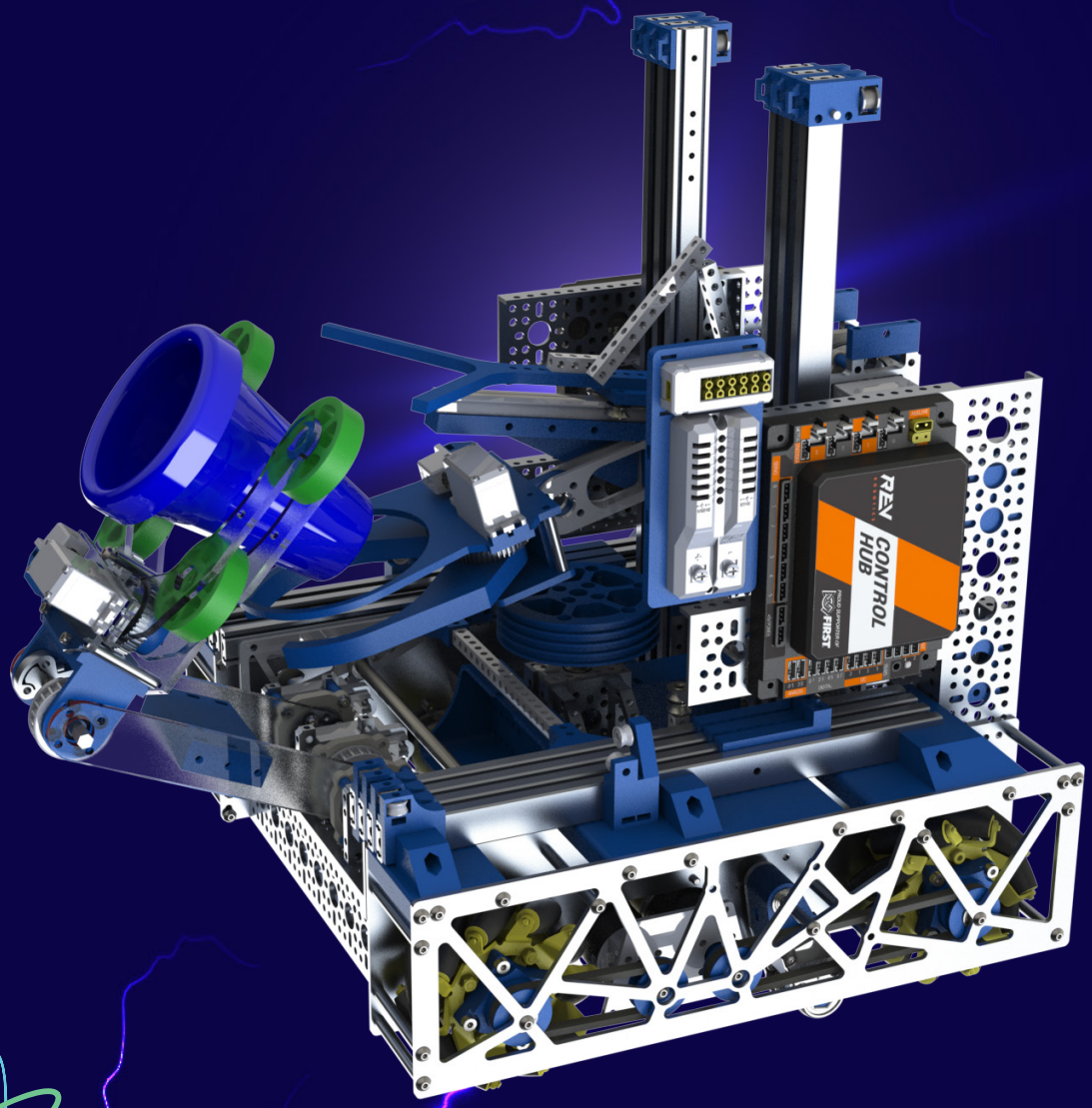
ENGINEERING PORTFOLIO

Quantum Robotics #14270 | RO077

FIRST Tech Challenge Romanian National Championship



QUANTUM ROBOTICS

We. Make. Smiling Robots.

Powered by:

ROEL

EXECUTIVE SUMMARY

We. Make. Smiling Robots.

Quantum Robotics #14270

As our team's first five year life-cycle has ended, this year we meticulously thought and developed a new long-term strategic plan for the following years: 2023-2028.

OUR LONG TERM GOALS:

1. Consolidate and incorporate the FIRST core values and GP in our lives
2. Improve the recruitment process and NextGenerationQR management of change
3. Outstanding addition of technology & innovation and build resilience to multiple changes
4. Strengthen the skills development framework and the effective transfer of robot construction know-how to the NextGenerationQR
5. Consolidate the relationship with our sponsors and school administration for a long-term sustainability

Through our work we succesfully represent FIRST, our school, and Romania everywhere we go. We are proud to always live up to the FIRST core values, and incorporate Gracious Professionalism in our daily lives.

Mentored	Assisted	CAD	Ran & Hosted	CNC	Supported	Advocated
50h	20h	765h	3183h	110h	120h	45h

WINNING is temporary, LEARNING is forever.

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This season we managed to acheive 21 sponsors - the highest number in our team's lifetime.

[redacted] - Season budget
[redacted] - Events budget
[redacted] – Lab & Tech budget
[redacted] - ROMSpace budget

OUTREACH

TIMELINE

August

FTC Workshops	p6
CadAthon	p5

September

KickAthon	p5
STEM in Schools	p6
Conference 1	p6
Science Fair	

October

Conference 2	p6
Speakers at workshops hosted by #12518 Almond	p6
Oxygen training starts	p5
XPonential	p7
STEM in Schools	p6

November

Conference 3,4,5	p6
Gala Lumina	p7
Speakers at Zilele Roboticii	p6
Quantum League Meet 1	p5
GoTech World	p7
STEM in Schools	p6

December

STEM in Schools	p6
Speakers at RoboWeekend	p6
Quantum League Meets 2&3	p5

January

Quantum League Meet 4	p5

February

Conference 6	p6
Speakers at WorldShop	p6
International FTC Conference hosted by #12808 RevAmped	

Future Events

Quantum League Championship	18-19.03.2023
Lab Grade	Feb-Jun 2023
Alumni Gala	

MANY THANKS TO OUR SPONSORS!

CELESTA COMEXIM SRL · SOLIDWORKS · KIWI FINANCE · MarcTel · MSL LOGISTIC · ROEL · LICEUL INTERNATIONAL TEORETIC DE INFORMATICA 1994 · TCM TUNING · Asirom VIENNA INSURANCE GROUP · LUMINA Institutii de Invatamant Educational Institutions

TEAM INFO

This year we have 1 new mentor*, 3 new assistant mentors*, 8 new members*, and 1 new volunteer*, resulting in a total of 15 members, 5 volunteers, 4 mentors and 6 assistant mentors.

Together with the new acquisition of a CNC Machine this season, our department organisation has changed as follows. The 3D Printing department became the Manufacturing department which has 2 sub branches: 3D Printing and CNC parts production.

PAST ACHIEVEMENTS:

- 1 Motivate Award
- 3x Alliance Winners
- 10 Inspire Awards
- 4 Think Awards

OUR GOALS FOR 2023:

1. win Bucharest FTC Regional, February 2023
2. win Romanian FTC Championship, March 2023
3. win a judged award and reach the final in Houston, April 2023
4. Inspire others through our outreach program

TEAM LEADER

Alex

PROGRAMMING

HEAD OF PROGRAMMING:
Ricardo

TeleOP, Autonomous, Game Strategy, Website

Alex, Tudor, Rares, David*, Justin

HARDWARE

HEAD OF HARDWARE:
Matei

3D Design, Assembling, Electronics

Alex, Ricardo, Tudor, Maria, Vlad, Daria, Rares D.*, Alice*, Luca*, David*, Matei B.*, Tudor M.*, Andu*, Alesia*

PR & MARKETING

HEAD OF PR & MARKETING:
Daria

Outreach, Fundraising, Social Media

Mada, Zehra, Matei*

MANUFACTURING

HEAD OF MANUFACTURING:
Tudor

3D Printing, CNC

Alex, Matei, Luca*, Andu*

MENTORS

Emre S., Asker A.*, Sacontala C., Alin P.

ASSISTANT MENTORS

Hardware: Andrei, Victor, Vlad*

PR & Marketing: Eliza*, Andrei

Programming: Radu, Mircea*

Quantum Robotics was established in September 2017 at the International Computer High School of Bucharest.

The team competes under RO077 in Romania and #14270 internationally. The team is structured in 4 departments: PR & Marketing, 3D Printing, Hardware, and Manufacturing.

Team Photo

Each year new mentors join us in our path to success, supporting, teaching and helping us achieve our goals

They are expected to provide guidance and share their professional expertise with team members to build their leadership, problem-solving skills, sense of belonging, and self-confidence.

New mentors: Asker, Eliza, Vlad, Mircea.

SUSTAINABILITY PLAN

Sustainability ensures that our team is able to maintain and improve it's success well into the future, develop team projects and to have a positive impact on the STEM community. **Building a sustainable team starts with these 4 foundations:** passionate human resources, financial stability, quality materials, infrastructure.

1. HUMAN RESOURCES

1.1 Recruiting NextGenerationQR

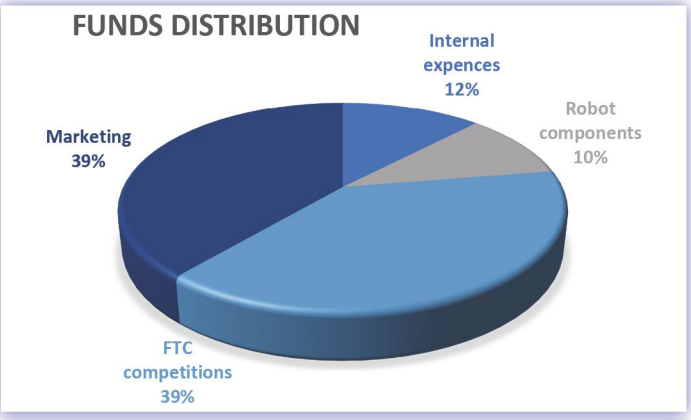
Our team recruitment process is designed to ensure **sustainability**. Every year begins with recruitment period, during which we attract, enroll, and train new members. QR developed a recruitment system which takes place in the **first week of September** every year. The selection of the members is split in 2 sections, according to the interest and skills of the students: **volunteers and members**. Furthermore, every season new members are **advancing in the hierarchy** of the team.

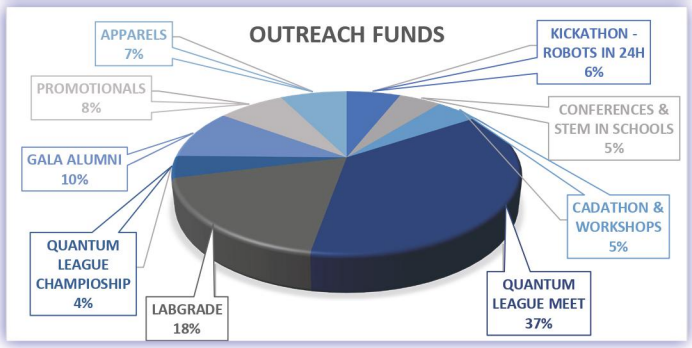
1.2 Training new members

The **QR training program** is an initiative designed to get our freshmen members on the right path to **FIRST values and STEM disciplines**. It teaches the juniors about FTC and encourages them to build their own robot and compete in **scrimmage competitions**. This season they participated to **6 demo competitions** with their own robot.

1.3 Adapting to change

QR team **faces the change** (by modifing the senior and junior members within) every year and struggles with handling it effectively. According to our long-term strategic goals 2023-2028, the team must be **equipped with skills and tools** to be resilient to changes. For this reason, the team proposed to **recognize behavioural patterns** based on senior experiences and to continue **investing in new technology** and encourage **innovative in thinking** in order to be **one step ahead**.





2. FINANCIAL PLAN

We focus on long-term **financial sustainability** to ensure **success**. Financial support comes from two different sources: **sponsors and contributions.** In 2019 we launched our own financial vehicle: "Quantum Robotics" Association, a **non-profit organization** created to support all students passionate about STEM disciplines. The association was founded by **parents, mentors and the ICHB Administration.**

Every season we plan the budget according to the team season strategy to cover the team necessities for: robot parts, robot spare parts, marketing costs, competition fees, accommodations, transport costs, etc. Our main financial sources are sponsorships. The main sponsorship goal is to convince the existing sponsors to keep financing us and acquire new sponsors every year.

The approved budget this season is **[redacted]** taking into considaration the multitude of events we want to invest into. Achieved budget by the end of February is **[redacted]** provided by our Platinum Sponsor Roel, and traditional sponsors MarcTel, Celesta, MSL Logistics, TCM Tuning and by 14 new sponsors including Kiwi Finances and Asociatia "Vreau sa invat",

The QR Association is a financial vehicle for collecting sponsorships and distributing the funds for Romspace Sattelit projects. Budget achieved to date: [redacted] Euro, from the following sponsors: Romanian Government, Banca Transilvnia, EximBank, Roel, Urgent Curier, Asociatia SuperBet, and other individuals.

3. NEW INNOVATION LAB

Recognizing our successful work over the past 5 years, the school administration awarded the team with the new robotics laboratory. The team appreciates the investments that help us improve our education and prepare us for high-tech careers. The whole team, alumni and mentors were involved in the arrangement and equipment of the lab during the summer.

Also, the team benefits from the school's modern infrastructure, having full access to the laboratory, materials, conference rooms, catering, etc.

What makes a robot truly perform at its best is testing it in full-time simulations of an official match, therefore our robot has to be ready 2 weeks before the competition. As a result, we came up with a strategy - while we're assembling and working on our robot for the upcoming competition, we split up in two teams: one is working on the current robot, and the other one is working on the changes for our next competition in CAD, which, most of the times result in a partial or even full rebuild.

IT'S MORE THAN ROBOTS

INVOLVEMENT IN THE ROMANIAN FIRST COMMUNITY

Quantum League

Innovating the Romanian FTC community once again

Unique event introduced for the first time in Romania. 4 league meets, held in: Iasi, Timisoara, Cluj ,Bucharest. We collaborated with other 3 ambassador teams: #19043 CyLiis, #17861 Team CSH and #19068 ABSO-Tech, creating diversity and accessibility to all teams around the country to participate.

Learnings: The huge logistical efforts require sharper leadership capabilities, as follows: the global perspective of the operation, proper and efficient communication, thinking forward, paying attention to details, network strategic partnerships and to be competitive at the same time by building the robot and playing the game.

GENERAL GOAL	Engaging the STEM community to play an essential part in their success	
SPECIFIC GOAL	Developing the team member's skills by playing a leadership role in promoting coopertition and Gracious Professionalism in FTC Romania	
KEY FIGURES	- 60 participating teams - 3 ambassador teams - +1350 attendees - +50.000 social media interactions	- +2800 km traveling - +750 kg materials - uncountable hours of work. - +100 volunteers

Quantum League staff during matches

LabGrade

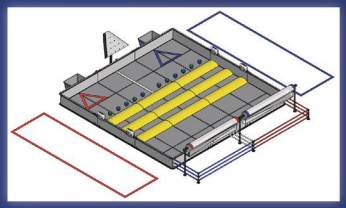
Unique fundraising event, first of this kind

Upgrading robotics laboratories worth [redacted]. Giving teams who don't have the same opportunities as us, but showing great passion and dedication, the opportunity to perform at the highest level of ftc. Rigorous winning criteria, chosen and evaluated by team members, alumni, mentors, sponsors.

CADAthon

For the first time in Romania -> interactive training 3D modeling session by creating our own innovative game rules and tasks similar to FTC themes. Designed as a competitive game and judged by our alumni mentors. Teams had 7 days to design a 3D robot for this theme and submit a 2 page flyer describing the engineering process.

GENERAL GOAL	SPECIFIC GOAL	KEY FIGURES
Engaging the STEM community to play an essential part in their success	Prepare for the upcoming season by challenging all FTC teams eager to develop their 3D modeling skills	- 16 teams - 50 students - 20 mentors



3D model of Townlet Trouble field

KickAthon

1 robot in 16 hours, first Word Record of the season

Combines the FTC season's KickOff and a Hackathon type competition, challanging the teams to build a robot for the POWER PLAY season in only 16 hours. Furthermore, we managed to set up 3D printing, implement brainstorming workshops, networking, and connect with other teams while discovering this year's challenge.

GENERAL GOAL	Helping the community understand the FTC theme	
SPECIFIC GOAL	Faster understanding of FTC new season challenge	
KEY FIGURES	- 20 FTC robotics teams (2x more than last year) - 120+ students from all around Romania - 20 robots designed and built during 16 hours of competition	- 103 points scored by alliance in the qualifier matches, First world record of the Season -2500+ social media interactions - 40+ volunteers

Kickathon Opening Ceremony

Robots on field during KickAthon

FLL National Championship - Volunteering

7 of our team members and one mentor were involved in the on-site event execution for the entirety of the FLL National Championship. Volunteered by planning, logistics and competition process. (reffees, pit administrators, scorekeepers, queuers).

IT'S MORE THAN ROBOTS

PROMOTING STEM & FIRST VALUES

STEM in Schools

The 4th edition goes beyond all expectations

Became an yearly event. Held STEM and FIRST focused presentations at six schools in Romania: Spectrum Cluj, Spectrum Bucharest, Spectrum Colentina, Middle School Ferdinand I, Magheru High School. Spread the FTC program to Africa, having an online presentation with a school director from Egypt.

We learned that many kids have passion for STEM projects and disciplines, but don't know how to express it. We are grateful to have inspired them to enter the STEM and FIRST communities. Connecting with other students and explaining to them what FIRST and STEM are, will always be a big goal of our team.

STEM in Schools program at Middle School Ferdinand

STEM & Robotics Conferences

Spreading STEM and FIRST values even further.

Audience: +200 School directors, administrators, inspectors and teachers from Romania, Republic of Moldova and the UK, Lithuania.

Hosting six conferences at our school. Presented: the FTC program, how we successfully apply STEM skills learned in school into this interactive-learning program, how we operate and organize as a FTC team, how we learn, while, at the same time, teaching other students skills which prove to be of utmost importance in the future's jobs and careers.

Results: Successfully managed to inspire and motivate them to implement this kind of educational method in each and every school, contributing to the future of the national and international school systems.

Photo from conference with Lumina directors

Sharing our experience, giving advice, helping other teams

1. Workshops hosted by #12518 Almond, topic: *Time management* 2. Zilele Roboticii, topic: *Robot rebuilding* 3. RoboWeekend, topic: *Dean's List* 4. WorldShop hosted by #12808 RevAmped, topic: *Event organizing*

WORKSHOPS AND TRAININGS

GENERAL GOAL	Improving the skills of team members by connecting them with specialists
SPECIFIC GOAL	Identifying critical learning, developing needs and allowing students to grow in their area of interests: science & technology, safety, marketing.

Identifying critical needs
- Technology
- Safety & Security
- Marketing

Contact and plan
- Contact CNC, Safety & Security and Marketing specialists
- Plan and schedule meetings

Meet and learn
- Meetings
- Training sessions

Applying learnings
- Producing metal parts
- Focused marketing plans
- Increased safety in the Lab

Workshops for FTC teams

This off season, in order to help FTC teams, we invited 3 of them: RO193 Andromeda, RO019 ViCyber, RO142 BroBots, two of which are rookies, to our new lab and presented them how a successful FTC team should operate, while teaching them different skills and tips we have learned throughout the past 6 FTC seasons.

Workshops about: CAD, Hardware & Assembling, Motors & Control Systems, FTC Team Organizing, PR & Marketing, FTC parts manufacturers (focusing on GoBilda).

Attendees: 3 FTC rookie teams, +45 pupils, +15 volunteers.

Workshops with rookie teams

Presentation in the amfitheatre

PR & Marketing Training

Reaching the highest number of members in the PR & Marketing department, we need to train and prepare them to perform at the highest level. Started a partnership with Oxygen advertising company, having periodic meetings.

Learnings: Organize all our events more thoroughly, promote our brand, reach the targeted audience through our social media posts => an increased number of participants, solve internal communication problems, raise funds and connect with sponsors.

Mentoring & Assisting

Continued to mentor 2 teams: Andromeda RO193 and FLL team Quantum Bits #1938. For the past months we increased interactions & meetings with these teams, having 4 designated QR members for this activity. Supported +25 FTC teams with tips, spare parts and answers.

IT'S MORE THAN ROBOTS

CNC Training, Safety & Protection Measures

Upgrading the lab with new tools and equipment challenges the team to learn how to use them properly. The most challenging is using the *Shapeoko Pro* CNC, for producing custom metal parts for our robot. We invited safety specialists from MarcTel to teach our members how to use the new power tools properly.

CONNECTING WITH ENGINEERING COMMUNITIES

XPonential Robotics

Successful techniques of studying science and other disciplines in schools

Specific goal: Consolidate our team identity, presenting our future plans, recruiting new supporters and sponsors. This is our annual conference concept for presenting the successful techniques of studying science and other disciplines in schools to our sponsors and supporters, using as a case study the QR team's evolution and performance.

Target Audience: school administrators, engineers, sponsors, and parents.

Photo with the atendees

GoTech World, Bucharest

Science and technology fair

Specific Goal: To connect with engineering, technology and programming communities from world-leading companies, to promote the FIRST program and to convince the specialists to be involved in FTC program.

Learnings: How STEM is applied into the real world, how companies innovate the world we live in, inspiring us to pursue our passion for robotics and follow their steps. We managed to discuss future internship opportunities and make them aware of the FIRST program.

Key features: Participated in devops, sustainability, management conferences and connected with +70 specialists from the technology sector including CEOs, department heads, and passionate employees. +30 sponsorship letters were sent.

ROMSPACE Satellite Project

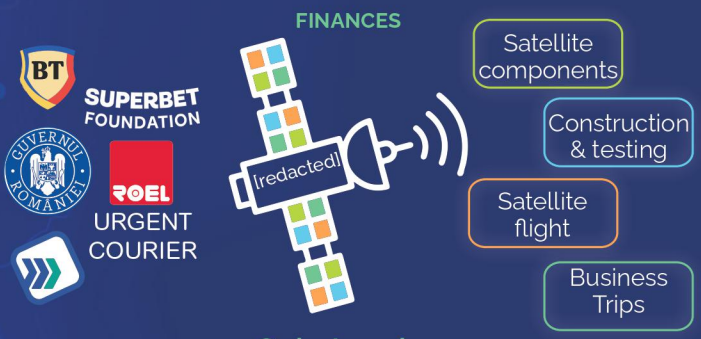
Launching the biosecurity pico satellites with SpaceX

GENERAL GOAL	Engaging the STEM community to play an essential part in their success. Promoting initiatives for developing STEM education in our community
SPECIFIC GOAL	Developing connections with individuals in the engineering, science, technology community. Expanding the team skills. Assuring active support in the fundraise, finance, and logistics process

Started 2 years ago, the project is ready to launch into orbit with a SpaceX rocket 2 pico satellites this year in May. Our team is actively involved with 2 members in the production and programming of the satellites and playing a leadership role in fundraising, financial planning, acquisitions, logistics process, and communication with engineers and specialists. The team recruited the Olympic students from ICHB, parents, mentors, teachers, engineers across the world: Nepal, Spain, Switzeland, Ireland, Scotland, US and sponsors (including the Romanian Government)

Learnings: This complex project helped us understand the role of team work for realizing a real scientific project.

Sponsorships: [redacted] Euro



Gala Lumina

Community values our contribution - Advocacy event

Following our outreach program and community efforts, our team was awarded during the Gala Lumina event in the social involvement category.

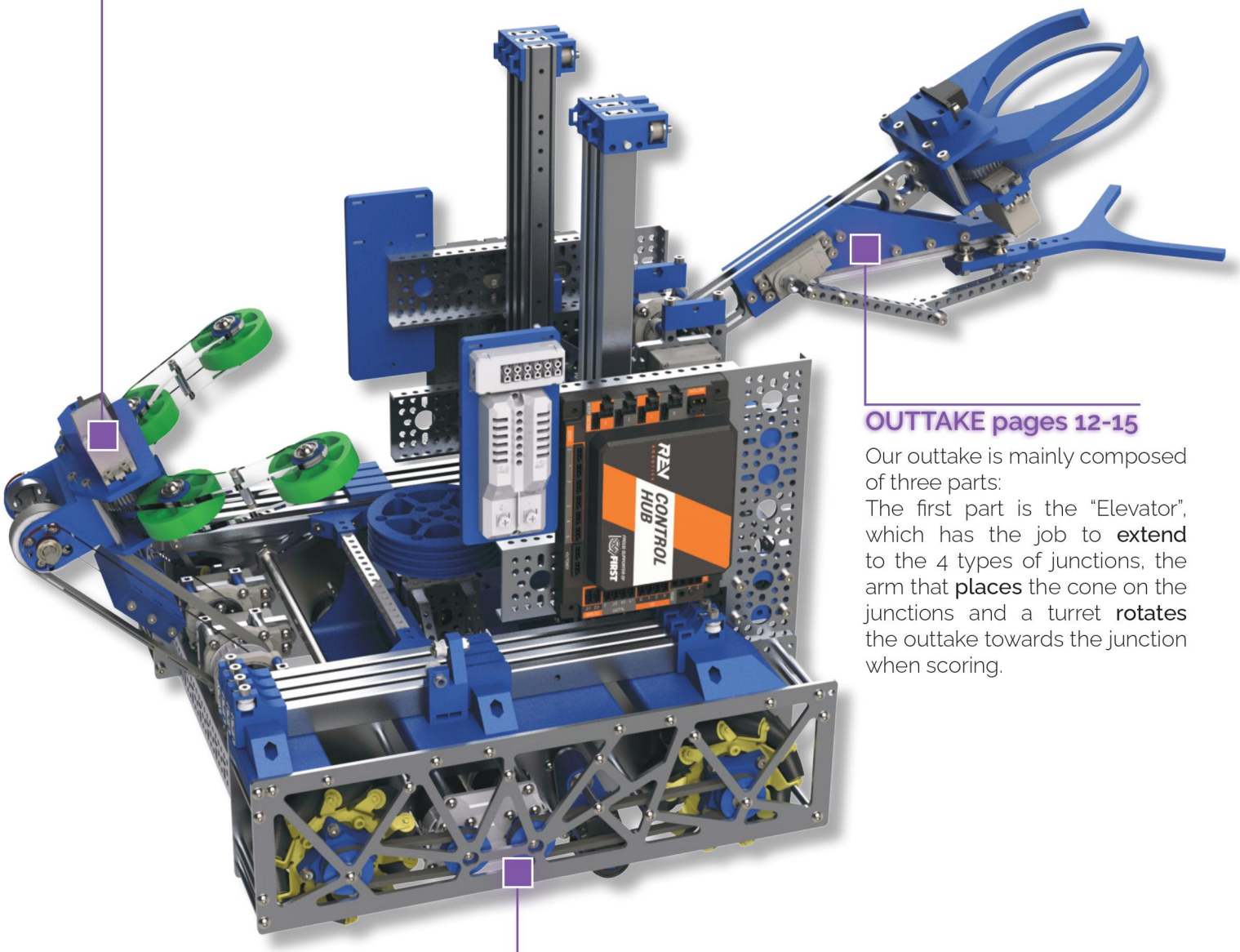
Learnings: Recognition helps teammates see that the community values them and their contributions to the success of their team overall.

Audience: +300 teachers, students, school directors, authorities, education specialists, Ministry of Education representants.

Quantum Robotics members during Gala Lumina

INTAKE pages 11,12

The intake is designed to collect the cones from a **long distance** to save time instead of moving with the drivetrain.



OUTTAKE pages 12-15

Our outtake is mainly composed of three parts:
The first part is the "Elevator", which has the job to **extend** to the 4 types of junctions, the arm that **places** the cone on the junctions and a turret **rotates** the outtake towards the junction when scoring.

DRIVETRAIN page 10

It is essential to have a good balance between speed, mobility, and durability. Within a robot, **synergy** is key to building a competitive mechanism. Therefore, the chassis is built **around the subsystems**. This year's chassis is a custom-made mecanum drive designed to be fast and efficient around the obstacles met on the field, having smaller width and shorter length. While cutting down on our robot's footprint, we reached a final dimension of **14inx14in**, that allows for optimal subsystem **performance**.

PROGRAMMING pages 15,16

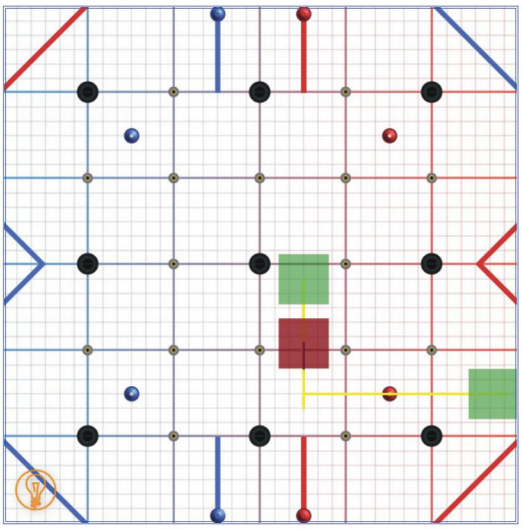
To program our Robot we use **Android Studio** and **Java.** The code is split into subsystems, each subsystem on the Robot having its class in the Java code. This makes it easy to program by simply setting the system's state (idle, in, or out for the intake, or the Elevator level), while the subsystem class handles the hardware commands. This makes the code **reusable and consistent** between TeleOp and Autonomous.

GAME STRATEGY

After closely inspecting this year's scoring tasks and updates to the ranking system, we concluded that the key part of winning a match is a high-scoring Autonomous Period, in order to gain a **high TBP1** score during qualifying matches, and maintaining good **ownership** across the junctions leading up to a circuit, as re-claiming a junction doesn't only gain points for our alliance, but also removes points from the opposing alliance, bringing us twice as close to a win.

AUTONOMOUS PERIOD

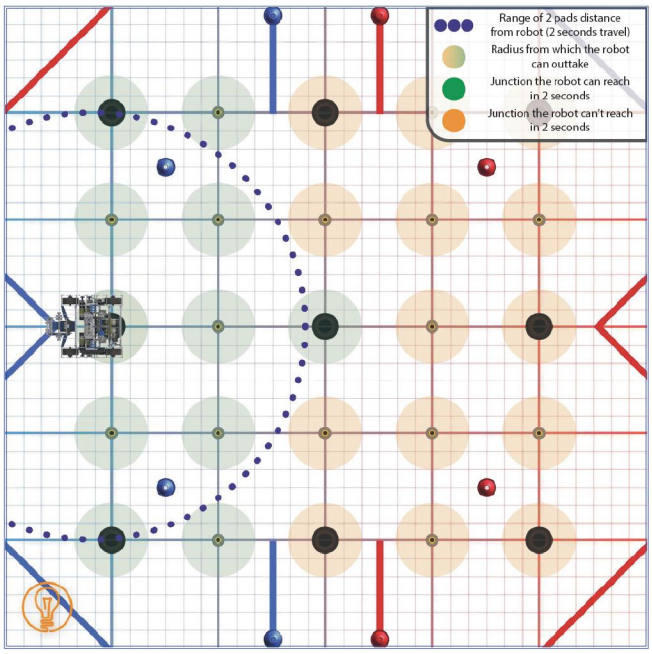
Scoring all the 10 Available cones available during autonomous on top of the 2 preload cones on the **high junctions**, would add up to **120 points** going into the Driver-Controlled period. In order to eliminate inconsistencies during autonomous, most of the movement of the robot is done by **sliders** while the drivetrain stays **still**. During all of our Autonomous paths, we navigate in front of the cone stack, and face our robot towards it. This path doesn't reach far enough into the field to cause **collisions** with opposing alliance robots, and maintains a very **safe** operating environment on the field. Then, using both our extension mechanisms alternatively, we can place cone after cone on the High junction, scoring all the 6 cones on our side of the field, earning us a total of **60 points** going into TeleOP.



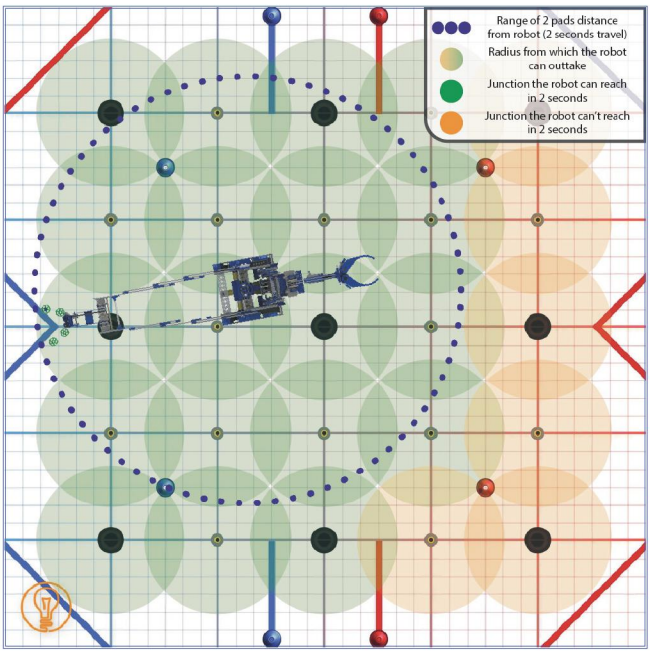
Autonomous path

TELEOP AUTOMATIZATIONS

During TeleOP, reaching any junction as fast as possible is crucial, and starting each path from the **substation** would provide an uneven path length to the junctions, and make scoring on the opposite side of the field a very **time-consuming** task. Our complex intake and outtake mechanisms enable us to get around this issue easily, as due to the length of our **extensions**, we can play around the middle of the field while collecting cones, in order to keep a much **shorter** distance to any junction that we need to score on across the field. After observing the gameplay of Powerplay for the first few months of the season, we realized that **continuously** scoring most of the cones on the **high junction** would end up **consuming** all cones available in a very short time, ending up in a very bad ownership on the junctions, and no way to **defend** from an opposing alliance circuit.



Reaching distance using 2 pads of movement - 1st robot iteration



Reaching distance using 2 pads of movement - 2nd robot iteration

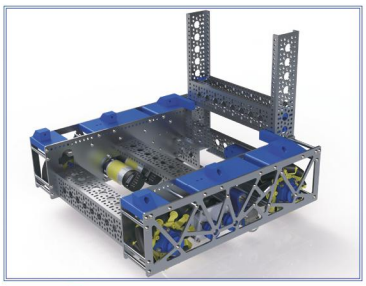
END GAME

For the EndGame period, we focus on placing our **Beacon** on a junction that will guarantee us a **circuit**, and we can easily park in one of our alliance's terminals by **extending** our mechanisms, earning the maximum score achievable during the EndGame period.

DRIVETRAIN

MECANUM BASED DRIVE

The mecanum based drive proves to be very efficient year after year. The main advantage of this drivetrain is the ability to **strafe**. The increased maneuverability can be a game-changer when speeding across the field to **quickly intake/ outtake** the cones and thus **increase** the total cycles.



Full chassis assembly

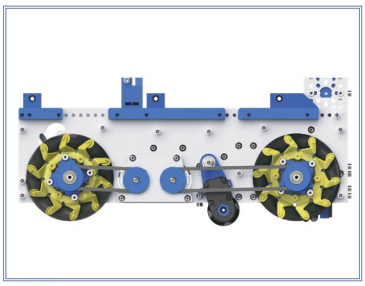
MOTORS AND TRANSMISSION

When choosing our motors, we settled on 13.7:1 ratio goBILDA motors that reach up to 435 RPM.

The **19.2:1 motor** is too slow for our needs and the **5.2:1 motor** is close to stalling, thus going through the battery pack too quickly, and is also uncontrollably fast.

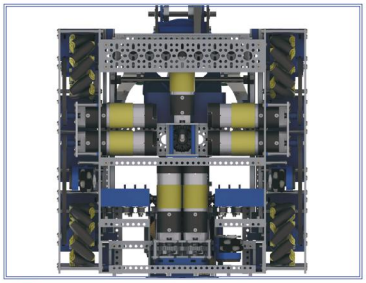
Motor Ratio	5.2:1	13.7:1	19.2:1
Time until battery drain	1min 30s	3min 20s	3min 40s
6 pad traverse speed	1.2s	2.9s	4.4s
Motor Length	108mm	118mm	118mm

Thus, the perfect motor to use on the drivetrain is the **13.7:1 motor**.



Sideview of belt transmission

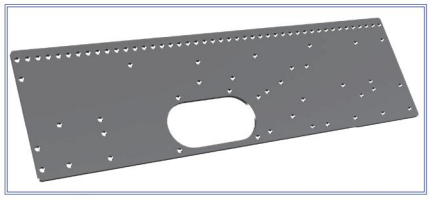
In order to help with keeping a low footprint, we used a **non-standard** width of **6mm** on our timing belts which were custom ordered from a belt manufacturer. These provide just enough stiffness to **prevent skipping**, and also **saves** us **space** between our chassis pods.



Motor placement - bottom view

CUSTOM PLATES VS COTS

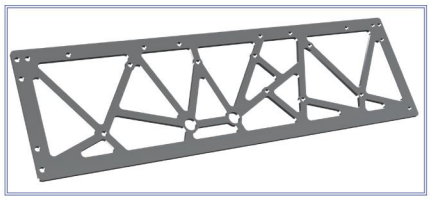
The subsystems are a priority throughout the robot's design process. The chassis is designed with the purpose of using the subsystems at full capacity. Rather than cutting down on the subsystems' capabilities, the **chassis enables them.** Our drivetrain motors are placed close to the exterior of our robot, to **preserve more space** in the middle of our robot, used for other subsystems, thus allowing us to keep all our **7 motors in line** with the wheelbase. This is important because 7 motors weigh **3.05 kg** (representing **21% of the robot's weight**), and this concentration of mass that is placed close to the ground aids in lowering the center of gravity of the robot. The ability to design our robot using custom aluminum plates, manufactured on our 3-Axis CNC cutter, allows us to provide rigid mounting for all our subsystems, no matter their location.



Custom inner chassis plate

POCKETING

In order to maintain a fast robot across the field, it's important to have a light build. In order to cut down on excess weight without damaging the **structural integrity** of the design, we cut out pockets or material on our exterior plates, worth a total of **320 grams.**



Custom pocketed outer plate

DEAD AXLE

As opposed to a traditional **live axle** system where the whole shaft rotates simultaneously with the system, a dead axle system relies on a **fixed axle**, onto which a rotating mechanism is attached. We focused our chassis on **reliability** and **performance**, thus it is very important for us to be able to easily service components in high pressure situations. Therefore, building the mecanum wheels on a dead axle system significantly **reduces space lost** (due to the absence of retaining rings, or collars), and also provides a more **modular structure**, by keeping the wheel, pulley and bearings always attached together during maintenance, for ease of access.

DRIVETRAIN

CUSTOM ODOMETRY PODS

Innovative solution

In order to maintain **accurate position tracking** during our autonomous period, we implemented 3 dead wheels on the bottom of our robot, connected to **3 REV Through-Bore encoders**. Unlike the motor encoders, these dead wheels are not transmitting any power and thus **will not slip**. This allows the robot to maintain **accurate tracking at high speeds**. In order to get better results, the two parallel wheels must be placed as **far away** from each other as possible. In order to achieve this, we had to fit the odometry pods between our drivetrain plates.

Custon odometry pod

1st design of odometry pod

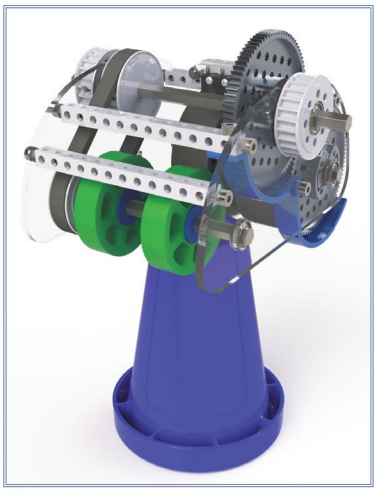
Due to the very compact design of our robot, we were pushed to come up with a new design that has **not been used before** when building this system, as we had very **little space** to work with inside of the drivetrain pods. We came up with an **innovative solution**, by designing a custom 3d-printed case for the encoder, to **replace the stock one**, for a much **smaller footprint**.

INTAKE

INITIAL DESIGN

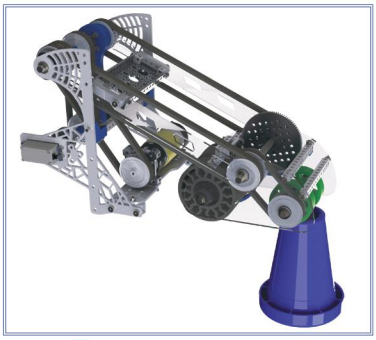
The initial intake system consisted of **4 compliant wheels** positioned on two parallel shafts spinning in opposite directions in order to raise the cone and lock it inside the system.

The intake is activated by a goBILDA **5:1 gear ratio motor** located on a 3D-printed plate between the outtake sliders. The intake is connected to the motor with two belts, one from the motor to the center of rotation of the V4B and another one from the center to the empty shaft on the top. On one side of the shaft there is a belt attached to one of the bottom shafts that contains the compliant wheels. On the opposite side of the top shaft there is a gear mated with the one located on the opposite compliant wheel shaft to make them spin in opposite directions and be connected together.



Initial Intake design while collecting

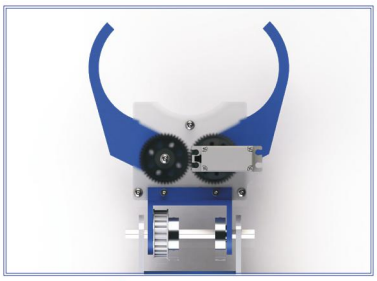
KEY FEATURES	DISADVANTAGES
• Fast and accurate collecting in teleop • Using only one system to collect and place the cones	• Heavy • Inaccurate collecting in autonomous • Can't collect cones really well if driving straight into them



Intake-V4B mounting

"HOW TO WIN" DEMO DESIGN (2nd)

As our strategy is to use the intake extension to cover as much of the field as possible, our intake went through a full redesign. In order to have a better collection of stacked cones, we designed a front-grabbing claw that sits on an arm powered by two goBILDA torque servos, which flips in order to transfer a cone into the outtake, using another goBILDA torque servo. This arm sits on **4 stages** of MISUMI SAR 230 sliders that extend horizontally **up to 1030mm** optimizing our paths during Autonomous, and playing a key role in our strategy during Teleop. The claw grabs the top part of the cone, and flips it around its own axis in order to transfer it to the outtake, which grabs the bottom side. Our claw is equipped with a **distance sensor** that allows us to **detect** when a cone enters our claw and **automatically grab it**.



First Intake claw

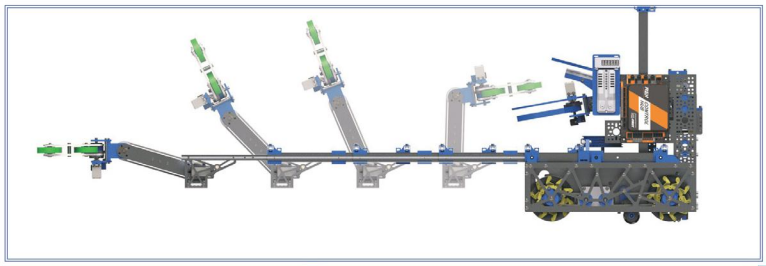
INTAKE

BUCHAREST REGIONAL DESIGN (FINAL)

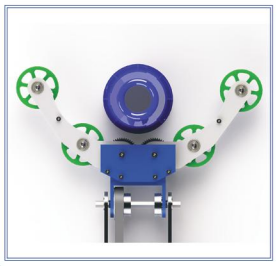
The previous simple plastic claw has been swapped for a new design involving four 2in **free spinning** compliant **wheels**, that regardless of its original position would **funnel** the cone between the wheels. In order to improve the consistency of our intake-outtake transfer, the **lower** part of the cone is now grabbed, and with the help of a much longer arm, is dropped inside the outtake claw, completing the transfer.

Innovative solution

Intake - final design



Intake Transfer

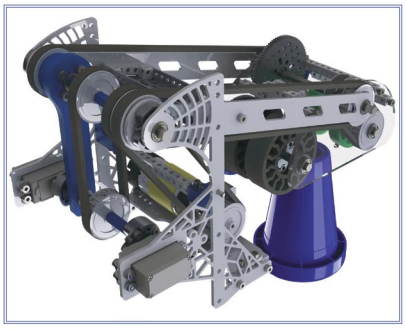


Cone pick-up: Intake top view

OUTTAKE

INITIAL DESIGN - V4B

For simplicity, instead of building a separate system for the transfer, our intake was mounted on a **Virtual 4 Bar** and acted like an outtake standing always **parallel** with the ground. We mounted the V4B on our Elevator with **2 custom made** plates at the perfect height for the intake to collect the cones and also to place them on all junctions. The V4B was powered by 2 goBILDA Torque Servos connected with a belt to the shaft at the center of rotation of the V4B.



Render of V4B

Scoring V4B

ELEVATOR

When we were searching for sliders for our robot we had a few criteria. We needed them to be very space-efficient so we could have a **slim** chassis and to also reach the **highest junction**, but they also needed to be **light** so we wouldn't put too much pressure on the motors. We decided to use **Misumi SAR 240** sliders, being both form factors allowing for great heights and also light-weight while keeping a low profile.

SAR 230 VS SAR 240 sliders

In order to reach the **highest junctions** we needed at least 33,5 inches (851mm) of elevator extension without occupying too much space with the stages. For these reasons we decided to use the longer version of Misumi sliders(SAR 240) instead of shorter ones(SAR 230).

- **Space saved with 3 stages instead of 4: 30mm narrower.**

	SAR 240	SAR 230
No. of stages needed	3	4
Maximum height	950mm ✓	1033mm (too much)
Thickness (on one side)	45mm	60mm

Belt VS String

When we built our elevator system, we had to choose between connecting our sliders with a **string** or with **belts**. In our experience with previously built robots where we used a string for our sliders, we discovered that it has many disadvantages compared to a belt-based system:

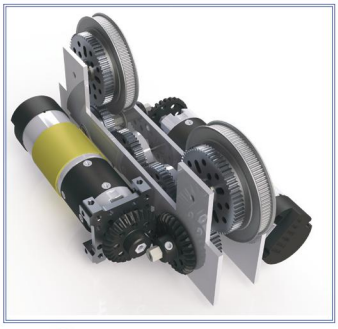
	Advantages	Disadvantages
String	• Takes up less space	• Snaps easier • If unspooled, very hard to place back • Overlapping string changes pulley radius
Belt	• More precise (it's on a loop) • A lot less prone to failure	• Gearbox takes up more space

Gearbox

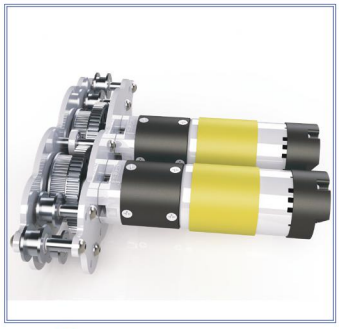
To power the elevator we decided to build a custom gearbox with the **2 DC motors**. The motors we chose are GoBILDA 5:1 ratio motors. This was done to maintain a **high elevator speed** while **counteracting the low torque** of this motor by using 2 of them.

Our gearbox was initially designed to fit in a narrower space, so we oriented the motors in the opposite direction of the pulleys, and with the help of some **bevel gears** we redirected the motion to the pulley driving the elevator.

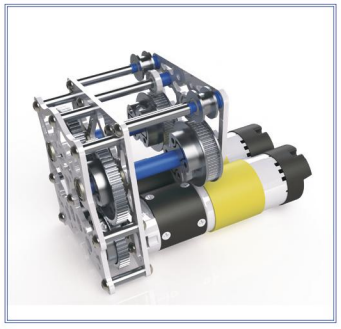
After some changes to the outtake we managed to save some space and allowed us to put the motors next to each other facing the front of the robot. With this change we connected the motors directly to the gearbox rather than with the bevel gears.



Initial Gearbox design

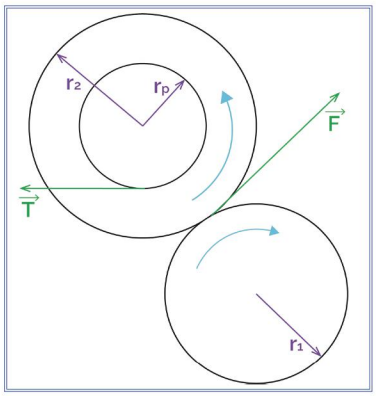


Gearbox design with motors facing front



HTW Demo & Bucharest Regional Gearbox design

In order to get as much power out of our motors, we decided to use a gearbox. This would enable us to run the motors at **peak power** output while delivering just enough **force** to be able to lift the outtake seamlessly. Before building the mechanism, however, we wanted to estimate the results different combinations of **gear ratios and motors** would yield us. We knew we wanted to use two motors to pull on the outtake so we will work on a system consisting of only one motor and we will assume it has to hold **half the weight** of the outtake.



Force diagram - Gearbox

Calculating the equilibrium of **torques** between the **output gear** and the **pulley** (T is the tension in the belt holding the outtake), we get the following:

$$Tr_p = Fr_2$$

The tension in the belt is simply half the weight of the outtake, so: $T = \frac{W}{2} = \frac{mg}{2}$

Since the force the **output gear** experiences is **the same** as the one generated by the **input gear** and the input gear is being **spun** by a motor with a torque of τ_M, it must follow that:

$$F = \frac{\tau_M}{r_1} \qquad \tau_M = \tau_{M,1} \cdot i_M$$

Here, the variable i_M is the **ratio** of the motor being used and $\tau_{M,1}$ is the **torque** of a 1:1 goBilda motor operating at **maximum** output power (around 2950 rpm). We will try different values of i_M in order to see which motors can **fit** our model and which cannot.

Rearranging our equations, we get a relation between the motor ratio (i_M), the gear ratio (which we will call i_G) and other parameters which can be determined from measurements on the robot:

$$i_G \cdot i_M = \frac{mgr_p}{2\tau_{M,1}}$$

Our **desired** $i_G \cdot i_M$ will be: $$i_G \cdot i_M = \frac{1.1\ \text{kg} \cdot 9.8\ \text{m/s}^2 \cdot 0.189\ \text{m}}{2 \cdot 0.095\ \text{Nm}} = 10.7$$

r2/r1		r1				
		19.20	24.00	32.00	36.00	38.40
r2	19.20	1.00	0.80	0.60	0.53	0.50
	24.00	1.25	1.00	0.75	0.67	0.63
	32.00	1.67	1.33	1.00	0.89	0.83
	36.00	1.88	1.50	1.13	1.00	0.94
	38.40	2.00	1.60	1.20	1.07	1.00

GoBilda gear ratios

im*ig		ig									
		1.00	1.07	1.13	1.20	1.25	1.33	1.50	1.60	1.88	2.00
im	1.00	1.00	1.07	1.13	1.20	1.25	1.33	1.50	1.60	1.88	2.00
	3.70	3.70	3.95	4.16	4.44	4.63	4.93	5.55	5.92	6.94	7.40
	5.20	5.20	5.55	5.85	6.24	6.50	6.93	7.80	8.32	9.75	10.40
	13.70	13.70	14.61	15.41	16.44	17.13	18.27	20.55	21.92	25.69	27.40
	19.20	19.20	20.48	21.60	23.04	24.00	25.60	28.80	30.72	36.00	38.40

Combined gear ratios of GoBilda Motors and 2 gears

OUTTAKE

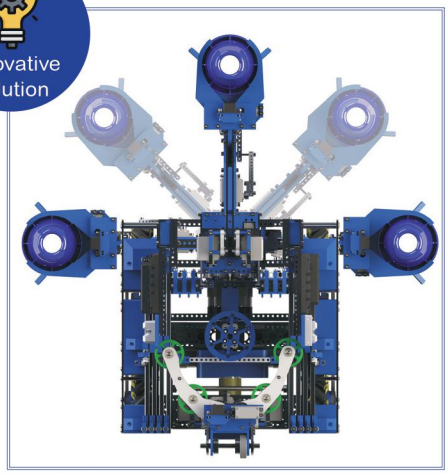
Possible i_G gear ratios are tabulated for the available goBilda hub mount gears. In the interest of keeping the overall dimensions of the gearbox **compact**, the gears considered are on the smaller end of the range. Therefore, the maximum **reduction** is of factor 2. These reductions are multiplied by the available goBilda DC motor gear ratios. This new table is now used to select the final combination of **gear reduction** and **motor gearbox**. The 3rd and 4th rows of the table contain **viable values**. To keep the outtake **speed** as high as possible, the 5.2 motors are preferred, used together with higher ratio gears. However, because space is limited we chose to use smaller gears to keep the gearbox compact, at the cost of lower efficiency.

CONCLUSION

These being considered, the combination of a **5.2 ratio** goBilda motor and **1.33 gear** reduction was chosen after some testing, resulting in a **compact transmission**, which can easily be fitted into the robot, while also being fast enough to not bottleneck our other systems.

KEY FEATURES	DISADVANTAGES
• Using only one system to collect and place the cones	• Restricted movement on only 1 axis • Slower to adjust above junctions

Innovative solution



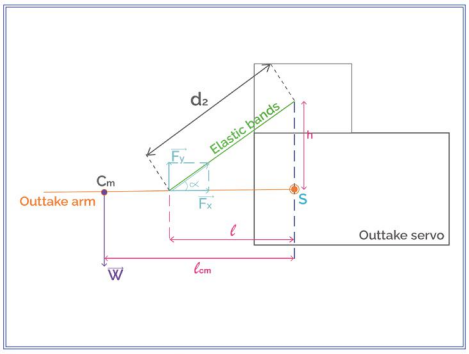
Turret - 180 degrees of rotation

"HOW TO WIN" DEMO DESIGN (2nd)

To be able to be more **flexible on the field**, we changed the design of the outtake and mounted it on a **turret**. To maximize the efficiency of the robot rather than rotating the drivetrain, the **turret can rotate 180°** to face directly to the junctions. The turret is powered by two GoBILDA torque Servos that are connected to the turret with 2:3 ratio gears, resulting in a total of **180° of rotation.**

To accommodate the turret we made an outtake arm with a claw in the end. After the transfer is released from the intake claw to the outtake, the arm **rotates 180°** to the scoring position, then places the cones on the junctions. The claw of the outtake is powered by a GoBILDA torque servo, while **two 25 kg DsServos** are powering the Outtake arm.

Because the Outtake arm is pretty **heavy** and we didn't want to apply too much force on the servos when they sustain the scoring position, as well as wanting to **avoid** overshooting during the rotational motion, we came up with the idea of using elastic bands to **counterbalance** the arm's weight. Before using the elastic bands, to make sure they work properly and to know exactly how many elastics to use, we calculated the equilibrium of the loads acting on the arm.



Force diagram - Outtake arm in scorig position

Because the arm has a circular motion, to calculate the influence of forces we need to calculate their **torques**. The sum of the torques has to be equal to **0**, considering that the arm must be held stationary. This means the two torques can cancel out each other: $\sum \vec{\tau} = \vec{0} \Rightarrow W l_{cm} = F_y l$

We can find Fy in terms of the total force exerted by the elastic bands, F, and calculate it using the formula for the elastic force. Here, n will be the number of elastic bands used and Fe will be the force of one elastic band.

$$\left.\begin{aligned} F_y &= F \sin\alpha \\ F &= nF_e = nk\Delta d \end{aligned}\right\} \Rightarrow F_y = nk\Delta d \sin\alpha$$

We can also find the **weight** of the outtake arm from its measured mass , as determined by Solidworks. $W = mg$

Substituting our formulas in the torque equation, we can isolate n and **calculate** it.

$$mgl_{cm} = nk\Delta dl \sin\alpha \quad \Rightarrow n = \frac{mgl_{cm}}{k\Delta dl \sin\alpha}$$

Most values can be obtained from **measurements** done on the robot, however, to find the elasticity constant of the elastic bands we had to conduct an **experiment**. Hanging a **1 kg** weight from one elastic band we got an average deformation of **26 cm** (over the course of 10 experiments). As a result, the following elasticity constant of an elastic band was estimated:

$$k = \frac{9.8\ \mathrm{N}}{0.26\ \mathrm{m}} = 37.7\ \mathrm{kg/s^2}$$

Plugging all the values in the formula, we got the following desired number of **elastic bands**:

$$n = \frac{9.8\ \mathrm{m/s^2} \cdot 0.423\ \mathrm{kg} \cdot 0.18\ \mathrm{m}}{0.27 \cdot 37.7\ \mathrm{kg/s^2} \cdot 0.037\ \mathrm{m} \cdot 0.12\ \mathrm{m}} = 16.5$$

OUTTAKE

Testing the recommended number of **16** elastic bands, we found that indeed, they would be able to **support** the entire weight of the outtake arm, Moreover, the discrepancies between the expected value and practice can come from the static friction in the servos driving the arm, as well as the non-linear behavior of the rubber bands.

CONCLUSION

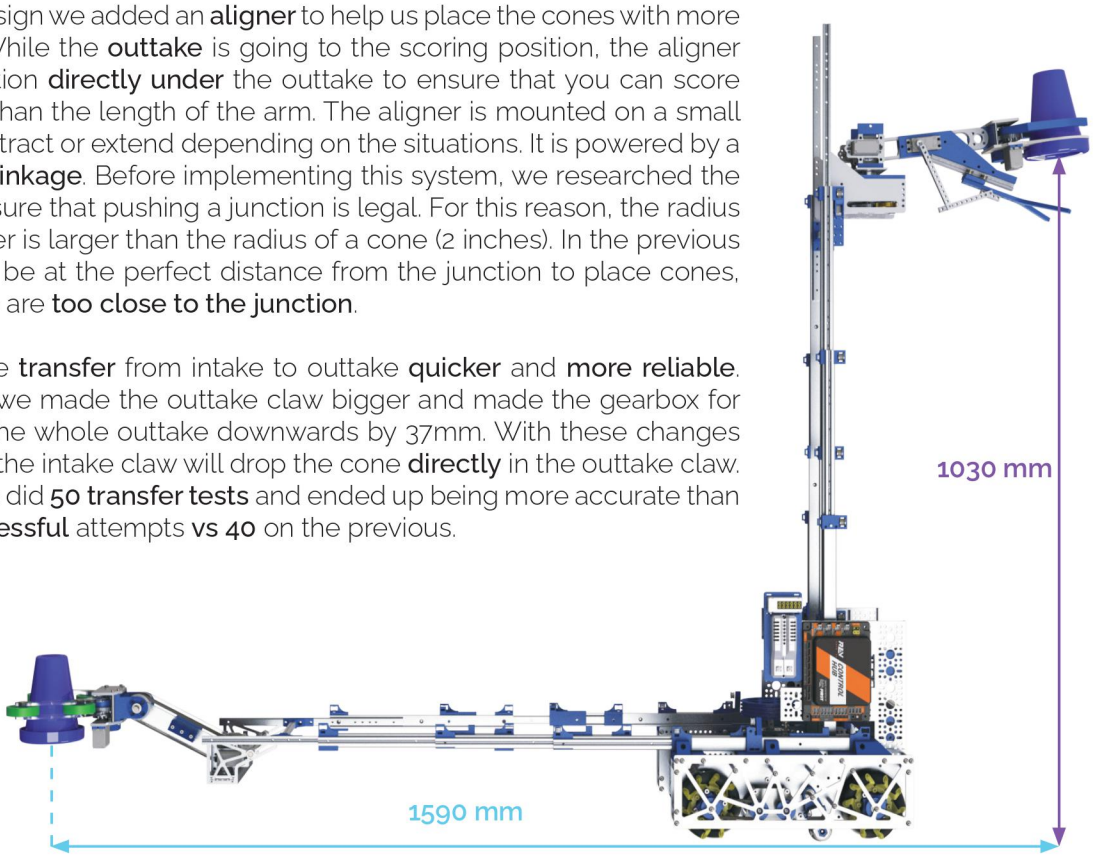
Thus, we ended up not using that many elastic bands on our final design as **10** are able to give **enough support** to the outtake servo while also allowing it to rotate more **freely** without straining it in the opposite direction.

BUCHAREST REGIONAL DESIGN (FINAL)

In addition to our previous design we added an **aligner** to help us place the cones with more accuracy on the junctions. While the **outtake** is going to the scoring position, the aligner extends to position the junction **directly under** the outtake to ensure that you can score from **closer to the terminal** than the length of the arm. The aligner is mounted on a small 11cm slider that allows it to retract or extend depending on the situations. It is powered by a GoBILDA torque servo via a **linkage**. Before implementing this system, we researched the **Q&A forum** deeply to make sure that pushing a junction is legal. For this reason, the radius of the inside filet of the aligner is larger than the radius of a cone (2 inches). In the previous design, the robot needed to be at the perfect distance from the junction to place cones, now we **can score** even if we are **too close to the junction**.

We also wanted to make the **transfer** from intake to outtake **quicker** and **more reliable**. After testing the first design we made the outtake claw bigger and made the gearbox for the turret slimmer to move the whole outtake downwards by 37mm. With these changes when transferring the cones the intake claw will drop the cone **directly** in the outtake claw. After changing the design we did **50 transfer tests** and ended up being more accurate than the previous design, **47 successful** attempts **vs 40** on the previous.

Y shaped aligner



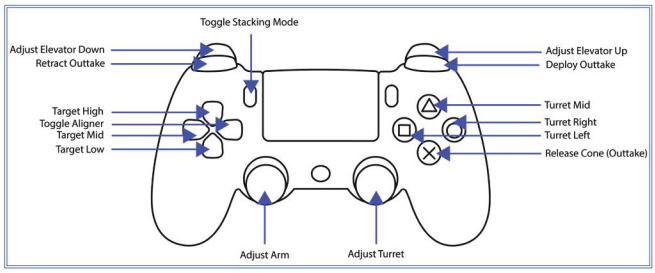
Maximum extension of robot

PROGRAMMING

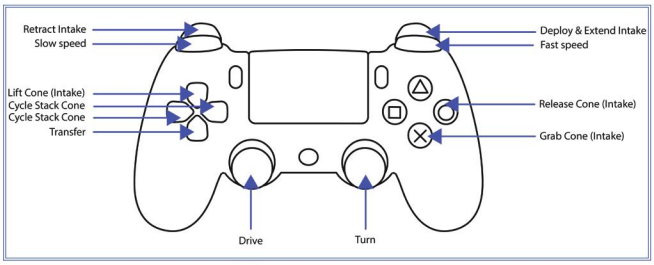
AUTONOMOUS AND TELEOP

For the **Autonomous** Period, we use **AprilTag** to detect the indicated zone on the Signal Cone by reading the tag on our custom made sleeve. This then picks one of the **predefined trajectories** generated using **Road Runner** and follows them using **2 PIDF** controllers (translation and heading).

On our Robot we have **3 Odometry Pods**, using REV Through Bore Encoders. They measure the rotation of the Rotacaster 35mm Omni Wheels, thus **counting** the **movement** of the Robot on the Field. This method of determining the Robot position, unlike the motor encoders, **does not lose precision** in the event of a **collision** with the Wall or another Robot and can be used to **correct** the Robot's **position** in real time.



Driver 2 controls



Driver 1 controls

PROGRAMMING

For **TeleOp**, **driver 1** controls the **robot movement** on the field and the **intake**, while **driver 2** controls the **Elevator**, the **Outtake arm** and the **Outtake turret**.

TELEOP OPTIMIZATIONS

To make driving the robot as easy as possible, we implemented a couple of **optimizations**. First, the **Elevators** automatically go to the **required height**. This is achieved by having **4 tiers of power** given to the motors based on the remaining **distance** to the **target height**. It is similar to a P controller, while being faster to tune. Combined with the Outtake arm and turret, a **single button press** will **extend** the elevator to either Low, Mid, High or Ground Junction, then **flips** the Outtake arm to the scoring position and **rotates** the turret to one of three positions that are selected before by the driver. Then the second driver can manually **adjust** the turret for **off angles**. After placing the cone, a single button will **retract all the systems** too.

Another optimization is two **REV Color v3 Sensors** placed on both the **Intake** and the **Outtake**. Using them, the Robot will know whether there is a **cone collected** or not. Furthermore, when a cone is detected by the sensor the claw will **close automatically**. And when a cone is in the transfer positions and it's detected by the outtake sensor the claw will close automatically and **announce** the second driver by **vibrating** the controller.

While collecting from the **5 cone stack**, the first driver can manually **select** from which **level** to collect. After successfully collecting the cone and transferring it to the outtake the stack level **changes automatically** to the next one.

AUTONOMOUS OPTIMIZATIONS

As no **PID algorithm** can be perfect, we use our **unique turret** design to ensure **perfect** cone scoring in autonomous period. Using odometry wheels, we know the robot's position and heading.

We can find the **slope** of line RJ, from which we can find the **angle** between line RJ and Ox.

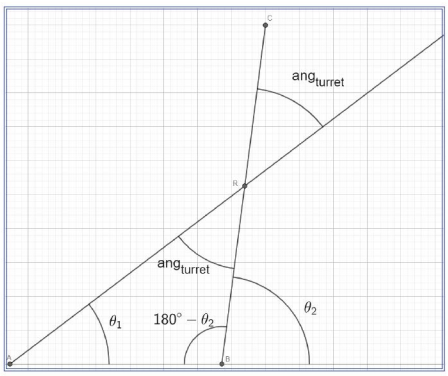
$$slope_{RJ} = \frac{\Delta y}{\Delta x} \qquad \theta_1 = arctan(slope_{RJ})$$

The angle between line RT and Ox can be easily found from the robot's **heading** H.

$$\theta_2 = H - 270°$$

For the **turret angle** we know that:

$$ang_{turret} + \theta_1 + 180° - \theta_2 = 180° \quad \Rightarrow ang_{turret} = H - 270° - \theta_1$$



Graphical representation

The distance from the robot's center to the turret pivot point is constant, so the pivot point is known. The distance d between the target junction and the turret pivot point is: $d = \sqrt{\Delta x + \Delta y}$

We know the arm length L. The height of the turret is controlled by the sliders, so we can consider the turret **pivot point** and **junction coplanar.** We want to **aim** the arm so that the cone falls directly **on top** of the junction. Therefore, the **arm angle** is:

$$armAngle = arccos(\frac{d}{L})$$

We empirically found sample servo **positions**, based on which we constructed a simple **formula**, given that both the angle and servo position **parameters** are linear.

ELECTRICAL

We are using a **Control Hub** rather than a phone to avoid any connection issues, and since we have 7 motors, we also need an **Expansion Hub**. They are placed on opposite sides of the Robot, with all the cables being routed around the Robot's sides as opposed to underneath the Robot in order to be **protected when crossing over the ground junctions**. We also have two **Servo Power Modules** which provide more power (**6v** instead of 5v and more current) for all 10 servos, so that they can have a bit **more torque**. In order to **avoid** possible issues with **electrostatic discharge** caused by the friction of the wheels or Robot chassis with the Tiles or Field Walls, we are using the **REV Grounding Strap**, which minimizes the charge difference between the electronics and the robot metal frame.