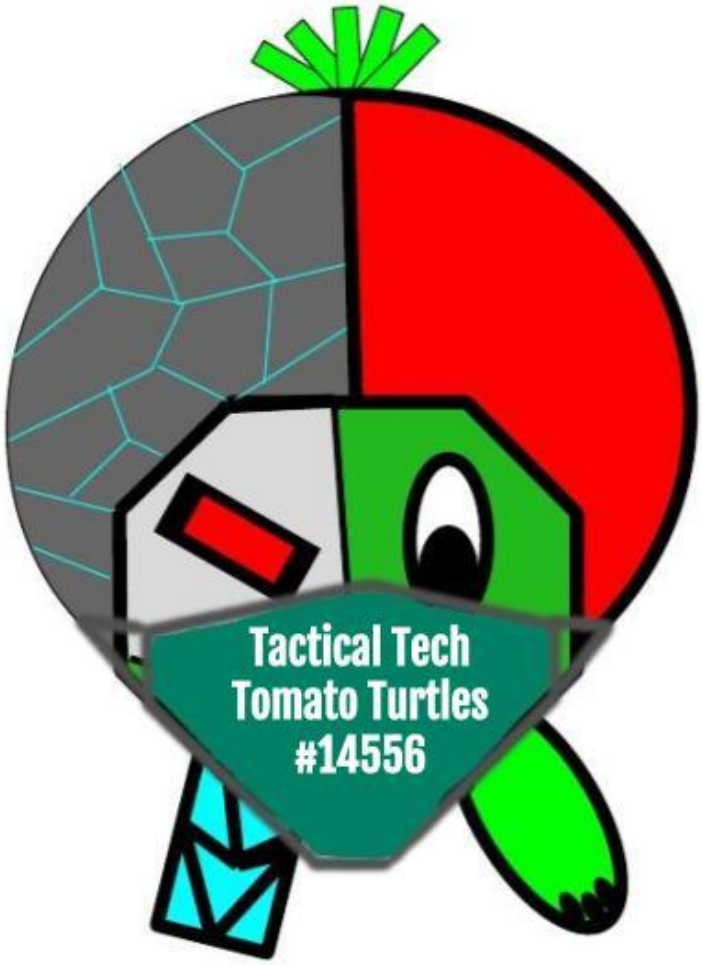
Team 14556

Tactical Tech Tomato Turtles State Portfolio 2020-2021



Turtle Favorite Connections

Carnegie Mellon University Robomechanics Lab

Allina Health

Lockheed Martin

PAR 3M Authorized Distributor

Securian Financial

STEM

girl scouts

Green Girls

Stratasys

Thomson Reuters

3M

Korn Ferry

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Fabric of Tactical Tech Tomato Turtles (TTTT)

Season Highlights

We've used our name to capture the fabric and essence of the Tactical Tech Tomato Turtles. Our fabric is built on Tactical standing for Outreach, Tech standing for Design, Tomato standing for Try and Test, and Turtles standing for Teamwork. Below we summarize some season highlights in each area.

TACTICAL *OUTREACH*

- ✓ Connect with professionals and apply what we learn
- ✓ Virtual Girl Scout curriculum to inspire youth in STEM
- ✓ Taught 136 Girl Scout badges
- ✓ Make a difference in community
- ✓ Support other FTC teams
- ✓ Expand STEM professional connections

TECH *DESIGN*

- ✓ Prioritized goals for design based on game strategy
- ✓ Designed robot components to allow parallel work
- ✓ Apply the engineering design process for all components
- ✓ Increased CAD in design
- ✓ Design 3D printed parts essential to game
- ✓ Created 3D printed parts with different materials

TOMATO *TRY / TEST*

- ✓ Established requirements & test criteria for components
- ✓ Used algorithms to determine angle of ring shooter
- ✓ Improved consistency with Vuforia, encoders & sensors
- ✓ Created sequence diagrams
- ✓ Created test scenarios and code to verify robot functionality

TURTLES *TEAMWORK*

- ✓ We use new ways to work together (Trello, Slack, Zoom)
- ✓ We have fun while learning new roles and skills
- ✓ We all actively contribute
- ✓ We share different ideas to get even better ones
- ✓ We incorporate branding to promote the team and FIRST

Team Plan Intro

Our team plan has 3 parts that reflect the effort we have put in for having a plan this season. These are **Skill Development Plan, Sustainability Plan,** and **Financials.**

Bios & Skill Development Plans' Overview

This year we created team and individual skill development plans. We created our current plans after meeting with an expert on learning. Our full bios (**pages AT3-AT9**) and skill development plans (**pages SDP1-SDP14**) are in our engineering notebook. Here we briefly highlight what we have each been focusing on learning this season.

Ben **Sub Teams:** Outreach, Building, and Notebook **Learning Focus**: Learn to apply templates and set formats to form professional documents that are easily presentable to others.I also want to get a better understanding of the principles of engineering, such as the design process and how individual pieces work together to form amazing and complex objects.	**Clare** **Sub Teams:** Programming and Outreach **Learning Focus**: Learn CAD along with learning how to integrate Vuforia. I took a CAD class at school, really liked it, and I want to learn more. I want to learn how to integrate Vuforia because we had finished the math last season, but did not include it into our autonomous...	**Natu** **Sub Teams:** Building & Outreach **Learning Focus**: Learn to do more with outreach and work on my speaking skills. When we are getting teams to draft us for alliances and when in outreach events talking to professionals I get a lot of practice in talking to people and that will come helpful later on.
Benjamin **Sub Teams:** CAD & Building **Learning Focus**: Learn some basic Java. I think that it's a really useful skill which I am lacking. Even if I learned it on a relatively rudimentary level, I would be happy.	**Caden** **Sub Teams:** CAD & Building **Learning Focus**: Learn to apply how I can do CAD more efficiently and how to 3D print parts from Onshape. I also want to learn how to put a bill of materials in drawings. .	**Sam** **Sub Teams:** Build, CAD, and Programming **Learning Focus**: Learn to code, and understand it well enough to be able to apply it to things other than our robot. I'd also like to learn how coding controls electricity, and which electronic components in the robot actually control electricity. ..

Sample: Caden's Skill Development Plan

Below is a Skill Development Plan for Caden to show what the updated format looks like.

Skill Area	CAD				
Goal	Learn how to update the cad drawing of the ring thrower				
Dates	**Actions**	**Resources**	**Connection**	**How to Overcome Obstacles**	**Progress Report**
1/23/21	Go onto the drawing and try the yellow refresh button.	Onshape, internet, coach Chris for help	Chris	Delete red dimensions and redo them. Fix BOM table.	Fixed. Drawing is completely updated.

Sustainability Plan

Our sustainability plan this year continues using the 3 main areas from last year. Recruit new people into FIRST programs, Support FIRST and High Tech Kids, and grow resources through sponsorship and fundraising to support our team and other teams. COVID-related changes have made it challenging to take action on some of our specific goals within each area, but we continue to work towards sustaining our team, other teams, and FIRST. Our complete sustainability plan can be found in the engineering notebook (**pages SP1-SP3**).

Financials

This year our funding came through donations from 3M. We made a number of purchases that were recorded on our financials spreadsheet. The sheet includes the date, description of purchase, and amount.

	Date	Description	Amount
2	6/2/2020	Initial Balance with EHS Robotics from Last Year	(199.99)
3		Donation from 3M	500.00
4		Donation from 3M	250.00
5		Donation from 3M	500.00
6		Donation from 3M	500.00
7	9/8/2020	Order 1: Gobilda yellowjacket motors	(199.88)
8	10/4/2020	Order 2: Rev chain breaker and links	(40.00)
9	10/10/2020	Order 3: Rev hex shaft parts and phone adpaters	(52.00)
10	10/14/2020	Order 4: Gobilda yellowjacket motor (partial)	(50.00)
11	10/28/2020	Order 5: Sprokets and hubs	(54.00)
12	11/15/2020	Rev Bearings	(14.00)
13	11/15/2020	Pitsco collors and bushings	(22.95)
14	11/15/2020	Rev hex shaft (partial)	(15.00)
15	11/15/2020	goBilda encoder adapter cables	(11.56)
16	1/6/2021	Pitsco chain, hubs, and CR servo (partial)	(49.40)
17	11/19/2020	L Series Timing Belt, Trade Number 255L050	(38.81)
18	11/14/2020	2:1 Ratio Bevel Gears and 1310 6mm Hyper Hubs	(71.92)
19			
20		Total	930.49

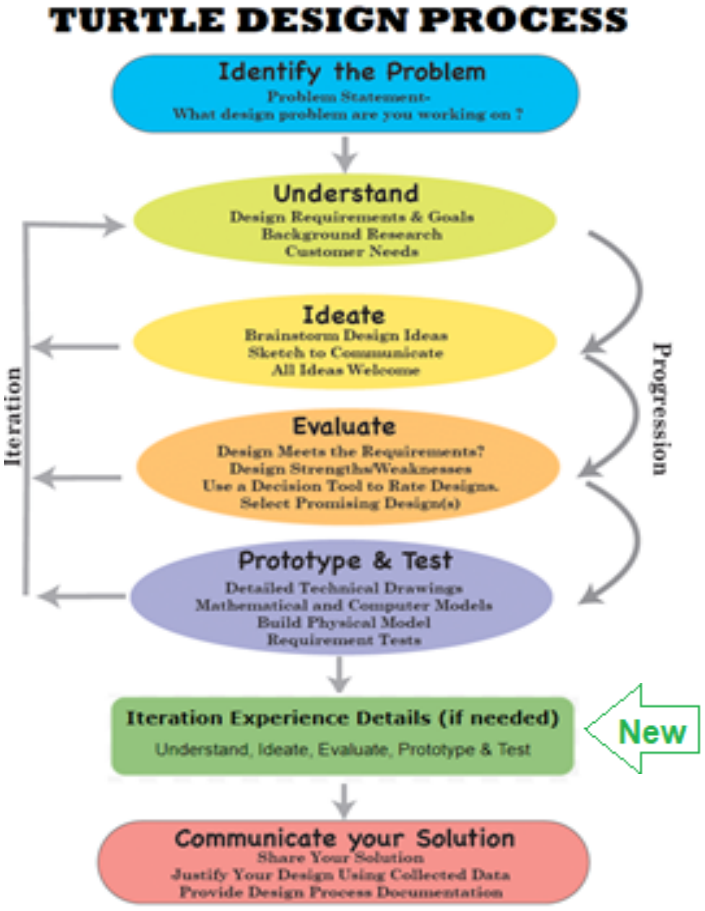
Engineering

Goals

- Have our robot design driven by game strategy.
- Update and continue to apply and our Turtle engineering design process
- Build components of the robot in parallel.
- Increase the speed of our robot.
- Incorporate professional design reviews.

Lessons Learned

- Communicate between team members working on different components so they fit together.
- Leave time to fit components together.
- Document mistakes, failures, learnings and successes.
- Share progress via online.



Turtle Game Strategy

After the kickoff, we created a spreadsheet of all the ways to score and came up with a strategy to score as efficiently as possible. The spreadsheet highlighted the points, amount of times we could go for the points and looked at toals for scoring. We also found that some of the information on how much we could score wasn't always perfect so we edited our strategy later on in the year. For example, we are working on delivering two wobble goals instead of just one since we found out that was within the rules. Changes like this have allowed us to become better at achieving our goals when working on the robot game and will allow for lots of trackable improvement as we continue this season.

Total Point Estimate - 132 points

Turtle Design Process

We updated and continue to apply the Turtle Engineering Design Process to build and improve our robot and its various attachments and activities to make a healthy and successful robot. In our engineering notebook, we have detailed our "Turtle Design Process" for each of our major components:

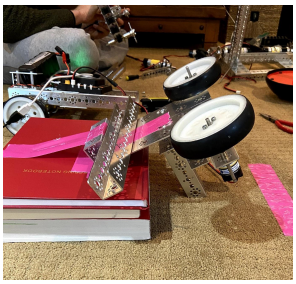
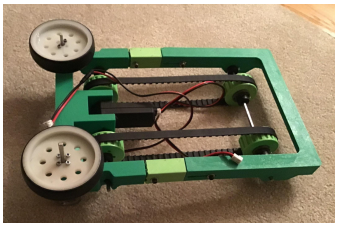
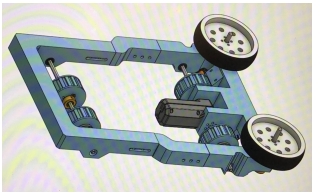
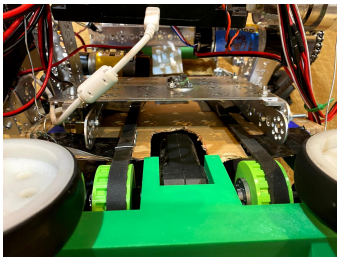
1. Ring thrower + Conveyor belt (**pages RT1-RT12**)
2. Goal grabber (**pages GG1-GG9**)
3. Ring picker upper (**pages RP1-RP6**)
4. Chassis (**pages CH1-CH6**)

Here we summarize **goals** and **lessons learned** for these 4 components. We also show the major iterations for each component with visual **Progress Highlights.** Finally, we share a **Design Process Sample** for the first iteration of the ring thrower to give an example of our documentation of our design process in our Engineering Notebook.

Ring thrower + Conveyor

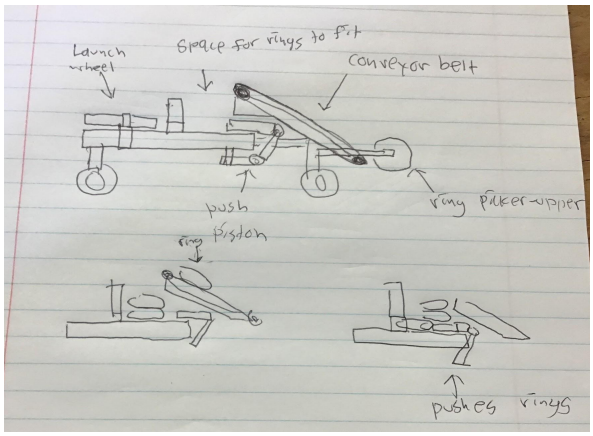
Goals	To create a ring thrower that was powerful and accurate enough to score in the top goal, and fit nicely into our robot. For our conveyor belt, we wanted to be able to securely have control over multiple rings at a time, and get them up to the thrower quickly.
Lessons Learned:	We learned about different motor RPMs and how speed, torque, and gear ratios affect power and grippiness. For the conveyor belt, we learned about different grippy materials, and how even the grippiest materials don't work too well at very steep angles.We learned how to use mathCAD to estimate the speed and angle needed to launch the rings. (**pages RT10-RT12**)

Progress Highlights **(Details in Engineering notebook pages RT1-RT12)**

Iteration 1	Iteration 2	Iteration 3	Iteration 4
Original metal test prototype with flywheels.	3D printed design with conveyor belt.	3D design to compensate for mounting problems.	Cover to keep rings flat
			

Design Process Sample

The tables below show the first iteration of the design process for our ring thrower and conveyor. For details on the subsequent iterations, please see pages **RT4-RT12.**

Identify the Problem: We need a way to launch rings. It is the main way to score points. The image shows some brainstorming.	

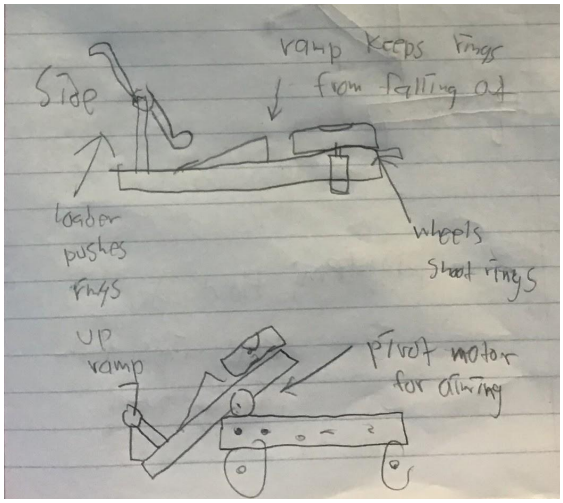
Understand:

We came up with a bunch of requirements for the thrower. It needs to be accurate, fast, strong, safe, and it needs to work with the picker-upper.

1	**Ring Thrower**
2	Needs to be repeatably accurate
3	Needs to be fast
4	Needs to be strong
5	Aim needs to be able to easily change
6	Needs to work with picker-upper
7	Safety
8	
9	1 = does not satisfy, 5 = perfect

Ideate:

We came up with 2 designs. One using two flywheels to launch the robot and another a spring-loaded arm to wind up and fire rings like a clay pigeon shooter. The image shows some more ideas.



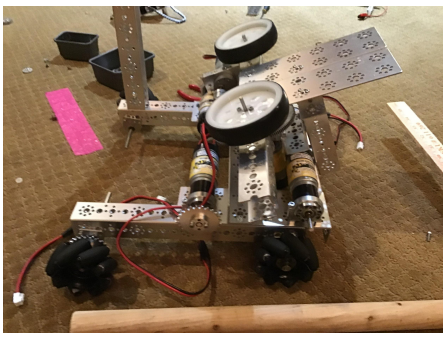
Evaluate:

We listed all the requirements for the thrower and gave our two designs (the Flywheel and spring loaded arm) scores for each requirement. As you can see the flywheel design won the votes.

1	**Ring Thrower**	Flywheel	Spring loaded arm
2	Needs to be repeatably accurate	4.5	2.5
3	Needs to be fast	5	2
4	Needs to be strong	4.5	3.75
5	Aim needs to be able to easily change	4	4
6	Needs to work with picker-upper	5	1.25
7	Safety	4	1.5
8		27	15
9	1 = does not satisfy, 5 = perfect		

Prototype and Test:

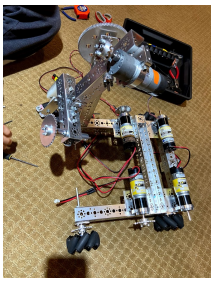
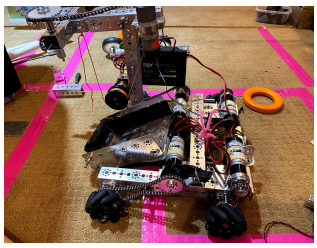
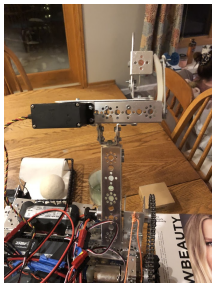
We built a metal prototype and tried many different gear combinations until we got it to shoot far. We tested our prototype at a 20 degree launch angle right up at the line from where the robot can shoot and it went into the top goal 8 out of 10 times.

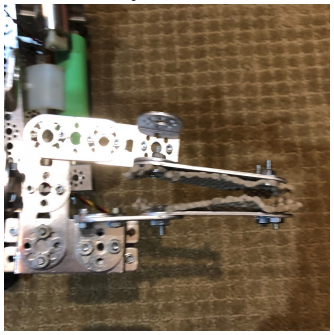
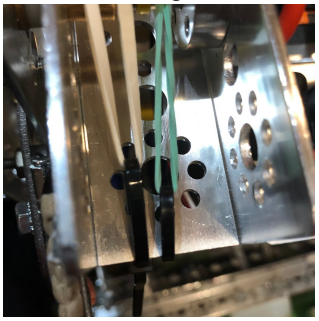


Goal grabber

Goals	We wanted a goal grabber that was sticky and strong enough to grab the heavy wobble goals. We also needed it to be tall enough to lift over the side walls while still fitting within the size limits.
Lessons Learned:	We learned about different lifting mechanisms through the different prototypes we made. One prototype was a pulley, which we learned was very strong and flexible, but occasionally got tangled in use. The chain and sprocket was stronger, and never got tangled.

Goal Grabber Progress Highlights **(Details in Engineering notebook pages GG1-GG11)**

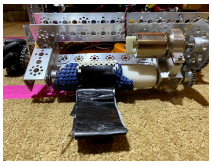
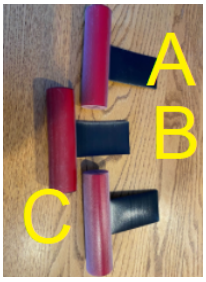
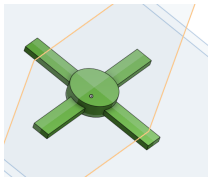
Iteration 1	Iteration 2	Iteration 3	Iteration 4
Gears controlling claw, claw opened/closed by rack and pinion. 	Replaced gears with rope and pulley design. 	Replaced rope and pulley system with gear and sprocket system. 	\Added L bracket to end of claw to stabilize grabber in claw. 

Iteration 5	Iteration 6	Iteration 7	Iteration 8
Claw now folds behind the arm with a rubber-band system. 	New claw design with more open space to pick up wobble goals. 	Foldable plate placed beneath arm to prevent it from lowering too far. Claw folding system made immobile with zip ties. 	“U” bracket added, preventing the wobble goal from slipping out the end and holding it more firmly. 

Ring picker upper

Goals	We wanted a ring picker upper that was able to feed rings quickly, precisely, and efficiently to the conveyor. We also wanted it to be able to pick up two rings at once.
Lessons Learned	We learned that it was hard to get a ring on the ramp with just one roller, so we improvised and added a duct tape flapper that “kicked” the ring up the ramp where the roller couldn’t, and improved the reach distance.

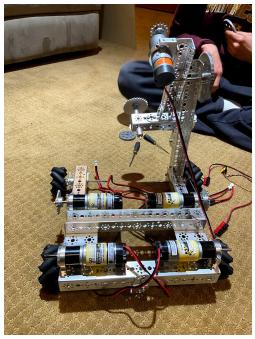
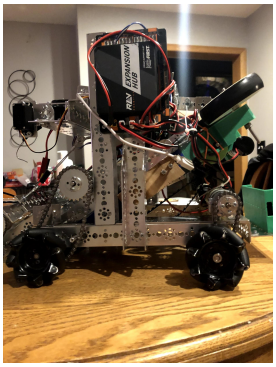
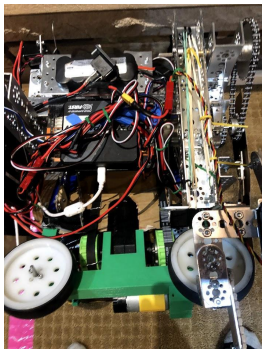
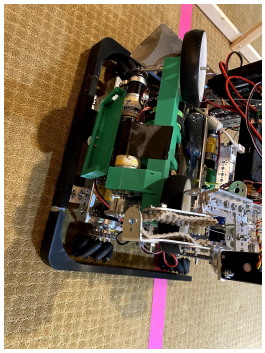
Ring Picker Upper Progress Highlights **(Details in Engineering notebook pages RP1-RP9)**

Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6
Cardboard model that didn’t work, but was useful for testing our design	Roller with foam roller base, added grip, and duct tape “flapper”	3D printed roller with soft, flexible flappers with 3 different hardnesses	3D printed roller with harder flapper, and added zip tie “spikes”	2nd ring picker upper (servo with duct tape and “For Sale Sign”) that helps the first ring picker-upper move the ring from the floor to the conveyor belt.	Updated 2nd ring picker upper, which was 3D printed with new materials. We also made it more space efficient.
					

Chassis

Goals	We learned from previous years that speed and stability were quintessential to the chassis, so this year we decided to keep both of those in mind when designing ours. To make it speedy we used higher rpm motors mounted with chains and sprockets. We also added a crossbar at the top so we could have more space in the middle for our ring thrower while keeping it stable.
Lessons Learned:	We learned that for wheels on the chassis, speed is a lot more important than torque, and having high rpm motors are very useful. We also learned that you can have ample space while having stability if you think outside the box and add supports in different places.

Chassis Progress Highlights (Details in Engineering Notebook pages CH1-CH7)

Iteration 1	Iteration 2	Iteration 3	Iteration 4
A design made quickly to get our robot running. Set an outline for future designs that would work better.	Added supports and strings to attach and hold the ring thrower at a precise angle.	Replaced the strings with wires, reinforcing the angle setter. We also added a plastic piece to stop rings from going under the robot.	Added custom bumper to prevent rings from getting stuck under the robot.
			

Failure Mode and Effects Analysis

We tried a Failure Mode and Effects Analysis (FMEA) following our second qualifying tournament. Our goal was to improve the consistency of our robot's performance by identifying breakdowns and prioritizing what to do to fix them. The updates we made are shown in our engineering design processes in the portfolio and notebook. They include adding a top to the conveyor, adding a small sweeper to the ring picker-upper, and adjusting our code to monitor the RPMs of the throwing wheel. Page **FMEA1** in our notebook shows the full FMEA. (Partial snippet here)

Failure Mode	Effect	Cause	Priority	Improvement
Inaccurate shots	unable to consitently score high goal or power shots	throwing wheels not up to speed between throws	8	Use encoder to sense the speed - if not up to speed... different buttons for conveyor - one that doesn't check speed, one that blocks the conveyor if not up to speed; sensor to detect if ring is close to thrower and stop conveyor if thrower not up to speed.
		rings not entering throwing wheels flat	8	Add a top cover over the conveyor - partial or full
		do wires on belts catch rings when throwing?		
		rings slipping down the belt when trying to fire	10	Add more wire clips, closer together
				Move the conveyor motor to positiong the belts toward the center - then the clips will be more in the middle of the conveyor
				Add a top cover over the conveyor, top strip to give pressure
				Use different belt material - print a belt? See the forum for ideas, prin belt segments and assemble? print full belt?

3D Printing

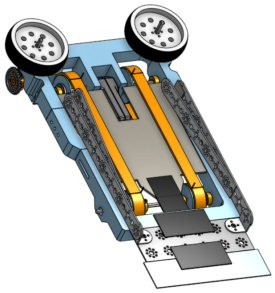
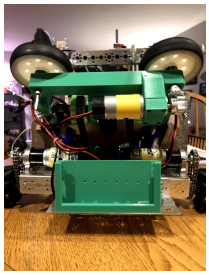
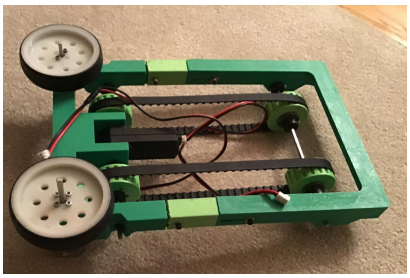
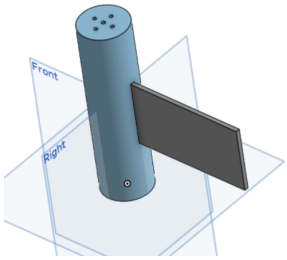
Goals:

3D print core part of the robot.

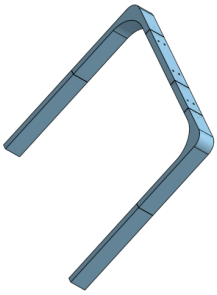
Lessons Learned:

To make sure the part we want to print fits on the bed, we found that we need to check the CAD model, not the slicer. We also learned to divide parts and how to set up our printer as we worked on these iterations. We learned about new printing processes (PolyJet) and materials (Alginate, Vero).

Our ring thrower and conveyer meet the goal of 3D printing a core piece of our robot. Our second and third iterations include printed parts. (More details can be seen in the Engineering Notebook under the Engineering Design Process for the Ring Thrower and Conveyor.) We also updated and printed a new phone case. After our first tournament, we explored 3D printing the sweeper/flapper on our ring picker upper. This gave us experience with additional printing processes and materials. For the state tournament, we also 3D printed bumpers and a small sweeper to improve our robot scoring. More details on **pages 3D1-3D3**.

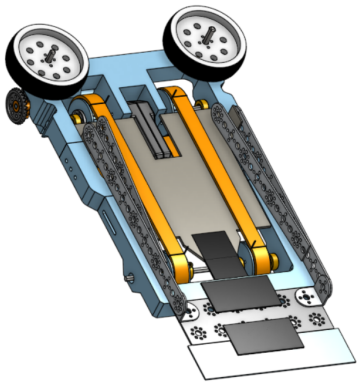
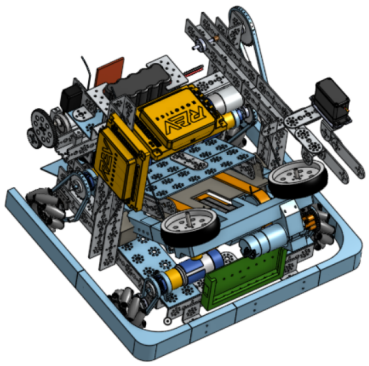





CAD

Goals: Build based off of the CAD, CAD the robot accurately enough to allow someone else to build our robot from the CAD.

Lessons Learned: Make sure that the CAD with modifications is done before any modifications to the physical prototype are made.

This built on our experience using CAD for 3D printing and portions of the robot in previous seasons. We used CAD for the major portions of the robot and have integrated them. More images from our CAD work, along with our Bill of Materials and assembly steps are shown in our Engineering Notebook (**pages CAD1-CAD9**).

Meeting Notes

This year we updated the template we use to take notes to make them easier to take and to more consistently capture important information. Each meeting we:

- Update our robot and outreach Trello boards showing planned, in progress, and completed tasks.
- Decide on the day's assignments and who is going to do them.

- At the end of the meeting, record progress made and actions to take before the next meeting.
- As shown in the example below, we discuss and note obstacles encountered.

Please visit the 150+ pages of meeting notes in our engineering notebook (**pages MN1-MN187**) .

Obstacles Encountered	Lessons Learned	Changes	Component	Date
Ring picker upper was not picking ur rings efficiently	Tape works well to flip the ring over the ramp	Tape added onto flipper	Ring picker upper	1/4/21
The servo didn't rotate the way we wanted it to	We learned that the "continuous" servo only rotated 800 rotations	We had to change the code, and motor settings to get the servo to rotate the amount we wanted it to	servo	1/4/21

Coding

Coding Strategy

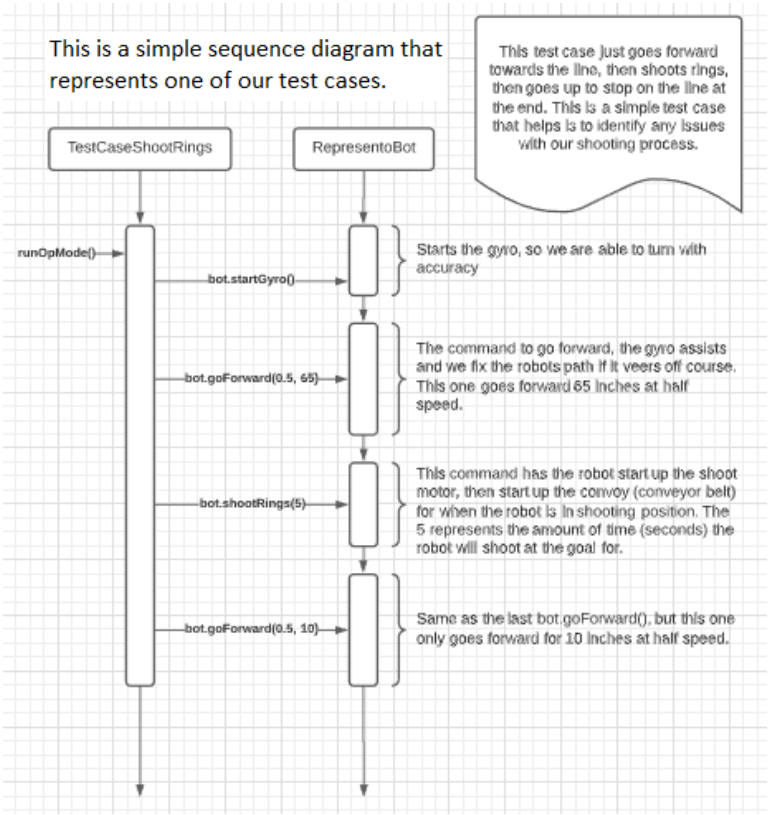
The strategy we used this season was to use a class with our reused functions for ease and readability. We used vision programs Vuforia and TensorFlow to have more accuracy while on the field.

Goals:

- Create a program that could move around the field by looking at the images.

Lessons Learned:

- You have to wait and be patient with the robot. It takes the robot a second to find an image and you to give the robot time to process the image before you can move on.
- Have one large superclass, for us this was a class we call Represento Bot. Represento Bot holds all of our repeatable programs such as "goForward", "shootRings", and "turnLeft" it helps get our coding done quicker and makes it much easier for people to step into programming.
- Test cases help to narrow down issues. By using test cases we were able to break down our code into smaller pieces to test and then bring it all together when it was ready.



Autonomous

In autonomous we start with the first wobble goal already attached to the robot, identify the rings using TensorFlow with a 100% accuracy, goes up to the line and shoots rings, then the robot brings the wobble goal to the correct box, uses Vuforia to navigate to the second wobble goal, bring the wobble goal to the correct box, then stop on the line.

Goals:

- Have the robot do as many tasks that are possible in the 30-second time that we are given.

Lessons Learned:

- We had to break apart the large autonomous runs to make sure that the smaller parts run correctly on their own.

Tele-Op

In tele-op we had commands such as shooting the ring and moving our roller that needed to happen at the same time for ease of the drivers. We were able to do both of the commands at the same time by having multiple commands set to the same button on the controller.

Goals:

- To set a button that would bring our robot to the preferred shooting position.

Lessons Learned:

- One thing we learned during tele-op is to make sure, and double check, which direction your motors need to move.

Please see the Control Award and **pages TC1-TC10** in our notebook**.**

Outreach

Goals Our major goals are in the table below

Lessons Learned

- Apply and use a consistent presentation format.
- Place outreach links in Google Calendar so everyone can access them.
- Incorporate visuals for those that are color blind.
- More time needed than in person Girl Scout badge events.

Turtle Outreach Strategy

Outreach allows FTC teams to connect with STEM experts and motivate others to get more involved with STEM. Our strategy this year for these two important parts of outreach were:

Connect

- Meet with professionals to improve our robot design for tournaments
- Focus on connecting with professionals and companies where we could apply what we learned to improve our skills around robot design, 3D printing, skill development, branding, and more.
- We met with professionals to learn about our futures in STEM and where it could take us
- Shared our experiences with STEM experts and encouraged them to help FIRST

Motivate

- Focus on Girl Scout to teach about STEM and inspire them to join FIRST
- Get involved with other FTC teams and learn from each other
- Help our community through food drives during the difficult year

Like many teams, we started our season working in person, but had to adjust our approach when pandemic restrictions started. Through Zooms, we continued connecting with STEM experts including professionals at 3M, Carnegie Mellon, Stratasys, and Thomson Reuters. We benefited from design reviews, and learned from and with other FTC teams. We also adapted and expanded our Girl Scout program very successfully. We have had tons of outreach experiences and grew a lot this year.

Progress and Results-- 50 Events Total!

Our goals this year:	Goal Number	Result Number
Connect with STEM experts that can improve our abilities in FTC	5	**12 meetings**
Lead Girl Scouts earning STEM badges	50	**136 badges**
To spread awareness of FIRST and High Tech Kids	10	**30 events**
50 outreach hours before the first tournament	50	**569+ hours**
Add a virtual option for all post COVID hosted events	100%	**100% online**
To continue to teach and learn with other robotics teams	5	**13 teams**

See Outreach details in Engineering Notebook **pages O2-O56**.

Outreach Activity Log Sample

Our 6 events between our second qualifying tournament and the state are shown below. See our notebook **pages O2-O3** for the log of all 50 events.

	Outreach Summary of Events						
Date	Event	Team # Attend	Prep Hours	Event Hours	Hours Total	Number Reached	Connect(C) Motivate(M)
3/16/21	Open Door Pantry Food Drive #3	3	3.5	3.5	7	unknown	C
3/21/21	Green Girl Design Review #2 (with FOTS)	5	3.25	11.25	14.5	5 adults	C
3/22/21	3M Design Review #2	5	2.25	7.5	9.75	2 adults	C
3/25/21	Girl Scout Entertainment Technology Badge	5	1.25	10	11.25	15 + adults	C & M
3/27/21	Follow-up Portfolio Feedback with Professionals	2	1	2	3	1 adult	C
3/28/21	Girl Scout Design and Showcase Badges	5	1.25	11.25	12.5	8 + adults	C & M
	TOTAL		154.75	414.65	569.4		

Outreach Activity Detail Sample

The details of all the events also are in our Notebook **pages O5-O53.** One example is shown below

Stratasys Meeting 02/03/21

Description:

We met with Colton from Stratasys to discuss 3D printing parts of our robot with their printers.

Goals:
Learn about different types of 3D printing materials and find one that best suits our needs

Type:
Connect

Impact:
We learned about options for two parts of our robot to be printed. Looking at our game plan, we decided to concentrate on improving one for the next tournament. We redesigned our sweeper part and submitted it for stratasys to print for us. We plan to test it on our robot soon.

Participants:
Colton from Stratasys

What went well:
We found materials that worked well for our needs and sent in a part to be printed the week after.

Number Reached:
6

What to improve (What we learned):
We learned that Stratasys has many different ways and materials to print with. This could lead to us partnering with them more due to the vast number of options that they provide.

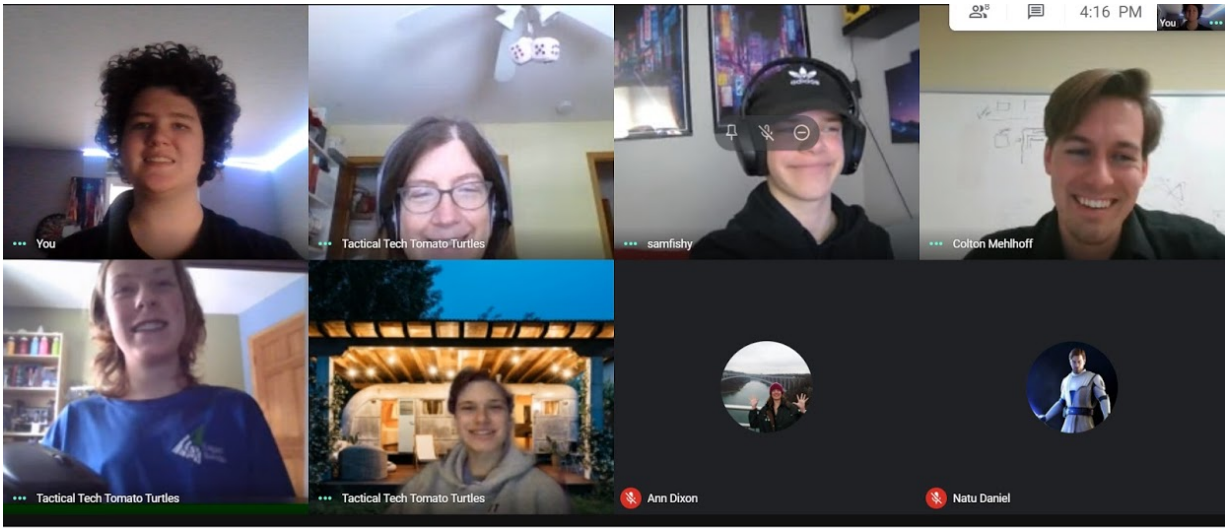
Prep Hours:
1.5

Event Location:
Our houses via Zoom

Event Length:
0.75

Team Members attending:
Benjamin, Clare, Sam, Natu, and Ben

Total Hours:
9.5



Social Media

Goals: To interact with other teams, and give as well as share ideas. We also wanted to be notified about any events that interested us, and tell other teams about our own events.

Lessons Learned: We learned about other teams' progress throughout the season, and how we would go about sharing our progression. We also learned about different recurring events, some of which (like the Crushbots Eagan team meetings) we still attend to this day.

This season, our social media consisted of Twitter and Instagram, which we posted on periodically. It was a great way to interact with other teams, and see the progress they'd made throughout the season. This year especially we made a lot of new connections with other teams, which we wouldn't have made without social media.
(**see more about our social media on page O57 in the Engineering Notebook**)
Instagram link and QR- https://www.instagram.com/tomatoturtles/

Branding

Goals:

Brand our materials to increase our reputation

Learnings:

How to create templates in Google docs and slides, apply branding professionally. create a brand representing the team, review content colors for how it will be seen by people with different color perception

To reach our goal we reached out to a professional for help. Veronica from Korn Ferry provided insight on formatting and presenting information to others in an easy-to-understand manner. We also applied what we learned to update our,

- Logo
- Main template for our presentations and documents
- Email signature

This branding helps people remember our team and our part in the community as well as our representation towards FIRST. More details on this are on pages **(page O58).**

Inspired Turtle Accomplishments

Gracious Professionalism	**First Ambassador at All Outreach**	**Engineering, Design, and Control**
• Inclusive and positive • Practiced teamwork • Fun meetings with games • Collaborate in outreach • Cohort contributors • Having fun with other teams • Sharing robot and progress • Mentoring rookie FTC team	• Girl Scouts • Thomson Reuters presentation • Food drives • Portfolio professionals • Supported FRC tournament zero • Stratasys connection • Carnegie Mellon Lab • 3M design reviews	• Determined game strategy • Established thorough requirements • Applied Turtle Design Process • Full robot CAD • 3D printed core components • Vuforia and TensorFlow • Gyro sensor