Potential Energy
#19706
Engineering Portfolio

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2024 *FIRST* World Championship

OUR TEAM

Abby (9th)
Outreach
Documentation
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Website

James (10th)
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Design
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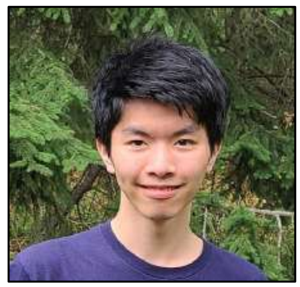
Ayana (9th)
Documentation
Design
Hardware

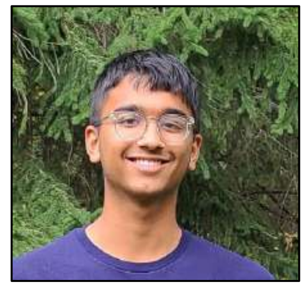
Saniyah (10th)
Outreach
Documentation
Design
Hardware

Isaac (11th)
Software

Antonin (11th)
Design
Hardware



Harry (10th)
Outreach
Software
Documentation



Sidharth (10th)
Design
Hardware

DISCOVERY

We learn new things and apply them to our robot and presentation in order to improve them. When we go to Outreach events, we try to learn new things from the people we meet.

INNOVATION

We are comfortable taking chances to try new things. This year, we made a multi-part system for intake and delivery of Pixels, which was new for us. We also teach ourselves things such as AI design of parts in order to help us with CAD.

IMPACT

This year, we have engaged in several high Impact projects. We started Project Momentum (p. 5) to promote *FIRST* programs in our school district. We also did Advocacy (p. 4) by meeting with legislators in order to support bills that benefit High Tech Kids, our Program Delivery Partner (PDP) .

INCLUSION

Everyone is included in our daily work, and we cross train team members in order to better include everyone. When our "frenemy" team in our neighborhood disbanded, we took on one of their members who otherwise wouldn't have a team to join.

TEAMWORK

If any of our team members need help with anything, someone else is there to assist them and work together to solve the problem. We cross trained people so that we can better work as a team and understand what everyone else is doing.

FUN

We love to have music playing during our meetings, and we have karaoke parties to show off our amazing singing skills. We also have lots of fun learning new things and working with small children.

GOALS

TEAM
- ➔ Cross-train so we aren't relying on just one person for anything – accomplished!
- ➔ Have more organized meetings – accomplished!

OUTREACH
- ➔ Double Outreach hours of last year, from 225 to 550 person hours – accomplished!
- ➔ Do more Advocacy (see page 4) – accomplished!
- ➔ Launch Project Momentum (see page 5) – accomplished!

ROBOT
- ➔ Learn and utilize odometry (see page 15) – accomplished!
- ➔ Use game strategy to direct robot design – accomplished!
- ➔ Have more than one person doing design – accomplished!

Areas we improved since last year:
- More structured meetings: we start every meeting together with a brief check-in, update on what has been done since the last meeting, progress on overall goals, discuss goals for that particular meeting, divide up the work
- Taking better notes, keeping track of homework, and recording what we've done
- Document every step of the way (with pictures) so we don't have to catch up later
- More Outreach with a focus on increased mentorship of younger teams
- Cross-training of team members, using multiple team members in each work area instead of relying on one person
- Kept a clean workspace so we could find parts more efficiently, so we didn't accidentally buy duplicates, and so we didn't make our coach crazy
- Use Loctite!

3-STEP DESIGN PROCESS

We had a marathon meeting after Kickoff and decided to improve our design process to be more efficient and exhaustive. In the past, we tended to work separately. Now we work collaboratively using MGH.

Potential Energy = MGH

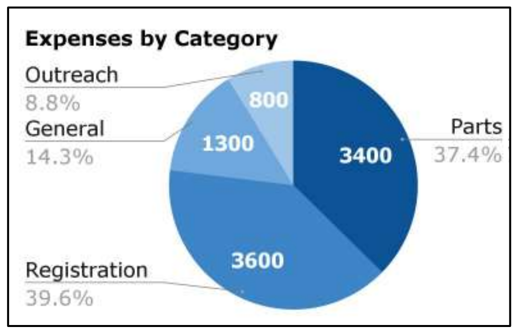
MAP out a plan:
- ➔ Define problem
- ➔ Brainstorm solutions
- ➔ Research ideas

GENERATE ideas:
- ➔ Choose an idea
- ➔ CAD
- ➔ Prototype

HONE our solutions:
- ➔ Test
- ➔ Refine
- ➔ Implement

Team Finances

Income	
Last season carry-over	1,000
Dues	2,200
Fundraising & Donations	8,000
Sponsorship	4,750
TOTAL	15,950



Team Organization

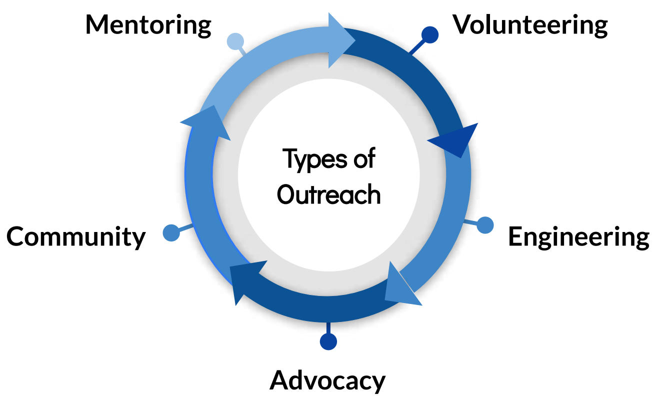
We use spreadsheets for organization. We track Outreach, upcoming events, robot design, and meeting attendance. Below is a sample of our Outreach spreadsheet.

Outreach Type	Date	Event	# team members	Hours spent	Person-hours	Project Momentum?	JC	ST	AU	IH
Advocacy	4/27/2023	Meeting with MN State Rep Kelly Moller	3	0.25	0.75	☐	☑	☐	☐	☐
Mentoring	5/2/2023	FLL Explore Meeting (Master Electrons)	2	1.5	3.00	☑	☑	☐	☑	☐
Mentoring	5/9/2023	FLL Explore Meeting (Master Electrons)	2	1.5	3.00	☑	☐	☑	☐	☐
Community	5/19/2023	Valentine Hills Carnival	5	4	20.00	☑	☑	☐	☐	☑
Volunteering	5/20/2023	FLL Explore Festival	3	3	9.00	☑	☑	☐	☐	☐
Community	5/29/2023	Cub Foods Fundraiser (Arden Hills)	7	6	42.00	☐	☑	☑	☑	☑
Advocacy	6/8/2023	Meeting with Rob Reetz	3	0.5	1.50	☑	☑	☑	☐	☐
Engineering	6/9/2023	Tour of Boston Scientific	6	2	12.00	☐	☑	☑	☑	☑
Engineering	6/21/2023	SPARCS Microsoft	4	1	4.00	☐	☑	☐	☑	☐
Engineering	6/27/2023	SPARCS Infinity Robotics	2	1.5	3.00	☐	☑	☐	☐	☐
Mentoring	7/13/2023	Meeting with Jackie/Spon Con about MVHS FTC Club	3	1	3.00	☑	☐	☑	☐	☑
Community	7/17/2023	Shoreview Library Story Time	3	1.25	3.75	☐	☐	☑	☐	☐

OUTREACH OVERALL

71 Events
746 Person Hours
2 Continents

Outreach goals this year:
➔ 550 person hours (2x last year)
➔ Do more Advocacy
➔ Launch Project Momentum



See page 5 for info on Project Momentum, a project we launched this year. Its events are marked with asterisks.

VOLUNTEER OUTREACH

Our team did **136 person hours** of Outreach at **4 Volunteer Outreach Events.**

<u>Volunteer Outreach Events (EN-90)</u>

- Anoka-Hennepin Robotics Challenge
- FLL Explore Festival**
- FTC Qualifier
- FTC League Qualifiers

Our roles included emceeing, refereeing, DJ-ing, queueing, and running kids' activities

Above: Isaac refereeing
Left: Harry emceeing

ENGINEERING OUTREACH

Our team did **128 person hours** of Outreach at **17 Engineering Outreach Events**.

<u>Engineering Outreach Events (EN-47)</u>

- Meeting with Dave Dinsmoor, Medtronic
- Software review with Dan Holmdahl, Boston Scientific
- Industry tours: Machining Technology; Boker's Inc; Stratasys; Microsoft; MnDOT; Boston Scientific; Infinity Robotics (x2)
- U of Minnesota Rocketry Club
- Drone design basics with Jacob Hairrell, Mounds View High School Physics Dept.
- Design reviews: Corey Knutson (U of MN); Infinity Robotics; Machining Technology
- Twin Cities Maker Club work session
- FRC Qualifying Meet

Engineering Outreach Spotlight: Infinity Robotics

- We had two tours and one design review with the President, a software engineer, a mechanical engineer, and a communications expert.
- Among many things, we discussed:
  - Making systems more reliable by reducing the number of motorized parts. We adopted this in our robot design.
  - Improving the accuracy of our color sensors
  - Strengthening our Delivery hinge
  - Simplifying language in our Portfolio

Engineering Outreach Spotlight: Design Review with Corey Knutson, U of Minnesota Interactive Robotics and Vision Lab

- Corey is a PhD candidate at the U of Minnesota who we met two seasons ago and have kept in touch with.
- After discussing several potential hardware causes, Corey guided us to use software, not hardware, to correct our robot curving while strafing.
- Corey mentioned that we could better pull Pixels into the Transfer by mounting our green compliant wheels at an angle or vertically, fixing an issue we had at our first Qualifier. We implemented this (see page 10).
- Corey stressed the importance of having adequate time for coding, and told us that we shouldn't implement any of his ideas if it would take time away from software.

Engineering Outreach Spotlight: Machining Technology Design Review

- Design review with the CEO
- We focused on material and structure questions because that's their expertise.
- We discussed 3 chronic design problems we have been facing. His suggestions were to:
  - Increase the thickness of the hinge attachment point on our Delivery to improve strength.
  - Connect both sides of our U-shaped Chassis with a thin metal shim in order to increase stability and better pull Pixels off the floor (see page 8).

ADVOCACY OUTREACH

Our team did **26.25 person hours** of Outreach at **7 Advocacy Events** this year, making contact with **9 State Representatives and Senators**.

Advocacy Outreach Events (EN-38)

- STEM Day at the Capitol (MN State Rep. Steve Elkins, MN State Rep. Amanda Hemmingsen-Jaeger, MN State Senator Nicole Mitchell, MN State Senator Carla Nelson)
- Phone call with MN State Senator John Marty's legislative assistant
- Meeting with MN State Rep. Brion Curran
- Meeting with MN State Senator Heather Gustafson
- Meeting with MN State Rep. Erin Koegel
- Meeting with MN State Rep. Kelly Moeller
- Meeting with Rob Reetz, Principal at Mounds View High School**

This year we did Advocacy by meeting with our state legislators and school principal to change public policies to benefit High Tech Kids (our PDP) and *FIRST* programs. Advocacy is defined on page 76 of Game Manual 1.

Meeting with MN State Rep. Moeller in the MN Capitol after calling her off the House floor

Meeting with MN Senator Gustafson in her office

We spoke to 9 State Representatives and Senators about Minnesota omnibus bills SB-1311 and HF-2497, which would benefit STEM programs and High Tech Kids (our PDP).

- What we learned from them:
  - How a bill becomes law
  - Daily legislative procedures like how busy the capitol is while in session and how to call legislators off of the House/Senate floor
- What we told them:
  - How kids like us could benefit if our PDP received state funding
  - How *FIRST* programs have benefitted us — they were especially surprised about the soft skills we have learned, like public speaking and other presentation/writing skills
  - We invited them to attend our FTC tournaments
- During Senate deliberations, MN Senator Gustafson mentioned our team on the Senate floor! The bill passed and our PDP and its partners received a grant of $730,000!

While we spent the fewest Outreach hours doing Advocacy, it will probably have a more lasting Impact than the other types of Outreach in the long run.

COMMUNITY OUTREACH

Our team did **327.5 person hours** of Outreach at **18 Community Outreach events.**

Community Outreach Events (EN-69)

- Cub Foods Fundraiser (x5)
- Valentine Hills Elementary Carnival**
- Ramsey County Library Story Time (x2)
- FLL Challenge recruitment meeting**
- North Tech Community Hub Fun Fridays
- Pinewood Elementary daycare demo**
- STEM Day at the MN State Fair
- FTC Kickoff Breakout Session
- Turtle Lake Elementary School Carnival**
- 3M Super Science Saturday
- Phone call with Milan Darji (RoboCyclers) re: Recycling Initiative
- Media interviews with U of MN and High School newspapers

Community Outreach Spotlight: 3M Super Science Saturday

We demoed our robot to kids at the 3M Super Science Saturday. There was also a physics demonstration for the kids.

Community Outreach Spotlight: Ramsey County Library

We demoed at two Ramsey County Library robot-themed storytimes, where we instructed a teacher from a German Immersion School on how to start an FLL team.

Plastic Recycling Initiative:
In the spirit of sustainability and Core Values, we contacted several experts to learn how to recycle 3D-printed plastics, which are difficult to recycle. We then set up a collaboration with RoboCyclers, a non-profit collecting e-waste for recycling. We worked together to collect plastic and e-waste from FTC teams at a booth at the Minnesota FTC State Championship Discovery Fair, which will be sent for recycling.

MENTORING

Our team did **128.5 person hours** of Outreach in **25 Mentoring Events**.

Mentoring Outreach Events (EN-9)

- Two meetings with Krispen Lam (Mounds View School District) re: Project Momentum**
- 13 FLL Explore meetings with 9 Explore teams**
- Target TWIST (Target Women In Science & Technology) event
- Meeting with Jackie Lee (FTC Alumna) re: Project Momentum**
- FLL Challenge: The Circuit Crew (x2)
- FLL Challenge: Gatorbots
- 3 mock judging sessions with FTC alumni, former FTC coaches, and FTC judges
- Dean's List Semi-Finalist meeting with former Dean's List Finalists (we organized this and invited other FTC teams to attend)

Video call with The Circuit Crew in Australia

Mentoring Outreach Spotlight: Master Electrons

One of the teams that we Mentored is the FLL Explore team Master Electrons. We met with them five times, teaching them basic programming on their WeDo and asking them judging questions to prepare them for their Festival. Many of the kids we Mentored last season continued this season!

Mentoring Outreach Spotlight: The Circuit Crew

We Mentored The Circuit Crew (rookie FLL Challenge team in Australia) in the areas of Robot Design, Software, and Project. They won at their Australian North Nationals competition and qualified for Worlds!

Software: We instructed them on how they could add parameters to their functions, to measure by time instead of distance. We encouraged them to use MyBlocks to improve consistency on runs. We advised them not to update Spike Prime software.

Project: Circuit Crew's project is an app to help people pick out just one sound from many, like one instrument in an orchestra. We recommended against using AI, which would likely be difficult to set up, integrate, and understand. Also, it would also have slow processing. We suggested WiFi could be a better option for real-time streaming via small microcontrollers.

Robot Design: The Circuit Crew was struggling to make an attachment for their arm, so we made a video tutorial to give them prototype ideas. We also helped them troubleshoot accuracy issues when driving.

PROJECT MOMENTUM

Our team did **111.5 person hours** of Outreach in **24 Project Momentum Events**.

Project Momentum Events (EN-7)

- Organizational meeting with Krispen Lam, Mounds View Schools
- FLL Explore meeting: Master Electrons (x5)
- FLL Explore meeting: Doodle Doods
- FLL Explore meeting: LEGO Guardians
- FLL Explore meeting: Potato Power
- Valentine Hills Elementary School Carnival
- FLL Explore Festival
- Meeting with Rob Reetz, Principal, Mounds View High School
- Meeting with Jackie Lee, FTC Alumna
- Meeting with Krispen Lam
- FLL Challenge recruitment meeting for Mounds View School District families
- Pinewood Elementary School daycare demo
- Turtle Lake Elementary School Carnival
- FLL Explore meeting: Potato Gamers
- FLL Explore meeting: BA Tigers
- FLL Explore meeting: Code J&M
- FLL Explore meeting: Behind the Brick
- FLL Explore meeting: Awesome Rock LEGO Winners

Our goal for Project Momentum is to establish a sustainable *FIRST* program in our school district. Our events are targeted to get kids and parents in our school district interested in *FIRST*, and span Mentoring, Community, and Advocacy Outreach. This is a multi-year project.

Project Momentum events are also listed in their specific categories in the pages above, marked with asterisks.

OVERALL GAME STRATEGY

- The last two seasons we competed in Leagues and did full redesigns of our robots several times. This took a lot of time and forced us to use suboptimal designs. This year we decided to minimize the amount of redesigning by spending our time before our first Qualifier getting a good foundation for later tournaments.
- We decided to focus on getting the main repeatable element of the game, movement of Pixels, to be as fast as possible. To minimize redesigning, we made our Arm strong enough to Suspend. We waited to add a Drone Launcher until Qualifier 2 because we knew it would be small and easier to fit into already existing hardware.

<u>Design and Software Priorities</u>:

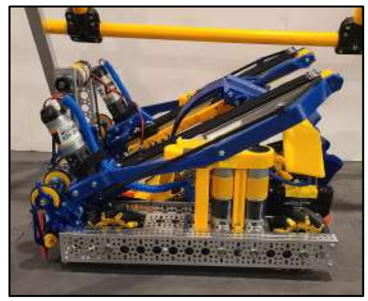
Qualifier 1	Qualifier 2	State/Worlds
Two Pixel fast intake	Drone	Pixel placement AI
Two Pixel delivery	Mosaics	White Pixel autonomous
Suspend from Rigging	Odometry	

GAME STRATEGY THROUGH DESIGN

- Build a complex, high-level robot, but keep all of our individual parts simple to reduce failure points.
- Have arm motors and slides strong enough to Suspend so we don't need separate systems.
- Intake and Delivery on opposite sides to reduce our cycle time because we don't have to turn around.
- Long Arm to reach the top of the Backdrop.
- Reduce cycle time whenever possible.

Robot fits under 12 inches

Freedom of movement is a major component of our design/game strategy this year. We designed our robot to be under 12 inches to drive beneath the Stage Door even when it is closed.



Under 12" height, fits under Stage Door

GAME STRATEGY THROUGH DRIVE TEAM

<u>Drive team wish list</u>:

- Drive team wish list: At MnDOT, one of our Engineering Outreach events, we learned about their IRIS system, which is a large piece of software that integrates all of their road safety control softwares into a cohesive whole. When one of their employees wants an update to IRIS, they send it to their supervisor, who creates a list and sends it to their lead programmer every month or so. This inspired us to create a wish list for our drive team to store suggestions for our software team.

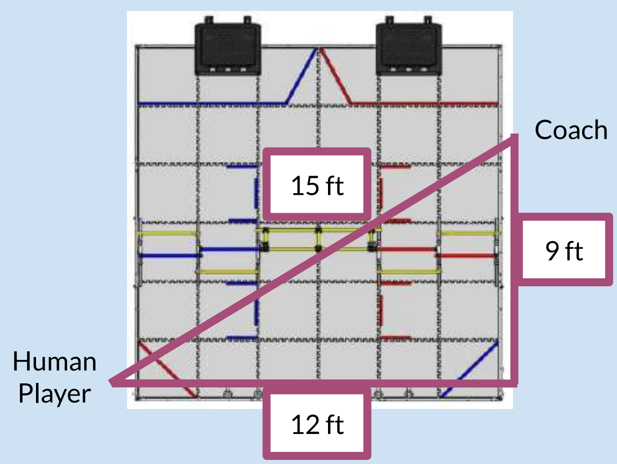
<u>Coach</u>:

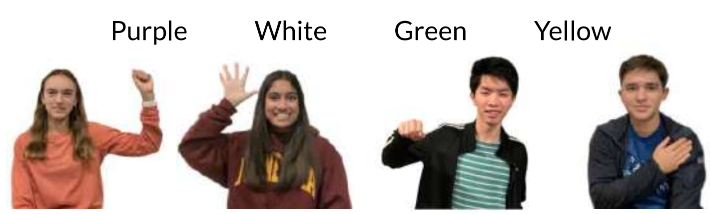
- Assess what color Pixel to deliver next to maximize chance to create a Mosaic
- Use hand signals to communicate with Human Player (assume we won't be able to yell to each other over the noise of the field)

<u>Human Player</u>:

- Some of our Human Player strategy was influenced by our Human Player's experience last year
- Only put the Pixel into the Wing when the robot is coming back so we know where to place it
- Always be ready to put a Pixel into the Wing, as directed by the Coach's hand signals (example hand signals to the right)
- Communicate with Alliance Partner about where we should place their Pixels based on their robot design

Need for hand signals: distance between Coach and Human Player could be up to 15 feet





GAME STRATEGY THROUGH SOFTWARE

Color sensors inside the robot's Transfer (see page 11) read the color of the Pixels the robot is carrying. LEDs on the robot's chassis then display those colors. The LEDs turn red when there are only a few seconds left in the match, alerting the drivers that it's time to launch the Drone and Suspend.

Our robot, top view

Our robot has:
139 custom parts
10 AI-generated parts
8 motors
4 servos
5 sensors
3 odometry pods
2 camera
LEDs

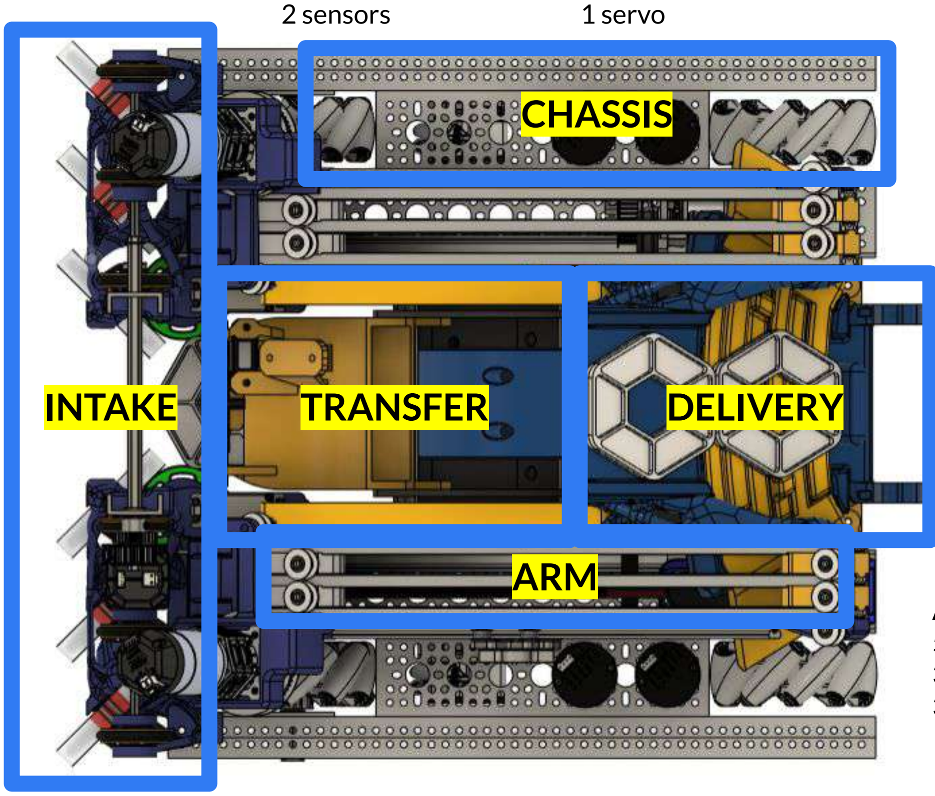
TRANSFER (page 10)
14 custom parts
3 servos
2 sensors

DRONE LAUNCHER (on underside, page 13)
7 custom parts
1 servo

CHASSIS (page 8)
26 custom parts
4 motors
3 odometry pods
2 cameras
LEDs

DELIVERY (page 11)
9 custom parts

Pixel enters here



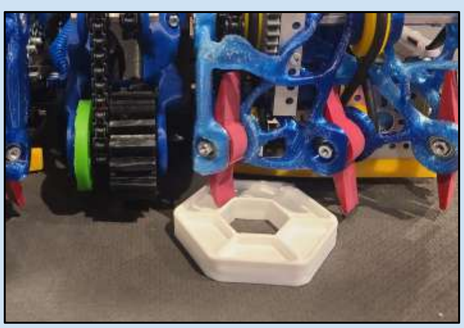
Pixel exits here

INTAKE (page 9)
20 custom parts
1 motor

ARM (page 12)
53 custom parts
3 motors
3 sensors

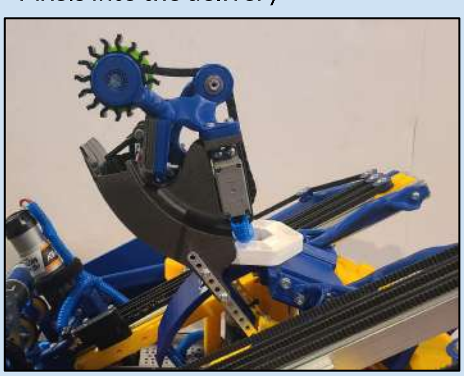
A PIXEL'S PATH

1) INTAKE (red Spintake brushes) funnels Pixels into the Transfer



2) TRANSFER - compliant wheels pull Pixels into the Spatula

3) TRANSFER - SPATULA flips Pixels into the delivery



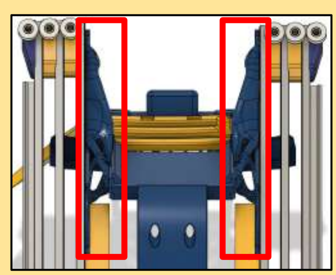
4) DELIVERY drops Pixels onto the Backdrop

INTEGRATION OF ASSEMBLIES

This year, we're especially proud of how well all of our assemblies integrate even though they were designed by separate people.

To ensure that we did not experience bottlenecks in design, we worked on designing connection points before finalizing other parts of our assembly.

To bridge gaps between assemblies, we used custom parts. This is because they can easily be changed if the relative position of the assemblies changes.



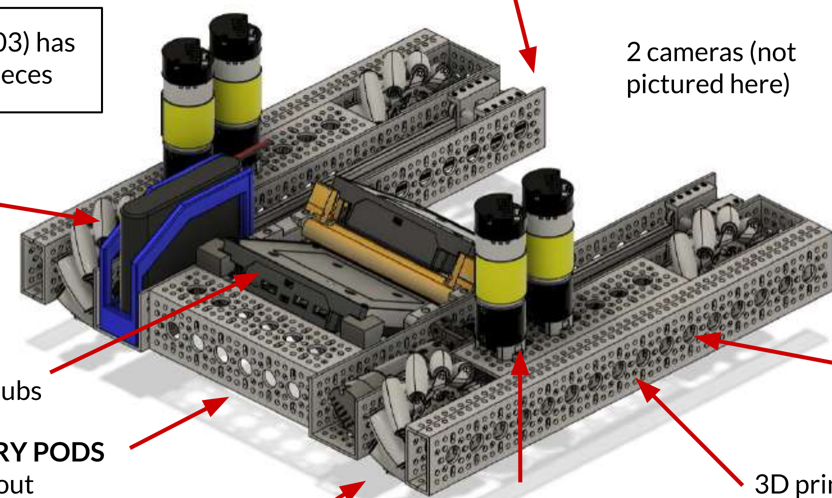
Above: The Delivery brackets (in red boxes) hold together the Delivery and Arm

Chassis, front angle view

Chassis (EN-103) has 26 custom pieces

ARM CARRIAGE (page 12)

2 cameras (not pictured here)



BATTERY HOLDER (blue)

Control and Expansion Hubs

ODOMETRY PODS (3, spaced out underneath the Chassis)

Mecanum wheels to allow U-shaped Chassis

MOTORS (yellow) Vertically mounted, 435 RPM

3D printed replica of GoBilda low-width U-channels hold LEDs, which change color to indicate what color Pixels the robot is carrying

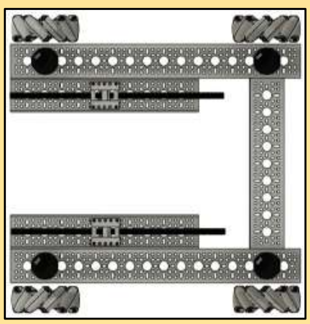
BELTS (hidden in low-width U-channels) Connect mecanum wheels to vertical motors

Game Strategies Addressed:

- Select high RPM motors to move quickly across the field, reducing cycle time
- U-shape design allows for Intake and Delivery on different sides of the robot
- Use mecanum wheels to increase mobility

CHASSIS DEVELOPMENT

Iteration 2 (top view):



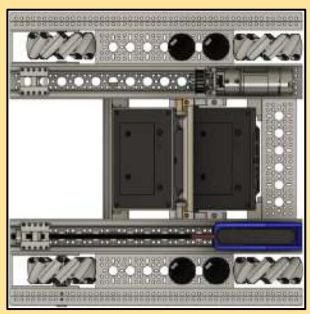
Key features:

- Exterior width 420mm
- Interior width 144mm

Areas for improvement:

- Wheels left exposed, could get stuck or drive up other robots
- Width makes it difficult to drive between Rigging
- Limited space for Intake and Transfer mechanisms

Iteration 3: (current)



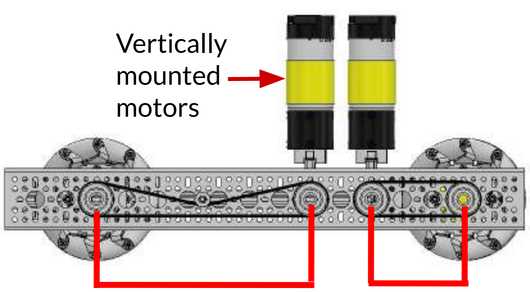
Key updates:

- Exterior width 408mm (better for driving between Rigging)
- Interior width 168mm (more space for Intake and Transfer)
- Wheels protected inside Chassis
- Leaves space for the motor that drives the lead screw (powers rotational movement of Arm mechanism)
- Added LEDs, 3 odometry pods

CROSS SECTION OF BELTS INSIDE CHASSIS

This area is typically hidden inside the low-side U-channels. We mounted the drive motors vertically and belted them to the wheels in order to create space for the lead screw channels of the Arm. The motors are mounted so far off to the side because otherwise the Arm would hit them when pivoting

Vertically mounted motors



Back mecanum wheel and associated motor, connected by a belt and pulleys

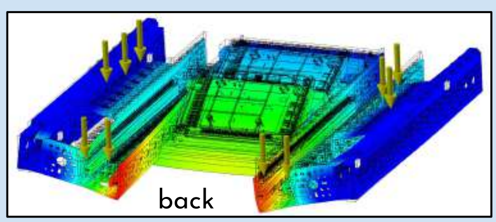
Front mecanum wheel motor, belt, and pulleys

CHASSIS STRESS ANALYSIS (EN-108)

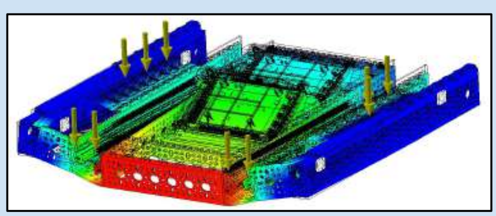
Problem: The robot curved towards the back of the chassis when strafing.

Investigation: We did a preliminary stress analysis in AutoDesk Inventor (upper picture) that showed the back of the chassis warping inward. When we looked at our Chassis it indeed did have a slight inward warp in the back. We did a second stress analysis (lower picture), placing a reinforcement U-channel in the rear of the robot. The stress analysis showed that this did not fix the warp in the Chassis.

Stress Analysis 1



Stress Analysis 2



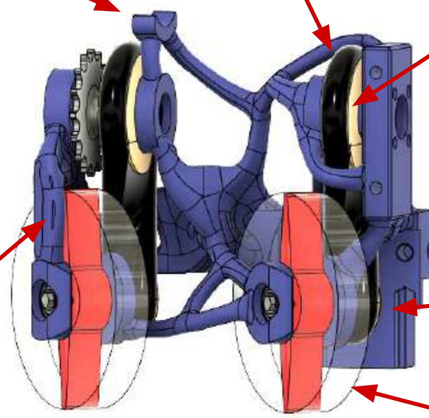
Conclusion: We realized that we would need to solve this problem with software. We did this by increasing the speed of the rear wheels and introducing a PID controller using odometry pods.

INTAKE

The Intake pulls Pixels from the ground and pushes them into the Transfer.

Intake, front view

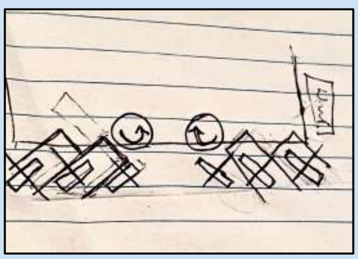
Game Strategies Addressed:
- Quickly intake Pixels, reducing cycle time
- Funnels Pixels into the Transfer from any point along the entire back edge of the robot



This drawing shows half of the Intake (EN-109). The full Intake includes a second set of “bones,” connected by belts and pulleys. The entire assembly contains 20 custom pieces and 1 motor.

INTAKE DEVELOPMENT

Concept Sketch:

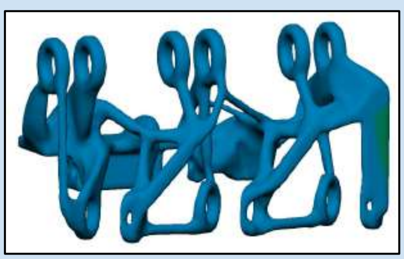


Iteration 1:

Key Features:
- Fusion 360-generated design
- Three spaces on top to hold the larger pulleys
- Three spaces on the bottom to hold the Spintake brushes and the smaller pulleys

Areas for improvement:
- Too much plastic surrounding the wheels due to a large load (constraints in generative design)
- Few connection points between the robot and bearing holders

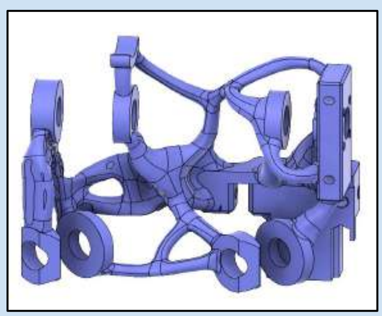
Iteration 2:



Key updates:
- Thinner profile uses less plastic
- More connection points

Areas for improvement:
- Make holes bigger for threaded inserts
- Add more tolerance to hub mount for Spintake
- Bigger screw holes
- Belt clearance

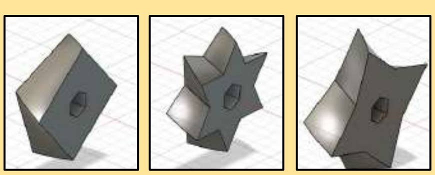
Iteration 7: (current)



Key updates:
- Reduced the number of brushes to accomodate for space, reduce breakage
- Motor held to one side, series of belts and pulleys allow the single motor to power both sides.
- Addressed all areas for improvement from previous iterations

BRUSH DEVELOPMENT

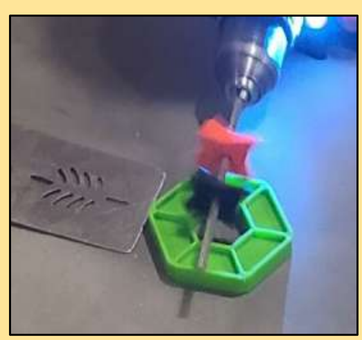
Initial Concepts



1 2 3

Prototype of Concept 3

Patrick Star from SpongeBob cartoon – we thought it would be fun to try



Left: Testing prototype with a drill, Pixel, and Iteration 0 of the Spatula

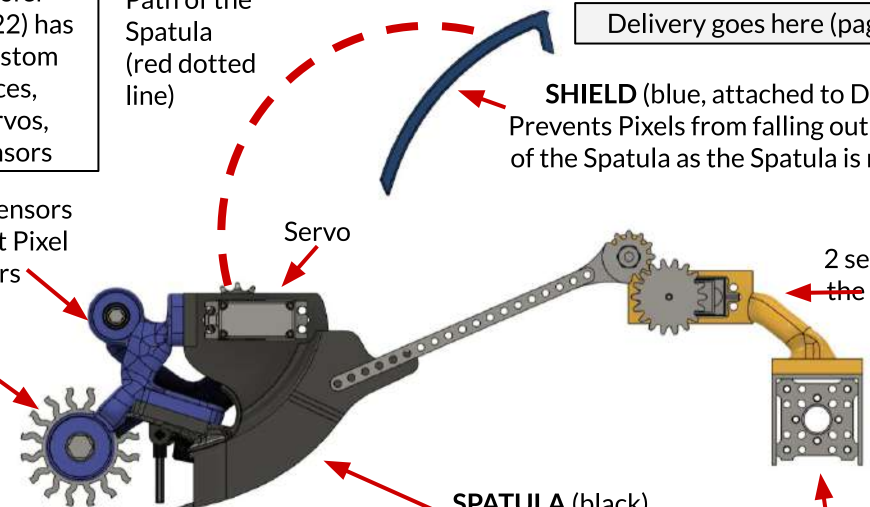
Conclusion:
Ended up using the AndyMark Spintake brushes

The purpose of the Transfer is to quickly move Pixels from the Intake to the Delivery.

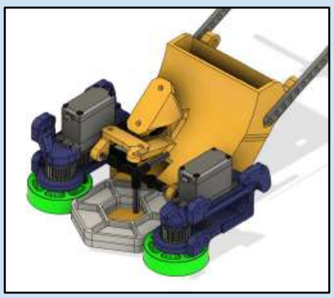
Transfer, profile view

Game Strategies Addressed:
- Carry 2 Pixels at a time (but not more)
- Transfer can run as robot is driving (lowers cycle time)

Transfer (EN-122) has 14 custom pieces, 3 servos, 2 sensors



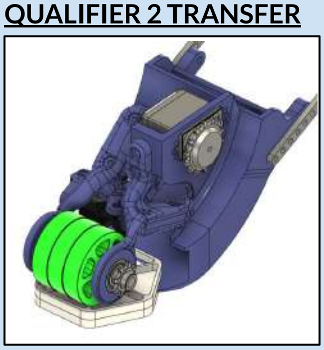
QUALIFIER 1 TRANSFER



Key Features:
- 2 distinct parts: horizontal compliant wheels (which move Pixels from Intake to Spatula), and Spatula (which flips Pixels into Delivery). Each part went through many iterations.
- Picks up Pixels even if rotated.
- Connection point to the Chassis is designed by AI
- Large space to store 2 Pixels (extra Pixels fall out the top onto the floor)
- 1-way door blocks Pixels from falling out once they enter
- Mounting points for color sensors

Areas for Improvement:
- Cannot pick up from Pixel stacks because of the 1-way door
- Pixels fly upward and get stuck on top of the Spatula

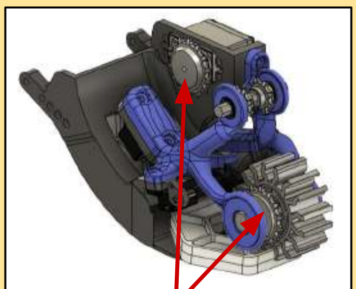
QUALIFIER 2 TRANSFER



Key Updates:
- Combined Spatula and wheels into a single assembly
- Switched to vertical compliant wheels after meeting with Corey Knutson (see page 3)
- We promoted modularity by:
  - Attaching the compliant wheels to the robot with removable, easy-to-reprint arms instead of printing it all as one piece
  - Using chain to drive the wheels, not belts, because of chain's variable length (chain not pictured here)

Areas for Improvement:
- Transfer assembly is too wide and interferes with the Intake brushes
- Pixels get caught on the Spatula lip

WORLDS TRANSFER (current)



Custom sprockets for mounting the chain

In order to ensure that we had enough torque to lift the Spatula before printing, we performed torque calculations for each iteration while they were still in CAD. See EN-167 for this math.

Key Features:
- Color sensors display Pixel color on LEDs
- Body is printed in black PETG to aid Pixel color sensors and improve strength
- Switched to a modified Gecko wheel after our design review with Infinity Robotics to help Pixels pass over the Spatula lip
- Width of the Spatula was reduced to stop interference with Intake. Idler sprockets were implemented to facilitate this.
- Spatula lip was curved downwards to better allow Pixels to pass over it

Spatula Prototype 1

Spatula Prototype 2

We prototyped the Spatula to experiment with curvature and filament type. We tried printing in PLA, flexible PLA, ABS, TPU, PETG, and PETG-CF. We chose PETG because of its good impact strength, low cost, and good layer adhesion. Pixels fell off our prototypes easily, so we installed a roof and a 1-way door.

The Passive Delivery reliably deposits Pixels onto the Backdrop.

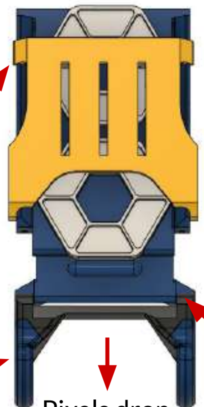
Delivery, top view

Delivery (EN-135) has 9 custom pieces

Transfer deposits 2 Pixels here

HOLDER (blue) Holds Pixels; connection point for all Delivery parts

HINGE (blue & black) Pushes against the Backdrop to release Pixels



Pixels drop from here onto Backdrop

ROOF (yellow) The roof prevents Pixels from falling off Delivery while the robot is driving

FRONT DELIVERY (blue) Front Delivery deposits two Pixels at a time. It is made up of two parts connected at a hinge point, which allows it to fit in the 18-inch cube.

Delivery, top angle view

SHIELD (blue) The Shield prevents Pixels from falling off the back of Transfer as it is depositing Pixels into the Delivery

BRACKETS (blue) AI-generated brackets connect Delivery system to Arm

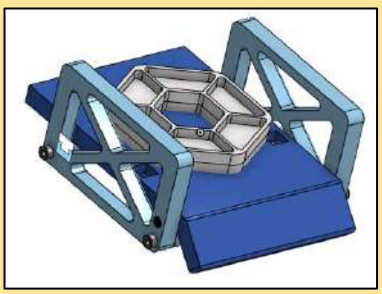
HINGE (blue & black)

Game Strategies Addressed:

- Deposits 2 Pixels at a time
- Reliable because of passive design

DELIVERY ITERATIONS

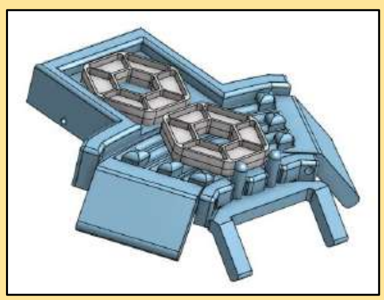
Iteration 1:



Key Features:
- Passive delivery system – no motor, which means no wires and more reliability
- Uses "pull back" system

Areas for Improvement:
- Can only deliver Pixel if perpendicular to Backdrop
- Only holds one Pixel

Iteration 3:



Key Updates:
- Added "pegs" so that Pixels don't fall off front and side of Delivery
- Can deposit from front and sides

Areas for Improvement:
- Too bulky
- Doesn't fit in 18-inch box

Iteration 4:

Key Updates:
- Added a hinge to front Delivery, fitting in the 18-inch cube
- Spaces for limit switches

Areas for Improvement:
- Pixels fall out the top
- Sides deliveries caused Pixels to miss Backdrop

Iteration 5: (current)

Key Updates:
- Removed side deliveries because they were inconsistent and in the way
- Added a roof to keep Pixels from bouncing off
- Reinforced the front hinge using polycarbonate with carbon fiber

SHIELD ITERATIONS

Iteration 2:

Mounts to Chassis

Key Features:
- Mounted to Chassis
- Blocks Pixels from falling out the top of the Spatula
- Large empty area beneath the Shield allows Pixels to fall to the floor if there are more than 2 Pixels.

Areas for Improvement:
- Mounting point is bulky and gets in the way of other parts

Iteration 4: (current)

Mounts to Delivery

Key Updates:
- Changed mounting point to the Delivery so it does not get in the way of other parts
- Changed curvature to begin holding Pixels from a lower point

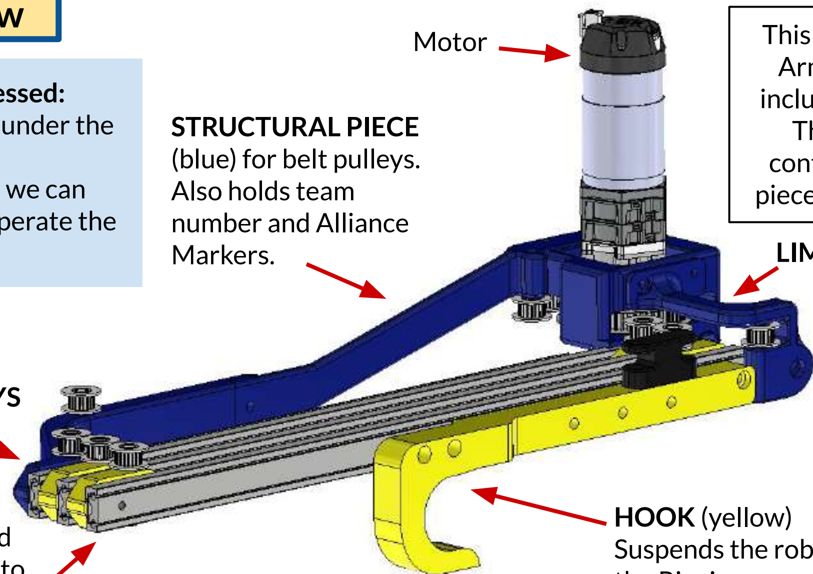
The Arm moves the Delivery system up to the Backdrop and allows the robot to Suspend.

Arm, front angle view

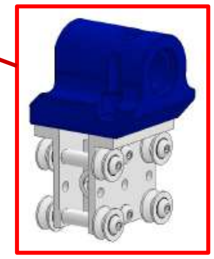
Game Strategies Addressed:

- Shorter than 12” so it fits under the Stage Door
- Pivots in order to hang so we can use the same motors to operate the Arm and Suspend

This drawing shows half of the Arm (EN-143). The full Arm includes a mirror image of this. The entire Arm assembly contains 53 custom designed pieces, 3 motors, and 3 sensors.

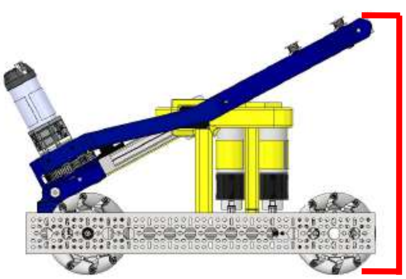


CARRIAGE Moves the arm’s base to pivot around a bearing

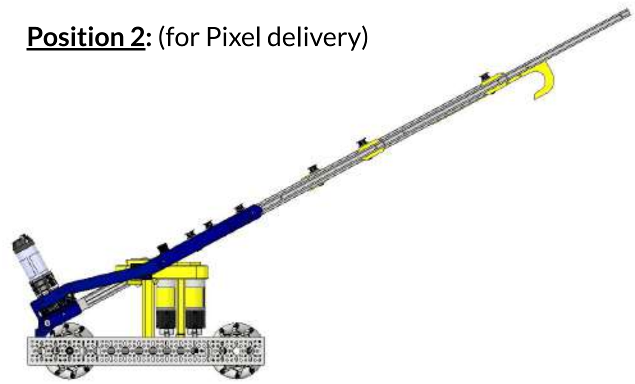


ARM POSITIONS

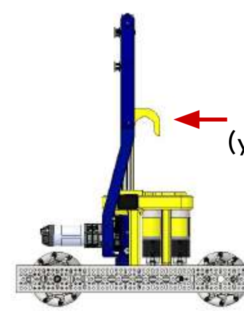
Position 1: (start of match and loading a Pixel)



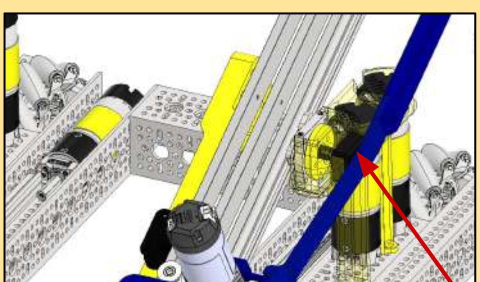
Position 2: (for Pixel delivery)



Position 3: (for Suspending)



Design feature: Potentiometer



A REV potentiometer is used to determine the angle of the Arm on the robot. Our TeleOp Opmodes enforce limits on this angle to prevent overdriving the motor and damaging the lead screws that drive the Arm’s lower ends.

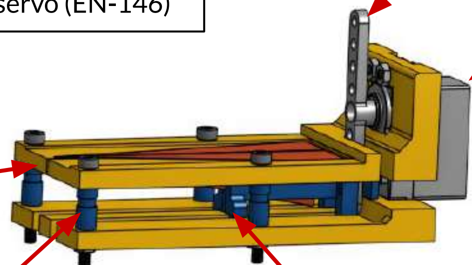
Other key design elements:

- **Hook:** We initially designed our hook with ABS because it is stronger than other plastics. To maximize its strength, we printed the hook so that the layer lines are in a flat plane against the hook, so that when force is applied to the hook it wouldn’t split. We later switched to a waterjet cut aluminum hook with a thinner profile to create more space for the Delivery mechanism in the center of the robot.
- **Belts:** At State last year we spent time researching linear slides at the GoBilda booth. We learned that belts have features that make them preferable to string in linear slides: belts are stronger, the tension remains constant throughout movement, and they don’t require a spring to use.
- **Slides:** We chose Misumi slides because they are more compact than others on the market.
- **Motors:** We chose to use REV UltraPlanetary motors because we can edit the gear ratio as needed to fine-tune the balance between speed and torque, which would allow us to Suspend. For more on motor selection, see page 13.

DRONE LAUNCHER

Drone launcher has 7 custom parts and 1 servo (EN-146)

Dual servo arm



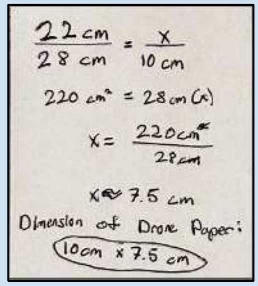
SERVO Turns the dual servo arm to release the rubber band

Slot in yellow piece holds Drone fuselage vertical

GROOVED STANDOFF (blue) Rubber band loops around, ensures rubber band is completely horizontal

DRONE CATAPULT (blue) Pushes Drone when servo releases rubber band

Math to determine Drone dimensions


$\frac{22\text{ cm}}{28\text{ cm}} = \frac{x}{10\text{ cm}}$

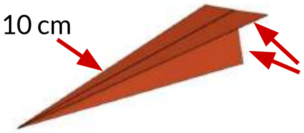
$220\text{ cm}^2 = 28\text{ cm}(x)$

$x = \frac{220\text{cm}^2}{28\text{cm}}$

$x \approx 7.5\text{ cm}$

Dimension of Drone Paper:

10cm x 7.5 cm



We talked to our AP Physics teacher about the best way to design our Drone. We discussed making its trajectory more like a projectile to aid in flight. We also tested punching holes in the paper and folding flaps.

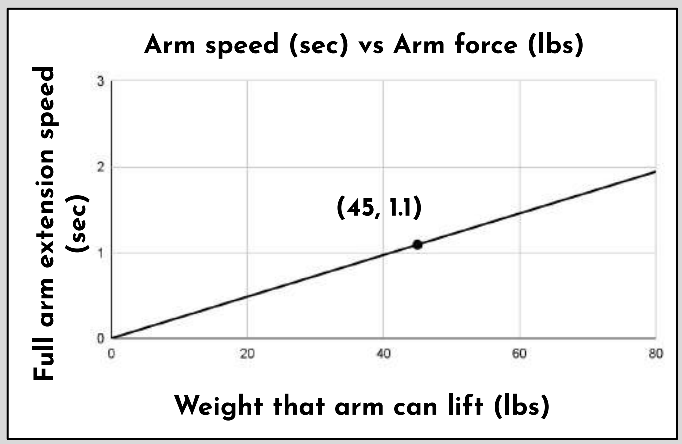
MATH

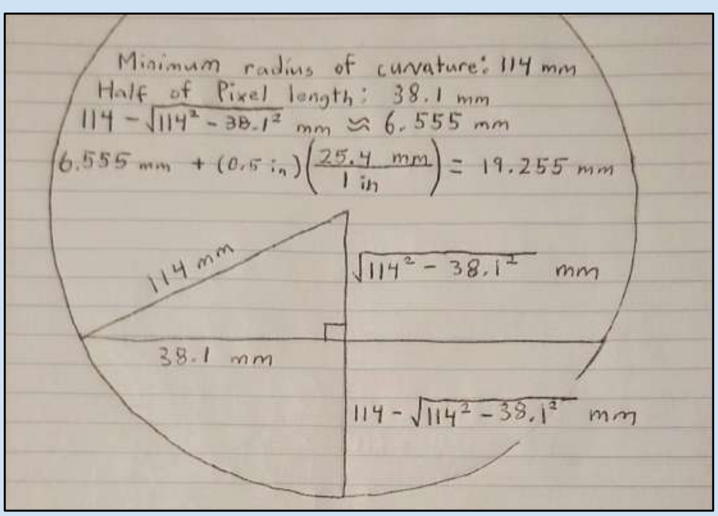
We needed a lot of math to design our robot because it was important to ensure that our designs would work before we built them. For more math, see EN-166.

Cycle time math (speed at which we need to move Pixels):
29 Pixels are needed to reach the third level on the Backdrop

- One Pixel is pre-loaded and will be dropped during the autonomous period. Need to move 28 Pixels during TeleOp.
- If carrying one Pixel at a time, this means 28 trips down and back to the Backdrop. With 2 minutes for TeleOp, we can spend at most 3.36 seconds for a single down and back from the Wings to the Backdrop (cycle time) - not accounting for the time that it would take to deposit the Pixel.
- If carrying 2 Pixels at a time, this means 14 down and backs from the Wings to the Backdrop. Our cycle time must be lower than 7.86 seconds for a single down and back - not accounting for time that it would take to deposit the Pixel.
- Conclusion: Must carry 2 Pixels at a time for it to be feasible to reach the third level. We should communicate with our Alliance Partner to see if they will take care of some of the down and backs.

Arm Suspension math:
So we don't have to use a separate system to Suspend, our Arm motors need to be powerful enough to lift the robot. This graph shows the relationship between the Arm extension speed and the Arm's lifting power. We use a pair of REV Ultraplanetary motors with a 27.4:1 gear ratio. This gives us 45 pounds of lifting power while also allowing full extension of the Arm in only 1.1 seconds. See EN-170 for the full calculation.




Minimum radius of curvature: 114 mm

Half of Pixel length: 38.1 mm

$114 - \sqrt{114^2 - 38.1^2}\text{ mm} \approx 6.555\text{ mm}$

$6.555\text{ mm} + (0.5\text{ in})\left(\frac{25.4\text{ mm}}{1\text{ in}}\right) = 19.255\text{ mm}$

114 mm

$\sqrt{114^2 - 38.1^2}$ mm

38.1 mm

$114 - \sqrt{114^2 - 38.1^2}$ mm

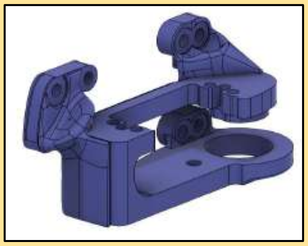
Spatula interior height calculation:
We had a problem with 2 Pixels stacking on top of each other in the Spatula, so we did geometry to calculate the optimal height needed to correct the problem.

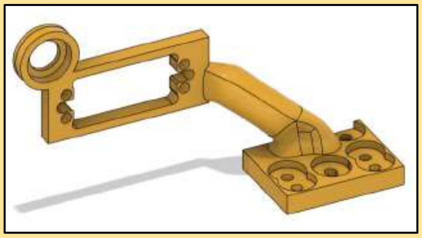
- The Spatula has a radius of curvature of 114 mm at its curviest point. A Pixel forms a chord 3 inches long along the 114 mm radius circle.
- We calculated the height of the chord, added the half inch height of the Pixel, and added a few millimeters of safety margin in order to calculate the minimum interior height necessary to allow Pixels inside but not allow them to stack on top of each other.

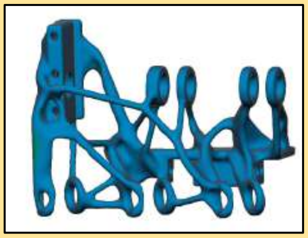
Cross section of Spatula. Ceiling low enough so Pixels can't fall on top of each other.

ADDITIONAL FEATURES

AI-Generated parts (EN-149):
We learned to use AI tools to assist with custom design. AI-generated parts are stronger, use less material, and are faster to design than normal parts. We have 10 AI-generated parts.



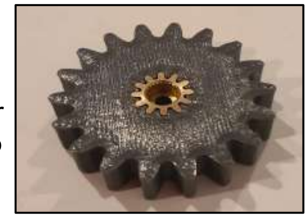




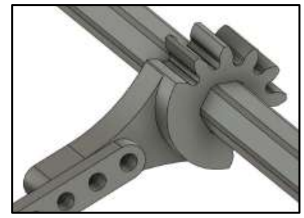
Custom gears:

We custom design and 3D print all of our gears in order to get perfect gear ratios. To attach our gears to servos, we fit them over factory-manufactured gears.

3D printing gears also allows us to modify the gear's shape. This lets us attach other parts directly to the gears instead of using an adapter (photo to the right).

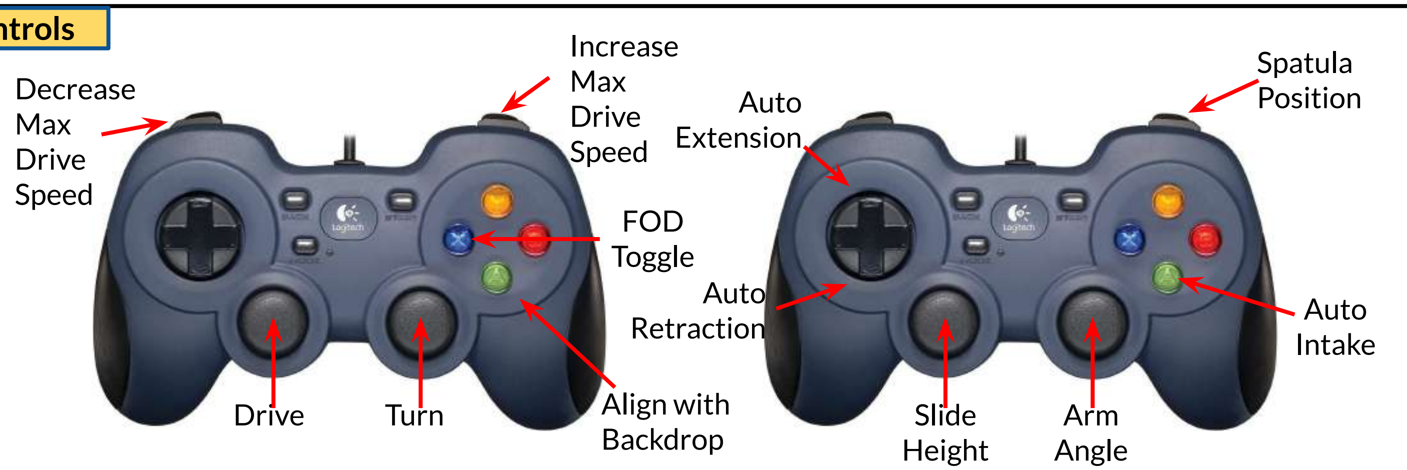


Above: Custom gear (gray) fits around GoBilda gear (gold)

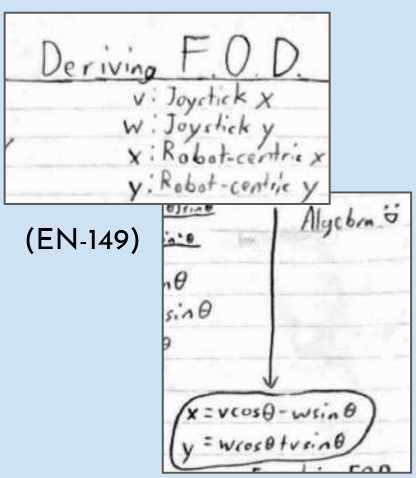


TELEOP

Controls



Driver Enhancements



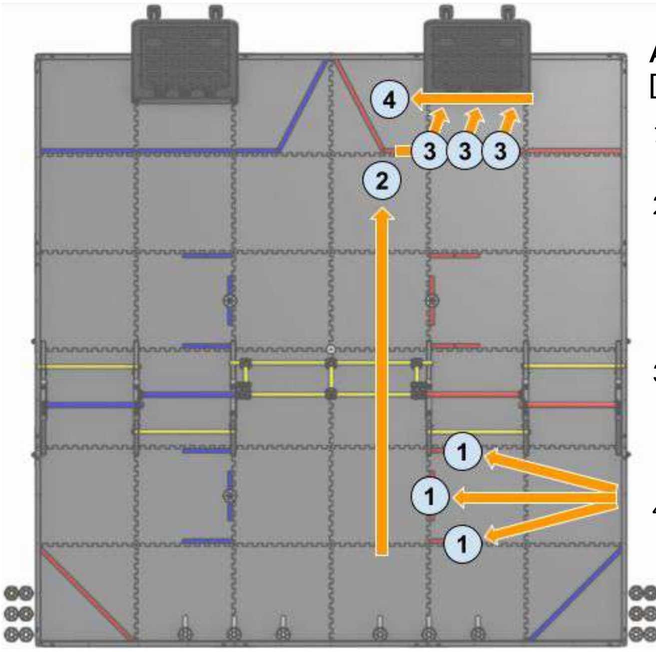
(EN-149)

Field Oriented Driving (FOD):
The drivers have the option to turn on FOD, which makes the robot drive relative to the field instead of relative to the robot. This means that even if the robot is spinning, the drive joystick always moves the robot in the same direction related to the field. This allows our drivers to control the robot's direction better and turn while moving.

Automated Intake:
We added a three stage, multi-purpose button to run the Intake and Delivery so that the drivers do not have to press as many buttons.

- **Stage 1 (Activated when button is held):** The Transfer is fully lowered. The Intake and Gecko wheel pull Pixels inward.
- **Stage 2 (Activated when button is released):** The Intake halts. The Transfer is raised halfway and the Gecko wheel slows down.
- **Stage 3 (Activated 3 seconds after stage 2):** The Gecko wheel stop moving.

Pixel Depositing:
We can automatically extend the slide to sit flush with the backdrop. We use the aprilTags on the backdrop to figure out the distance to the backdrop and what angle the backdrop is facing. Then we use that to turn the robot to face to face the backdrop, and use an equation that we derived in order to find out how far the slides have to extend.

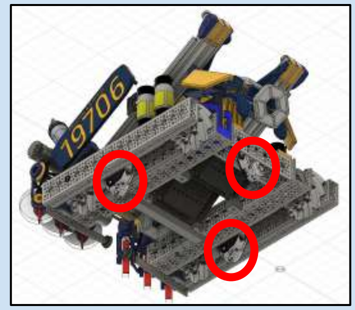


Autonomous OpMode [53 points]

1. Push purple Pixel to the designated Spike Mark
2. Drive to the Backdrop, avoiding pushing our Prop into opposing alliance's way, and avoiding our partner's purple Pixel
3. Align with the AprilTag that corresponds with the randomized position; drop yellow Pixel on Backdrop
4. Park in Backstage

Localization through Odometry

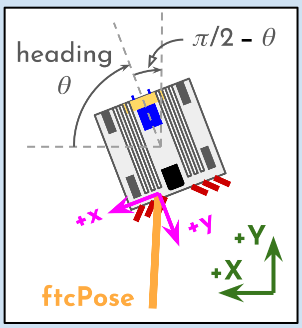
The robot uses FTCLib pose exponentials to convert odometry pod feedback into x and y position coordinates, and the current heading θ.

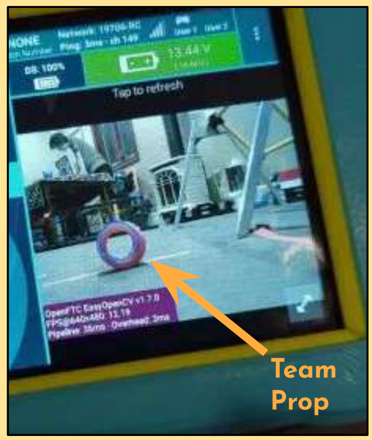


= Odometry pods

AprilTags and Trajectories

After determining an AprilTag's camera- relative "ftcPose," we rotate it into field coordinates, and then generate a trajectory to the AprilTag. (EN - 163)





HoughCircles Processing Method

After filtering the camera input for Alliance-appropriate color values, we further process the detected shapes by applying an algorithm called HoughCircles to filter for only circles. This immensely brings down the rate of false positives. To accomodate this we did have to rotate our Team Prop to face the camera as a circle, with the unfortunate consequence that our prop can now roll. We avoid unnecessary contact to prevent making the the prop roll away.

SOFTWARE ARCHITECTURE

Subsystems

Controllable parts of the robot are separated into individual subsystems, making our software more modular. This allows more overall organization, and makes adding new subsystems less confusing. This also allows each subsystem to work independently so that if one part of the robot breaks, the rest will still be functional.

Commands

We can specify a sequence of commands to run which allows us to define modular, reusable, and abstract discrete actions to complete a task. This also makes it easier to improve certain tasks without affecting other areas of the code.

```
2 usages  PotentialEnergyRobotics +1 *
public void setOutput(double output, boolean override) {
    RobotLog.dd(this.m_name, format: "Slide ticks : %s", getSlideTicks());
    if ((((getSlideTicks() <= MAX_SLIDE_TICKS) || (output < 0))
            && ((getSlideTicks() >= 0) || (output > 0))) || override) {
        slideLeft.set(-output);
        slideRight.set(output);
    }
    else {
        slideLeft.set(0);
        slideRight.set(0);
    }
}
```

```
robotcore
  command
    action
      DriveToPoint
      LaunchDrone
    driver
    scorer
      DroneScorer
      NavigationScorer
      RandomizationScorer
    AutoCommand
    DriverCommand
```