

ENGINEERING PORTFOLIO

Florida FTC
R.O.B.O.T League
2022-2023 Season

Team Member:

Colin "Valus Valoo, Ignition Bill, Valroth"

Coaches:

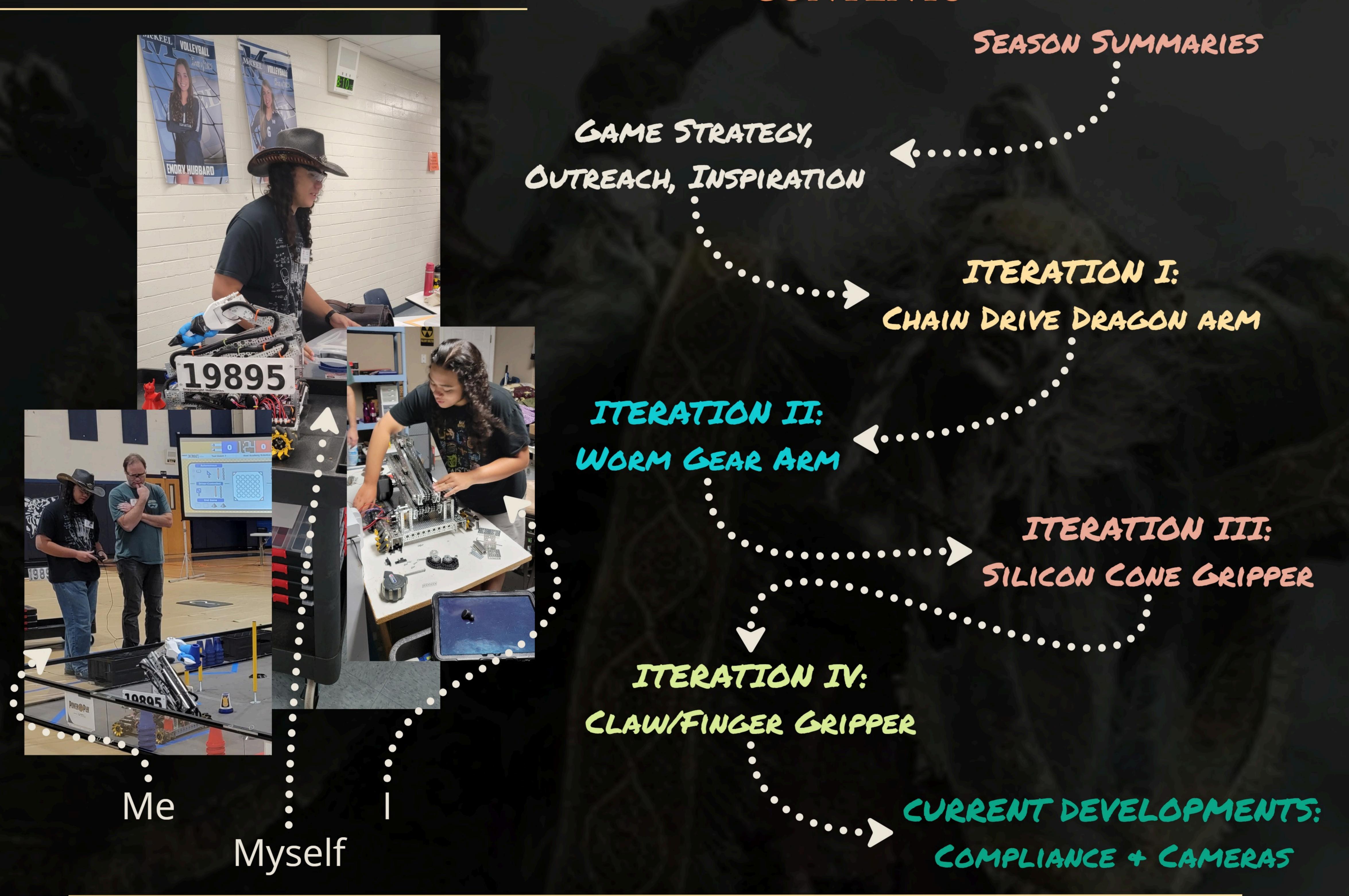
Randy Huegele

Indah B. Huegele

INTRODUCTION

This Engineering portfolio contains a summary and illustrations of Team 19895 robot design and building process for FTC 2022 - 2023 season.

CONTENTS



SUMMARY OF DISCOVERIES AND INNOVATIONS

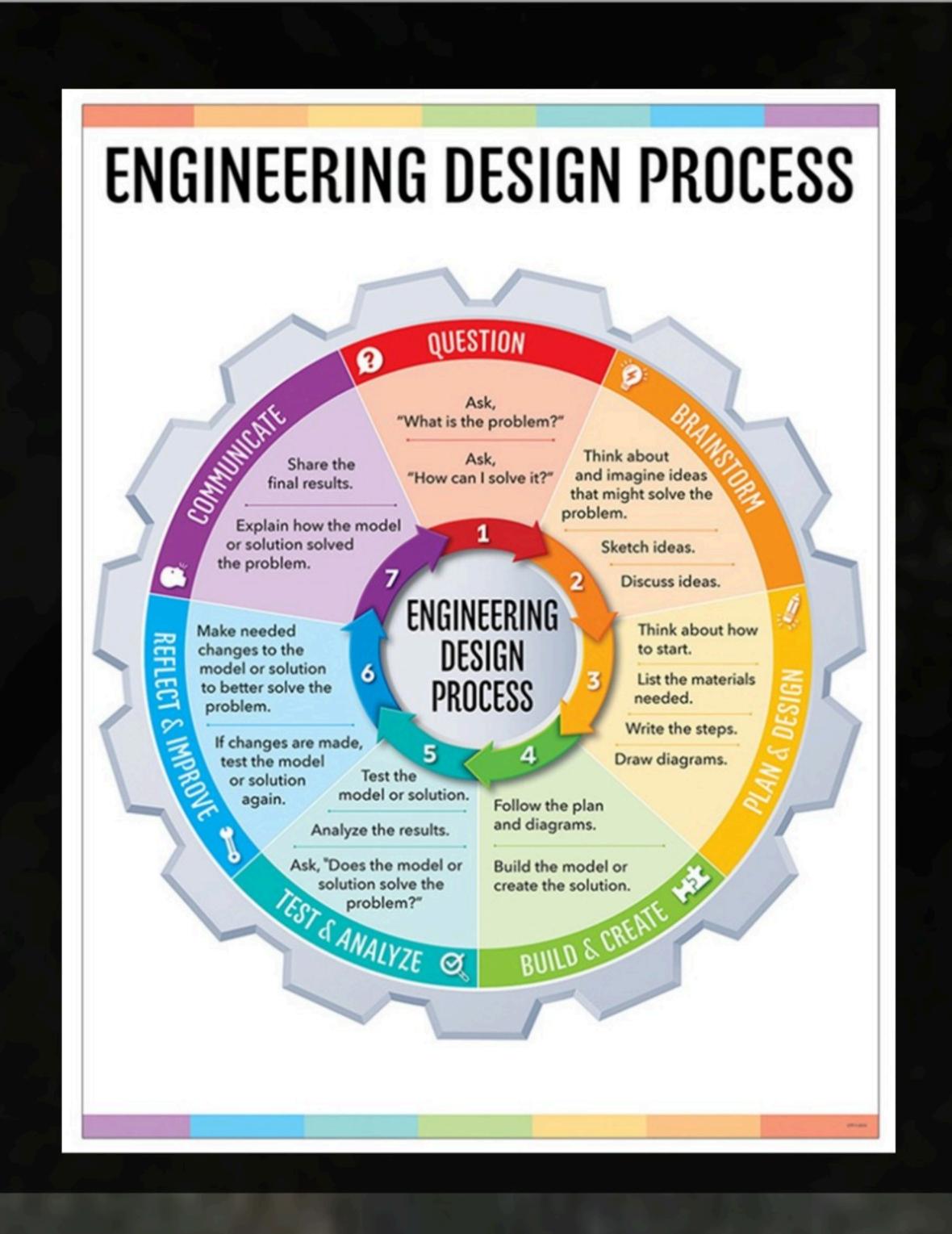
New Skill/Discovery	How it was used
Resin Printing	Gripper designs, masters for casting team elements and gripper parts
Casting and molding	Gripper parts, team elements
Offset joint application	Robot arm from Iteration II onwards
Chain drive arm	Robot arm from Iteration I
Cable-driven gripper	Gripper from iteration IV
Router	To cut plastic pieces for turntable
Machine Learning with Tensor Flow Lite	Custom sleeve recognition for autonomous parking
Inverse Kinematics	Robot arm control
Tracking and Distance Camera	Navigation and game element recognitions
Calculus and Trigonometry	To calculate the inverse kinematics, or angular speeds of the arm

SUMMARY OF DESIGN ACTIVITIES

Iteration	Component Designed	Tool
Iteration 1	Robot base and 4-segment arm	OpenSCAD
Iteration 1	Dragon head gripper	OpenSCAD, FDM print
Iteration 2	Offset worm gear arm	HAMMER
Iteration 2	Turntable	Router
Iteration 2	Fishtail gripper	OpenSCAD, FDM print, Silicon molding & urethane casting
Iteration 3	Conical Gripper	OpenSCAD, MSLA print
Iteration 3	Gripper Rubber casting	OpenSCAD, MSLA print, Silicon molding & urethane casting
Iteration 3	Custom Camera mount	OpenSCAD, MSLA print
Iteration 3	Cube Team Element	OpenSCAD, MSLA print, Silicon molding & urethane casting
Iteration 4	The Finger (gripper)	OpenSCAD, MSLA print
Iteration 4	New Team sign	OpenSCAD, MSLA print
Iteration 4	Engineering Portfolio	MIRO

LEARNING FROM ENGINEERING COMMUNITY

Organization	Activity	
Alumilite	Learned to use the casting and molding products. Sent request for sponsorship [NO RESPONSE]	
Intel	Learned to use D405 and T265 cameras. Sent request for sponsorship [DENIED]	
Anycubic	Learned to print using tough resins. Sent request for sponsorship [NO RESPONSE]	
Team 7719 RISE	Learned about different pit setups for state championships from Gabi	
Team 21477 Kraken	Learned about outreach to homeschool communities from coach Ingried	
Team 11954 Mario Mechanics	Started collaboration with Nicholas on programming	
FTC 265 Community	Resolved T265 library compilation by following advice on discord channel	
Gary Galle, Co Founder of Learned that the most crucial part of the Engineering Process is the customer, an starting a business, it is imperative to know your market.		



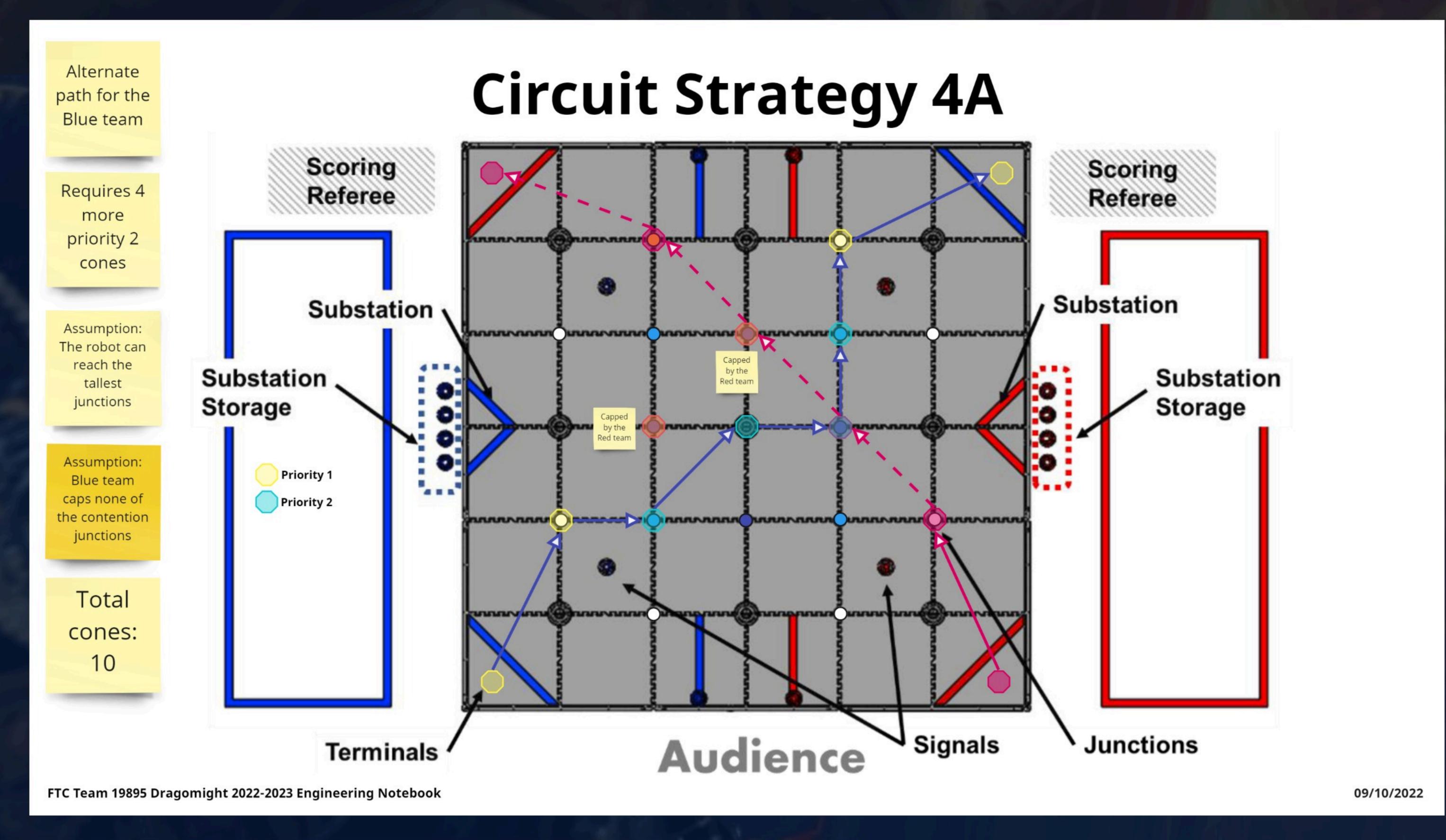
THE ENGINEERING PROCESS

We used the engineering design process (Question, Brainstorm, Plan & Design, Build, Test, Reflect, and Communicate) to guide our efforts for each iteration.

For the sake of space in our portfolio, each iteration of the robot includes sections that reference several parts of the engineering process under one heading (**Motivation** = Question; **Solution** = Brainstorm, Plan & Design, Build; **Issues** = Test, Reflect, Communicate).

GAME STRATEGY

In this season's game, most points are scored by placing cones on terminals, which have variable heights. In order to reach these terminals, the "team" (Colin) decided to design an arm rather than an elevator-like system, which is used by many other teams. Arms represent are a more generalizable system for placing objects than elevators and introduce their own interesting design challenges. An arm design also presents the opportunity to pick up toppled cones.



The team identified 6
variations of the
scoring strategy for the
alliance

The team simulated the game using 4 pretend-robots as part of the Open House event



OUTREACH





MAKER FAIRE....



Seahorfe Energy*



Connected with a professional engineer and
 business owner to learn about the engineering process and gain career advice!

Gary Galle, Owner and Co-founder of **Seahorse Energy®**



We helped a local high school (Trinity High School) in Ocala, FL, start their own FTC team, Cell-Ticks 22220!



We introduced FTC to Yangti Utari, the founding member of Asri Madani Argopuro Islamic school in Pekanbaru, Indonesia. She would like to introduce robotics to schools in Indonesia. We planned for future collaboration.

ITERATIONI

CHAIN DRIVE

MECHANUM. WHEELS

Original Arm Design

Motivation (What problem did we try to solve?)

How to access long or distant terminals with an arm design?

Solution

Use chain-drive (like that in bicycles), which facilitates a longer length This design was long enough to reach across half of the course!

ISSUES

- Too heavy to use full reach without falling; no space for a counterweight.
- Difficult to maneuver due to large size, especially between junctions.
- Wobbliness, caused by slack in chains, made it difficult to control.



Inspired by a villain with a dragon head arm in the SD-print to be like a sl

The 3D-printed PETG gripper was designed to be like a skeleton over which we planned to put a rubber mask that looked like a dragon head.

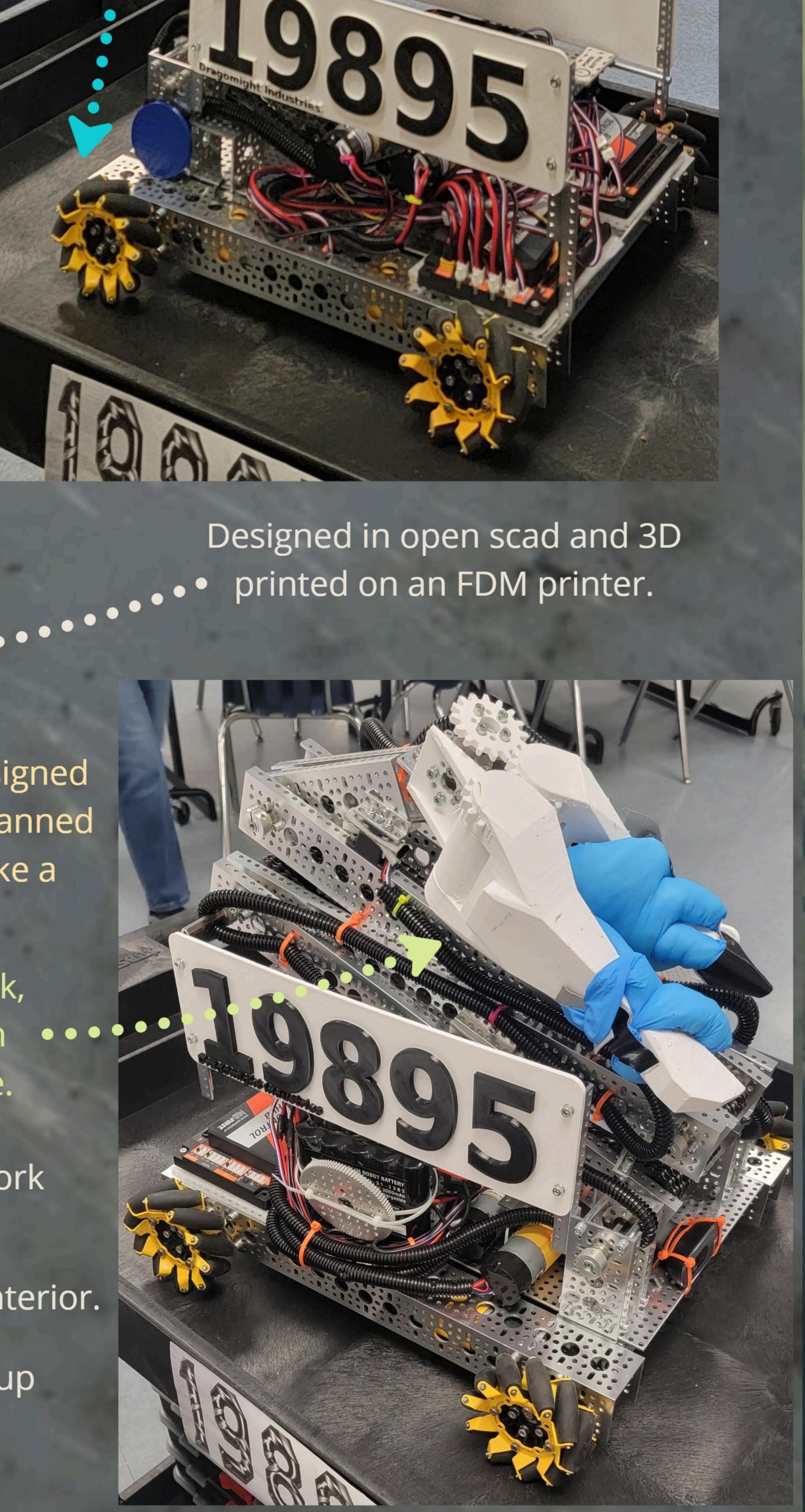
We did not have time to make the rubber mask, so instead we filled rubber gloves with cotton balls to duck tape onto the PETG gripper base.

Motivation A gripper that is generic enough to work for most objects, including cones

Solution A simple, claw-like gripper with a rubber interior.

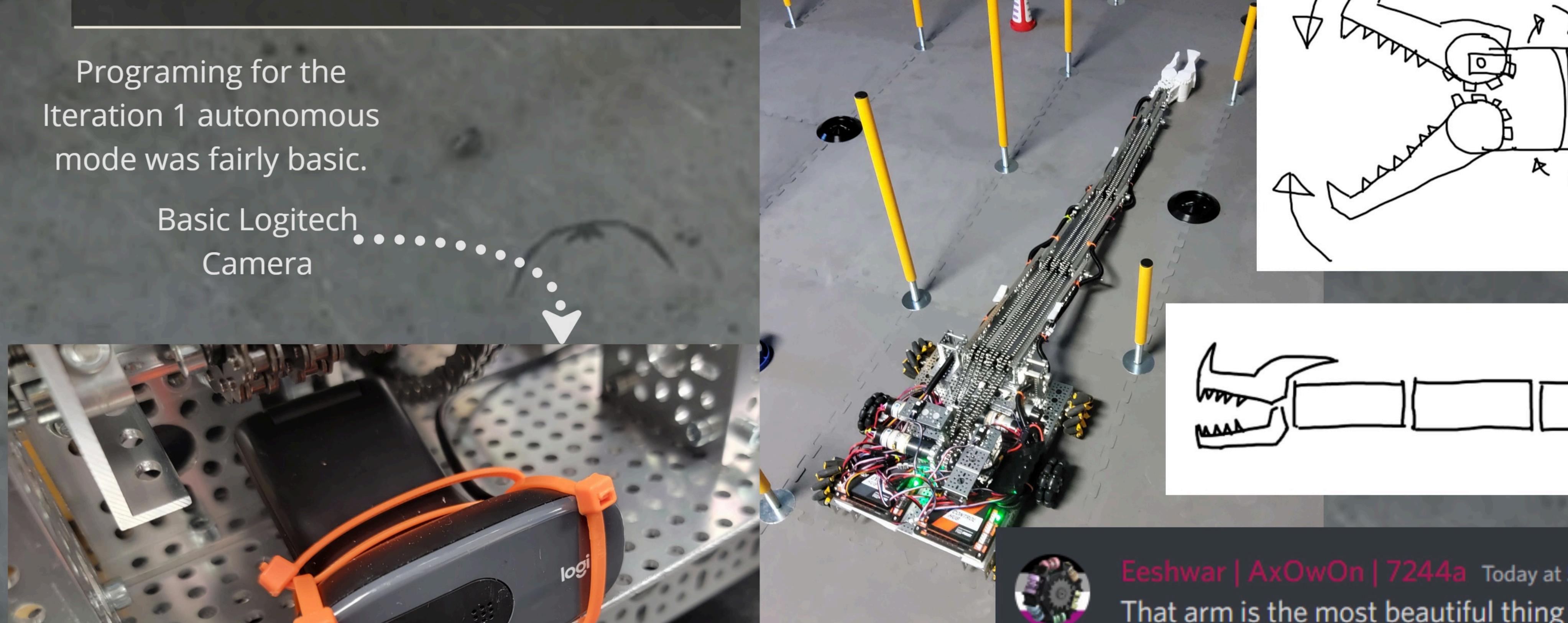
ISSUES

Difficult to grab cones. The gripper failed often because picking up cones required carefully maneuvering the arm to get a good grip.



ITERATIONI

Autonomous Mode



Today at 5:59 PM That arm is the most beautiful thing I've seen this season

We used the image recognition software provided by First.

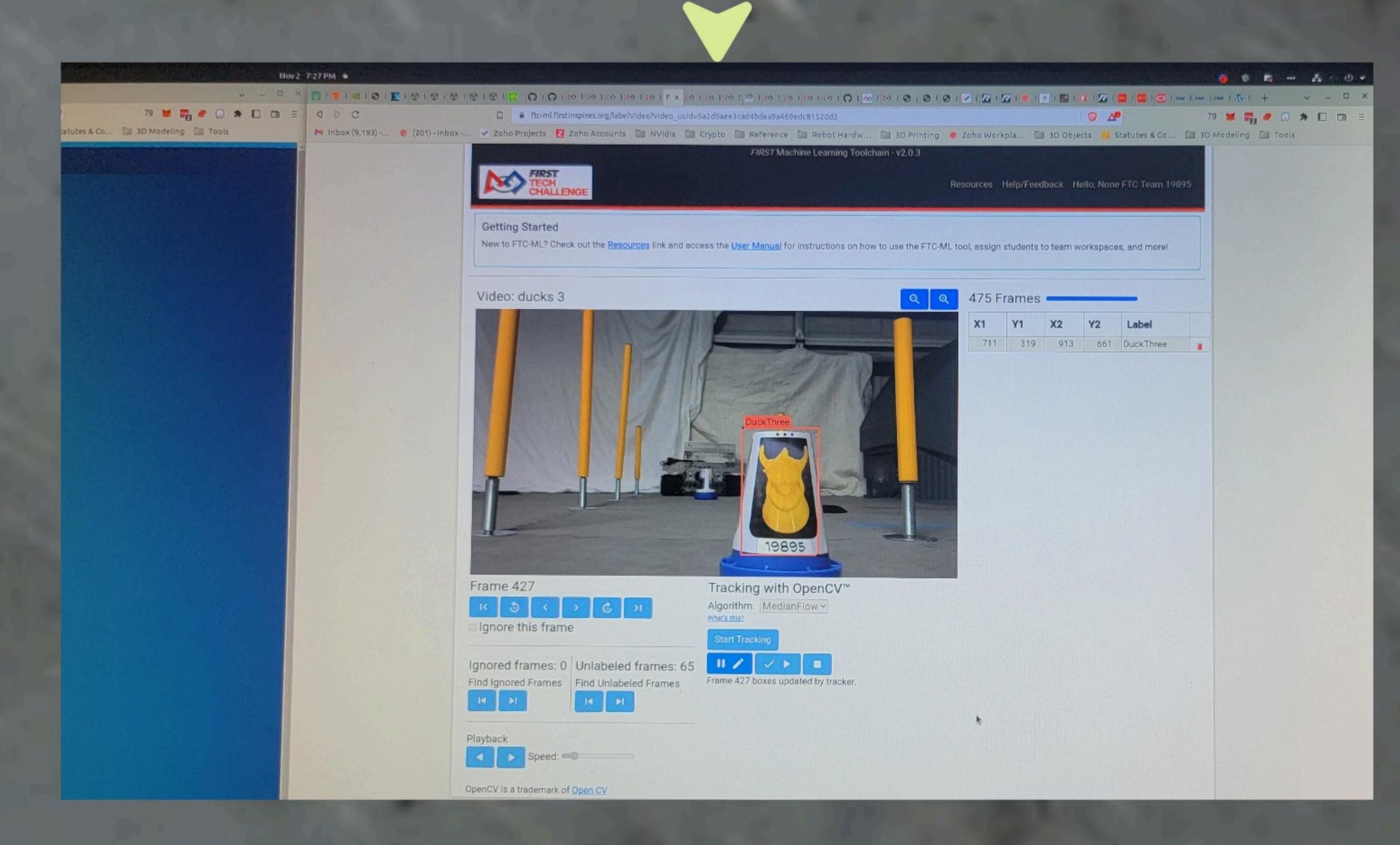
This works by you recording video from the robot then specifying the object(s) you want to be recognized in each frame of the video.

©

Difficulty differentiating cone from background. On the original design we recorded and trained the image recognition and could get it to work roughly 90% of the time. However, when we went to competition we found that it only worked around two thirds (66%) of the time. At first, we thought this was due to the fact that the CNNs used in image recognition rely somewhat on the background when recognizing objects. We later realized that the custom images were too similar to each other.

Possible solutions we considered

- Using images that are easier to recognize
- Moving the robot closer so the object fills more of the screen
- Using a better robotics camera



INSPIRATION

The "team" has many sources of inspiration for robot design, including biological organisms and the sophisticated animatronics used at Disney parks. The "team" wanted to make a unique, inspirational design for this season's robot that could be more general purpose than the typical elevator design used by most teams.

The "team" also has interest in experimenting with a variety of materials to create elegant and functional parts. Choosing an arm design allowed the "team" to synthesize these varied sources of inspiration and learn numerous manufacturing techniques.



ITERATIONII

Iteration 2 saw a complete rebuild of the arm. We also developed a turn table for increased maneuverability.

SAME GRIPPER.....

COMPLETELY NEW ARM......

(UKN (MDLE

SAME DRIVETRAIN....

New Arm Design

From Chains to Worm Gears

Motivation How do we make an arm that is more stable, maneuverable, and uses less power?

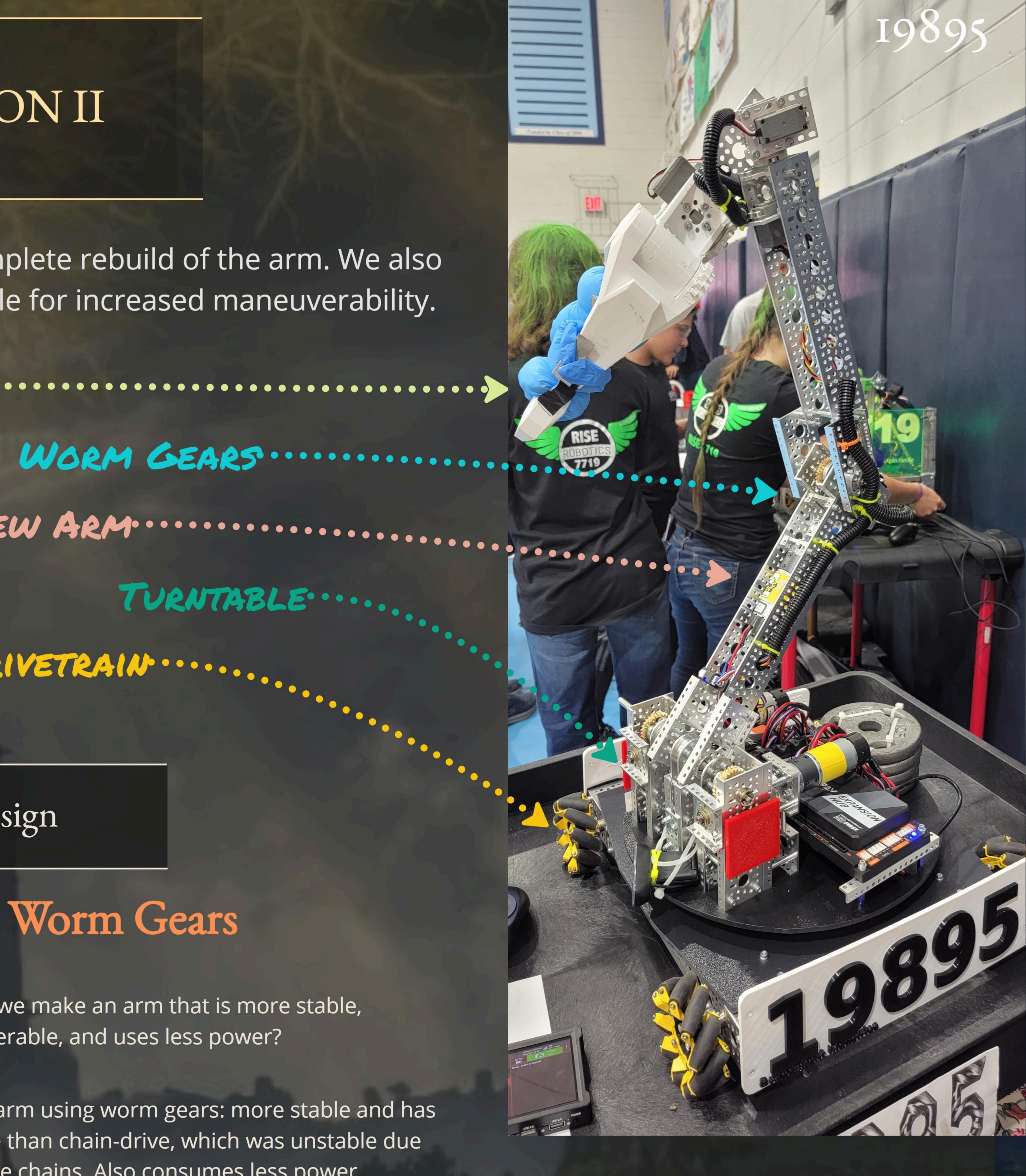
Solution Rebuild the arm using worm gears: more stable and has more torque than chain-drive, which was unstable due to slack in the chains. Also consumes less power.

Turntable

Motivation Rotation of the drivetrain is inaccurate.

Solution Sacrifice a dc motor in the arm to make a turntable.

- By using a turntable, the arm would not require the drivetrain to turn thus making the robot more maneuverable at the cost of range of the arm (i.e., the arm is shorter now).
- Cutting custom pieces. The team learned to use a router to cut the plastic surfaces for the turntable.





ITERATIONII

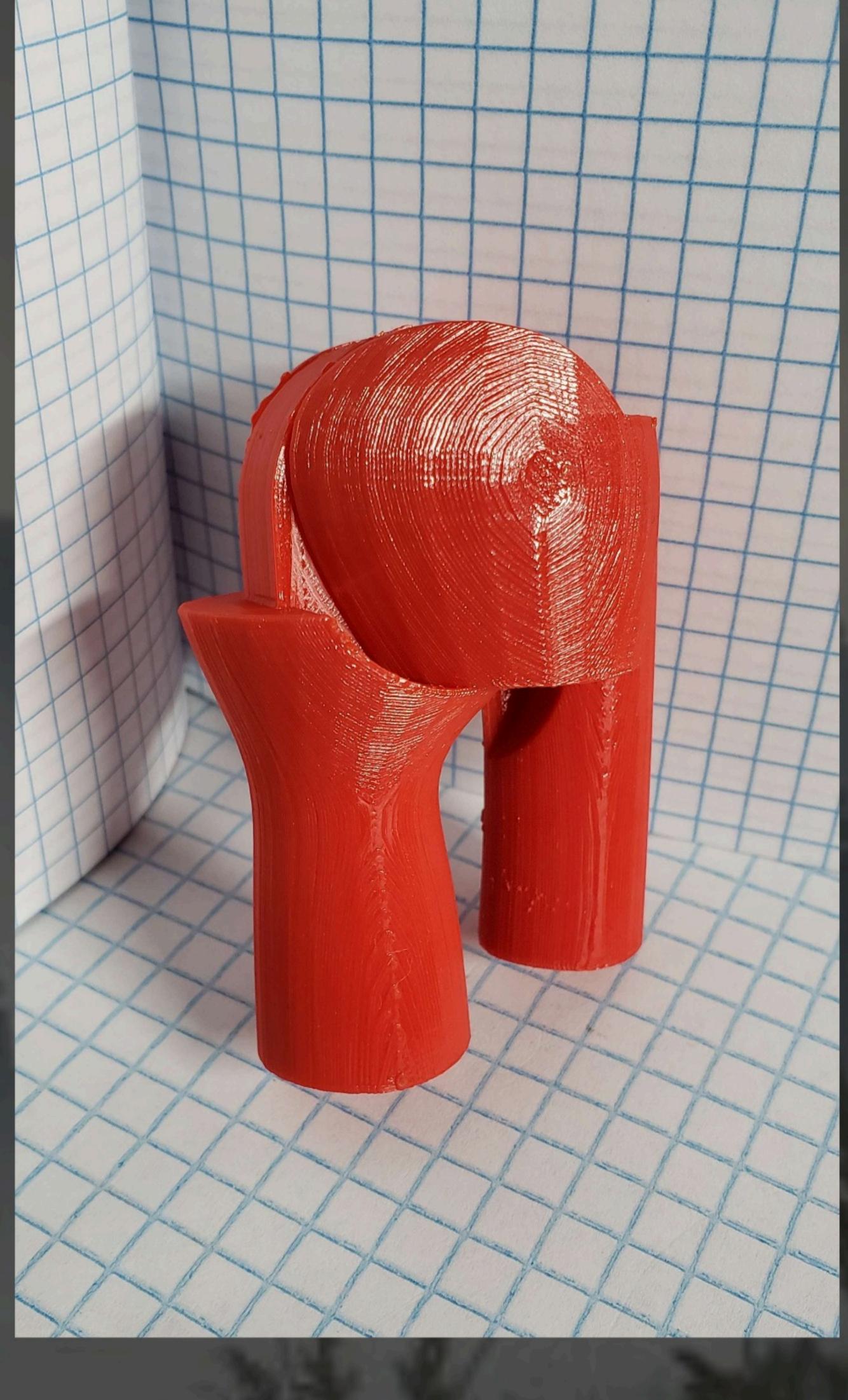
Strength problems in Iteration I

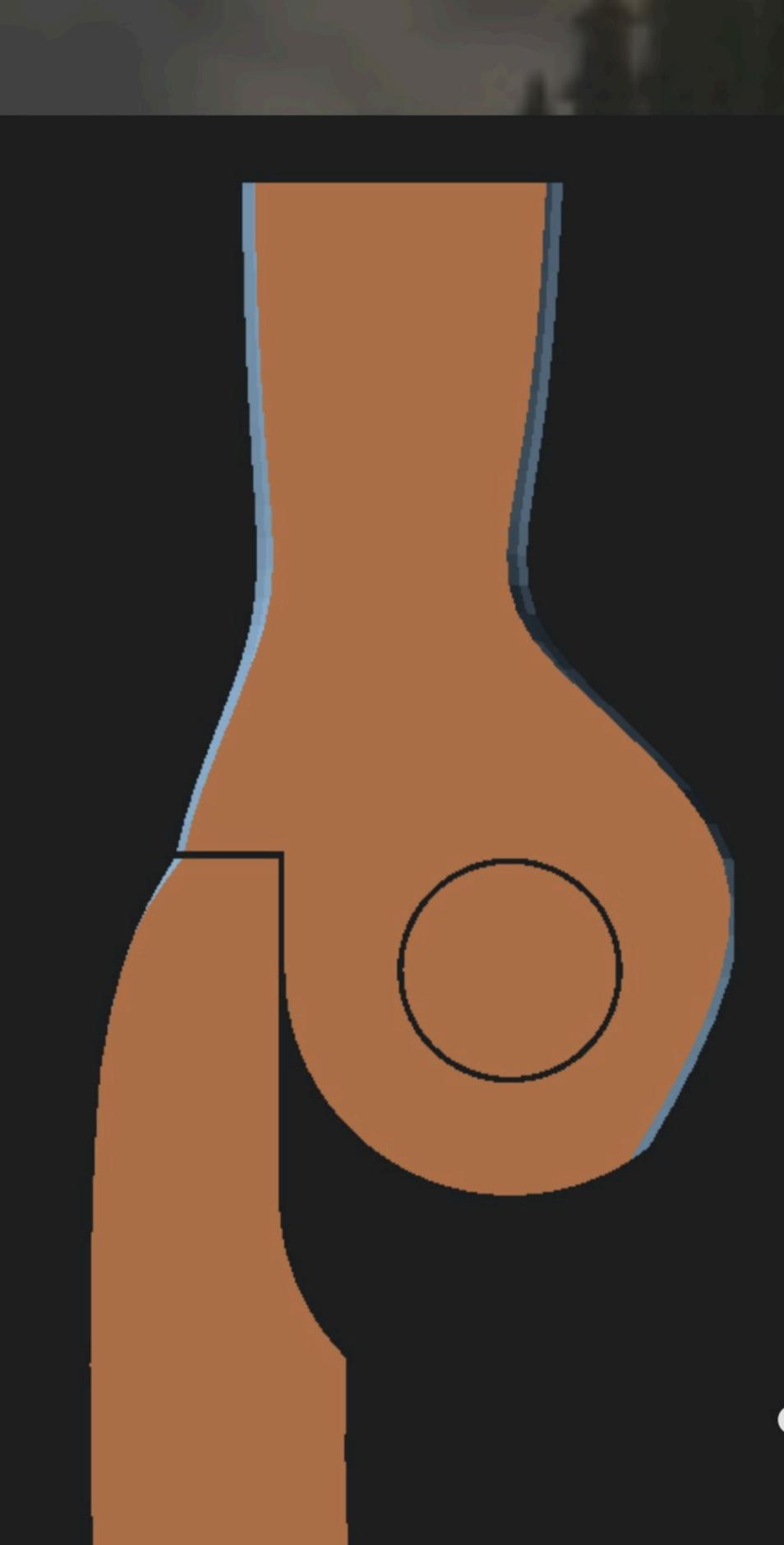
The joints in the original design had an extensive range of motion. That wide range of motion was achievable because **the center of the arm was open to allow the travel of chains**. By having a large opening in the center of the segments, the joints could almost bend all the way around (340°). **The downside of having such large open spaces was that the strength of each segment was deficient, which caused much instability.**

Solving the strength problem... only to encounter new problems!

Our new design removed a segment of the arm and replaced the chains with worm gears. Because of this, **the structure was stronger but no longer had open space to allow the joints to bend as far.** Joints could bend at most 180°; in order to fold into the 18 inch box the arm had to bend further than 90° from (TERM for 0°).







Test elbow-like
joints from other
projects made by
"the team". Right
image from cad
model shows offset
of joint.

SOLUTION: Elbow Grease!

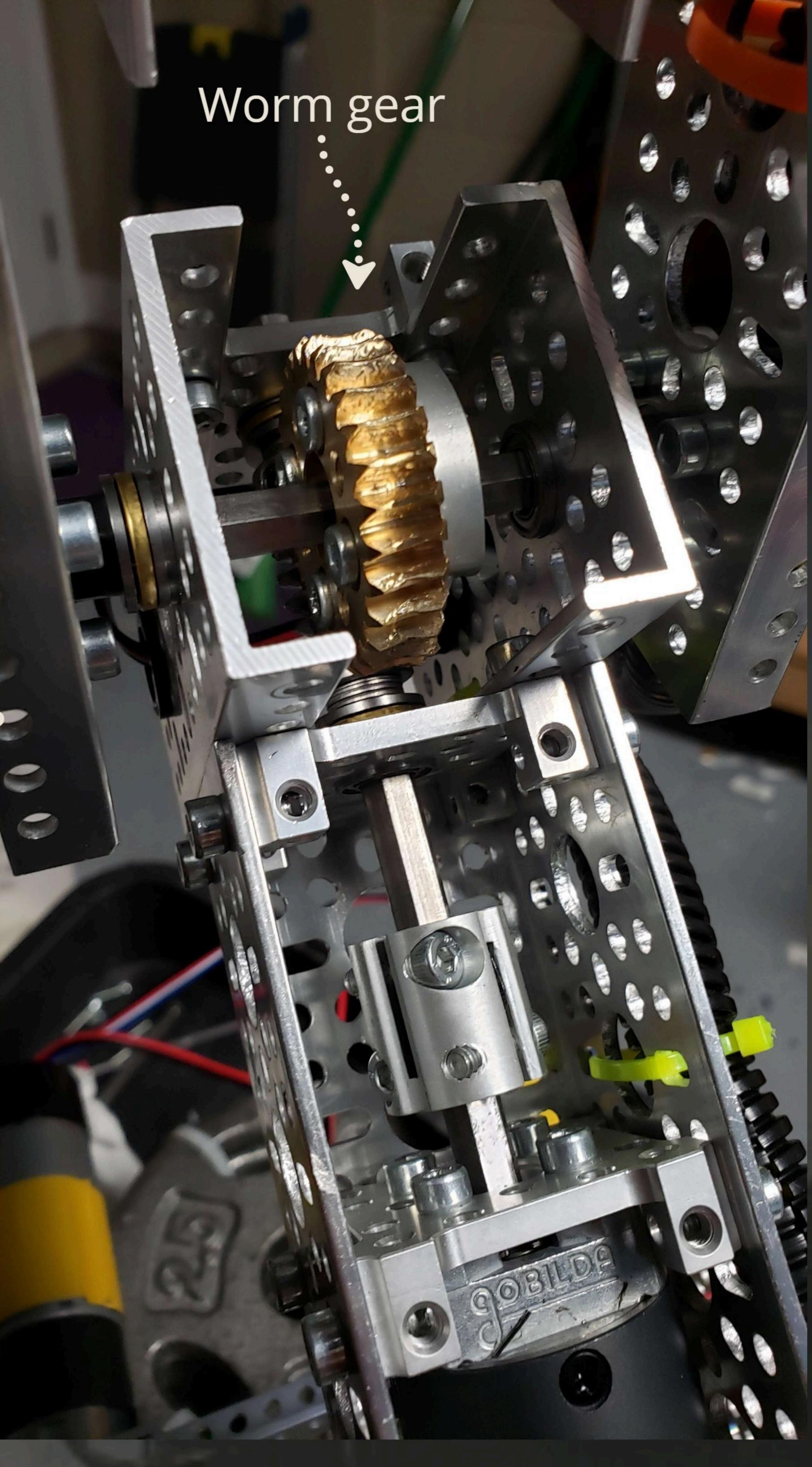
In order to fold the arm far enough to fit the robot into the 18-inch box, we offset the joints away from the center line of the arm. This allows the arm to bend 180° to fold, however, the arm cannot bend far in the opposite direction due to this. The knee and elbow joints in many animals are configured like this.

ITERATIONII





Allows the arm to fold 180°



REJECTED DESIGN: Fishtail Gripper

Motivation How can we make an gripper with a tighter grip?

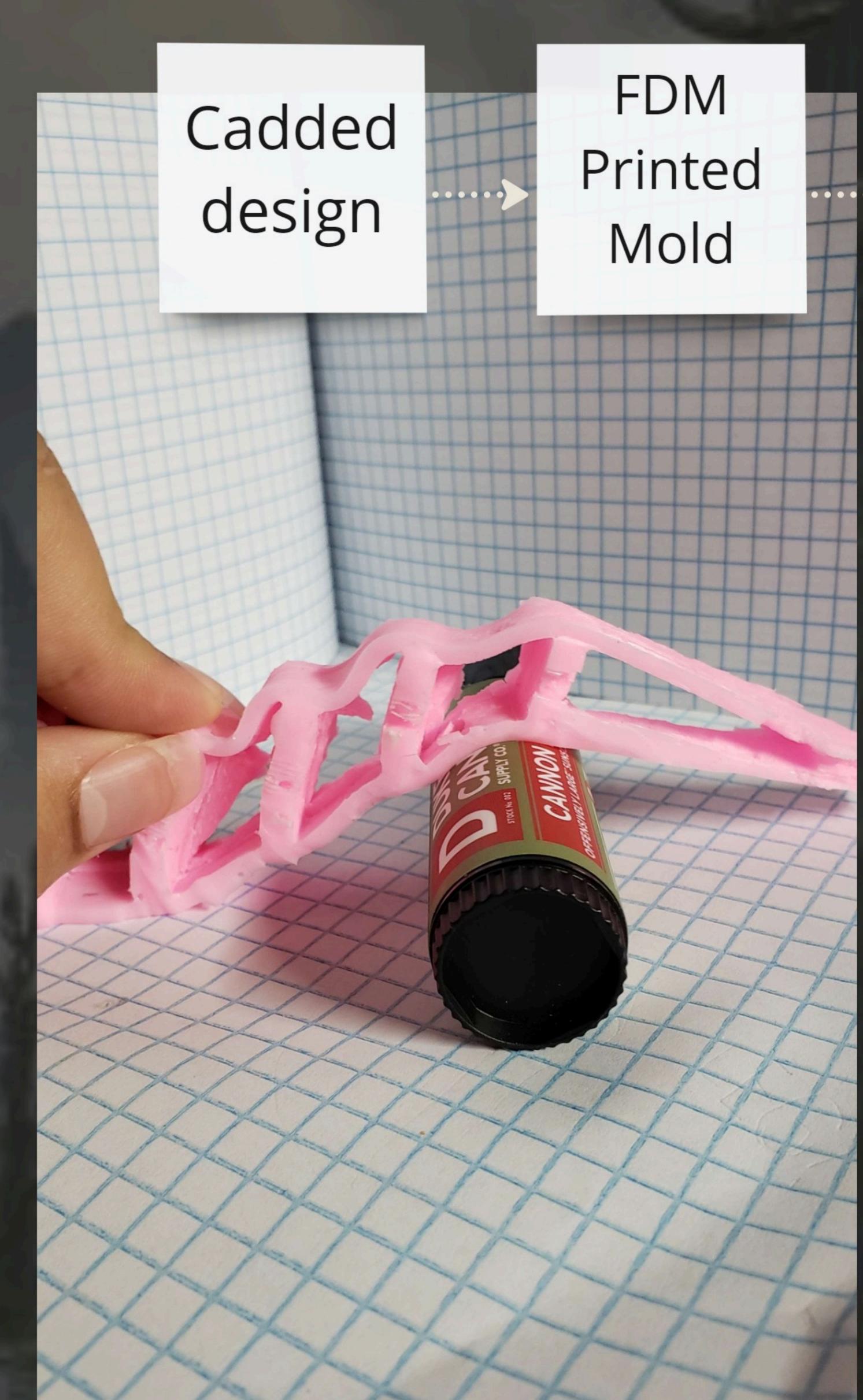
Solution Create a more flexible gripper out of silicon so that it can wrap snugly around the cones.

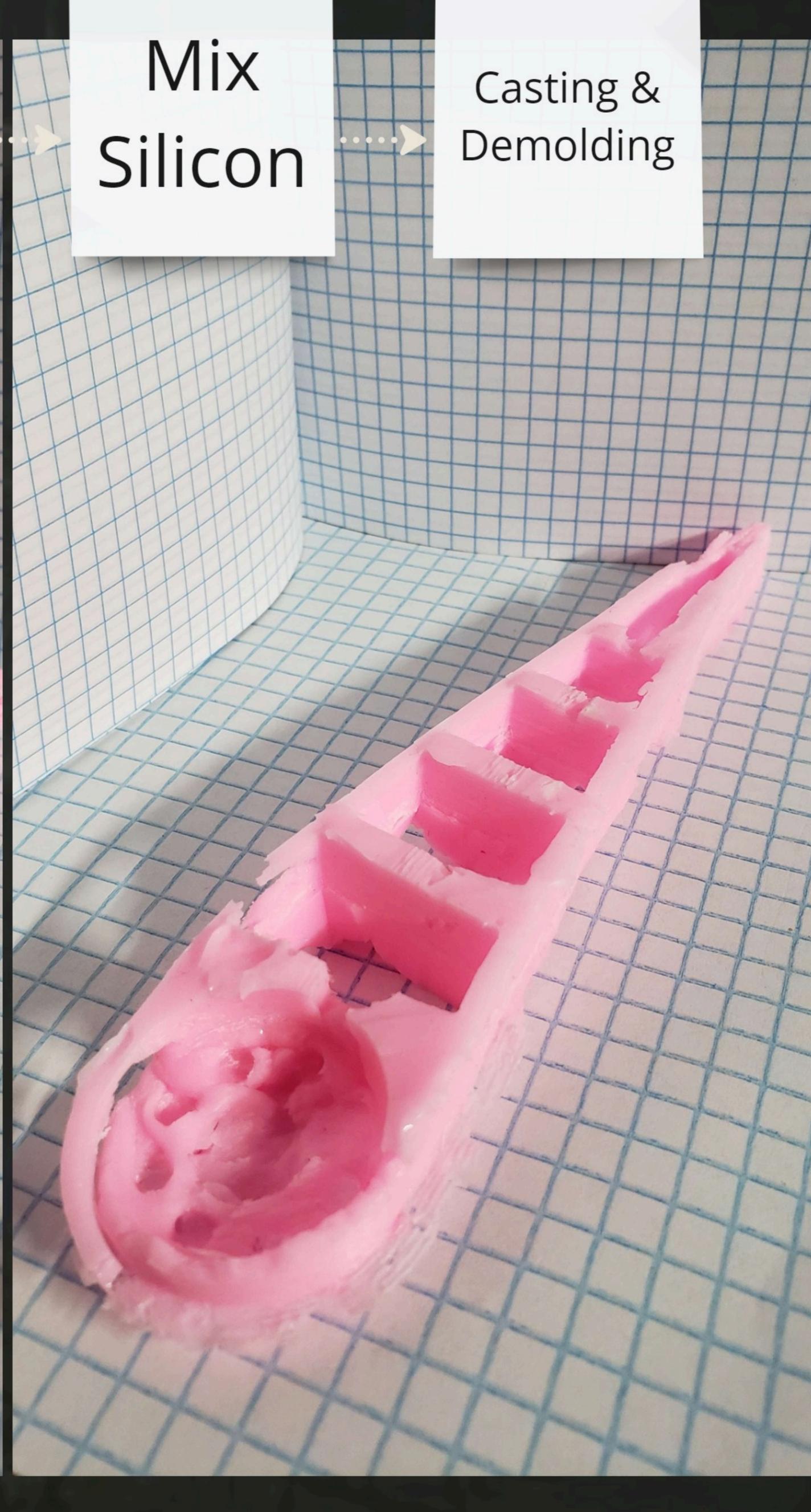
- This gripper design based on the mechanics of fish tails; it closes by flexing two triangles.
- The process for casting silicon was entirely new to the team and had many impediments as we learned how to do all of the steps appropriately.

ISSUES

Only partially wrapped around cones; could not gain a strong enough grip to be used!

Difficulty producing quality silicon cast.





ITERATIONIII

Rebuilding Arm Base

Motivation Base motors out of sync!

New Gripper Design

Motivation Could the gripper be more efficient at picking up cones?

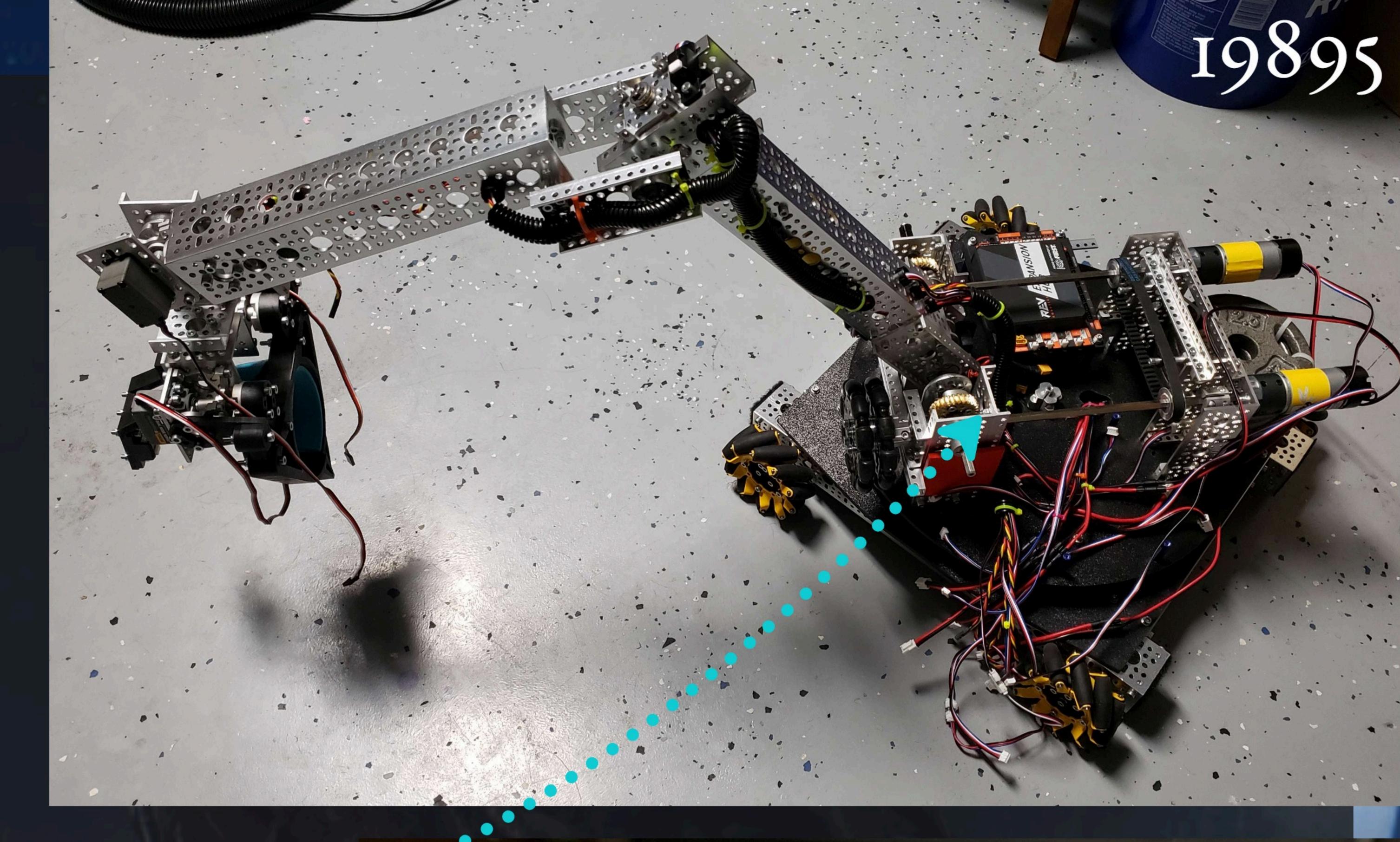
Solution Design a new gripper optimized to pick up cones. It was printed on an SLA printer.

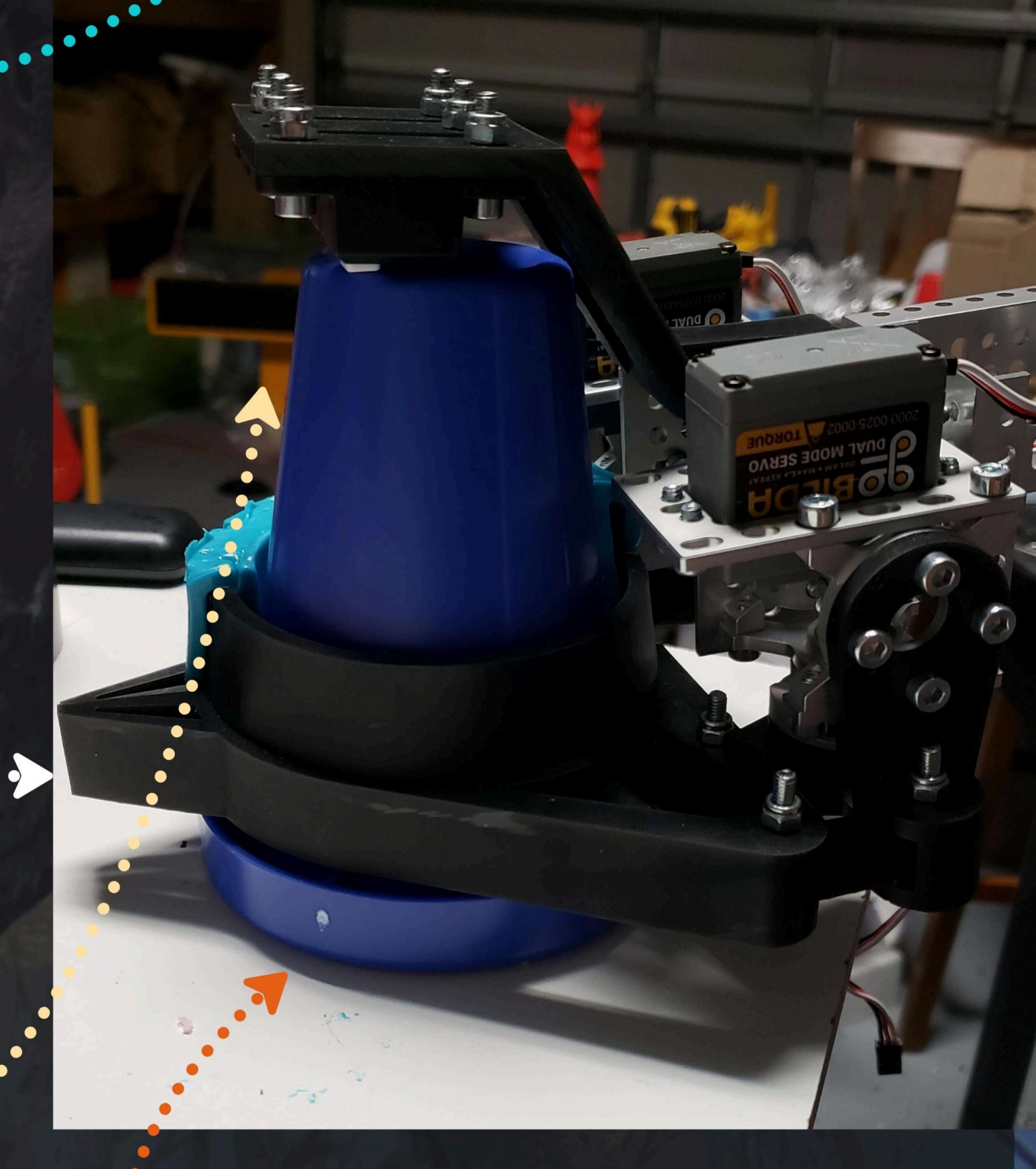
Conical opening at the bottom guides the cone into the center of the gripper while the gripper is being lowered.

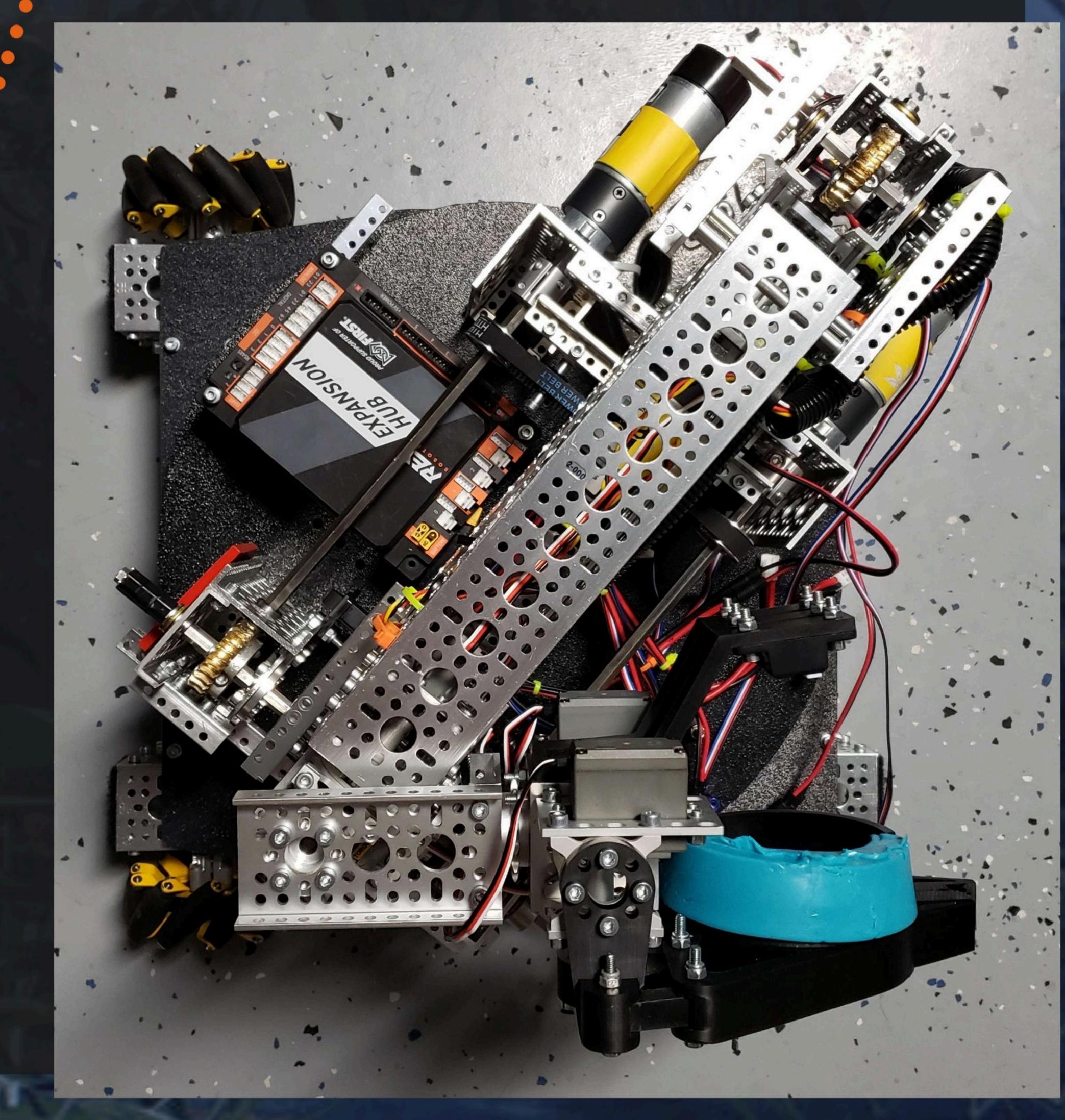
Another button located in the center releases the cone; this is pressed by the junction when placing a cone.

ISSUES

- Requires more accuracy controlling the arm in order to pick up cones.
- Cannot pick up tipped over cones. However, it should be more efficient at picking up upright cones.
- Difficult to release cones. The gripper hold onto cones too well and cannot pick up other objects.







ITERATIONIII

Creating the New Gripper

Resin Printing

Cadding in open scad

Supporting and slicing in Chitubox

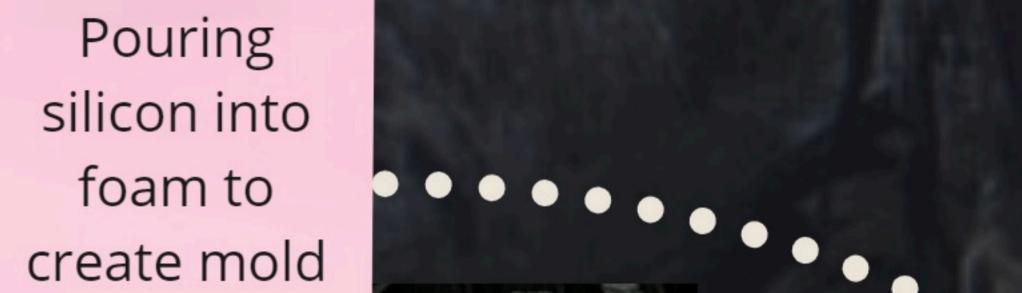
Printing

on Elegoo Saturn 2

Rubber Casting

Resin printing master

Carving foam to put master in





Remove mold from foam



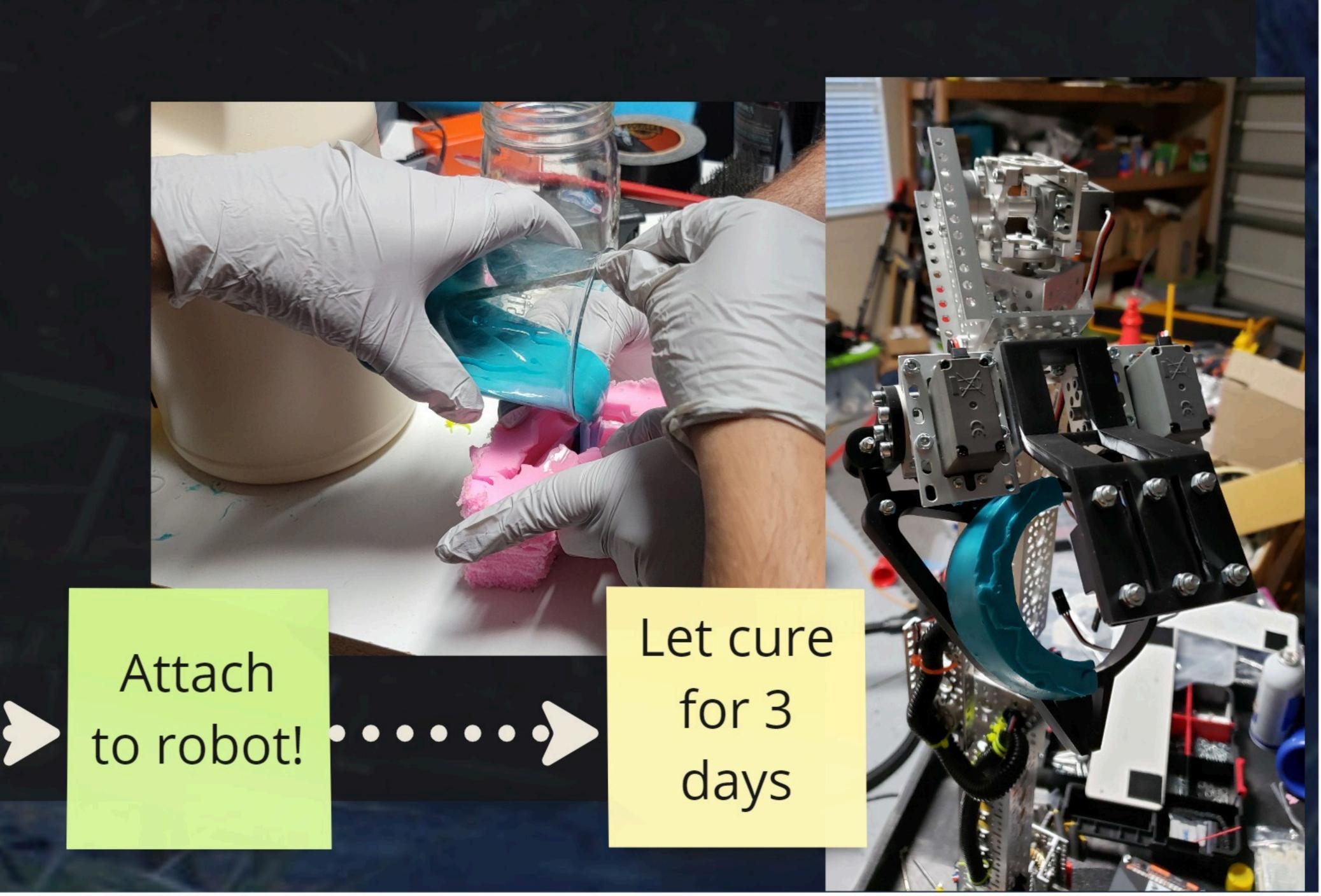
Remove master from mold

Heat mold in oven





Dye rubber, then pour it into mold



ITERATIONIV

New Gripper Design

Motivation Iteration III gripper gripped cones too well (i.e. could not release cones effectively. It could not grip anything other

than cones (difficult for team element)

Solution Develop a new gripper that can more easily release cones and grip objects other than cones.

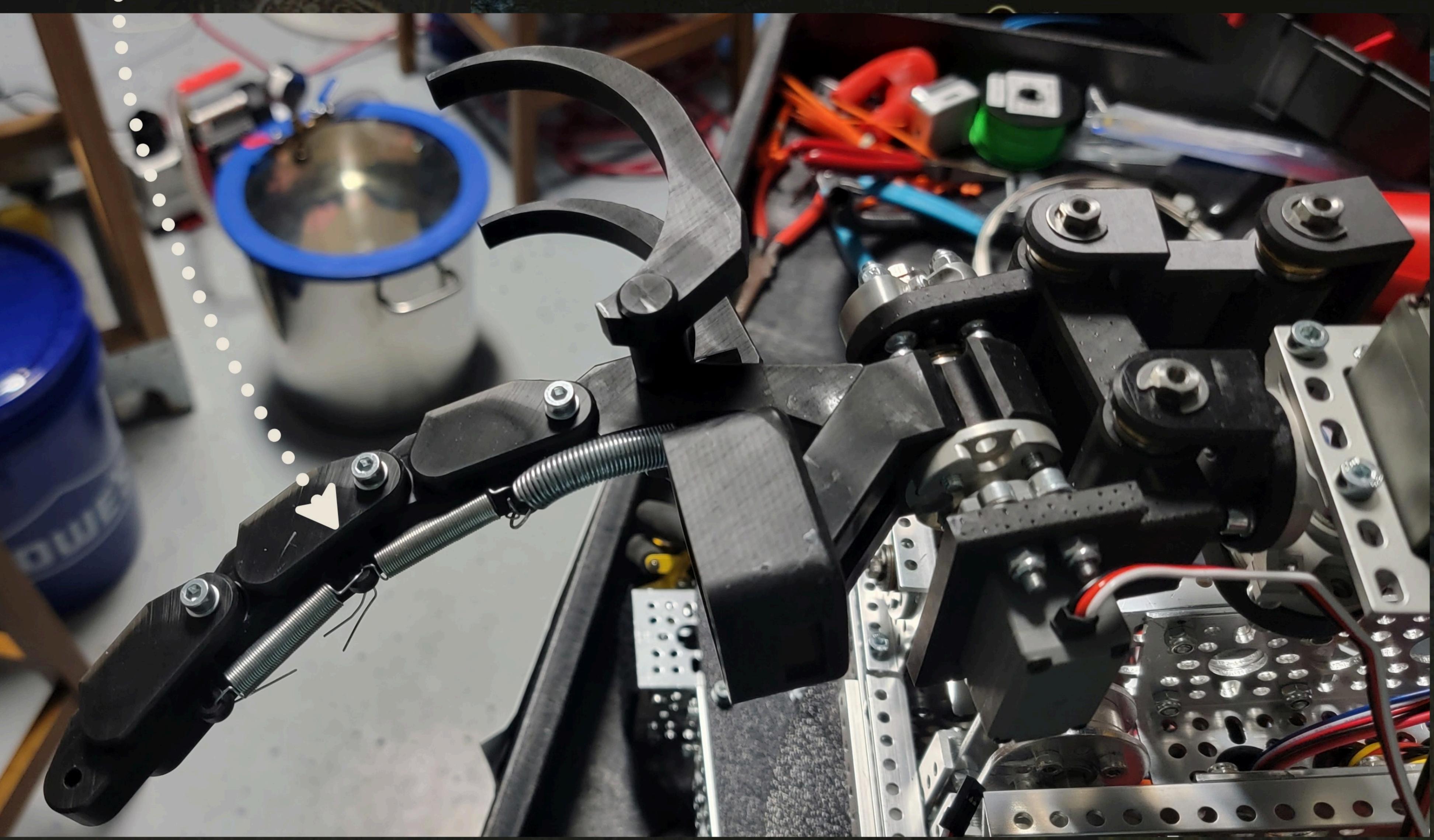
Printed on MSLA printer.

Operated through cable drive!

Inspired by articulation in fingers

Springs for tension



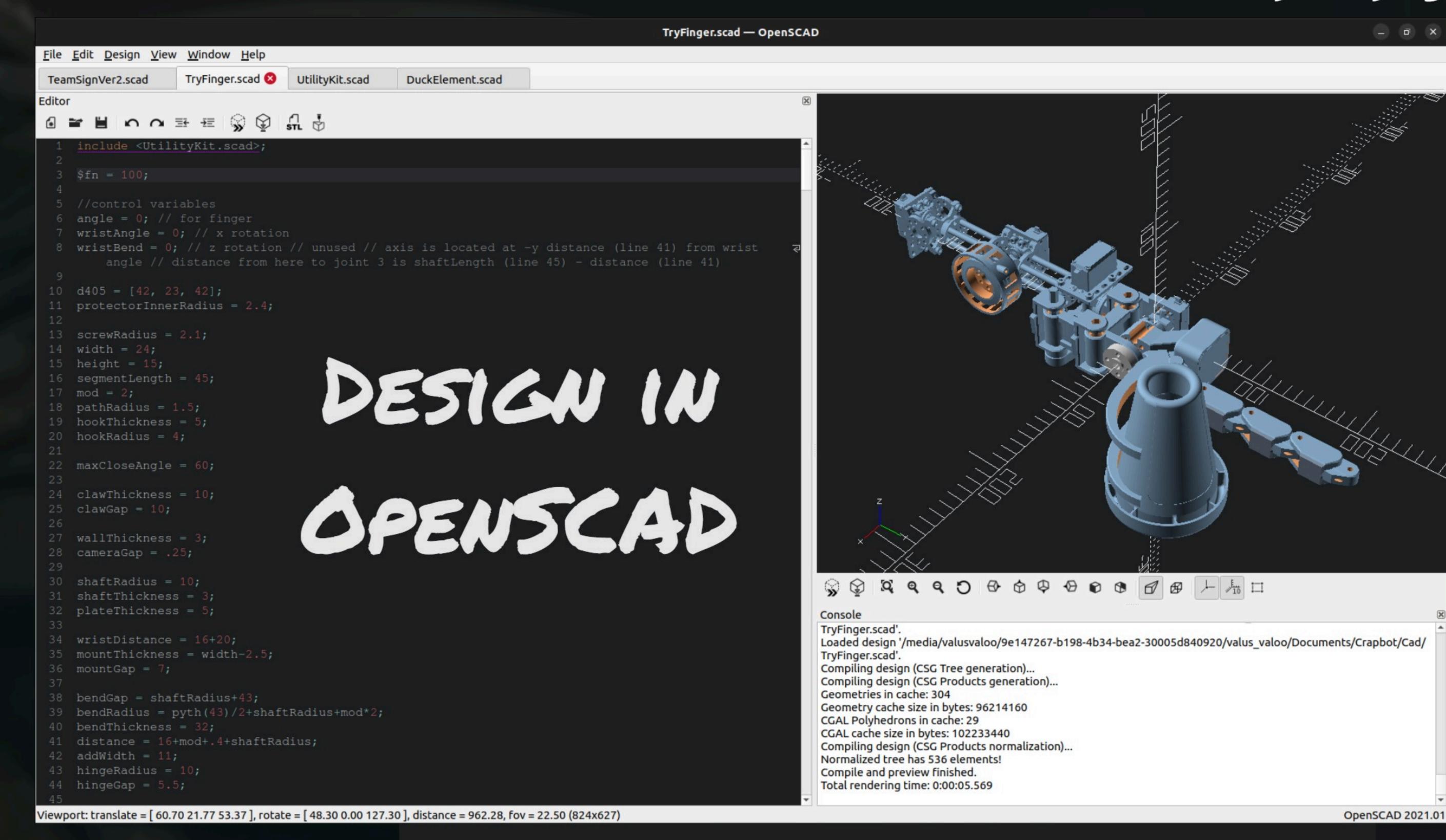


The springs hold the finger gripper open without needing to add a degree of freedom.

ITERATIONIV

NEW TEAM 576N

Plans for Advanced Autonomous Functions

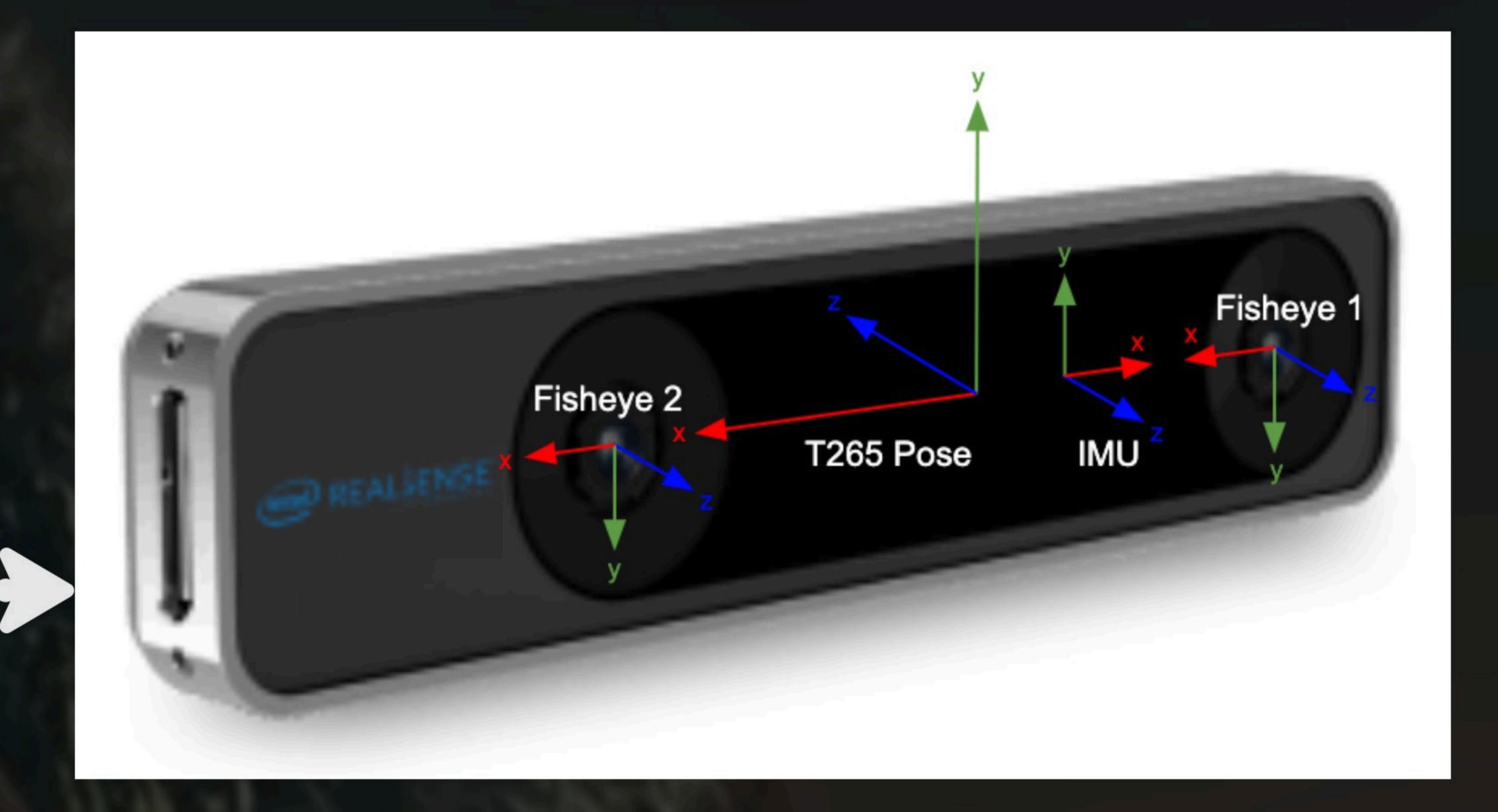


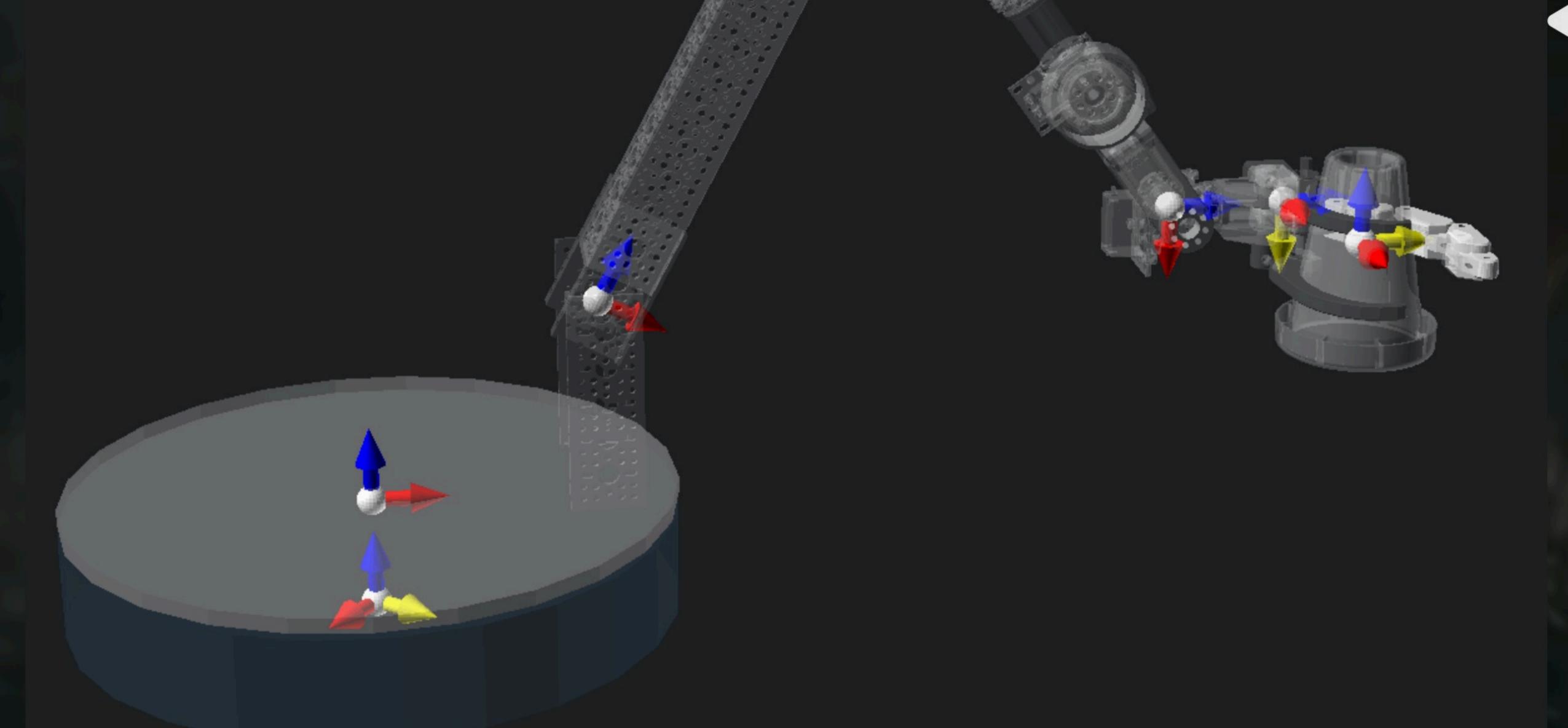




Motivation

Controlling an arm with seven degrees of freedom is very difficult therefore we need some automation.





TZ65 CAMERA COORDINATES ...

Solution

When we read the D405 camera we are given a vector in relation to the camera. To do inverse kinematics for that coordinate it must be translated to the robot's coordinate system. By using matrix multiplication we can translate the vector through each joint of the arm. We used coordinate transformations based on video game programing we did a few years ago.

Extra tidbit

We used distance multiplied by weight, to find the maximum torque required for each motor! Thus we can pick the best motors for the job! Huzzah!

ITERATIONIV

Cameras



Dragomight Industries 114

• Coming soon to a Tindie near you!!!

CUSTOM RESIN-PRINTED

CAMERA HOLDER

Tracking Camera:

- Used to track the robot's position on the field. This special robotics camera uses an internal IMU and video, combined with wheel telemetry, to judge its position more accurately.
- Calculations are done internally on the cameras chip so it removes some computational burden from the control hub.
- The camera also has a wide field of view giving a better range of awareness, so that the robot can avoid obstacles.

Distance Camera:

 Provides distance values for each pixel in the image in addition to color values.

Combined:

Combined with the tracking camera, it
performs VSLAM (Visual Simultaneous
Localization And Mapping), to map the
environment while determining the robot's
location in the environment. It can also
solve the lost robot problem, meaning that
if it loses track of its position it can try to
figure out where it is from camera views.

Using these cameras is not at all easy! We were able to leverage FTC team code from Github to run the tracking camera after a few weeks of work just setting it up. Extending it to the distance camera presented additional problems. We worked from Intel's Realsense library of examples and SDK to develop a point cloud. The point cloud provides a persistent representation of the game field that is used as the map.

ITERATION IV

New Cone Designs



Discovered early on that complicated images were NOT easy to recognize

Sleeve Instructions

1. Signal sleeves must follow the rules outlined in Game Manual Part 1, section 7.5

2. Place vision content (images, etc.) in the white trapezoidal areas of the template, and Team number areas on the template.

• Team Signal Sleeves must be fully completed (with vision content and Team numbers) prior to ariving at the Competition. Please refer to rule <5,500±2

3. Cut out the perimeter of the Signal Sleeve, including the tab

4. Cut the Signal Sleeve into a cone with the tab under the far side of the template.

5. The Signal Sleeve must be connected at each end

1. Any tape or adhesive may be used to connect the ends as long as the method used does not damage the Signal.

IMPORTANT NOTE: Due to the fragile construction of the Signal Sleeve, damage should be anticipated during normal gameplay. Teams should bring multiple copies of the Signal Sleeve to the competition.

PLACE TAB UNDER FAR SIDE

SOLIDWORKS Educational Product. For Instructional Use Only.

SOLIDWORKS Educational Product. For Instructional Use Only.

We switched to a simpler duck design for most of the iterations.

Current design with clear

shapes and colors!

We learned that

having diverse

outlines with

different

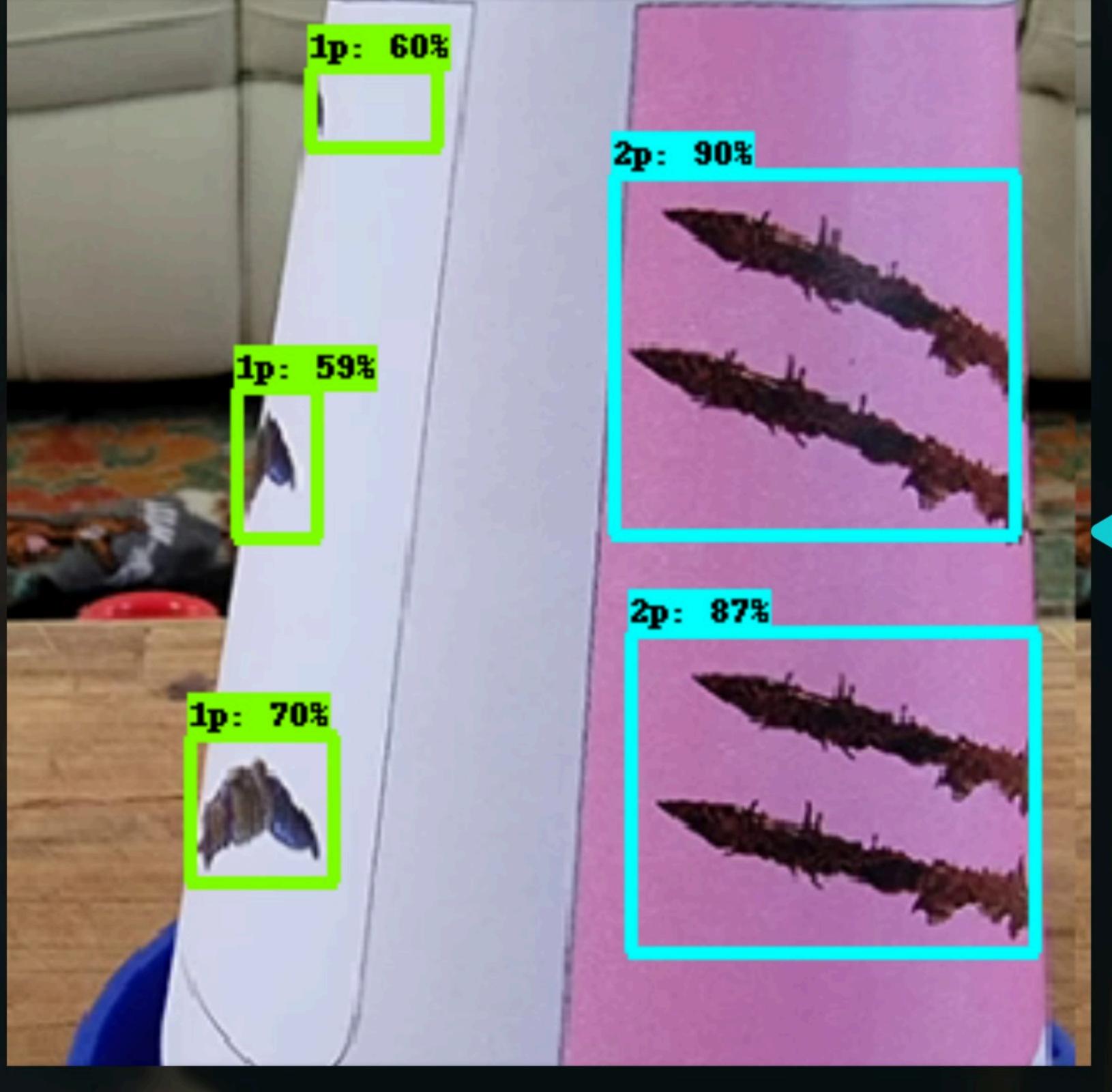
orientations is

helpful for the

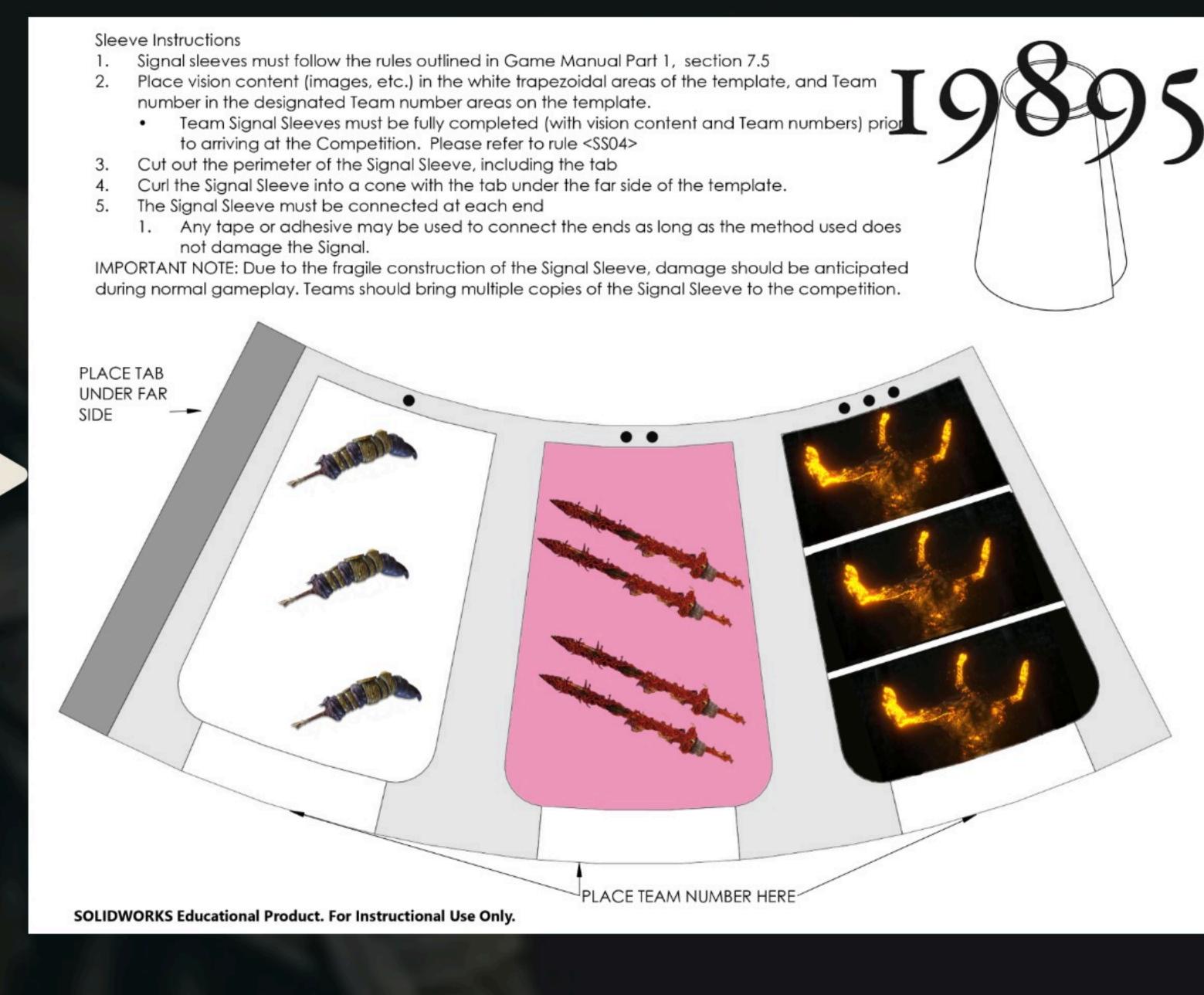
training.



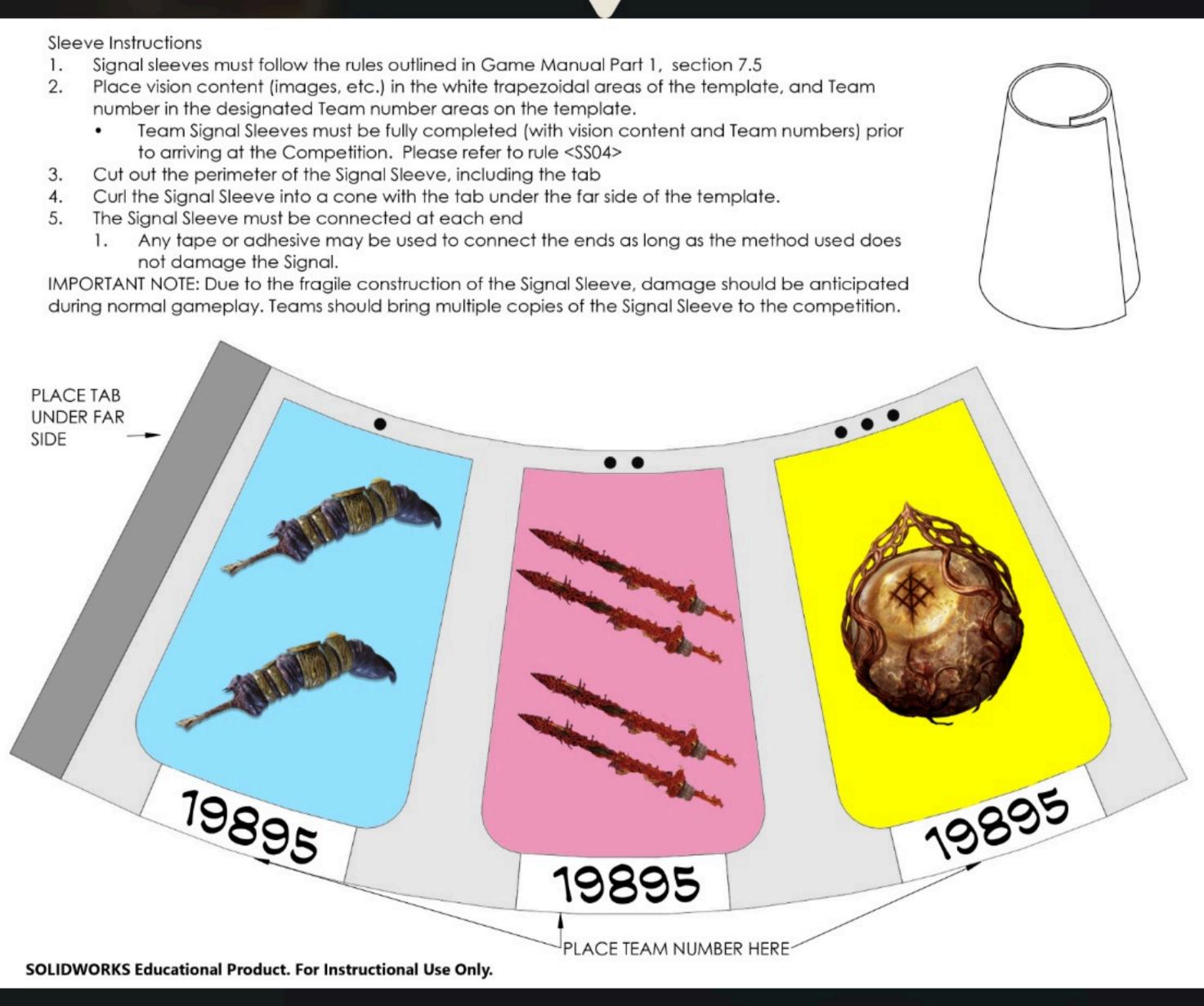
Model was less confident identifying the old duck images (deep valleys in graph = less confidence)

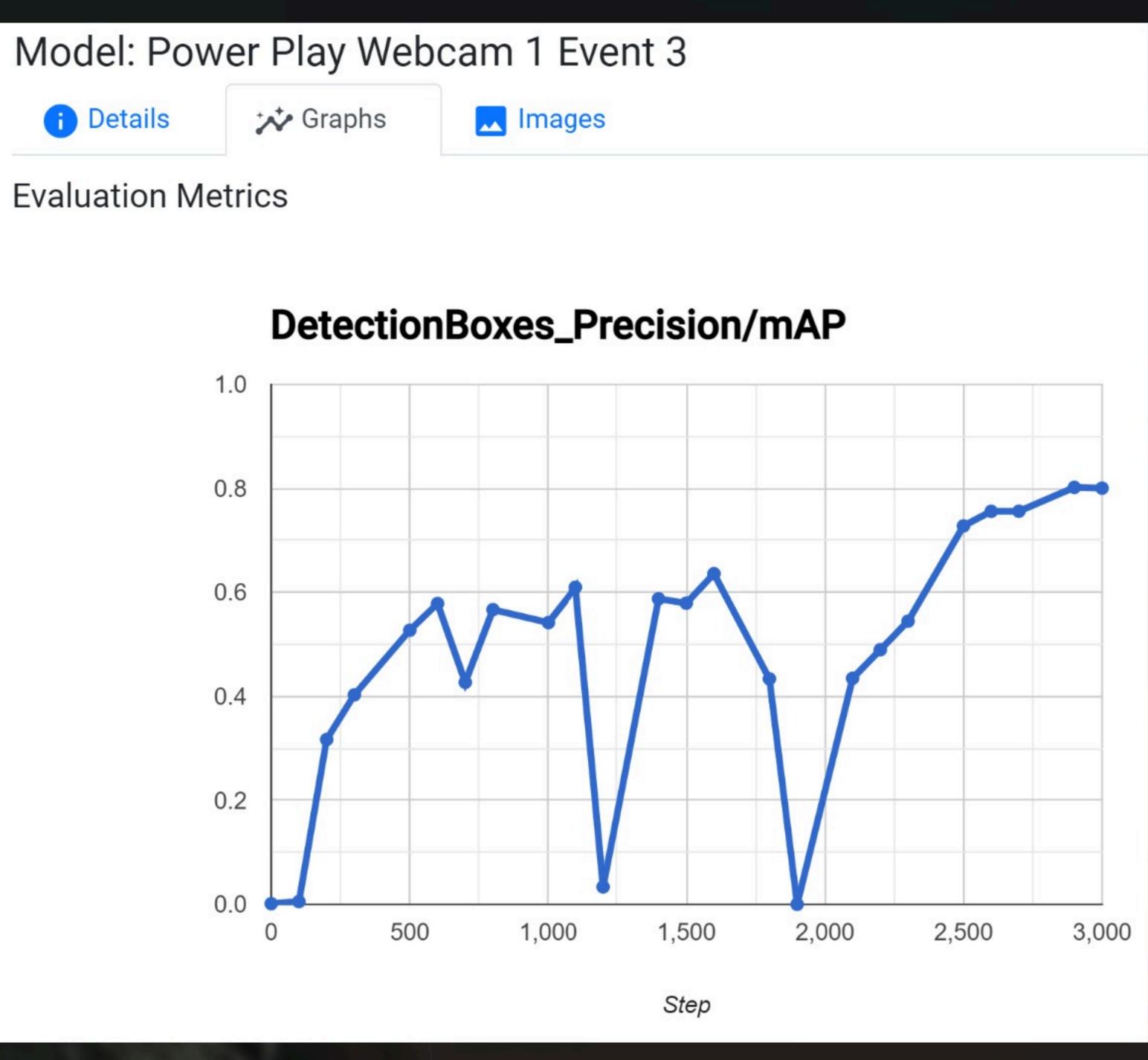


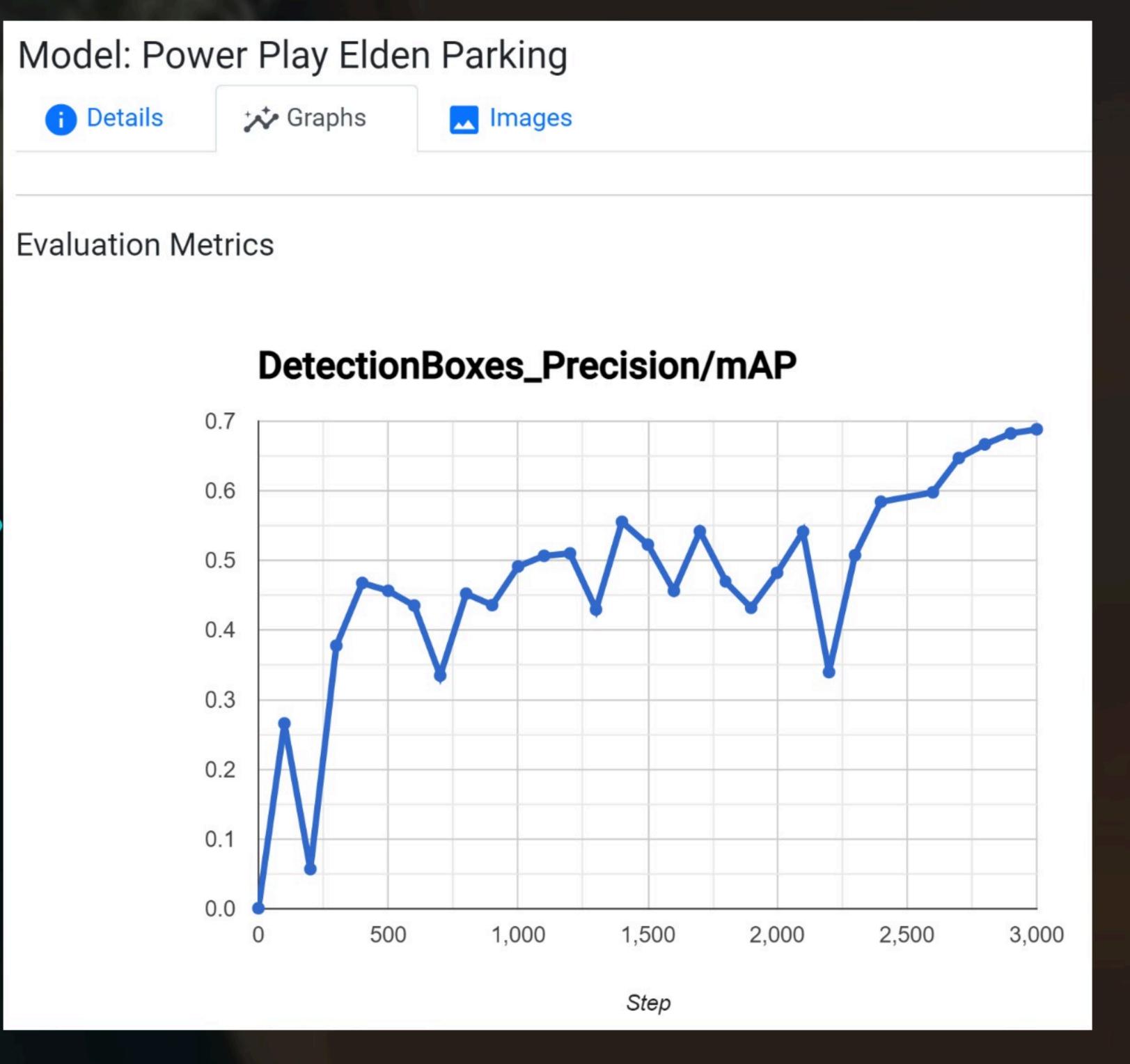
More confidence
with new images!
(No deep valleys
in the graph!)



The pink background in the new design worked the best







Levels of Arm Control

Our control comes in three layers. In the first layer, high-level control, we dynamically generate playlists of positions that the arm will travel to. For example, to pick up a cone, we use the D405 camera to find the position of the cone, then create a sequence to pickup the cone.

The second layer, mid-level control, is where we use inverse kinematics to find the angles that the motors need to take to reach a position specified by the highest level of control. Since we have a two-segment arm, to do these inverse kinematics we can use the law of cosines from trigonometry to easily find the angles. We also use calculus to calculate the derivative of the angle as a function of position over time. Thus we get the angular velocity of each joint to obtain smooth x-y motion.

In the third layer, low-level control, is where the PID (Proportional, Integral, Differential) controller directly controls the motors. This third layer was simple to implement because we could use the PID controller in the DCMotorEX class in the FTC library.

REJECTED DESIGN: Eurathane Rubber Team Element



Custom CAD design of team element to fit 4"x4" box



Resin-printed master molded in silicon



team element
Rejected at the meet for

Rejected at the meet for being too similar to a cone!

Future Plans



Robot:

- > Incorporate bend sensors to provide compliance
- > Incorporate point cloud to improve robot navigation
- > Complete fully autonomous mode so "we" don't need to drive anymore
- > Use T265 tracking camera to improve navigation
- > Add a fourth segment once again to increase reach
- > Turn arm into full custom parts
- > Add theme elements
- > Add more finger

Other:

- > Assist contacts in starting FTC in Indonesia
- > Perhaps one day get another team member
- > Sell robot parts from Dragomight Industries
- > Trade mark Dragomight Industries

We learned so many skills from our knowledgeable coaches such as:
Programming,
Communication, CAD, Resin Printing, Project Planning,
Technical Writing, Calculus, and Applied Physics.