Team 7842 Engineering Portfolio 2022-2023

INTRODUCTION

The Browncoats, Team 7842, is a community-based *FIRST* Tech Challenge robotics team made up of students from an approximately 500 square mile area of North Alabama. Currently, the team is made up of eleven students - ranging from 7th to 12th grade. Between them, these students represent public, private, and homeschools from across the area. This is our tenth year competing as an *FIRST* Tech Challenge team.

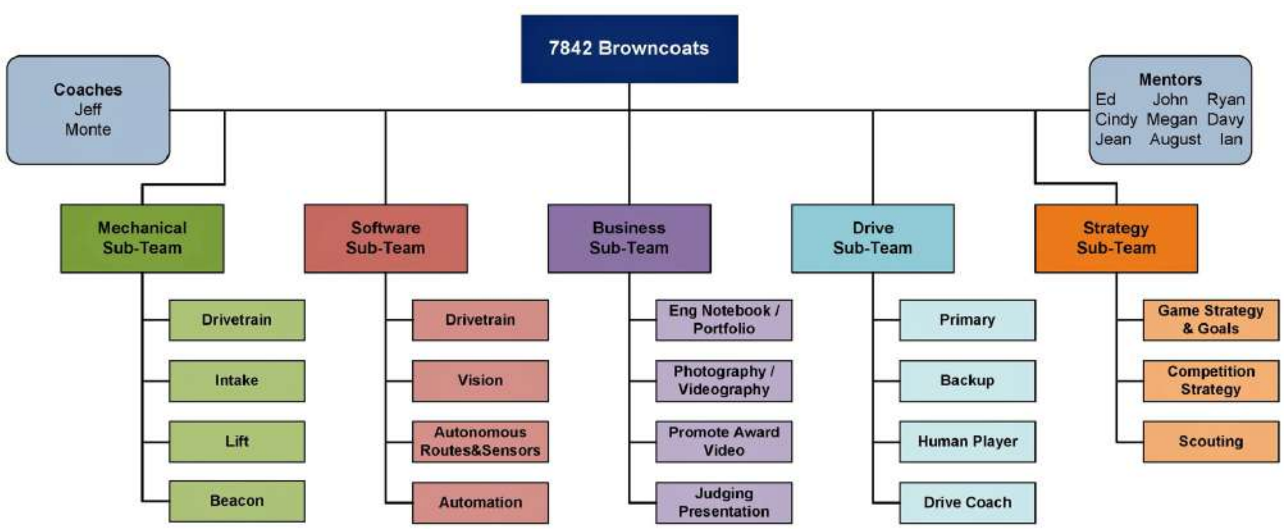
Browncoats' Mission Statement

- spread awareness and recognition of *FIRST* robotics and STEM throughout our community
- exhibit the Core Values of *FIRST* with respect to Gracious Professionalism and Coopertition
- teach important life skills such as teamwork, communication, cooperation, experimentation, public speaking, building, programming, technical writing, community service, marketing, fundraising, and more.

MEET THE BROWNCOATS

Our team has been fortunate to have mentors from many different fields, including a physicist who has worked with NASA; several engineers who coach the students on engineering principles, computer programming, and construction; and former team members, now university students, who share their experience with the current team. Team members take on the responsibility of managing the team, deciding roles, and completing project tasks.

The Browncoats are separated into five main sub-teams. Every team member chooses one sub-team to be a part of, but they can join multiple or all of the sub-teams if they want. The sub-teams are: Mechanical, Software, Business, Drive, and Strategy.



MEET THE BROWNCOATS - continued

Students:

Joel
Software Lead
Subteams:
Software, Mechanical
4^{th} Year on Team

David
Mechanical Lead
Subteams:
Mechanical, Drive
3^{rd} Year on Team

Ellie
Business Lead
Subteams:
Business, Strategy
3^{rd} Year on Team

John
Strategy Lead
Subteams:
Strategy, Mechanical, Business, Drive
3^{rd} Year on Team

MJ
Subteams:
Mechanical, Drive
2^{nd} Year on Team

Lee
Subteams:
Software, Strategy, Business, Drive
2^{nd} Year on Team

Isabella
Subteams:
Business, Strategy, Mechanical
2^{nd} Year on Team

Bronner
Subteams:
Software, Mechanical
2^{nd} Year on Team

Amelia
Subteams:
Business, Mechanical
1^{st} Year on Team

Cash
Subteams:
Software, Mechanical, Drive
1^{st} Year on Team

Caleb
Subteams:
Software, Mechanical, Drive
1^{st} Year on team

Personal Proud Moments

Joel: Winning 2nd place Control Award
David: The whole process
Ellie: Winning the Think Award
Ella: Winning the Inspire Award
John: Creating our Judging Script
MJ: Accidentally making a good intake
Lee: Cone Signal Sleeve software
Bronner: The Pole Navigation Software
Mia: Seeing my pictures in the portfolio
Cash: First time the Lift software worked
Caleb: Helping design and build the Intake

Coaches:

Jeff
8 Years with the Team
B.S. in Electrical Engineering

Monte
10 Years with the Team
Ph.D. in Physics

Mentors
Ed
Jean
Cindy
Davy
August

Alumni Mentors
John
Ryan
Megan
Ian

TEAM PLAN

Goal	Action
Expand Awareness and Help Grow the *FIRST* Program in Alabama	• Spread awareness in our community by hosting informational meetings at public libraries • Reach out to local schools and homeschool covers to introduce students and faculty to the *FIRST* program • Reach out to *FIRST* Lego League to introduce them to the *FIRST* Tech Challenge program by volunteering and providing demonstrations at FLL events
Retain Teams in Alabama	• Participate in Scrimmages and Build Days to connect with other Alabama teams and to give teams more opportunities to improve their strategy and designs
Recruit New Team Members	• Attend outreach events related to *FIRST* and STEM • Reach out to local homeschool groups • Encourage friends and family to participate in *FIRST* • Host informational meetings at local libraries • Place Announcements on Social Media
Retain Team Members	Retaining team members and keeping their interest levels up between the competition seasons and through the summer is accomplished through: • Numerous recruiting and community and engineering community outreach opportunities • Mentor-led classes intended to train new team members for the upcoming season and allow existing team members to sharpen their design and building skills
Connect with Teams from other areas	• Expand our annual Rocket City Invitational by hosting it at a bigger venue • Increase our social media presence by posting team updates more frequently
Develop and fully implement the team's design process	• Apply engineering principles and mentor the team in STEM-based curriculum • Expand CAD skills to support the process • Document design work in the Engineering Notebook and Portfolio

Team Sponsors

Axient has graciously given us a grant this year

PTC/Onshape has provided our team with free educational subscriptions.

AUVSI Pathfinder has given us the space during their annual symposium to demonstrate our robot.

Tennessee Valley Robotics has graciously given us a grant this year.

National Space Club Huntsville has graciously given us a grant this year and awarded us the Rising Star Award at the Wernher Von Braun Memorial Dinner.

SOLIDWORKS has provided all of our team members with free student licenses.

Huntsville Hamfest has given us the space during their annual ham radio festival to demonstrate our robot.

TEAM PLAN - continued

2022-2023 Proposed Income		2022-2023 Proposed Expenses	
Amazon Smiles	$200.00	Team Registration	$295.00
Kroger Rewards	$100.00	Field Elements	$450.00
Axient	$2,000.00	Kentucky State Championship	$500.00
National Space Club- Huntsville	$2,000.00	Arkansas State Championship	$350.00
New Team Member Fees	$300.00	Alabama State Championship	$300.00
Yard Sales	$1,000.00	World Championship	$2,000.00
Miscellaneous Donations	$300.00	Miscellaneous Robot Parts	$3,000.00
Income Total	$5,900.00	**Expense Total**	$6,895.00

Fundraising: As a team, we work together to raise money and come up with ideas for fundraising opportunities. We've put together sponsorship packets that we take to local businesses and STEM companies, and we reach out to as many people as we can. Some of our methods for fundraising include:

- Yard sales
- Amazon Smiles
- Axient Grant
- National Space Club-Huntsville Grant
- Kroger Rewards
- AUVSI Pathfinders Grant
- Facebook fundraisers

OFF SEASON TEAM TRAINING

Mentor-led classes are intended to help train new team members and allow existing team members to sharpen their robot design and building skills. Classes include:

- **Engineering Design Process**: Briefs the Browncoats' "Divide and Conquer" process, discusses needed changes, and buy-into the process.
- **Computer Aided Design**: Hands-on introduction and advanced topics in the use of OnShape and SolidWorks.
- **Introduction to 3D Printing**: Overview of how to prepare an object created in a CAD program for 3D printing using the slicer tool, Cura.
- **Programming**: Multiple hands-on activities covering Java programming; Android Studio and the FTC Control System; GitHub and software configuration management; and the Browncoats' Software Framework.
- **Building**: Hands-on instruction in the use of GoBilda parts, tools, prototyping, and building for strength and reliability.
- **Public Speaking**: Guest mentors (theater coaches and Toastmasters members) lead the team through exercises designed to make them more comfortable speaking to an audience.
- **Soldering**: Fun hands-on activity where each team member learns to solder and builds a small electronics kit.

OUTREACH

In accordance with our Team Mission Statement, our team aims to spread awareness and recognition of *FIRST* and STEM throughout our community. To achieve this, our team participates in outreach events with different age groups and demographics, including children, students, teens, adults, teachers, the engineering community, the local amateur radio community, and more.

Community Connections

Boy Scout Demonstration - July 7, 2022 *(Reach = 30)*
We gave a *FIRST* Tech Challenge robotics demonstration for the scouts working on their Robotics Merit Badge. We were surrounded by quite a few scouts and parents and answered many questions about how the robot was built, how the control system worked, what matches were like, and how the robot was programmed.

Huntsville Hamfest - August 20, 2022 *(Reach = 300)*
This was the sixth year of helping to run the Youth Lounge at the Huntsville HAM Radio Club's annual Hamfest. We hosted many different activities that helped kids learn about STEM, engineering, HAM radio, and *FIRST* robotics. These activities included soldering, Arduino programming, Morse code bingo and bracelets, domino-stacking robots, snap circuits, and, of course, driving our demo robots.

Madison Street Festival - October 1, 2022 *(Reach = 500)*
We were able to set up our booth in the Teen Zone of the Madison Street Festival to attract as many kids as possible. Most of the young people loved driving our demonstration robots, and the adults were interested in acquiring pamphlets and learning about *FIRST* and the team.

Huntsville's Science Festival, STEAMFEST - October 29, 2022 *(Reach = 200)*
We were invited to participate at the Huntsville's STEAMFest, a science and arts gathering geared more towards kids. We showed visitors how to drive our demonstration robots and answered all questions about *FIRST* robotics, *FIRST* Tech Challenge, and the Browncoats. We also demonstrated our robot from last year's season.

Midtown Elementary School STEM Night - January 26, 2023 *(Reach = 250)*
Midtown Elementary School's STEM Night was an opportunity for school kids to learn about Science, Technology, Engineering, and Math. Several STEM-related businesses and organizations, including our team, hosted crafts and activities. We gave out our 3D printed robot pencil holders and let everyone drive our two demo bots. We also demonstrated our robot from this year's challenge.

Engineering Connections

Huntsville Ham Radio Field Day - June 25, 2022 *(Reach = 100)*
We did an outreach event with the local Amateur Ham Radio club called Ham Radio Field Day. Throughout the day we talked to many people from the Ham Radio community about 2021-2022 competition robot, Vera, and how she works and all about the *FIRST* robotics programs.

OUTREACH - continued

Space & Missile Defense Symposium - August 8-11, 2022 *(Reach = 300)*
Our team hosted a booth at the 3-day Space and Missile Defense Symposium. The Symposium is a gathering of local defense businesses to see what companies in the field of engineering have been doing. We brought our robots from previous seasons along with our demonstration robot. We were excited to show the attendees what we and our robots could do through *FIRST* robotics.

AUVSI Pathfinder's Symposium - August 30, 2022 *(Reach = 200)*
Our sponsor, AUVSI Pathfinder, invited us to attend their annual symposium. Because this year's symposium was held at the U.S. Space and Rocket Center again, we not only had several STEM companies attending, but there were many kids and families visiting the museum as well. We handed out a lot of information about all of the *FIRST* programs to people (students, parents, and teachers) about starting, joining, or mentoring a team.

National Space Club Rising Star Award-Werner von Braun Dinner - October 26, 2022 *(Reach = 1,500)*
We were notified by the National Space Club-Huntsville Education Committee Co-chair that we had been nominated and selected for the Rising Star Award, which would be presented to the team at the annual Werner von Braun Dinner. Bronner, David, Ellie, Ella, John, Lee, and MJ (all looking very classy) attended the Werner von Braun Dinner and accepted the award on stage.

Giving Back to *FIRST*

Robot Demonstration at FRC Rocket City Regional - April 9, 2022 *(Reach = 200)*
We were invited to do a robot demonstration at the *FIRST* Robotics Competition Rocket City Regional. We set up in the room where the *FIRST* Lego League Explore Festival was being held. We drove our 2021-2022 robot to show everyone some of what the challenge involves. We had a lot of FLL team members and coaches come and watch, and they were all very interested!

Assisting FTC Team 21394 DAR Robotics - Summer and Fall 2022 *(Reach = 8)*
We donated GoBILDA and electronic parts that we had received from the now defunct Endeavor team. We also gave their coaches and mentors software support as they were getting started by visiting their school and working with them during the Build Day.

Build Day - October 22, 2022 *(Reach = 20)*
Our Software Mentor assisted several teams with their autonomous and teleop programs.

Community Service

Samaritan's Purse: Operation Christmas Child - November 19, 2022 *(Reach = 24)*
Last year, we learned about a wonderful community service project called Operation Christmas Child, so we decided to do it again this year. The team decided to put together 24 boxes of toys and essentials for children in need - (12 girl, 12 boy, ages 10-14). At our meeting on November 19th, we sorted through the items collected and filled all of the boxes.

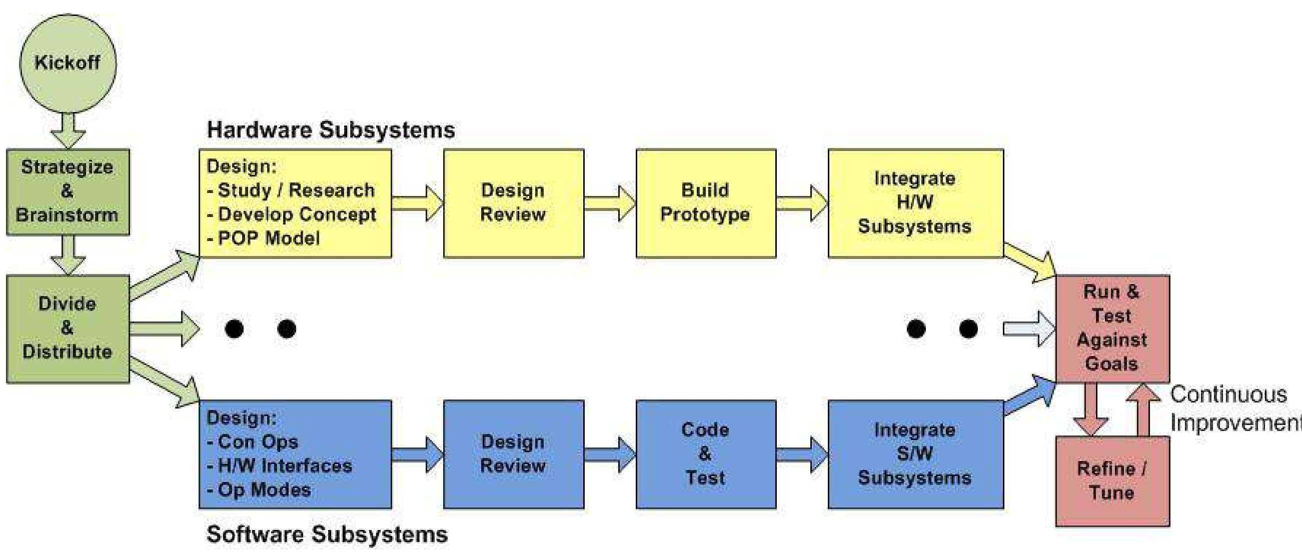
OUTREACH - continued

Social Media					
	Followers		Followers		Followers
Facebook	362	Twitter	1,568	Instagram	1,483

ENGINEERING OVERVIEW – Development Process

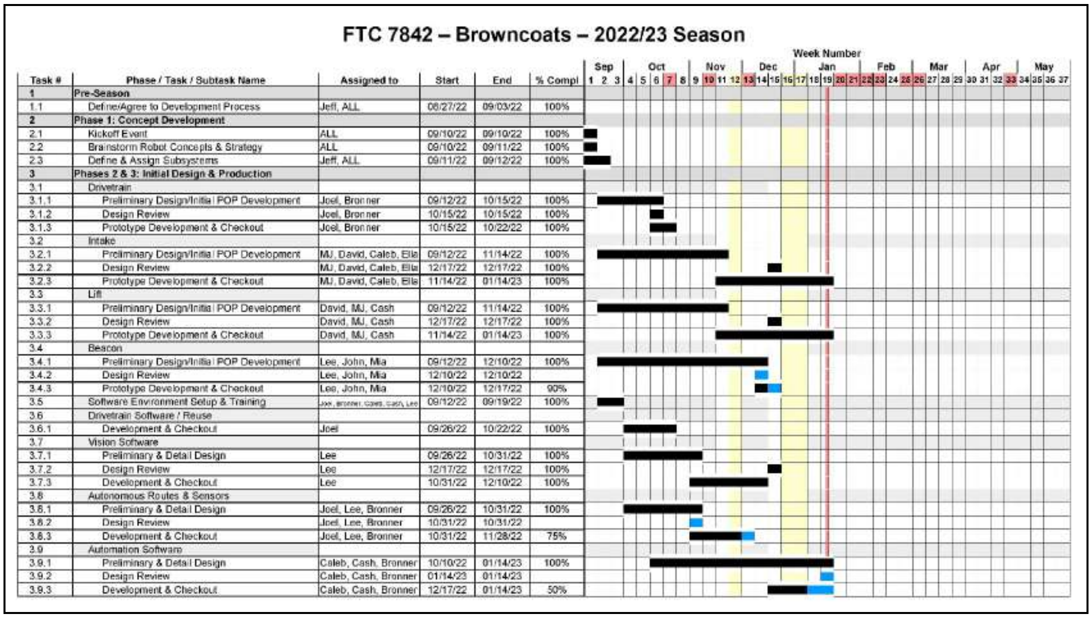
The Browncoats designed and built their robot using a simple but well-defined engineering process, which was agreed to prior to kickoff. At kickoff, the game and its rules were revealed to the team. Immediately afterwards, the team met and began brainstorming about how the game might be played (game strategy) and what the robot needed to do to play the game that way. Over the course of multiple sessions, the components of the robot (subsystems), and the jobs they needed to perform, emerged from the brainstormed ideas.

Each subsystem was then assigned to a student, or a small team of students, to design. Where possible, rookie team members were teamed with more experienced members so that they were helped through the process. This step of the process is where the "Divide and Conquer" process name came from.



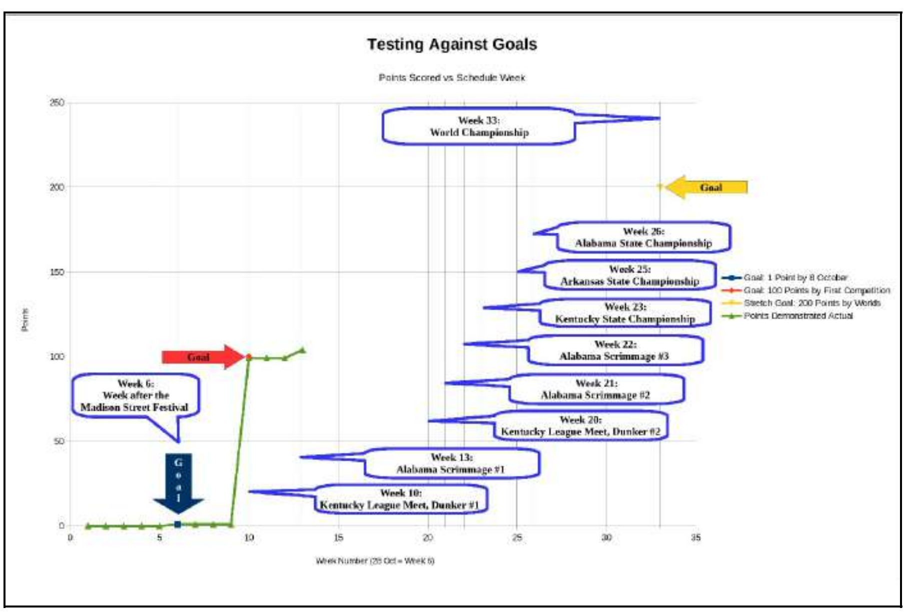
ENGINEERING OVERVIEW – Development Process

As the design work was completed, each student or sub-team conducted a design review; typically a brief show-and-tell where each student shows off his preliminary prototypes, explains how his subsystem is going to work, and describes how it will be built. Once the entire team understands the idea and agrees, final prototypes of the subsystem are built and integrated into the robot.

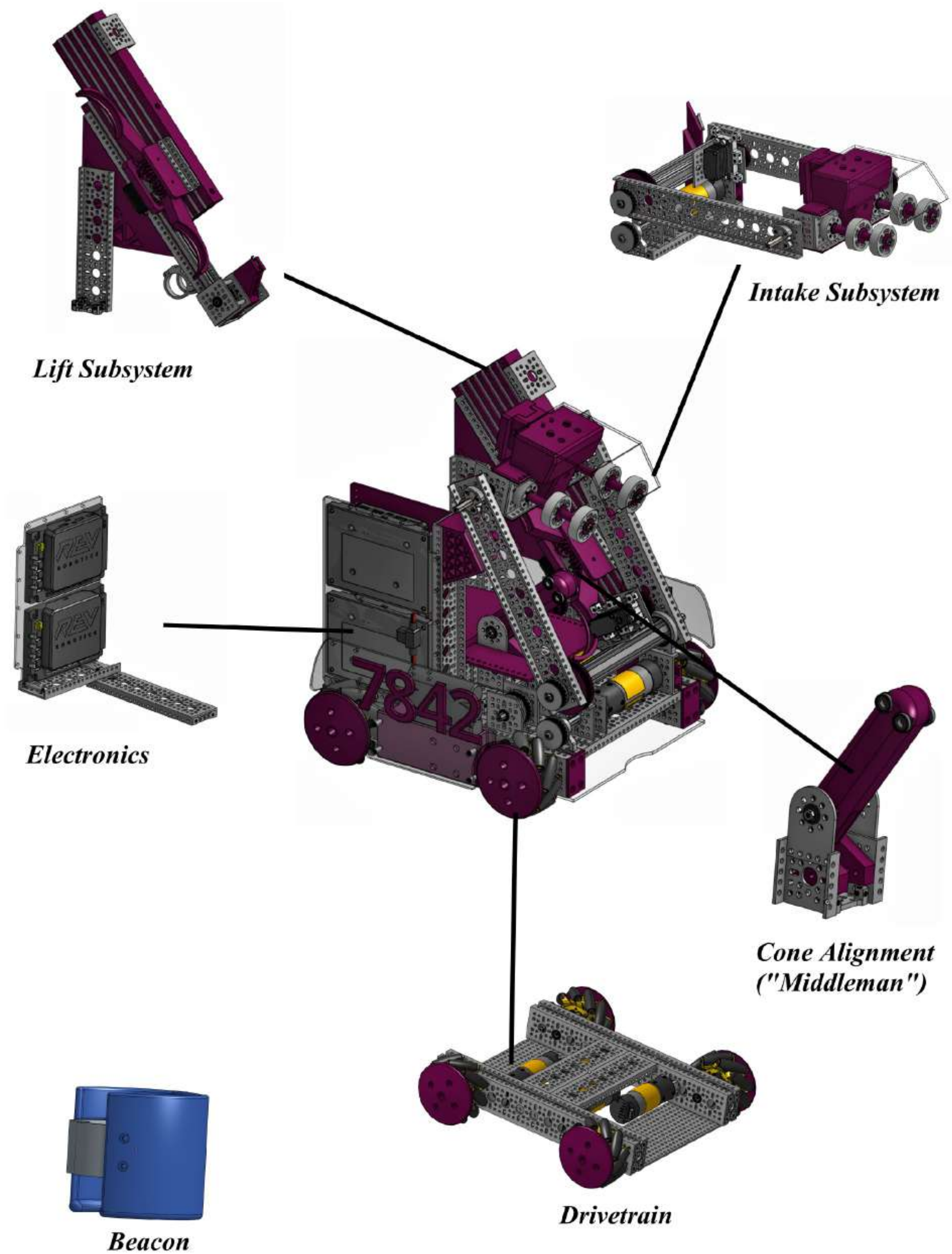

FTC 7842 – Browncoats – 2022/23 Season

Task #	Phase / Task / Subtask Name	Assigned to	Start	End	% Compl
1	**Pre-Season**				
1.1	Define/Agree to Development Process	Jeff, ALL	08/27/22	09/03/22	100%
2	**Phase 1: Concept Development**				
2.1	Kickoff Event	ALL	09/10/22	09/10/22	100%
2.2	Brainstorm Robot Concepts & Strategy	ALL	09/10/22	09/11/22	100%
2.3	Define & Assign Subsystems	Jeff, ALL	09/11/22	09/12/22	100%
3	**Phases 2 & 3: Initial Design & Production**				
3.1	Drivetrain				
3.1.1	Preliminary Design/Initial POP Development	Joel, Bronner	09/12/22	10/15/22	100%
3.1.2	Design Review	Joel, Bronner	10/15/22	10/15/22	100%
3.1.3	Prototype Development & Checkout	Joel, Bronner	10/15/22	10/22/22	100%
3.2	Intake				
3.2.1	Preliminary Design/Initial POP Development	MJ, David, Caleb, Ella	09/12/22	11/14/22	100%
3.2.2	Design Review	MJ, David, Caleb, Ella	12/17/22	12/17/22	100%
3.2.3	Prototype Development & Checkout	MJ, David, Caleb, Ella	11/14/22	01/14/23	100%
3.3	Lift				
3.3.1	Preliminary Design/Initial POP Development	David, MJ, Cash	09/12/22	11/14/22	100%
3.3.2	Design Review	David, MJ, Cash	12/17/22	12/17/22	100%
3.3.3	Prototype Development & Checkout	David, MJ, Cash	11/14/22	01/14/23	100%
3.4	Beacon				
3.4.1	Preliminary Design/Initial POP Development	Lee, John, Mia	09/12/22	12/10/22	100%
3.4.2	Design Review	Lee, John, Mia	12/10/22	12/10/22	
3.4.3	Prototype Development & Checkout	Lee, John, Mia	12/10/22	12/17/22	90%
3.5	Software Environment Setup & Training	Joel, Bronner, Caleb, Cash, Lee	09/12/22	09/19/22	100%
3.6	Drivetrain Software / Reuse				
3.6.1	Development & Checkout	Joel	09/26/22	10/22/22	100%
3.7	Vision Software				
3.7.1	Preliminary & Detail Design	Lee	09/26/22	10/31/22	100%
3.7.2	Design Review	Lee	12/17/22	12/17/22	100%
3.7.3	Development & Checkout	Lee	10/31/22	12/10/22	100%
3.8	Autonomous Routes & Sensors				
3.8.1	Preliminary & Detail Design	Joel, Lee, Bronner	09/26/22	10/31/22	100%
3.8.2	Design Review	Joel, Lee, Bronner	10/31/22	10/31/22	
3.8.3	Development & Checkout	Joel, Lee, Bronner	10/31/22	11/28/22	75%
3.9	Automation Software				
3.9.1	Preliminary & Detail Design	Caleb, Cash, Bronner	10/10/22	01/14/23	100%
3.9.2	Design Review	Caleb, Cash, Bronner	01/14/23	01/14/23	
3.9.3	Development & Checkout	Caleb, Cash, Bronner	12/17/22	01/14/23	50%

The final steps of the process consist of a continuous improvement loop: The robot is run with an eye towards meeting team goals (scoring goals and the ability to execute the desired game strategy, for instance) and any identified fixes, refinements, and improvements are incorporated. Progress metrics are kept with a weekly Gantt chart development schedule. In addition, several team milestone goals are defined during the brainstorming (usually of the form of points scored by a specific date/event) and tracked throughout the season.



ENGINEERING OVERVIEW – Development Process - continued



ENGINEERING AND DESIGN - DRIVETRAIN SUBSYSTEM

DESIGN DECISION: Limit chassis size to about 14" square while keeping the CG as low as possible.

Pros: Fits well between the junctions and allows the drivers room to maneuver and turn. Low CG allows the drivetrain to be fast and maneuverable while keeping all four wheels firmly on the mat.

Cons: The low CG goal means that the drive motors must be mounted horizontally and low to the ground, yet the chassis is too narrow for the motors to be mounted end-to-end in the center of the robot as in the past.

Solution: Mounted the motors horizontally but staggered them and used two different sizes drive belts.

DESIGN HISTORY:

- During brainstorming, the team realized that a normally sized, 18" square chassis would not be able to maneuver between the terminal poles very well. Also, given the team's experiences with vertically mounted motors last season, they knew that a robot with a high center of gravity (CG) was very likely to fall over when accelerating hard, especially if top-heavy features like a lift were mounted on it. Worst case, the robot would fall over and be disabled for the remainder of the match. Best case, the robot would have to be slowed down, which was unacceptable to the team.
- An experiment was run using a very small footprint demo bot that the team was using for outreach. Cardboard skirts of various sizes were fit to the demo bot and driven around the field. The drivers concluded that they liked a chassis of about 14 x 14" the best. ***(See Image 1 below)***
- The next decision was what wheels to use. The team has used mecanum wheels over the past several seasons because of their maneuverability, but they also knew that they slip against the mat quite a bit, making precise navigation for autonomous difficult. An omniwheel X-drive chassis was built and driven, but it was quickly realized that there was no time to properly evaluate it. So, they settled on mecanum wheels again. ***(See Images 2-3 below)***
- Motor placement became the next issue. Due to the experience of past seasons, the team has come to prefer mounting the motors horizontally in the center of the chassis and using 3D printed pulleys and timing belts to power the wheels. That would not work in this case, because the motors were too long to fit back-to-back in the reduced size chassis. Several alternatives were explored, including vertically mounting the motors and using bevel gears (CG much too high) and stacking the motors on top of one another (used too much room in the interior of the robot). The solution decided upon was to stagger the motors so that they were not mounted back-to-back but side-to-side and then to use two different lengths of drive belts.***(See Image 3 below)***
- 3D printed hub caps were added to the mecanum wheels to prevent the metal bits on the outside of the wheels from contacting the metal field walls, the metal bases of the junction poles, or other robots and generating a static electric discharge. During testing, such discharges were causing the robot to become uncontrollable, requiring a power cycle before control could be restored.***(See Image 4 below)***

Image 1

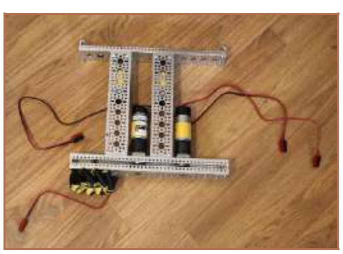


Image 2

Image 3

Image 4

ENGINEERING AND DESIGN - INTAKE SUBSYSTEM

DESIGN DECISION: Pick up cones with a motorized set of spinning compliant wheels.

Pros: Positive, fast cone pick-up, easy for the drivers to use.

Cons: Cones may be pulled into the wheels off center or too hard, jamming the intake and leading to a slow and inconsistent hand-off.

Solution: Incorporated a physical stop to position the cones consistently and a motor current sensor to detect when a cone has been picked up.

DESIGN HISTORY:

● Built several Proof of Principle models to test different approaches:
a claw; a powered rubber band combine; powered, hourglass shaped 3D printed rollers; and powered conformal wheels.
All these prototypes were built in a four-sided cage. The team learned: 1) The intakes all had to be flexible or spring-loaded in order to grip the cones; 2) That it was possible to pull the cones in too far and jam the mechanisms; 3) That the cage got in the way, especially when trying to retrieve cones positioned against the field wall; and 4) That rubber bands frequently break and need to be replaced. Based on the testing, conformal wheels mounted on cantilevered axles were chosen as the most practical. ***(See Images 5-9 below)***

● The next challenge was to figure out how to spin the intake wheels in opposite directions. Several different approaches were explored, including a gear trains and timing belts. The simplest solution was a pair of opposed bevel gears driven by a single horizontal axle. That axle is driven by a series of belts and pulleys, through a co-axial mechanism, to a motor on the body of the robot.

● To make it all fit on the robot, the prototype intake mechanisms went through several rounds of size and weight reduction.

● To mount the intake and power the wrist joint, a virtual four-bar mechanism was first attempted. Once installed, it was realized that the wrist joint had to move independently of the arm to be able to intake cones singly or from a stack of five. The wrist also had to pivot almost 180 degrees to hand the cones off to the lift mechanism. A servo-driven and software controlled wrist was the solution. ***(See Images 10-12 below)***

● Sensors were added to the intake to detect when cones had been picked up. A color sensor was originally used, but it could easily be fooled by ambient lighting. A micro switch under a flexible finger of Lexan was used successfully, but it was found that the cones needed to be guided into a consistent position by a stop, so a motor current sensor was implemented in software to detect when the cones stop the intake wheels.

Image 5

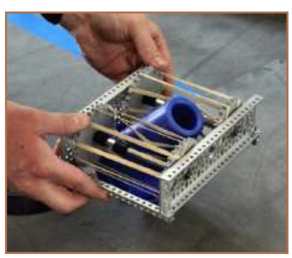


Image 6

Image 7

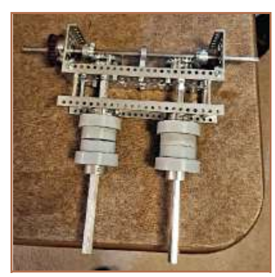


Image 8

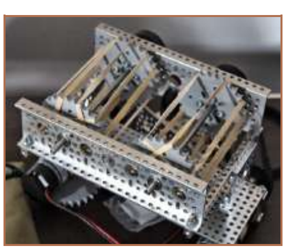


Image 9

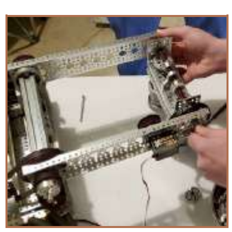


Image 10

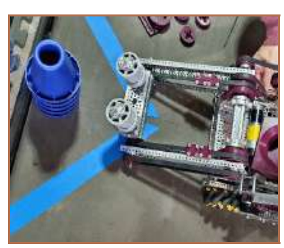


Image 11

Image 12 - Final

ENGINEERING AND DESIGN - LIFT SUBSYSTEM

DESIGN DECISION: Use a lift angled at about 60 degrees instead of straight up. This minimizes the need to reposition the entire robot while scoring cones during autonomous.

Pros: Potentially faster and more precise deposit of cones while minimizing the need to reposition.

Cons: Difficult to predict the exact angle that the lift needed to be for the best balance between reach, height, and stability.

Solution: The lift mount is adjustable, and the drive belts are mounted on the center of rotation, allowing for experimentation and driver preference.

DESIGN HISTORY:

- During brainstorming, many different mechanisms were considered for getting cones onto the terminal poles, including slides, scissor lifts, double-reverse four-bar lifts, and tape measures. Ultimately, slides were chosen for their reliability, strength, and familiarity.
- The team also considered giving the lift some reach. Ideas included a combination of horizontal and vertical slides, pivoting arms, turntables, and angling the slides. Angled slides were chosen because they were simplest and the least top-heavy.
- Several slide alternatives were evaluated. Rev slide kits using 15mm extrusions have been used in the past, but they were ruled out as too fussy. A 4-stage GoBilda slide kit was experimented with but judged too heavy. Misumi drawer slides were chosen because of their strength, light weight, and ball bearing slides. 3D printed inserts were designed to attach each slide stage and to house the v-pulleys for the rigging. ***(See Image 13 below)***
- Lift mounting angles from 45 degrees to vertical were suggested, but no option was clearly superior. As a compromise, the mount was made adjustable by loosening four screws. The belt drive system was modified with a double pulley at the center of rotation so that the lift spool and motor are unaffected by changes in the lift angle. A 60 degree angle was settled upon after a series of experiments.
- A servo-powered claw grasps the cones as they travel up the lift. Initially, a horizontal claw with a fixed lower half was used but was found to be helpless if a cone landed inside the robot. Next, a front-mounted claw was used, but it put a good bit of weight several inches from the slides, twisting them and causing alignment problems. The current claw is side-mounted and both halves are driven through a pair of gears. This mechanism is attached directly to the lift, minimizing any twisting moment, and is able to reach around any cones loose inside the robot. ***(See Images 14-17 below)***
- The cone hand-off between the intake and lift also required several iterations. Initially, a squat, 3D printed cone shape was used, but it required that the intake deposit the Cones very precisely onto it, resulting in failures more than half the time. Next, a 3D printed receptacle that the outside of the cones would nestle into was tried. It worked better, but about 20% of the time the cones either fell out or were misaligned. Finally, a tall cylinder with a rounded top and hinged, spring loaded base was installed. This has proven to be very forgiving to how the intake drops cones onto it, and the spring loaded hinge allows the cylinder to be pushed out of the way as the lift claw grabs and slides the cones upwards.

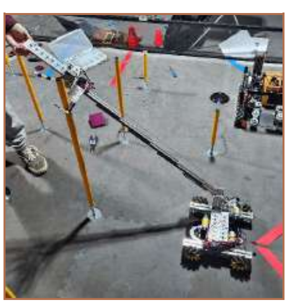


Image 13


Image 14

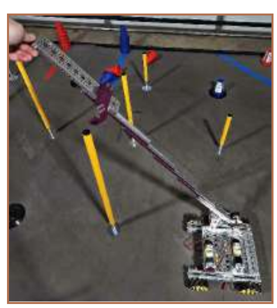


Image 15


Image 16

Image 17 - Final

ENGINEERING AND DESIGN - BEACON SUBSYSTEM

DESIGN DECISION: The beacon design is based on that of a carabiner and is capable of being pushed onto a junction pole instead of having to go over the top.

Pros: Simple. Does not require a tall lifting mechanism to place the beacon onto the tall junction poles.

Cons: Requires a door that allows the junction pole to easily pass through but will reliably and completely close once on the pole.

Solution: Used doors made of a flexible, 3D printed TPU, shaped so that the pole passes through easily but will naturally spring completely closed afterwards.

DESIGN HISTORY:

- During brainstorming, one of the team wondered out loud if the beacon had to go over the top of the junction poles? The team seized upon the idea that a C-shaped beacon with a spring loaded door, much like a carabiner, would be faster and easier to place than going over the top. Game Manual 2 only stated that the beacon must be "completely around the circumference of a Junction pole" and says nothing about how it gets there.
- The initial design was a proof of principle model of a 3-D printed box with a single, spring loaded, hinged door. It was found that the pole could easily go through it but that it would not always reliably close afterwards.
- A cylindrical shape was decided upon for the body of the cone so that it could easily nestle into a ground junction, could also sit on top of a cone, and would be easy for the scorekeepers to see. ***(See Image 18 below)***
- Several door designs were also considered, including a single door on a spring-loaded hinge, double spring-loaded doors, a door with a magnetic catch, and doors fashioned out of a flexible material. Experiments showed that 3D printed doors made of flexible TPU worked best because the shapes could be easily designed to make it easy to push through the poles and to completely close afterwards. They also resisted pulling back off the pole.
- A special servo-driven 4-bar mechanism was first considered to pickup and place the beacon. But once the intake mechanism's wrist became powered by a servo and placed under software control, it became the obvious choice to pickup and place the beacon. The drivers currently can select an intake mode where the magnetic beacon catch faces forward. From there, picking up and placing the beacon has become a matter of driver practice. ***(See Image 19 below)***

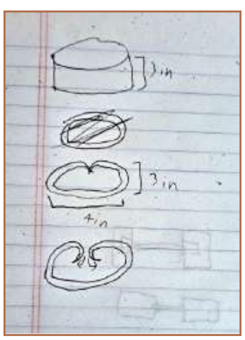


Image 18

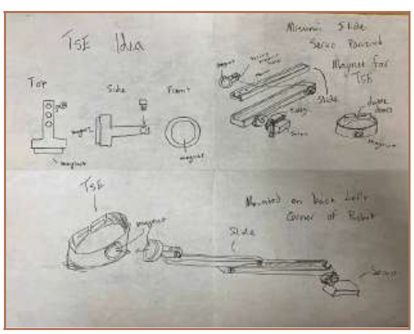


Image 19

Beacon Iterations

Beacon - Final

ENGINEERING AND DESIGN - SOFTWARE SUBSYSTEM

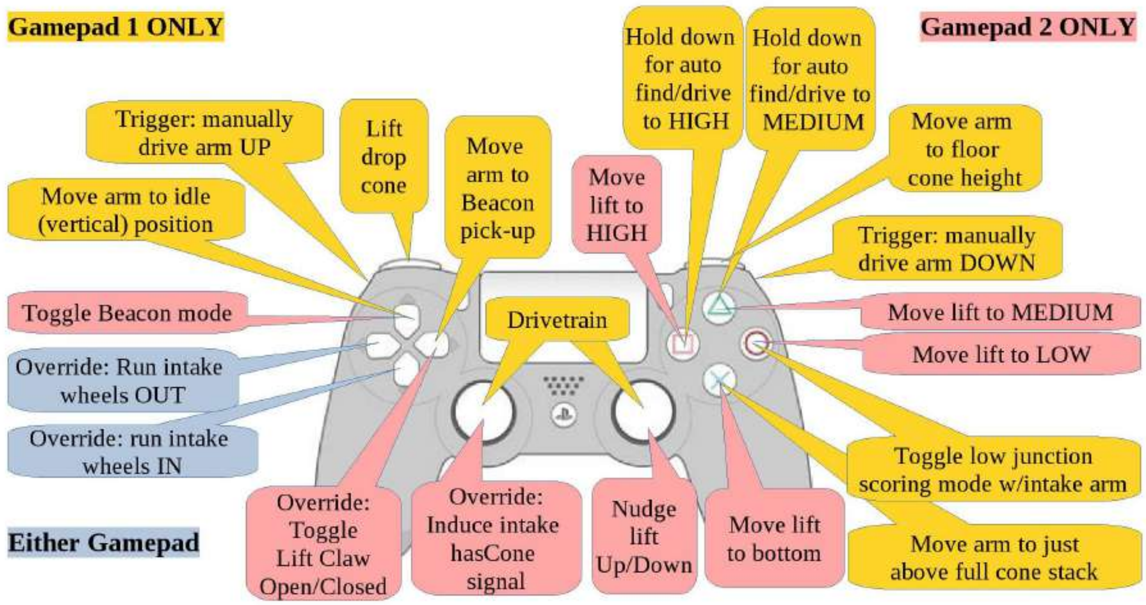
SOFTWARE

Key Algorithms	
Signal Sleeve Vision	OpenCV pipeline completes during init. Operations performed: 1) Webcam servo points horizontal. 2) Image is converted to grayscale. 3) Extract small box containing signal cone. 4) Calc average pixel brightness for entire box, top half, and lower half of box. 5) Compare these averages using "pad values" derived empirically from testing under many different lighting conditions. 6) If the top or bottom is significantly darker, then zone 2 or 1 is selected, otherwise zone 3 is selected.
Find Pole Vision	Webcam switches to FindPole pipeline as soon as the signal sleeve processing completes. Operations performed: 1) Webcam servo tilts the camera to view the portion of the target pole above the level of 4 stacked cones. 2) Image is transformed to YCrCb and then uses the Cb (blue component) only. Yellow then shows up very dark. 3) Median blur is applied w/large 21x21 window to remove hot/cold spots (critical since our up-looking camera is affected by overhead white light reflections along the center-line of the pole). The blur gives the pole a uniform dark gray appearance. 4) An "in range" threshold operation produces solid white poles against a black background. 5) The widest rectangle is selected from a findContours search operation. The center of this rectangle provides our delta yaw and its width provides our distance-to-pole estimate.
Vision Auto-Drive To Pole	In Autonomous, the Road Runner / pole vision system performs closed-loop control of the robot drivetrain to drive toward and score on the target high/medium pole. In TeleOp, the same system can be used to auto-drive the robot into scoring position for a pole if the user holds down a gamepad button.
Intake Wrist Auto-Angle and Wheel Auto-Spin	Wrist (for the active wheel intake) position is auto-calculated relative to the intake arm. The wrist is typically positioned at an offset angle from the intake arm angle. This creates a "virtual four-bar" as the intake arm moves. This offset angle differs depending on the intake mode, 1) Cone intake: 40-45 degrees from horizontal, 2) Beacon mode: 180 degrees. The intake is used to score cones on low poles: a constant 160 angle. Intake wheels auto-spin inward when intake operation is underway, and auto-spin outward for transfer/eject to lift middleman.
Vision Auto-Drive to Cone Stack	In Autonomous, Road Runner performs closed-loop control of the drivetrain as it approaches the Cone Stack. Color sensors beneath the robot inform a left/right adjustment to intake a cone from the stack.

TeleOp Driver Aids	
Presets for Intake Arm and Wrist	Intake arm has gamepad button preset positions for 1) floor cone, 2) cone stack (5 cones), 3) beacon pick-up, 4) low-pole scoring, and 5) idle (near vertical). For cone stack presets, a gamepad trigger moves to level 4 when barely pressed, to 3 when pressed about halfway, and to 2 when fully pressed. All presets are controlled via motor encoder and run-to-position mode (with a PID-tuned motor), based on trigger-switch zeroing on startup. The wrist angle (servo) and active intake/eject wheels (motor) are fully software-controlled (see key algorithms).
Presets for Lift and auto-grab / release of Cones	The lift has gamepad preset buttons for 1) high pole, 2) medium pole, 3) low pole, and 4) bottom/load position. All of these presets are controlled via motor encoder and run-to-position mode (with a PID-tuned motor), based on trigger-switch zeroing on startup and each time the lift returns to the bottom. The cone class automatically grabs the cone before moving to a pre-set position, and on descent, automatically releases the cone (if needed) to prevent a cone from being driven back into the robot.
Cone auto-transfer	Auto transfer of cone from intake to middleman (amp monitoring), auto-ejects. When the cone enters the intake, it pushes a flex hinge to release a touch sensor. This touch sensor causes the intake to automatically retract and transfer the cone into the "middleman".
Gamepad vibrate on cone intake	A color/distance sensor detects when a cone arrives on the middleman and rumbles the lift operator gamepad (who may be looking elsewhere on the field for strategy purposes).
Gamepad vibrate for low-junction mode	Whenever the driver toggles low-junction mode there is a rumble (2 rumbles for on, 1 for off). Low-junction mode has to be selected PRIOR to cone intake (to prevent auto-transfer to the middleman). This feedback ensures the driver knows what mode is selected.
Overrides	A few operations have driver overrides (see gamepad diagram)
Automatic alliance for TeleOp	When transitioning to TeleOp, the drivers do not need to worry about selecting BLUE or RED TeleOp. During autonomous, the software writes the alliance to the sdcard memory, which TeleOp reads on startup. This allows alliance-specific automation operations in TeleOp (e.g., for software assisted cone stack approach/intake the software would know what color of tape to detect).

ENGINEERING AND DESIGN - SOFTWARE SUBSYSTEMS - continued

ROBOT TELEOP CONTROL



DEVELOPMENT PROCESS/HISTORY

Software subsystems were assigned to each team member after hardware subsystems were identified in brainstorming. New team members learned how to control devices that would likely be a part of their subsystem (motors, servos, sensors, camera, state machines, etc.). Alan G. Smith's book "Learn Java for FTC" was used in conjunction with a **breadboard**. The team has a ***framework*** that allows for ***Re-Use*** each year, so there is a clear path to begin coding the classes for each subsystem. The framework is has three ***layers***: OpMode (high-level), Middleware (logic level), and Hardware Interface (low level). Subsystems are divided into separate classes so programmers can work ***independently*** of one another (in GitHub) and git merges become trouble-free.

Signal Sleeve vision software was started early with development of an OpenCV pipeline to detect a sleeve with Red, Green, and Blue sides. After experimenting with lighting conditions, this proved fairly unreliable. We migrated to a solution using solid black and white, with black on the top or bottom half of the sleeve, or entirely white. We like how this resembles a pattern on the Saturn V rocket on display in our own Rocket City.

Our intake and lift coders implemented software and state machines in parallel with the hardware build.

In early scrimmages we watch teams struggle to score cones in autonomous. We realized seeing/sensing the poles was vital. At this time, we began developing the Find Pole vision pipeline.

Early in the season we were not using Road Runner. As a result we spent (and perhaps wasted) a good deal of time developing a distance sensor Pole Navigation system to provide localization info as the robot passed poles on each side. This system used least-squares line fits to determine actual position and orientation after each drive. This system was scrapped after moving to Road Runner a few weeks before Worlds. This late transition resulted in far fewer autonomous routes being developed and perfected than usual.

AUTONOMOUS ROUTES

Our most mature route has the goal of scoring the pre-load cone on the medium pole, and then scoring the five cones from the stack on the same pole, and then parking in the correct zone.

VISION ILLUSTRATIONS

The signal sleeve vision is shown below. To the right are images of the progression of operations performed by the Find Pole pipeline. The 1st shows the original image (with the detection shown as the thick white bar). The 2nd shows the Cb plane with median blur. The 3rd shows the in-range threshold result. The thin white bars at the top are references to show the nominal positions and widths of high and medium poles.