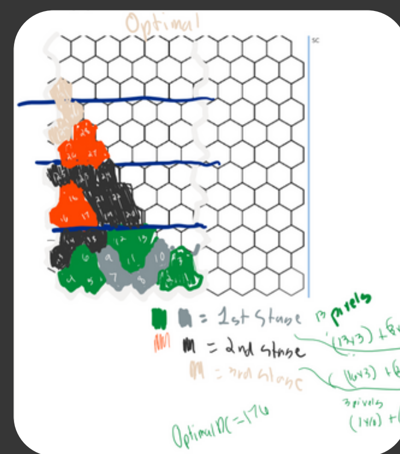


DESIGN PROCESS

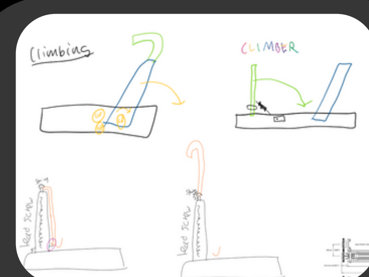


1. We took a *distinctive approach* to game analysis this year. Rather than immediately discussing designs, we refrained for talking about ideas the first five days after the game reveal. This served two purposes: *to ensure a thorough understanding of optimal game strategy and to prevent premature design enthusiasm.* By resisting early discussions, we prioritized thoughtful consideration over hasty decisions, **fostering a team dynamic that valued strategic clarity before diving into the design phase**. This approach resulted in a more deliberate and effective design process.

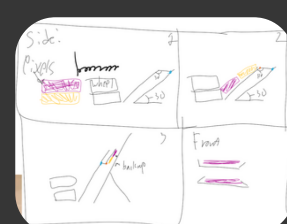
We identified the *optimal strategy of independent pixel release with side-by-side pixels*. Our robot parameters focused on maintaining a **short** and **thin** profile, ensuring a height under **12"**. To streamline gameplay, we incorporated a design to deposit pixels on one side without turning around. Additionally, our emphasis on a **quick airplane mechanism** and exploring **integration possibilities** with the climbing solution aimed at achieving a rapid endgame with fast cycle times.



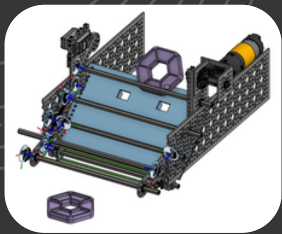
2. In the second stage of our design process, we use **drawings** to communicate ideas for subsystems, robot strategy, and mechanisms. This step **facilitates collaboration** and allows team members to modify observations easily. Crucially, this stage serves as the *decision-making hub*, helping us eliminate designs and narrow down our robot design path efficiently.

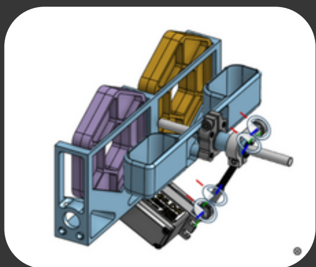


3. In the "Geometry Studies" phase, we systematically tested subsystem and full robot designs for compatibility with game elements, utilizing simplified shapes and components. Using motion mates, we manipulated robot parts to assess the interaction of various elements. Our focus this year was optimizing extension and dimensions for smooth pixel passage from the intake to the deposit mechanism. Through rigorous testing, we pinpointed an effective slider angle range of 34-38 degrees, proving invaluable for successful pixel deposition on a 30-degree backdrop, even in the presence of floor pixels.

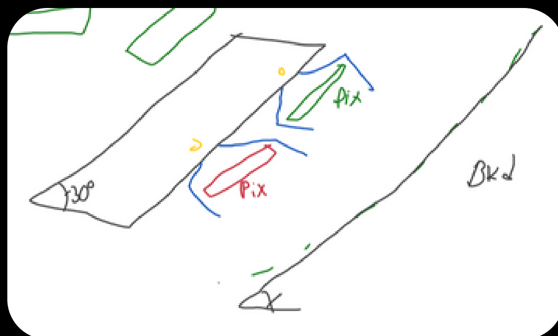


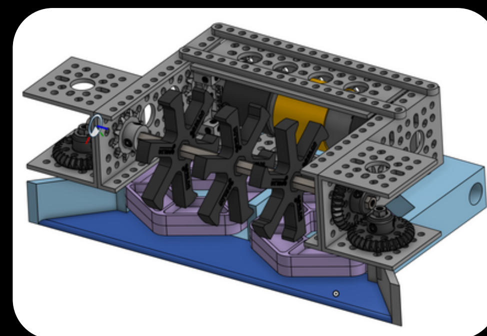
DESIGN PROCESS

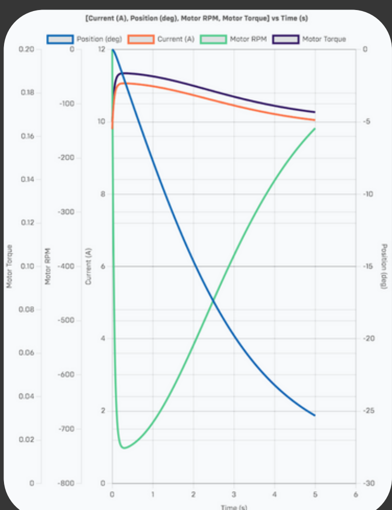




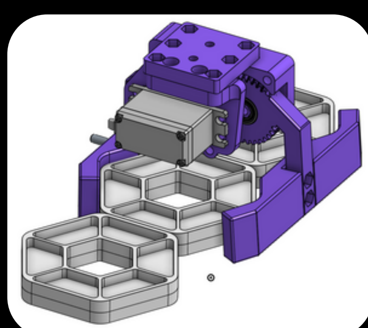
4. In the "Subsystem CAD" phase, we translate our geometry studies into **detailed** designs for five key subsystems: chassis, intake, deposit, climber, and airplane. Notably, our innovative *"pseudo-custom"* chassis houses elevators and belt-driven motors within, enhancing autonomous accuracy. This **efficient packaging meets tight constraints**, ensuring the robot fits under 12" while maintaining a slim profile.

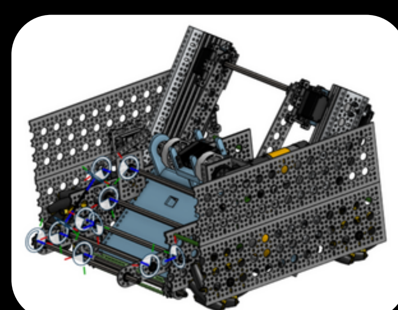


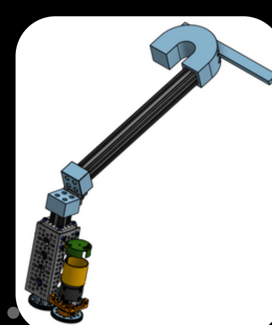


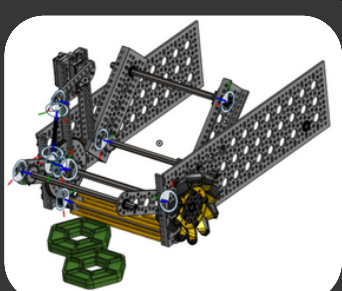


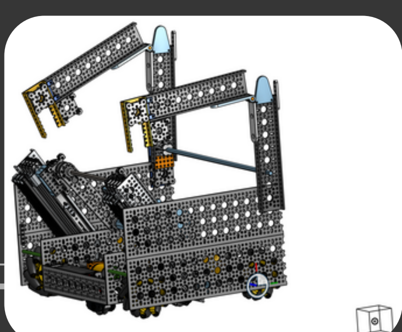
5. In the "Design Reviews" phase, we conduct a battery of tests on subsystem CADs. This includes stress testing for structural integrity, evaluating weight distribution, and scrutinizing key motion aspects such as motor efficiency and actuator response. Precision in alignment and reliability under simulated scenarios are also assessed, ensuring optimal functionality and durability in our final robot design.







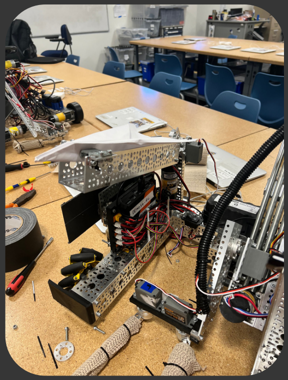


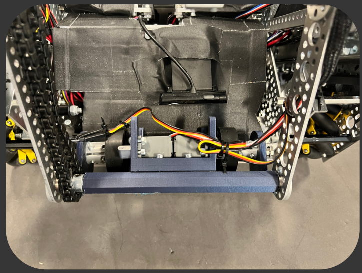


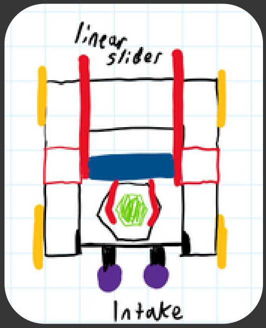
6. In the "Final CAD" stage, our meticulous design process culminates in a detailed virtual blueprint of the entire robot. Using careful versioning in Onshape, this comprehensive CAD not only encapsulates every detail, including screws, but also serves as precise building instructions. This final step marks the seamless transition from virtual design to the physical construction phase, ensuring accuracy and efficiency in bringing our robot to life

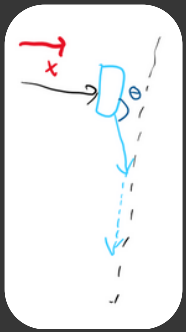
DESIGN PROCESS

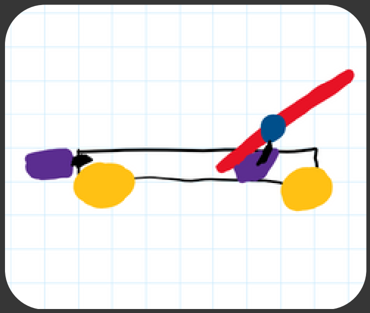
7. In the build phase all our hard work over the past few phases comes to fruition as the design begins to take shape in real life. First, we assemble a Bill of Materials and take inventory of the parts we have vs the parts we need to buy, vs the parts we can print on a 3d printer. After placing this order and receiving the parts, we will assemble the subsystems together, focusing on a modular approach for increased maintenance.











8. In the "Review" stage, we scrutinize the final robot's performance, emphasizing the identification and resolution of any issues that may compromise its functionality. Our focus extends to evaluating the reliability of mechanisms, ensuring they operate seamlessly and consistently in real-world scenarios. Performance issues, including factors like speed, precision, and responsiveness, are carefully assessed, with a deliberate weighting towards projected consistency. This comprehensive review not only validates the effectiveness of our design decisions but also informs future iterations, ensuring continuous improvement in the pursuit of a highly functional and reliable robot.

9. In the "Maintenance" stage, the chief goal is to keep the robot as functional and competition-ready as possible. Our team uses a lengthy Pre Meet Checklist to ensure all subsystems have been properly reset, are functioning as expected, and are ready for competition. The checklist runs through steps as basic as resetting the slider, unspooling the climber, to checking our gamepads for drift.

633 Pre-Match Checklist

Drivetrain:

- ☐ Odo sprung
- ☐ Odo wheels spinning fairly well
- ☐ Skirts off the floor
- ☐ No friction on wheels axles (front and back skirts?)
- ☐ Tighten arc-slot tensioners
- ☐ Hyperhubs on mecanum wheels tightened against the drivetrain
- ☐ Pixel guide screws tightened
- ☐ Camera facing up

Intake:

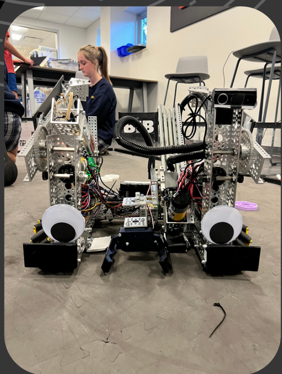
- ☐ Axles collars/screws are in
- ☐ No dead spots
- ☐ O ring on the pulleys
- ☐ Linkage screwed in on both sides
- ☐ Servo hub secured

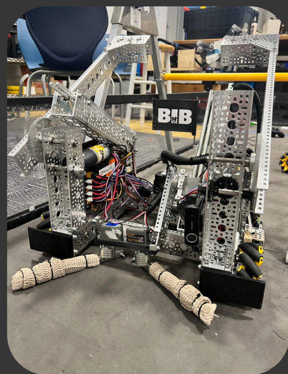
Outtake:

- ☐ Compliant wheel axles secured
- ☐ Compliant wheels still sticky
- ☐ Servos still working
- ☐ Shared hub is secured to sonic hub on wrist side
- ☐ Hyperhub on shared axle is tight
- ☐ Collar on shoulder side secured
- ☐ Sonic hub on wrist side secured

INTAKE & TRANSFER

Version 1&1.5 Claws





Version 1:
- simple, goBilda
- large surface area

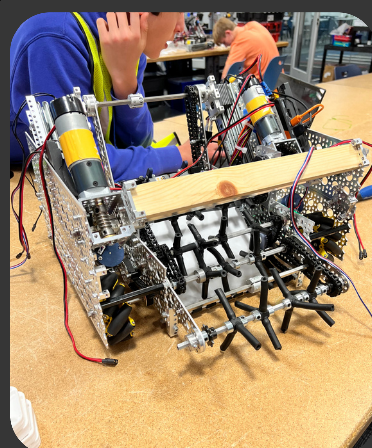
Version 1.5:
- one servo
- geared together

Why did we decided to move on:
- claw required high level of precision.
- gearbox not durable

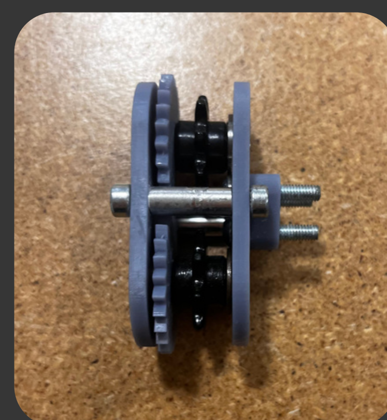
Version 2 Custom Gearbox

Version 2:
- Motor powered
- 3 front rollers
- 2 transfer rollers
- 1 bottom roller
- Custom 3D-printed reverser for bottom roller

Why we decided to move on:
- 3 front rollers frequently jammed gearbox not durable

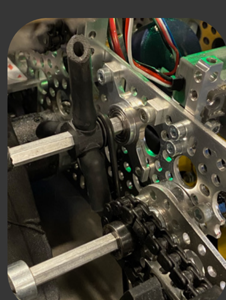


ROLLING INTAKE CONSTRUCTION



INTAKE GEARBOX

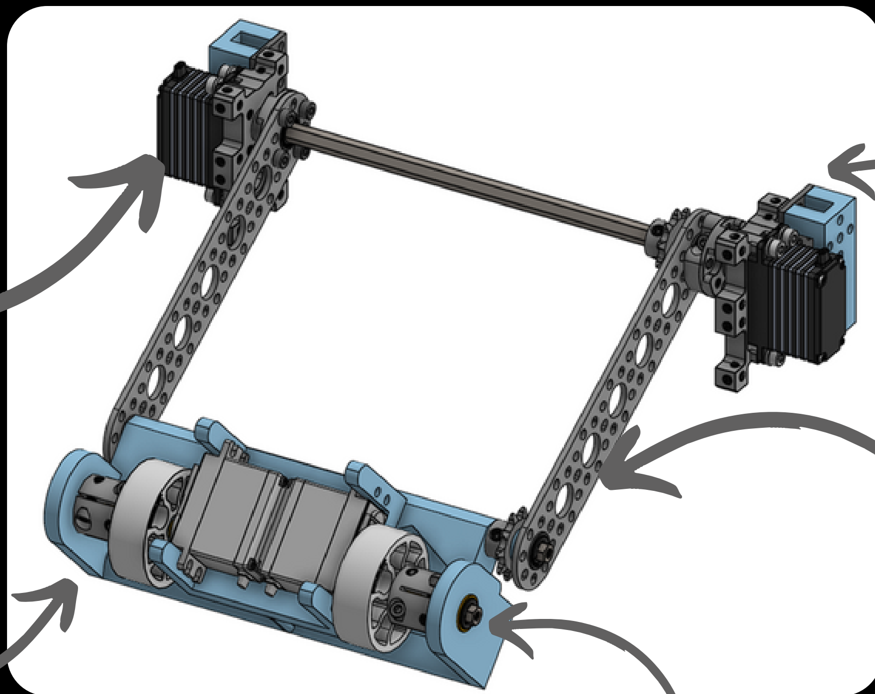
Version 3 O-Ring



Version 3:
- builds on version 2
- less rollers
- roller distance tuned
- roller material changed from surgical tubing to bootwheels
- O ring

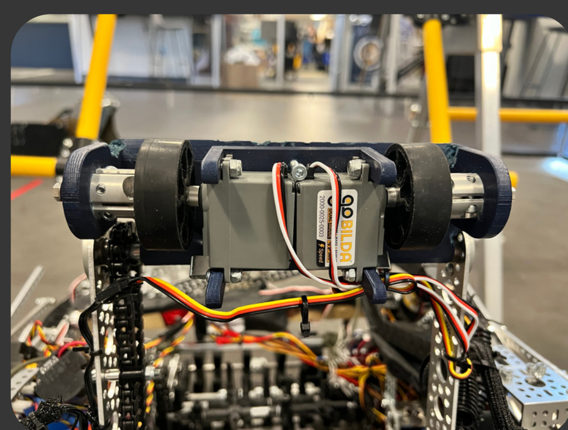
ARM HOPPER

Breakdown



HIGHLIGHTS

-Passthrough allows for scoring without turning
-Axon servos for speed and durability
-2 servos connected with one axle for stability
-Holds 2 pixels side by side for easy mosaic construction
-Independent release allows for more precise placement of each pixel
-Long shoulder allows for easy scoring when pixels block the backdrop



CLOSEUP OF PIXEL DEPOSIT

KINEMATICS

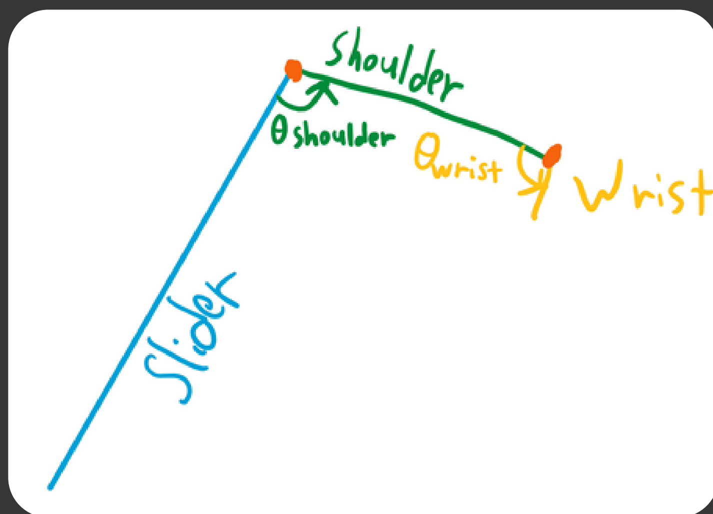
- Unique servo combination:
  - Shoulder servo: Moves the ArmHopper in a large arc, translating it from the middle to the back of the robot.
  - Wrist servo: Utilizes a chain mechanism to turn a sprocket attached to the ArmHopper.
- Shoulder servo functionality:
  - Executes a large arc motion for repositioning the hopper.
- Wrist servo functionality:
  - Adjusts the angle of the ArmHopper at the end of the shoulder.
  - Uses a chain mechanism to facilitate smooth movement.
  - Enables precise control for depositing pixels at an optimal angle.
  - Allows room for adjustment to achieve the desired configuration.

$$G(s) = \frac{\theta(s)}{V(s)} = \frac{K}{Ts+1}$$

END EFFECTORS POSITION

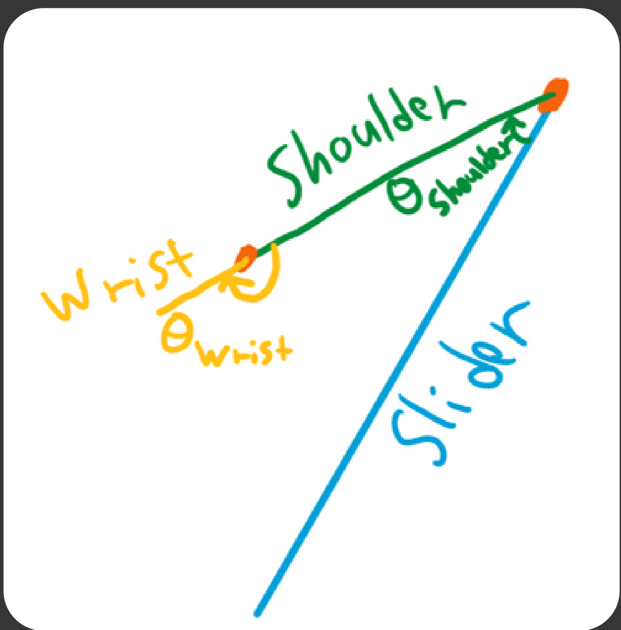
$$X = l_1 \cdot \cos(\Theta_1) + l_2 \cdot \cos(\Theta_1 + \Theta_2);$$

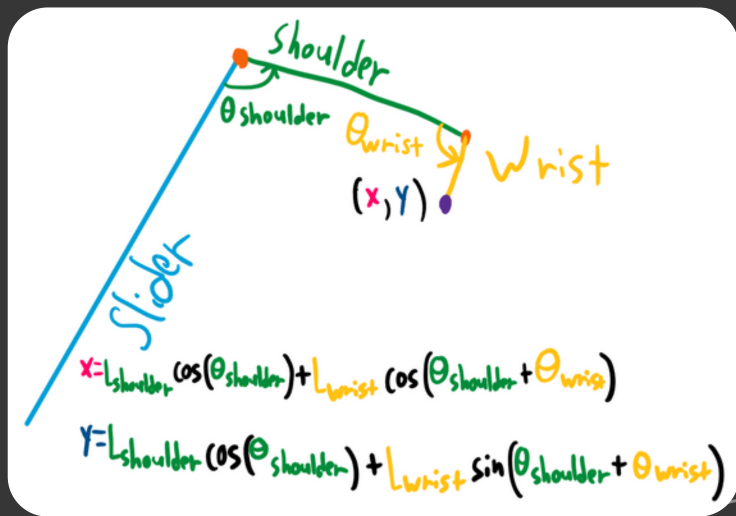
$$Y = l_1 \cdot \sin(\Theta_1) + l_2 \cdot \sin(\Theta_1 + \Theta_2);$$



OUTTAKE KINEMATICS

OUTTAKE KINEMATICS





OUTTAKE KINEMATICS

Climber

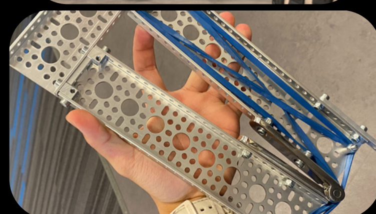
V1

Folding Rotating Climber
Pro: uses 1 motor, fits under 12 inches
Con: torque required was high

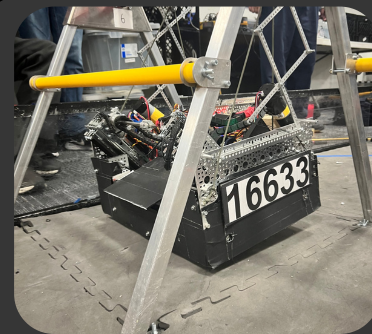
Tape Measure Climber
Pro: Fairly Small Contraption *space, fast*
Con: Tape measurers bent, didnt work

V2

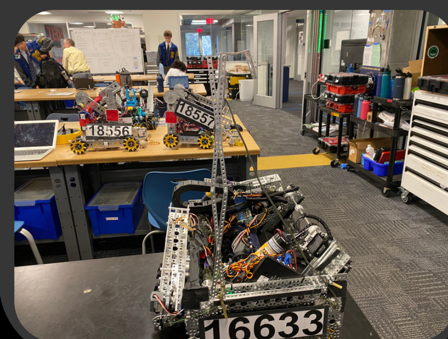
V3



Rotating climber
Pro: fast and easy to build, fast climb
Con: uses 2 motors, does not fit under 12 inches

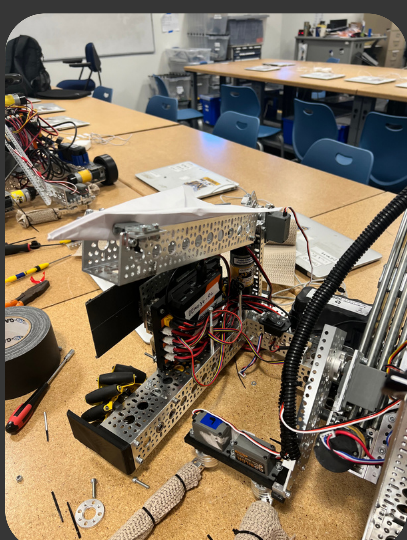


V4



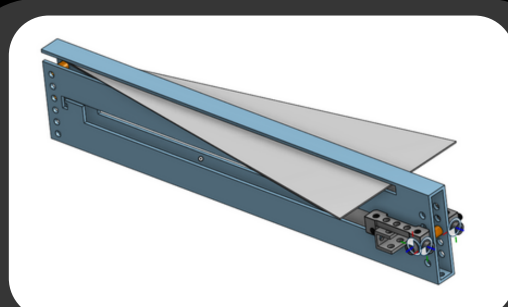
Scissor lift climber
Pro: fast deployment of hooks
Con: occasionally jams when climbing

Airplane



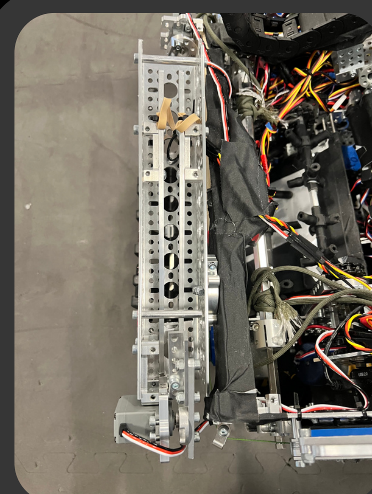
V1

Airplane shooter
Pro: fast and easy to build
Con: takes up a large volume



V2

Custom 3D printed airplane shooter
Pro: small and compact, string release for flexible servo placement
Con: too fragile, angleing mechanism was unreliable



V3

Airplane shooter (current)
Pro: durable, easy to maintain
Con: still takes up space but empty space is available

SOFTWARE

Software Objectives

LESS ESOTERIC CODE

- SUBSYSTEM AND ACTION BASED STRUCTURE PG11
- BUILDING BLOCK" AUTO PG 10

TELEOP OPTIMIZATION

- FIELDCENTRIC DRIVE PG 9
- "HOPPER LOCKING" PG 9
- APRIL TAG TELEOP ALIGNMENT PG9
- ENCODER "STATE" SYSTEM PG 9

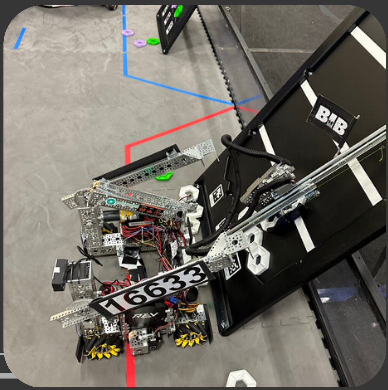
IMPROVE AUTONOMOUS CONSISTENCY

- APRIL TAG ALIGNMENT PG 10
- ROADRUNNER PG 10
- AUTO VISULIZATION PG 10
- VISION PG 11

TELEOP ENHANCMENTS

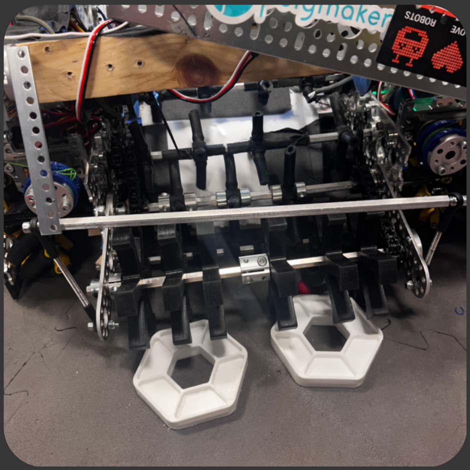
ENCODER "STATE" SYSTEM FOR OUTTAKE

- OUR OUTTAKE IS MADE OF THREE PARTS WHICH WORK IN CONJUNCTION TO ACCURATELY DEPOSIT PIXELS: SLIDER, WRIST, AND SHOULDER
- . THE ENCODER "STATE" SYSTEM STORES SET POSITIONS FOR OUTTAKING PIXELSSUCH AS A HIGH, AND LOW POSITIONS ON THE BOARD , OR A POSITION FROM FARTHER AWAY
- THE "STATES" ARE RUN AT THE PRESS OF A BUTTON



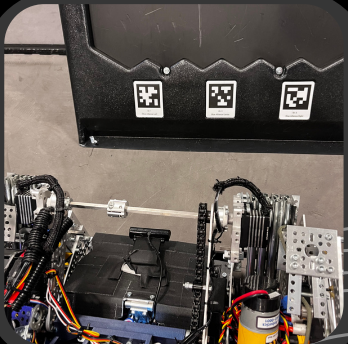
"HOPPER LOCKING":

- PROBLEM: DRIVERS CANT SEE THE PIXEL BEING INTAKED AND SOMETIMES ACCIDENTALLY OUTTAKE PIXELS
- COLOR SENSORS MOUNTED UNDER OUR HOPPER DETECT WHETHER A PIXEL IS IN EACH SLOT OF THE HOPPER
- ONCE A PIXEL HAS ENTERED A CERTAIN SLOT IN THE HOPPER, THAT SIDE "LOCKS" WHILE THE OTHER SIDE, PREVENTING THE DRIVE FROM ACCIDENTALY OUTTAKING IT



TELEOP APRIL TAG ALIGNMENT

- DRIVERS CAN HOLD DOWN A BUTTON WHILE DRIVING TO AUTOMATICALLY ENGAGE THE CAMERA
- ONCE AN APRIL TAG IS PICKED UP THE ROBOT WILL SMOOTHLY DRIVE TO IT AND AUTO ALIGN
- ALLOWS FOR CONSISTEN PLACEMENT OF PIXELS WITHOUT RISK OF KNOCKING THEM

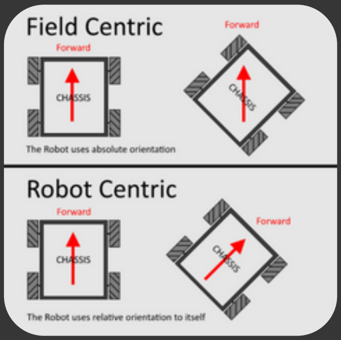


SOFTWARE

FIELDCENTRIC DRIVE

Uses Internal IMU of the robot to offset the robot's drive heading based on gamepad input

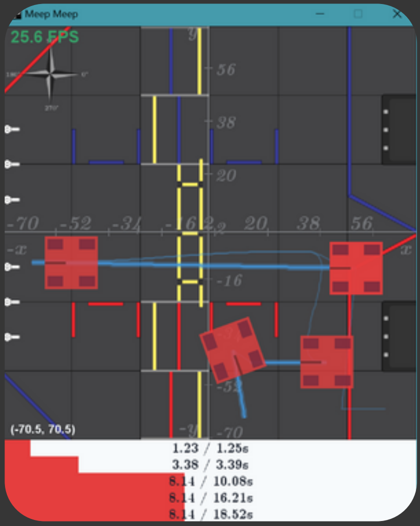
- It changes the movement of the robot to be relative to the field rather than relative to it's concept of forward and backward.
- if you turn you robot so it is facing the left, when you push forward on the joystick it will still move forward relative to the game field, as opposed to moving left which would be forward relative to the robot's POV.



AUTONOMOUS FEATURES

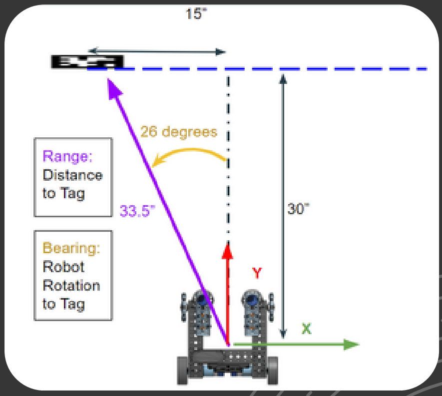
ROADRUNNER/ODOMETRY

- Roadrunner is a motion planning library which enables the fast and simple creation of complex spline curves and paths
- OUr robot has three dead/odometry wheels to aid our robot in localization (knowing where it is on the field at all times).
- roadrunner uses a PID loop with feedback from dead wheels to correct for errors mid path.
- Our team is on of the first to use the latest 1.0 Roadrunner beta which has changed the strucuture of roadrunner to work around actions instead of trajectories.
- Path Visualizers such as meeep meep and RRPAthGen help us plan out our autonomi before we write them



APRIL TAG LOCALIZATION

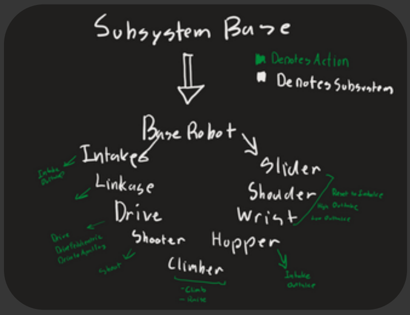
- Camera Mounted on the Back of the Robot uses the FTC SDK April Tag Processor combined with a simple proportional gain loop to center the robot on the tag
- Increases deposit accuracy and serves to relocalize roadrunner pose estimate



SOFTWARE

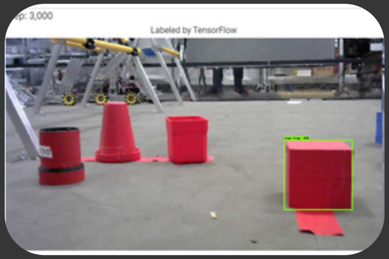
SUBSYSTEM/ACTION BASED CODE

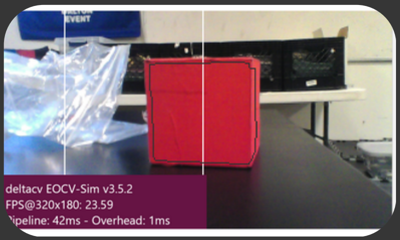
- Subsystems divide all the actuators (motors/servos/sensors) on our robot into groups based on their function
- Each Subsystem performs certain actions
- Actions can be chained together for an autonomous routine or run at the press of a button in teleop
- Subsystems Include: DriveWrist, Shoulder, Slider, Hopper,

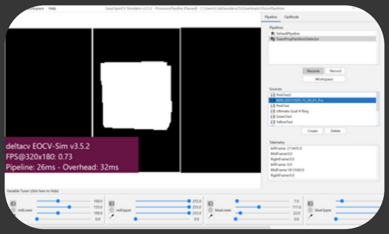


SUBSYSTEM BASE DIAGRAM

VISION SOLUTION







Vision Solution	Process	Pros	Cons
Tensorflow Model	• Created and Trained TF Model for Red and Blue Block Props using FTCML Toolchain • Integrated with Vision Portal and used x position of prop to determine the zone	• Easy Implentation • Fairly Consistend • Good for sharing with other Atlanta Marist Teams	• Occasional Driver Stations Crashes • Camera must see all three zones
CV Contour Detector	• Uses camera image to find red and blue contours where there are drastic changes in color. Basically finds the edges of objects. • FInds Greates Area of Contours and determines x position which determines the zone	• Consistend, only requires one side of the prop to be visible • crashes less bc using Open CV	• Camera needs to see edges of block • Impacted by lighting condiions and background noise
OCV Partitioner	• Converts camera image to hsv and filters for red and blue • Divides the camra image into three zones and sums the red and blue in each zone • Zone with the greatest red and blue contains the prop	• Requires only a small bit of the prop to be seen • Not heavily affected by noise	• Lighting conditions still affect results, but the gain/exposure can be tuned to account for it