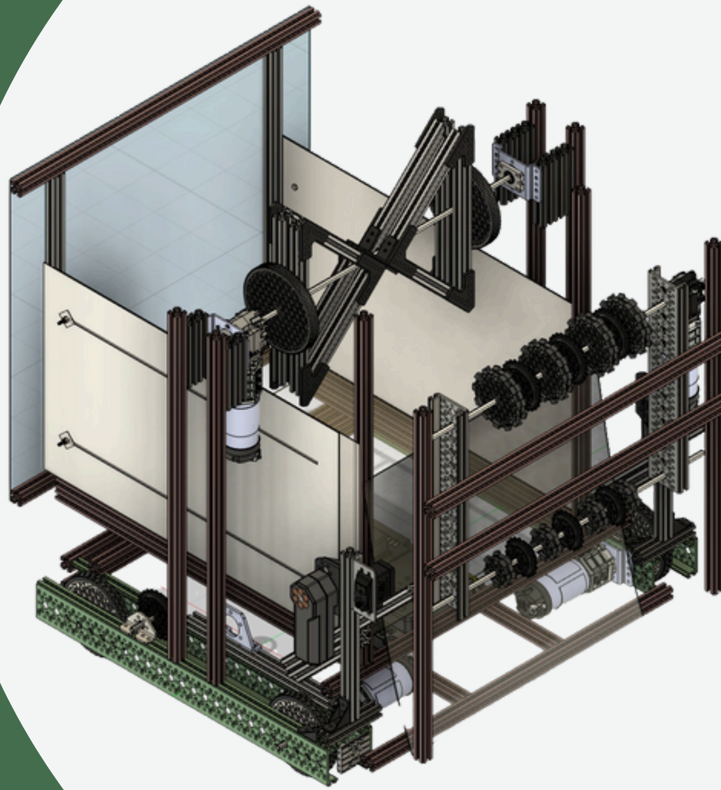
FIRST GLOBAL

TEAM GEORGIA ENGINEERING NOTEBOOK



2025

FIRST GLOBAL CHALLENGE 2025
PANAMÁ CITY

TEAM SUMMARY

Welcome to Team Georgia's *FIRST* Global 2025 journey! We are a passionate group of five students: Alexandre, Nikoloz, Mariam, Luka, and Saba, aged 14 to 17, united by our shared love of STEAM: science, technology, engineering, arts, and math. Hailing from Tbilisi, our team blends diverse backgrounds, from Alexandre's early propeller-powered "Karlson" costume engineering to Nikoloz's competitive programming roots, Mariam's creative pivot from coding to Arduino and art, and Luka and Saba's strong environmental drive inspiring sustainable robotics. Under the expert guidance of mentors Nikoloz Lobzhanidze and Guranda Gogaladze, who bring national-level coaching experience, AI and robotics curriculum development, and a deep commitment to social innovation, Team Georgia is ready to take on FIRST Global's 2025 "Eco Equilibrium" Challenge. Together, we're excited to build, innovate, and collaborate on the world stage—protecting our planet one robot at a time.

I'm Alexandre, a 16-year-old student at Ilia Vekua Physics and Math School in Tbilisi. My STEAM journey began when I built a working Karlson costume with a real propeller! Since then, I've been deeply involved in robotics, taking part in local and international competitions. A highlight was joining the 2024 FIRST Global Challenge as a guest team member. I believe STEAM is a universal language that unites young people to solve global challenges, and I'm excited to keep learning and innovating.

Hi, I'm Saba, 16, from the European School in Tbilisi. I love every part of robotics: designing, building, testing, and problem-solving. My school gave me the tools to turn that interest into action. I also care about the environment, which is why I'm excited for this year's FIRST Global Challenge. Being part of Team Georgia is an honor, and I look forward to working with diverse teams for a shared global cause.

Hi, I'm Nikoloz, 15, from the G. Zaldastanishvili American Academy in Tbilisi. My interest in STEM started with competitive programming at Mziuri School, and I've since won math and coding contests nationally and internationally. Programming led me to robotics, and I'm eager to contribute to Team Georgia's unique robot for the 2025 FIRST Global Challenge, especially with its focus on biodiversity and innovation.

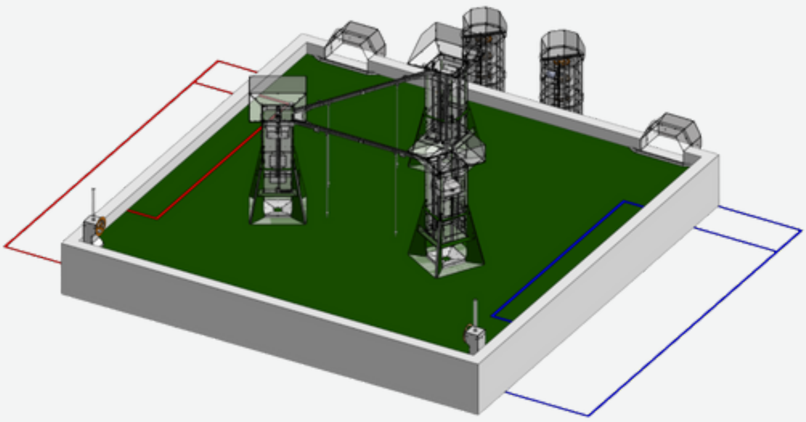
I'm Mariam, 15, from Konstantine Amirajibi's Avlev Public School. I got into robotics during the COVID lockdown through Scratch and Technovation Girls. That sparked a passion for Arduino, which I now study online. Although I'm still gaining experience, I'm excited to grow and learn with my amazing team. I also love digital and traditional art, and sometimes illustrate my book club reads just for fun!

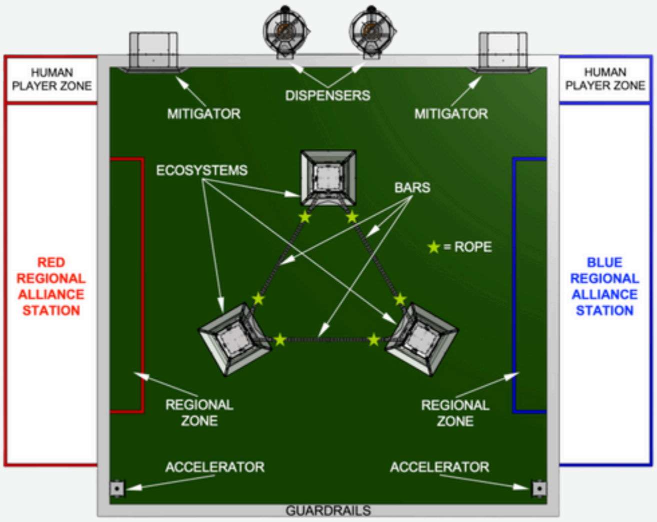
Hey, I'm Luka, 14, from the European School in Tbilisi. I've always been curious about how robotics can solve real-world problems. My current school gave me the chance to dive into robotics seriously. I also care deeply about ecology, which makes this year's FIRST Global Challenge, focused on biodiversity, especially meaningful. I'm excited to collaborate with diverse teams from around the world and build something purposeful together.

CODING TEAM RESEARCH & DEVELOPMENT SOCIAL MEDIA

Assigned to Engineering Team	
Chassis	Balancing strength, weight, durability, and ease of maintenance within size constraints.
Intake	Designing a compact and effective intake that fits within size limits while ensuring reliable units collection and smooth deployment.
Basket	Maximizing ball capacity while ensuring smooth, reliable extension and secure locking of sliding walls.
Shooter	Shooting the Biodiversity balls with accuracy – maintaining stable power and precision despite of high speed of the shooter.

Assigned to Coding Team	
Code of each functionality of the robot	Write code that is simple and can be understood cooperatively by all team members, yet matches the requirements of the robot – feasible to make it functional.
IMU installization	To make the shooter more accurate, initializing the IMU, which allows us to find the yaw of the robot, is essential to align it with the Ecosystems.
AprilTag identificication	Similarly to the IMU, it allows us to find the distance and angle that we are facing the Ecosystem – helping the robot shooter to be more accurate.





The Game:
In Eco Equilibrium, six national teams unite as one GLOBAL ALLIANCE to restore the planet's ecosystems. ROBOTS must remove BARRIERS, collect and distribute BIODIVERSITY UNITS, and energize ACCELERATORS to increase the rate at which biodiversity is released onto the PLAYING FIELD. In the final 30 seconds, known as the END GAME, the teams divide into two REGIONAL ALLIANCES of three teams each to climb ROPES and earn PROTECTION POINTS for the future of biodiversity.

Each MATCH lasts 2 minutes and 30 seconds. The first two minutes form the GLOBAL ALLIANCE PHASE, during which all six ROBOTS collaborate to remove BARRIERS and deposit them into the MITIGATORS. ROBOTS then collect BIODIVERSITY UNITS, multi-color size 1 soccer balls, from the DISPENSERS, which begin at a default release rate of one UNIT every five seconds. ROBOTS may rotate the ACCELERATORS at or above 250 RPM to increase that rate to one UNIT every three seconds (medium) or every one second (high). These actions represent the technological effort required to accelerate biodiversity recovery through cooperation and innovation.

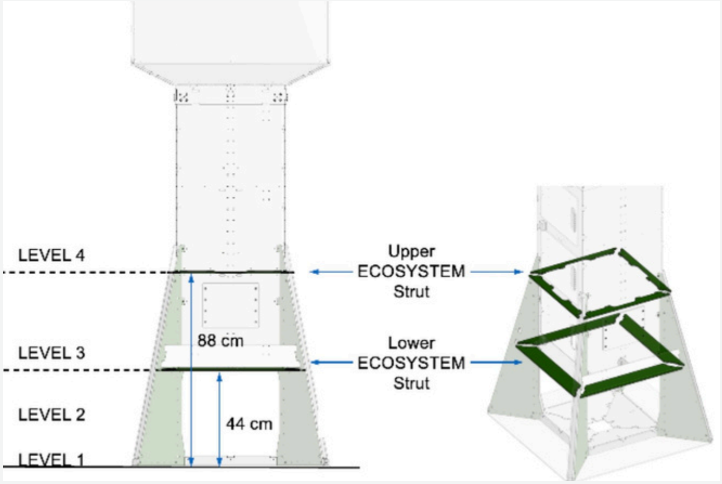
HUMAN PLAYERS, positioned in the REGIONAL ZONES, can collect BIODIVERSITY UNITS from the PLAYING FIELD and either load them into their ROBOT or throw them directly into the ECOSYSTEMS. There is no autonomous period; instead, ROBOTS may use AprilTags placed on the ECOSYSTEMS for vision-assisted navigation and precise scoring. All ROBOTS are driver-controlled throughout the MATCH.

The GLOBAL ALLIANCE earns points for each BARRIER placed into a MITIGATOR (1 point) and each BIODIVERSITY UNIT remaining in any ECOSYSTEM at the end of the MATCH (1 point). Balanced restoration across all three ECOSYSTEMS is encouraged through the DISTRIBUTION FACTOR, calculated from the standard deviation (σ) of BIODIVERSITY UNITS in the freshwater, marine, and terrestrial ECOSYSTEMS. Even distribution ($\sigma \leq 1$) applies a 1.0 multiplier; moderate distribution ($1 < \sigma < 10$) 0.6; uneven distribution ($\sigma \geq 10$) 0.5.

End Game:
During the last 30 seconds, six ROPES drop from the BARS above the ECOSYSTEMS. The two REGIONAL ALLIANCES attempt to SECURE PROTECTION by climbing to various levels, each providing an incremental PROTECTION MULTIPLIER:

Level	Description	Increment per ROBOT
1	ROBOT in contact with ROPE and floor	+0.125
2	ROBOT fully supported by ROPE, not touching floor	+0.250
3	ROBOT above 44 cm (lower strut)	+0.375
4	ROBOT above 88 cm (upper strut)	+0.500

The total PROTECTION MULTIPLIER multiplies the ALLIANCE's BIODIVERSITY and BARRIER points. If five or more ROBOTS are fully supported by ROPES, all six teams receive a COOPERTITION® BONUS: 15 points for five climbs or 30 points for six.



ROBOT SPECIFICATION

Robot Dimensions & Build

- Start Size: 50 × 50 × 50 cm (compliant with match start constraints)
- Expanded Size: ~90 cm length with deployed basket
- Weight: Approx. 17 kg
- Materials: Aluminum frame (C-channel and sheet), plastic sliders, polycarbonate walls, steel chains, round belt

Drivetrain

- Type: 4-wheel tank drive (skid steer)
- Motors: 2× REV HD Hex motors (20:1 planetary gearbox)
- Wheel Type: 90mm traction wheels
- Transmission: Chain-driven with tensioning sprockets
- Top Speed: ~1.4 m/s
- Torque: Sufficient to push 1-2 barriers simultaneously

Subsystems

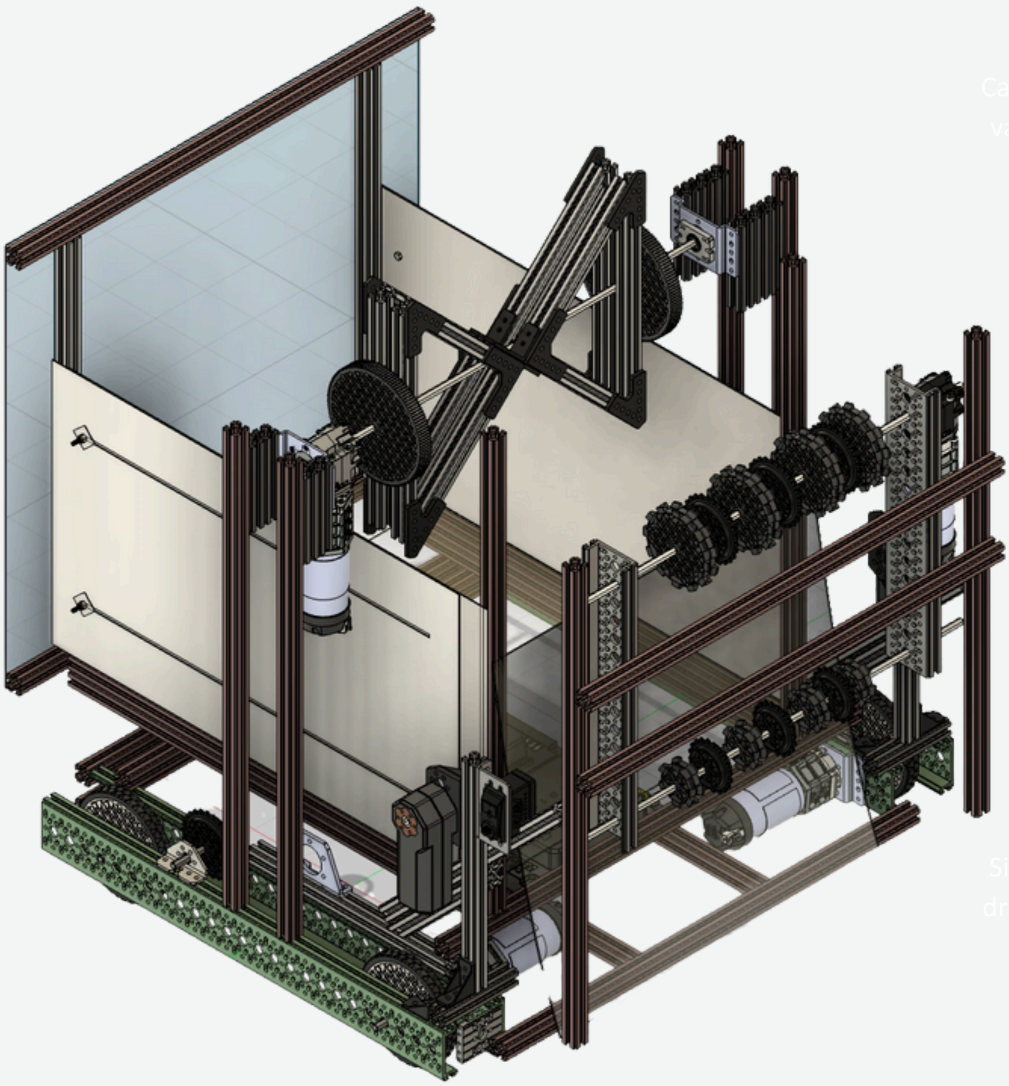
- Intake: Roller intake with round belts
- Shooter: Dual-wheel vertical flywheel with servo-actuated capstan hood
- Basket: Sliding wall system with rack-and-pinion expansion
- Climber: X-frame rope lift with auto-locking guide system
- Sensors: IMU, Color Sensor, Magnetic Limit Switches, Potentiometer

Control & Vision

- Main Controller: REV Control Hub + Expansion Hub
- Programming Language: Java (on Android Studio)
- Vision: TensorFlow (object detection), AprilTag (targeting)
- Training Platform: Synthesis simulator + real driver drills

Anti-jam logic with voltage & encoder feedback (intake)

Capstan aiming for variable shooting angles

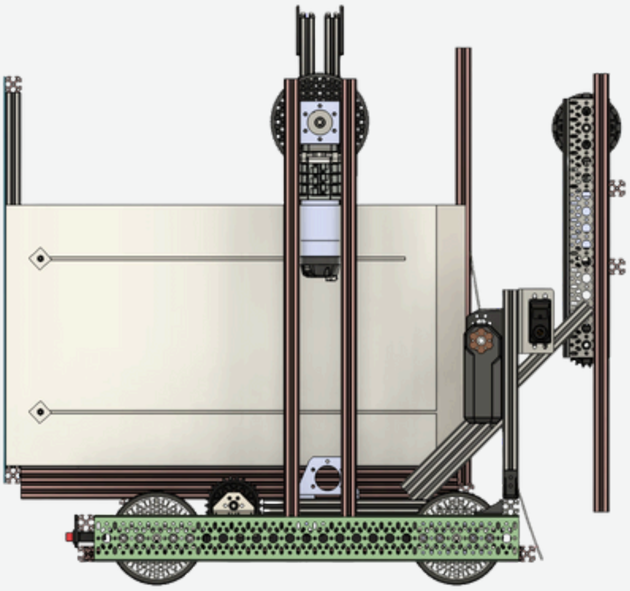


Modular component layout for quick pit repairs

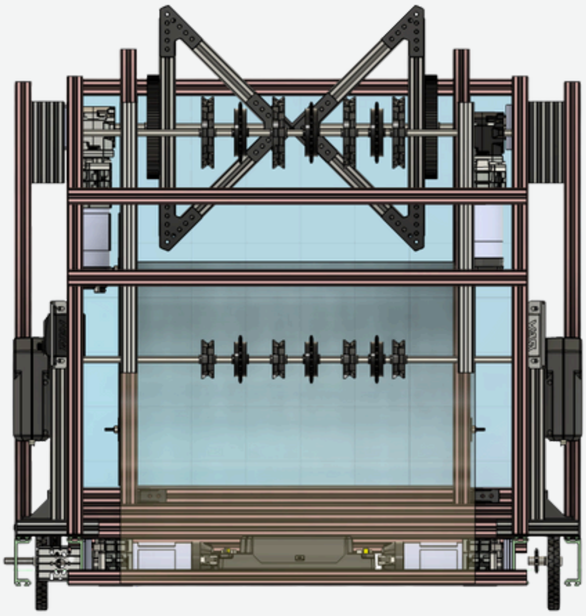
Simulation-based driver training and AI-assisted automation

ROBOT SPECIFICATION

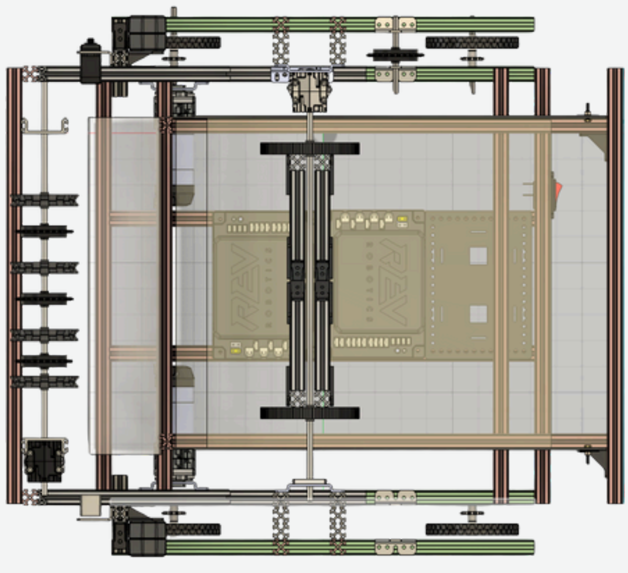
LEFT SIDE



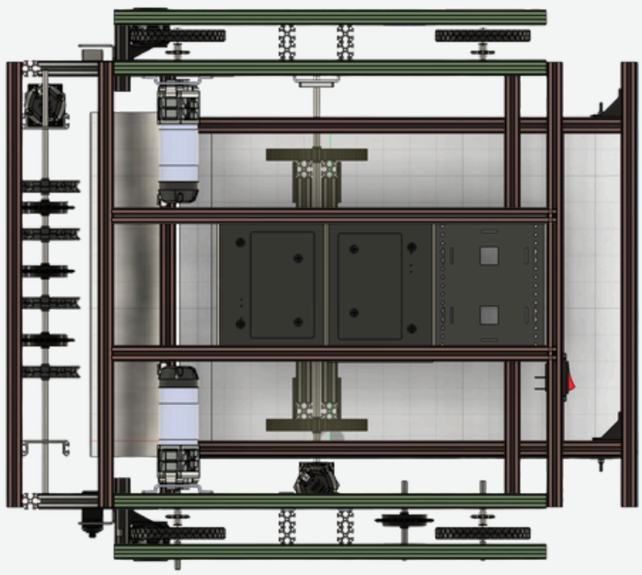
FRONT



TOP



BOTTOM



CHASSIS

OVERVIEW

The drivetrain serves as the foundation of our robot, directly affecting every aspect of performance. For Eco Equilibrium, the field contains numerous barriers and other robots, so our chassis had to balance traction, torque, and reliability while conserving motors for other mechanisms.

DRIVETRAIN TYPES

TANK DRIVETRAIN

Uses traction wheels that move forward and backward, turning by running each side at different speeds or directions. It prioritizes traction, torque, and obstacle handling over agility. Simple yet powerful, this system performs reliably on any surface and remains a proven solution for competition-level robots.

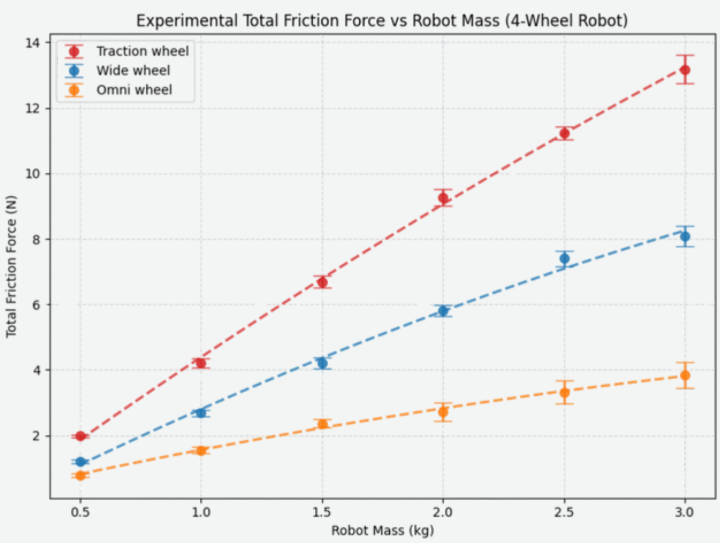
HOLONOMIC DRIVE

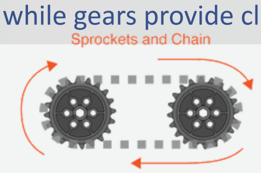
Employs mecanum or omni wheels with angled rollers, enabling movement in any direction. While it offers excellent maneuverability, it sacrifices traction and pushing force, requiring more motors and tuning precision. It's ideal for high-mobility challenges but not optimal for limited-motor setups.

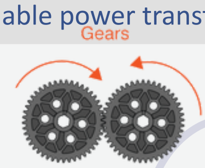
DRIVETRAIN SELECTION

When designing a drivetrain, it is important to define key performance goals that ensure consistent operation and reliability during matches. Our design priorities are as follows:

1. **Reliability:** The drivetrain is the foundation of the robot, and reliability determines success. Planetary gearboxes were selected over spur types for their higher load capacity and durability under impact, especially for heavier designs.
2. **Agility:** Agility depends on top speed, acceleration, turning radius, and control response. Turning radius, often underestimated, plays a major role in achieving precise maneuverability in tight spaces.
3. **Motor Count and Gear Ratio:** Although a two-motor drivetrain is possible, four motors offer improved control. Gear ratios between 9:1 and 20:1 suit 90 mm wheels, with 19.2:1 providing the best balance between torque and speed. Ratios above 40:1 reduce efficiency and are not suitable for FGC fields.
4. **Traction and Pushing Power:** Pushing force measures a drivetrain's ability to maintain motion and overcome obstacles. Wheel type, size, gear ratio, and total robot weight all influence traction. The goal is stable grip without sacrificing maneuverability.
5. **Power Transmission:** Common transmission methods include direct drive, chain, gear, and belt. Direct drive was avoided due to gearbox stress under shock loads. Chain and gear systems were preferred for strength and simplicity; chains require proper CAD-based tensioning, while gears provide clean and reliable power transfer.







Challenge Lead: Aleksandre Tediashvili
Challenge: Balancing strength, weight, durability, and ease of maintenance within size constraints.

OUR IMPLEMENTATION

The drivetrain forms the mechanical foundation of our Eco Equilibrium robot. The field's dense barriers and limited space required strong traction, minimal slippage, and efficient motor allocation. We selected a 2-motor, 4-wheel tank drive with chain transmission, emphasizing robustness, simplicity, and easy maintenance, while preserving motors for scoring mechanisms like the shooter, intake, and climber.

Alternatives Considered

Drive Type	Pros	Cons	Notes for 2025 Game
2-Motor Tank (Chosen)	Simple, durable, high pushing power, uses only two motors	Less agile, requires chain tensioning	Ideal for fast maintenance and reliability
4-Motor Tank / 6-Wheel Drop	Smooth turning, strong traction	Heavier, motor-intensive	Upgrade option if motors are available
Mecanum / Omni	Excellent alignment and strafing	Low traction, complex control	Not needed—traction prioritized
X-Drive / Holonomic	Full holonomic control	Low pushing power, resource-intensive	Too complex for this year's objectives
H-Drive	Adds lateral movement	Extra motor, complex design	Unnecessary for this game's tasks

Why We Chose 2-Motor Tank with Chain?

- **Motor Allocation:** Two motors reserved for drive, freeing others for intake, shooter, and climber.
- **Reliability:** Chain-driven system minimizes wheel slippage during barrier interaction.
- **Maintenance:** Chain and sprocket design allows fast replacement and adjustment in the pit.
- **Control Simplicity:** Straightforward skid-steer operation, enhanced with optional IMU correction for straight-line stability.

4-wheel skid steer (tank)

2 × REV HD Hex motors (20:1 ultra-planetary gearbox)

90 mm traction wheels

Chain and sprocket with adjustable tensioner

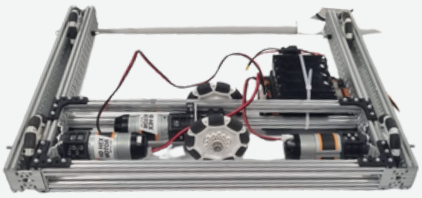
300 RPM (calculated ~1.4 m/s)

Balanced for both pushing and maneuvering

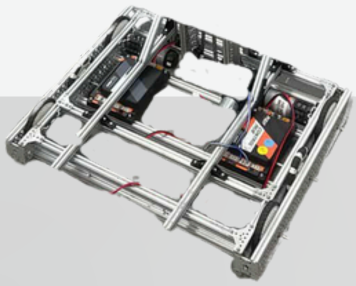
Detachable side panels and master-linked chains

1

The first chassis was a holonomic H-drive with engageable traction wheels and a center omni wheel. A lever system allowed the middle wheel to lift or lower, providing good versatility. However, the design was heavy, required multiple motors, and proved difficult to maintain, reducing its long-term reliability.



2



The second chassis used a 2WD layout focused on reducing weight and simplifying maintenance. It was easier to assemble and repair than the previous version, allowing faster field adjustments. However, it had problems with lower traction and pushing power, limiting maneuverability under competition load.

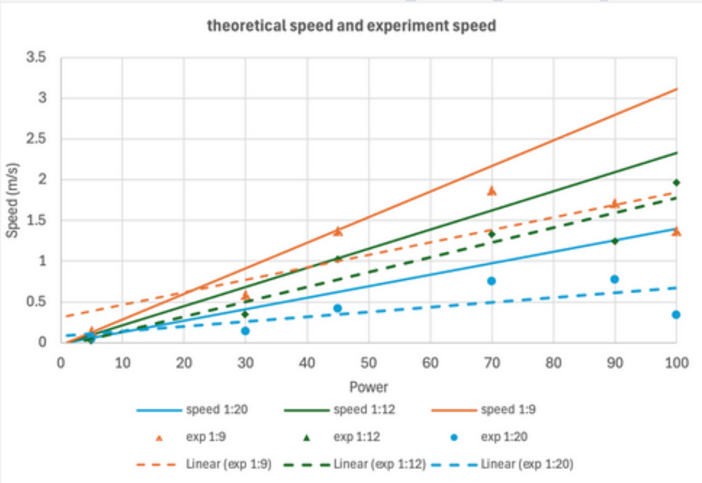
3

The final chassis is a 4WD skid-steer (tank) drive powered by two motors, with wheels linked via chains and sprockets. A tensioning sprocket maintains chain alignment, improving reliability. This configuration achieves balanced traction, torque, and control while remaining compact and easy to service during matches.

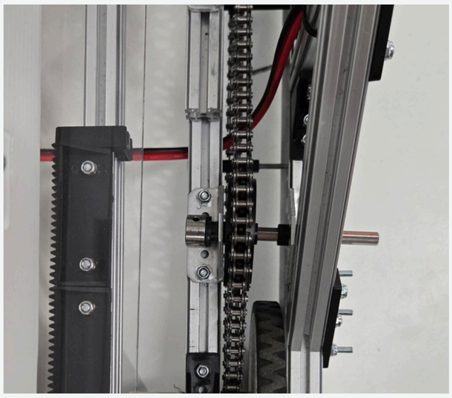
“ - A drivetrain’s strength lies not in speed, but in consistent, controllable torque”
- Saba

SPECIFICATION

- Wheels Diameter: 90 mm traction wheel × 2 (REV-41-1354)
- Motors: HD hex motor × 2 (REV-41-1600)
- Gear Ratio (motor → wheel): 20 : 1
- Top Speed : 300 rpm

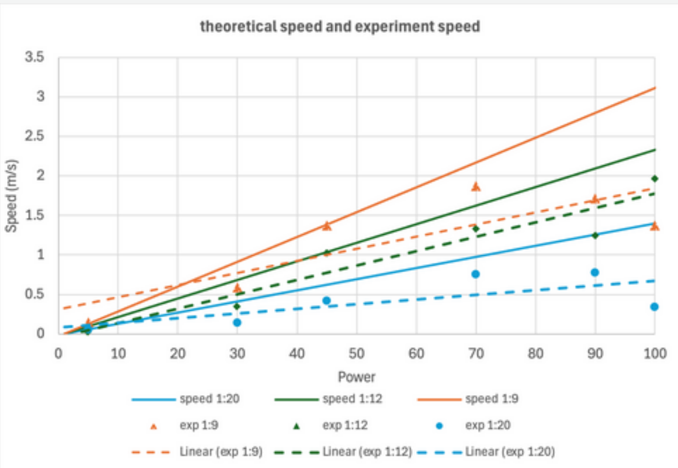


TENSIONER



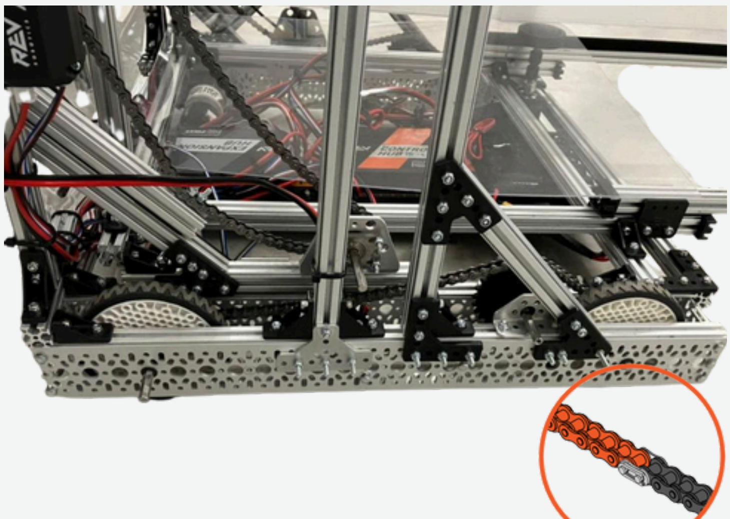
The tensioning sprocket is mounted on top of the chassis and allows precise adjustment of chain tension. By moving the sprocket, the chain's tightness can be increased or decreased to ensure smooth operation. This design prevents chain skipping, minimizes wear, and maintains consistent drivetrain performance throughout extended use.

ANALYSIS



We analyzed the speed–pushing force characteristics of our two REV HD Hex motors with ultra-planetary gearboxes. As rotational speed increases, pushing force decreases — illustrating the trade-off between torque and velocity. The selected 20:1 ratio provides an optimal balance, delivering sufficient torque for barrier interaction while maintaining competitive drive speed and efficiency.

MAINTANANCE



Our drivetrain was engineered for fast and reliable servicing. Removable side panels allow clear access to internal components, enabling quick inspections or part replacement during matches. Master links on the drive chains simplify removal without tools, improving pit-time efficiency. Together, these features reduce maintenance time and ensure consistent mechanical performance under competition conditions.

INTAKE

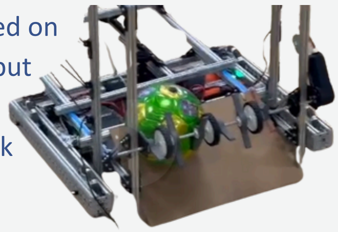
To handle 152.5 mm Biodiversity Units, we developed an active roller intake driven by sprockets and round belts. The mechanism stays compact within the 50×50×50 cm starting frame and deploys via a tilting front wall, allowing the rollers to lift units from the carpet and deliver them smoothly into storage.

Challenge lead: Saba Robakidze
Challenge: Designing a compact and efficient intake that fits within size limits while ensuring reliable collection and smooth deployment.

"An effective intake manages flow, friction, and flexibility in perfect balance."
- Aleksandre

1

The first intake used flaps and a round-belt roller mounted on the front wall. It directly collected units into the basket, but the layout wasted space and lacked a separation wall between storage and intake. This caused units to roll back and jam, interrupting the collection process.

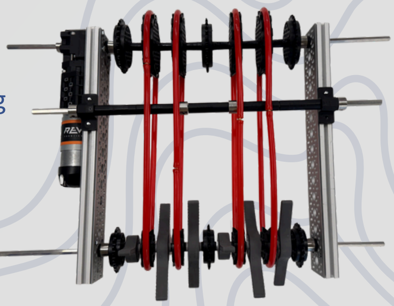


2

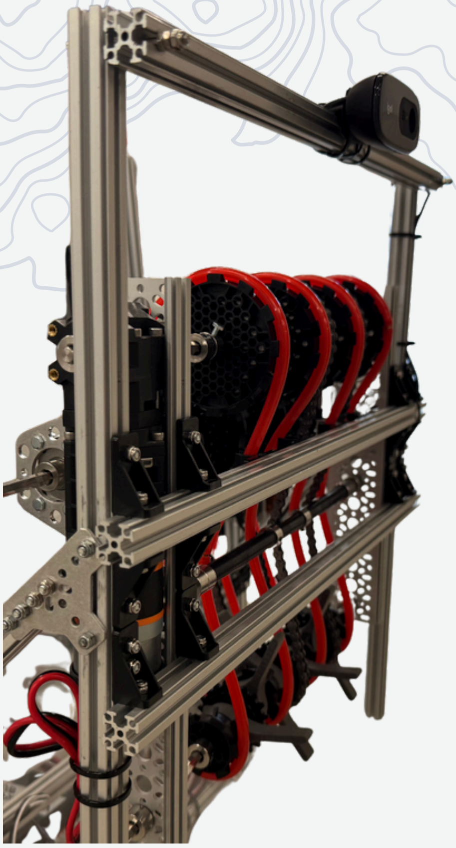
The second version added an extendable front wall and a back guide wall for better unit control. Biodiversity units rolled on belts and chains through sprockets and pulleys, assisted by an inclined path for smoother movement. The 45° extendable wall improved efficiency but increased width, requiring merged hex shafts.

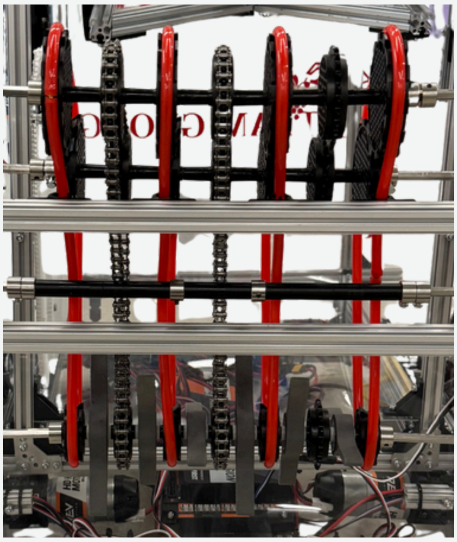
3

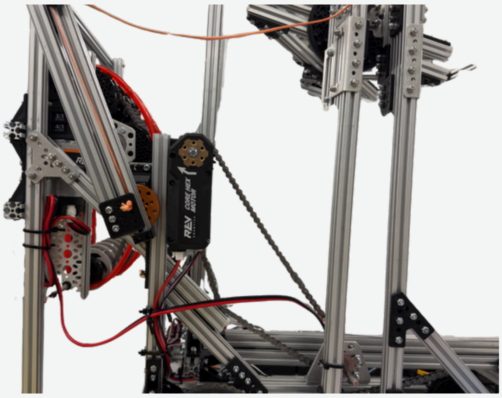
The final design rearranged the expansion motor and roller assembly to fit standard 400 mm hex shafts. A tensioning shaft and C-channel mounting system simplified belt adjustments, improving serviceability and precision. This version offered the most stable and compact performance while remaining easy to maintain.



EXTANDER

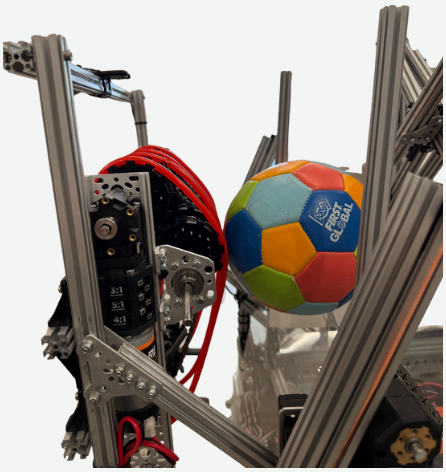






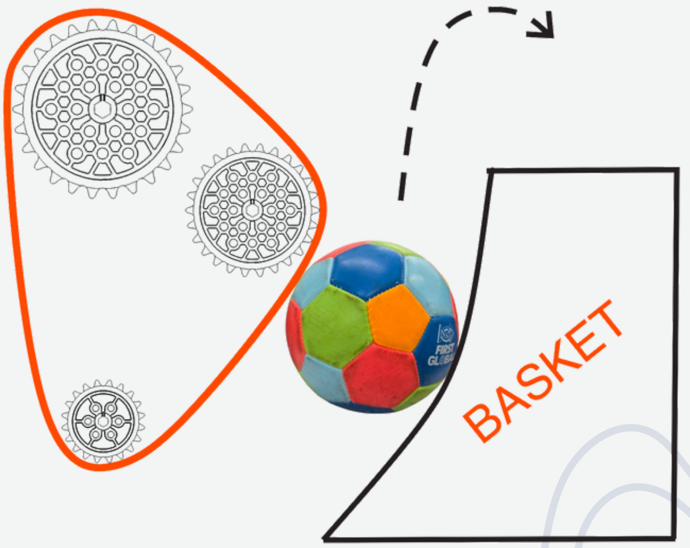
The intake features an extending front wall that moves forward and tilts upward during deployment. This extension increases the system's reach, allowing it to collect biodiversity units directly from the ground while remaining compact within the 50×50×50 cm start limit. The geometry was optimized to maintain stability and consistent contact during operation.

ANTI JAM



The intake employs voltage and encoder feedback to detect jams in real time. When abnormal readings indicate a blockage, the motor automatically reverses to clear the obstruction and then resumes forward motion. This control logic minimizes downtime and ensures continuous intake performance under varying field conditions.

ROLLER



The intake utilizes round belts on rollers, driven by chains and sprockets, to guide units smoothly into the basket. The rollers' compliant round belt surfaces provide reliable grip with minimal deformation, ensuring stable transfer at consistent speeds. This configuration achieves efficient, controlled collection from the carpet to storage.

OVERVIEW

To store multiple Biodiversity Units, we required a basket that could expand beyond the 50 cm starting cube while remaining compact at match start. The system needed to hold units securely during rapid motion without deformation. Several extension mechanisms were evaluated before selecting a rack-and-pinion system with flexible sliding walls, combining precision, strength, and reliability.

Rack-and-Pinion HOW IT WORKS

A pinion gear drives a rack, converting rotational motion into precise linear movement of the basket wall.

ADVANTAGES

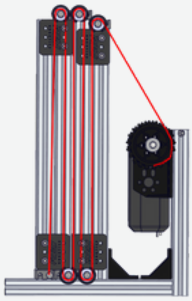
Strong, accurate, and compact; prevents slippage.

DISADVANTAGES

Requires precise alignment, lubrication, and rigid mounting.

Linear Slide (Extrusion + Bearings) HOW IT WORKS

A carriage slides along a rail using bearings, driven by motor or pulley.



ADVANTAGES

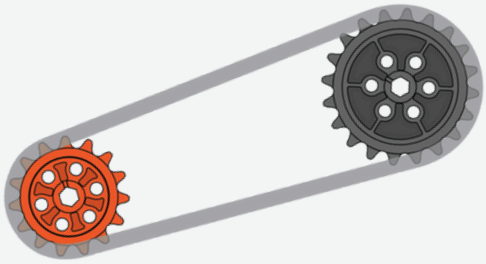
Smooth, low-friction movement.

DISADVANTAGES

Misalignment can cause drag; less rigid under load.

Chain-Driven Slider HOW IT WORKS

Operates similarly to a linear slide but uses chain and sprockets for higher strength and reduced stretch.



ADVANTAGES

High load capacity, consistent motion.

DISADVANTAGES

Heavier, noisier, requires chain protection.

Linear Slide (Cable/Elastic Powered) HOW IT WORKS

Utilizes elastic bands to retract sliding rails for simplicity and low cost.

ADVANTAGES

Lightweight and easy to prototype.

DISADVANTAGES

Limited precision, prone to jamming, and poor long-term durability.

Challenge Lead:
Challenge: Maximizing ball capacity while ensuring smooth, reliable extension and secure locking of sliding walls.

1

The basket is expandable to hold multiple BIODIVERSITY UNITS. In the first version, expansion was done using rubber bands, which only allowed it to open once and could not close. This made climbing the rope at the end of the match difficult, and rubber bands were prone to tearing.

The second basket used a rack and pinion system, making it fully reliable. Rubber walls were added to keep the biodiversity units secure. However, the system generated high tension, causing the expansion motor to struggle and requiring more power to keep the basket open. Additionally, this design did not provide any significant increase in capacity.

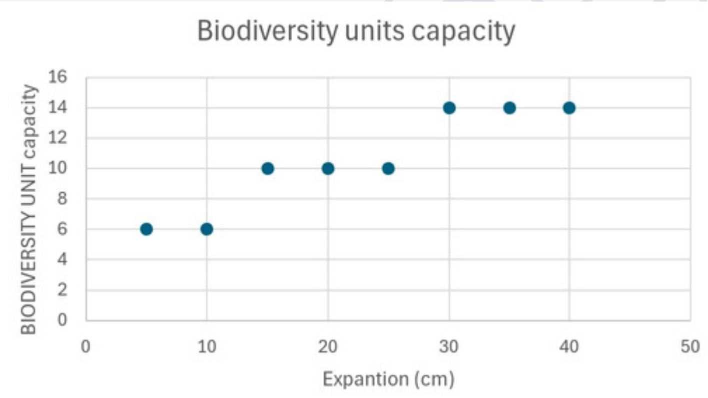
2

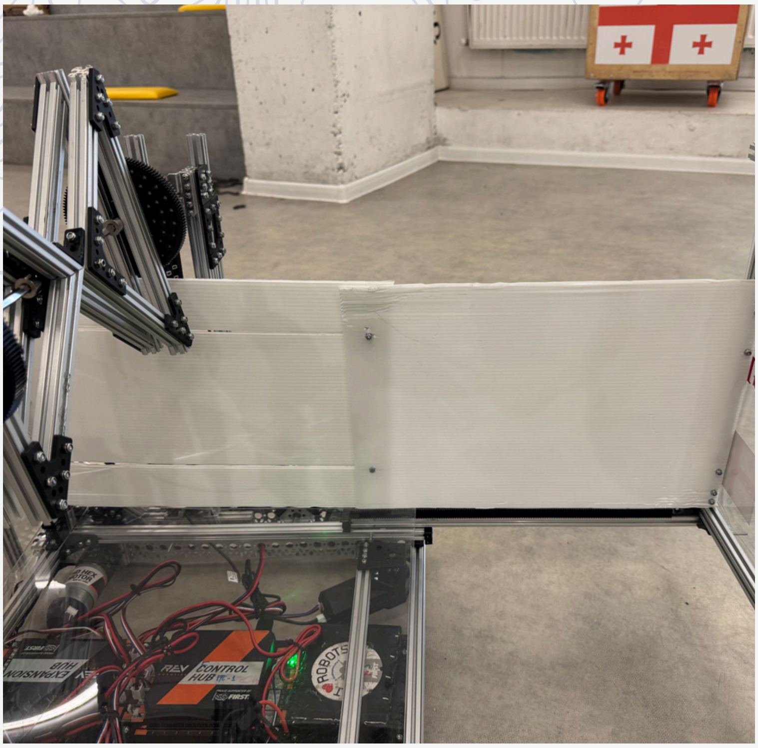
3

In the last version, the rubber walls were replaced with sliding corrugated plastic sheets. We laser-cut “rails” and mounted screws that slide along them, keeping the two parts of the walls perfectly aligned. This design is durable, allows controlled expansion and contraction, and improves reliability compared to previous versions.

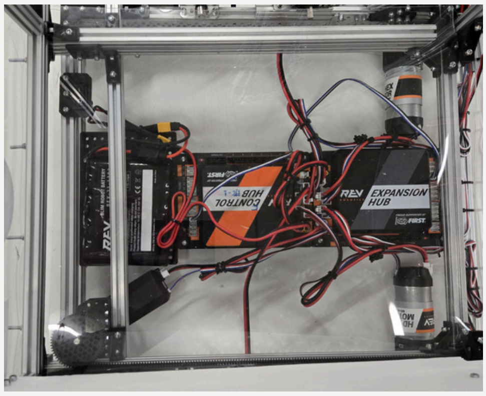
SPECIFICATION

- Contracted capacity: 6 Biodiversity units
- Fully expanded capacity: 14 Biodiversity units
- Expansion time: approximately 9 seconds without the shooter
- Average Expansion speed: 9 cm/s without the shooter





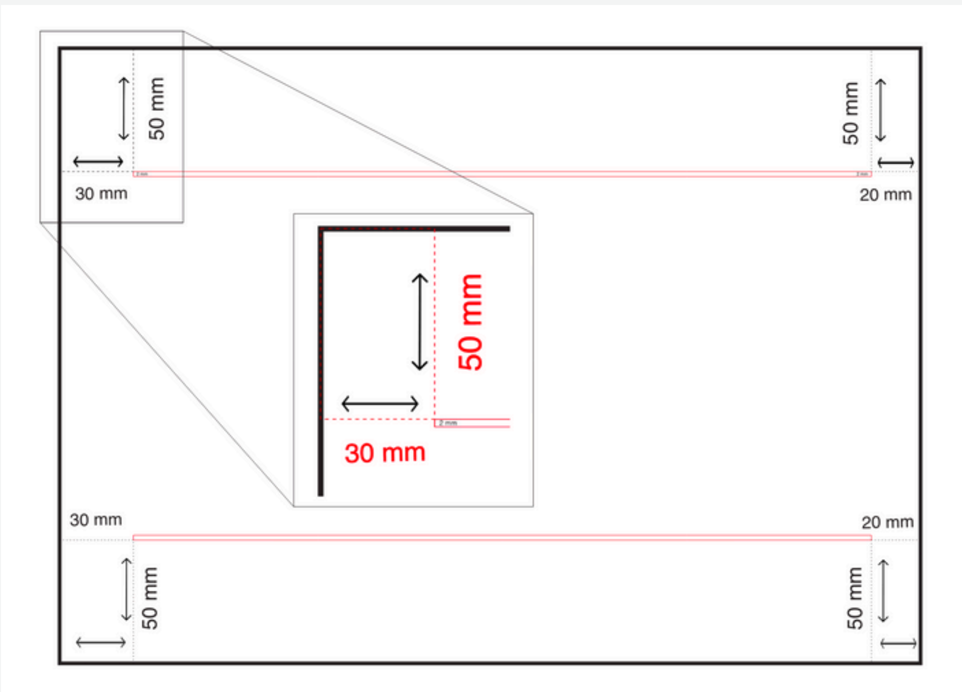
ELECTRONICS ACCESS

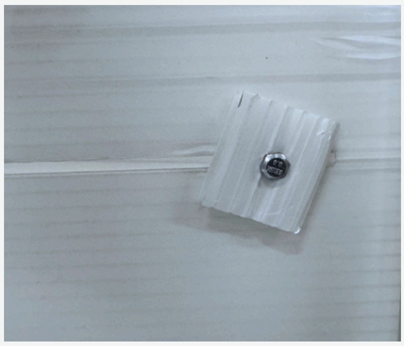


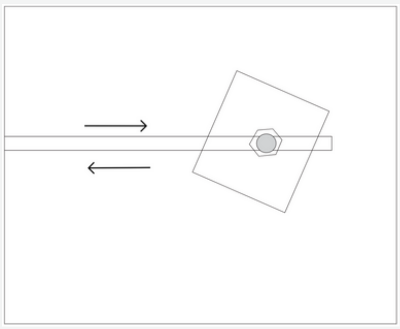
The basket is designed with an openable bottom, allowing easy access to the electronics housed underneath. This feature simplifies maintenance and troubleshooting without the need to remove the entire basket, saving time and effort during competitions or repairs.

Sliding walls allow the basket to expand or contract smoothly, providing adjustable space to hold more balls when needed. They are designed to move easily along guided tracks, ensuring precise alignment and stability during operation. This feature makes loading and unloading faster and more efficient, while also helping to keep the balls securely contained during movement.

SLIDING WALLS

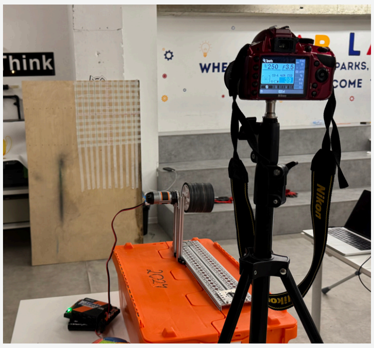


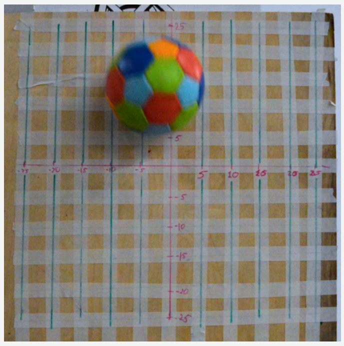




Shooter Accuracy Testing

To test shooter accuracy we made grid with 5cm distans parallel and perpendicular lines aimed shooter to its center and tracking hit points with bubble chart.

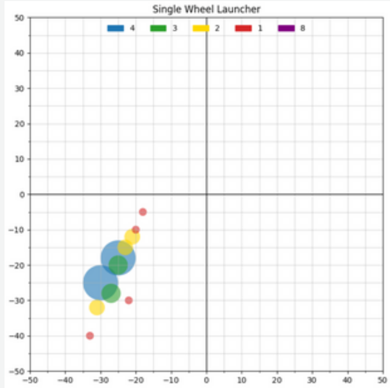




Single-Wheel Flywheel

A single motorized wheel spins at high speed, and the ball is pressed against it and a fixed surface.
Key points:

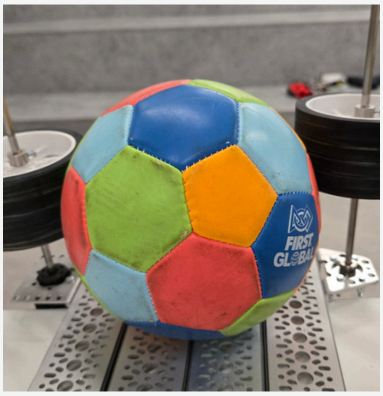
- Simple, lightweight, and compact.
- Backspin can be created by adjusting the contact angle.

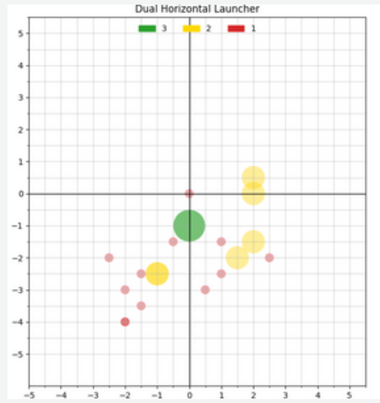


Dual-Wheel HORIZONTAL

A dual-wheel horizontal launcher uses two counter-rotating wheels mounted side by side to propel the ball forward.
Key points:

- stable setup
- Spin can be adjusted (sidespin or no spin)

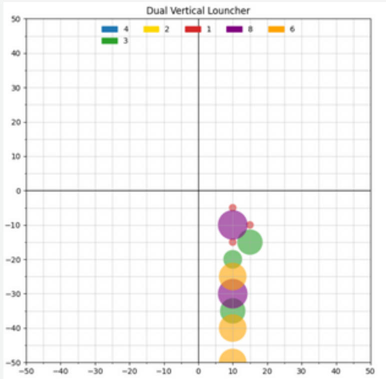




Dual-Wheel VERTICAL

A dual-wheel vertical launcher uses two counter-rotating wheels positioned opposite each other

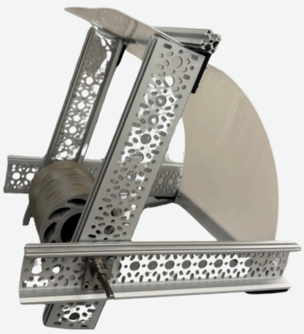
- balanced design with symmetric wheel arrangement.
- Spin can be controlled

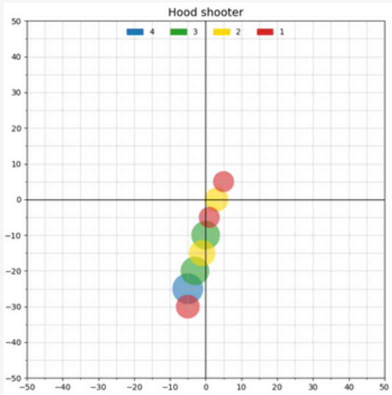


Variable-Angle Flywheel (Adjustable Hood)

Flywheel shooter with a movable hood or backplate to change the launch angle dynamically.
Key points:

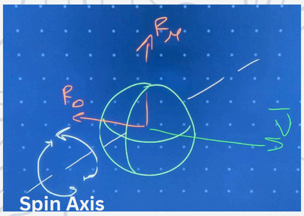
- Can aim at multiple target heights without changing robot position.

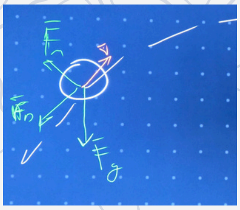




Objective:

To develop and experimentally validate a physical model for the motion of a spinning spherical football considering gravity, aerodynamic drag, and the Magnus lift effect. The purpose of this study is to accurately describe and predict the ball's curved trajectory for use in robotic kicking and control systems.





Forces that act on flying spinning ball

In theoretical formula we have two (drag and lift) functions that should we calculated with experiment do we made external experiments and fitted those functions

Symbol	Force Name	Direction	Expression	Units
F_g	Gravitational force	Downward (–z)	$F_g = -mg\hat{z}$	N
F_D	Aerodynamic drag	Opposite to velocity	$F_D = -\frac{1}{2}\rho C_d(S)Av^2\hat{v}$	N
F_M	Magnus (lift) force	Perpendicular to both spin and velocity	$F_M = \frac{1}{2}\rho C_L(S)Av^2(\hat{\omega}\times\hat{v})$	N

Symbol	description	Units
ω	angular velocity vector(spin axis)	$\frac{rad}{s}$
$\omega = \lVert\overline{\omega}\rVert$	spin rate	$\frac{rad}{s}$
$\hat{V} = \frac{V}{v}$	unit vector in direction of motion	–
$\hat{\omega} = \frac{\omega}{\omega}$	unit vector along spin axis	–
$\hat{z}$	Upward vertical unit vector	–
$S = \frac{r\omega}{v}$	Dimensionless spin parameter	–
$r = (x,z)$	position vector	m
t	time	s

We wrote newtons 2nd law to calculate path of motion

$$m\bar{a} = \overline{F_g} + \overline{F_D} + \overline{F_M}$$

$$\dot{x} = v_x \quad \dot{z} = v_z$$

$$m\dot{v_x} = -\frac{1}{2}\rho C_d(S)Av^2\frac{v_x}{v} \pm \frac{1}{2}\rho C_L(S)Av^2\frac{v_x}{v}$$

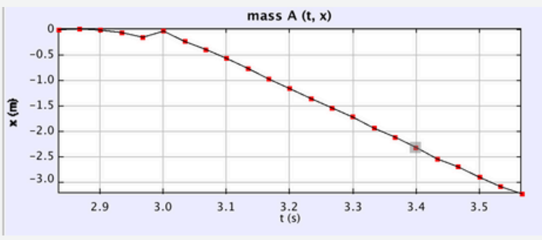
$$m\dot{v_z} = -mg - \frac{1}{2}\rho C_d(S)Av^2\frac{v_x}{v} \mp \frac{1}{2}\rho C_L(S)Av^2\frac{v_x}{v}$$

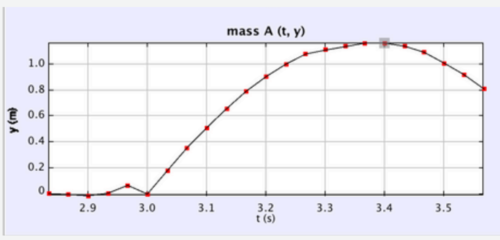
Symbol	description	Units
m	mass of the ball	kg
r	radius of the ball	m
$A = \pi r^2$	cross sectional area of the sphere	m^2
ρ	density of air	$\frac{kg}{m^3}$
g	gravitational acceleration	$\frac{m}{s^2}$
C_d	drag coeficient(dimensionless, depends on spin)	–
C_L	lift coefficient(simensiionless, deoends oon spin)	–
$V = (v_x, v_z)$	velocity vector of the ball	$\frac{m}{s}$
$v = \lVert V\rVert$	magnitude of velocity	$\frac{m}{s}$

"Theoretical model and experiments with help of AI will make shooting easier"

-Bagrati

With the fitted function, we graphed the theoretical model with empirical error final charts help us analyze from what distance and at what angle we should lunch the biodiversity unit

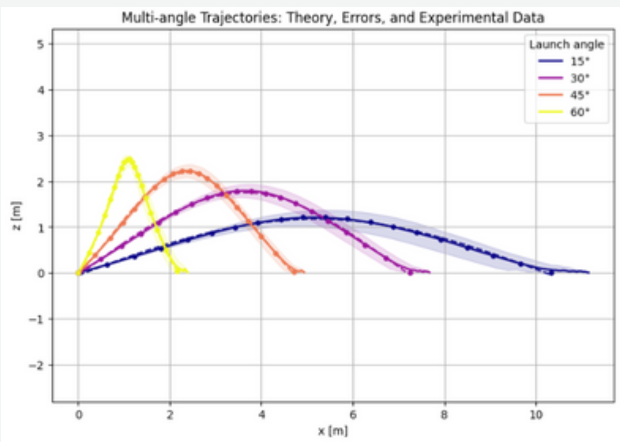


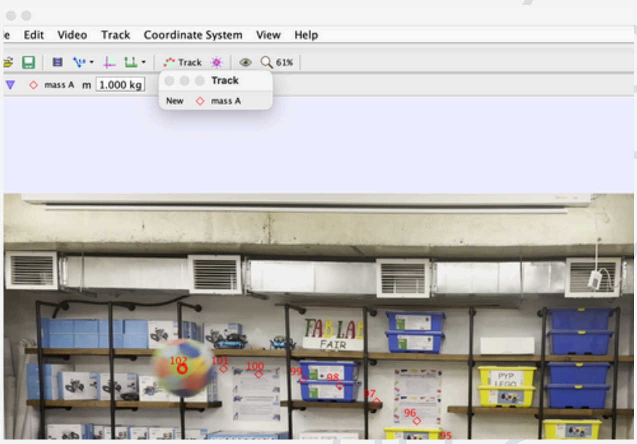


t (s)

Columns ▾ mass A

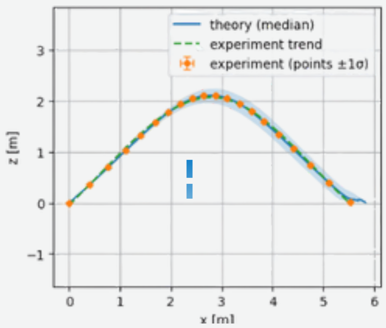
t (s)	x (m)	y (m)	v_x (m/s)	v_y (m/s)	v (m/s)	a_x (m/s²)	a_y (m/s²)
2.833	-3.790E-3	3.790E-3					
2.867	1.895E-2	-3.790E-3	-5.687E-2	-0.227	0.234		
2.900	-7.579E-3	-1.137E-2	-1.194	0.171	1.206	-32.67	20.97
2.933	-6.063E-2	7.579E-3	-2.161	1.194	2.469	34.14	-10.24
2.967	-0.152	6.821E-2	0.512	-0.114	0.524	-12.19	25.36
3.000	-2.653E-2	0.000	-1.251	1.706	2.116	-60.47	61.44
3.033	-0.235	0.182	-5.516	5.346	7.681	-70.71	56.57
3.067	-0.394	0.356	-5.004	4.948	7.037	1.951	-11.22
3.100	-0.568	0.512	-5.516	4.549	7.150	-17.07	-11.70
3.133	-0.762	0.659	-6.142	4.208	7.445	-3.901	-12.68
3.167	-0.978	0.792	-5.914	3.696	6.974	2.926	-16.09
3.200	-1.156	0.906	-5.687	3.128	6.490	5.852	-16.09
3.233	-1.357	1.000	-5.744	2.616	6.311	1.463	-23.41
3.267	-1.539	1.080	-5.459	1.649	5.703	-4.876	-23.89
3.300	-1.720	1.110	-6.028	0.853	6.088	-2.926	-14.14
3.333	-1.940	1.137	-5.914	0.796	5.968	0.000	-7.802
3.366	-2.115	1.163	-5.687	0.398	5.701	-3.901	-16.09

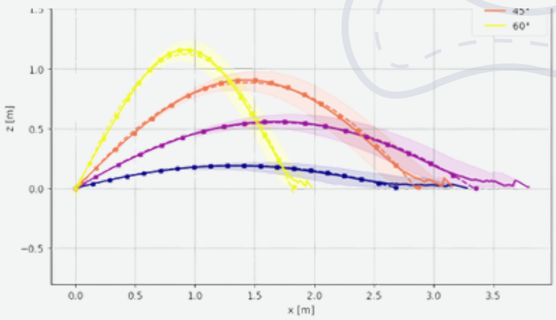


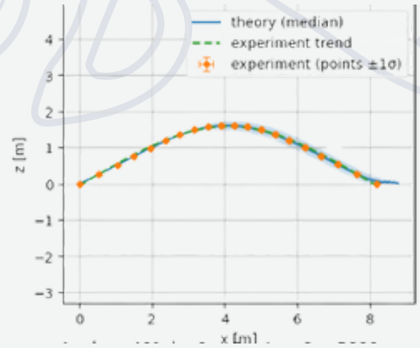


Challenge leads: Ilia Berbichashvili
Challenge: The goal of this challenge was to design, test, and optimize a reliable mechanism that could launch game elements (biodiversity units) with accuracy, power, and consistency.

PROJECTILIE MOTION

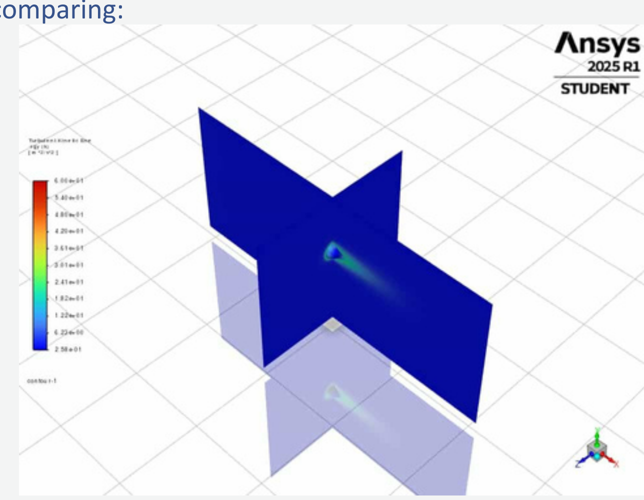






Our team conducted a series of tests to analyze projectile motion using different shooter configurations. The graphs below compare theoretical vs. experimental trajectories under different angles and launch conditions.
The graphs above represent our projectile motion experiments, comparing:

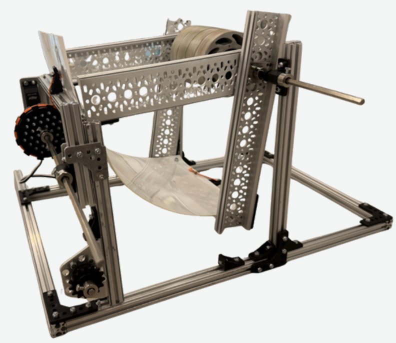
- Theoretical median vs. actual experimental trends
- Angle variation effects on range and height
- Energy loss trends across prototypes

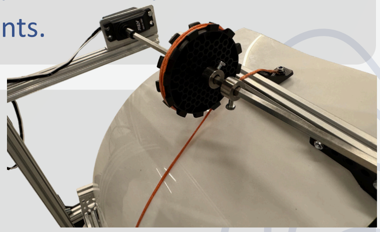


The setup features a cross-shaped geometry with flow interaction analyzed via turbulent kinetic energy contours. The colored scale on the left indicates varying levels of turbulent energy, ranging from low turbulence (blue) to high turbulence (red).

CAPSTAN DRIVE

The capstan drive in FGC's projectile launching mechanism is innovative, adapting a rope-driven speed reducer, typically used in climbers, though in our case being used for launcher angle adjustment In the Eco Equilibrium game, it helps make the launcher shroud more rigid, as well as allows for angle regulation for consistent and predictable projectile trajectories.
Benefits include zero backlash for accuracy, low inertia for quick response, high torque efficiency, and reduced wear compared to gears. It's lightweight and cost-effective, fitting FGC's kit constraints.

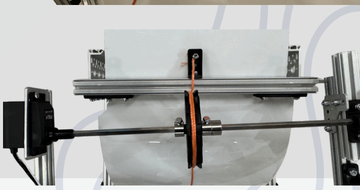




The final version integrated:

- A servo-powered adjustable hood
- A redesigned intake mechanism
- Reinforced chassis and improved shot power

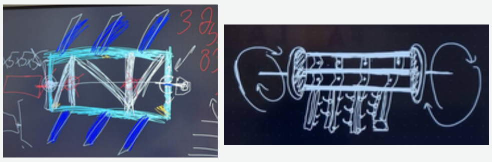
This setup delivered better consistency, dynamic control, and reduced energy loss, making it our most competitive solution.

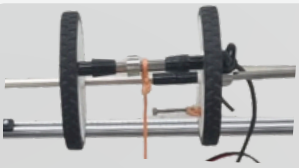


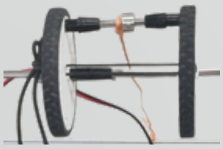
Challenge Lead: Bagrat Davitashvili
Challenge: Developing a climber that fits our space requirements, while being able to consistently climb the rope to the challenge's given lenght.

1

This is our first iteration of the rope climber. The damaged bolts worked well as teeth, giving the mechanism a strong grip on the rope. However, when climbing, the rope shifted to the side, which made it difficult for the climber to go up very high.





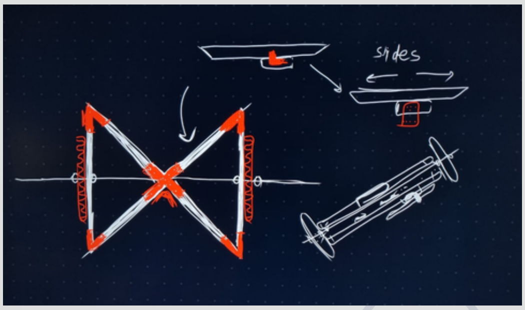


This is our second iteration of the rope climber. It used two wheels connected with a rubber band and a locking stickthat stayed open until the rope entered. When the climber rotated, the stick would pop out and lock the rope in place. It worked well once, but the system only functioned one time per run and required very precise aiming to get the rope inside correctly.

2

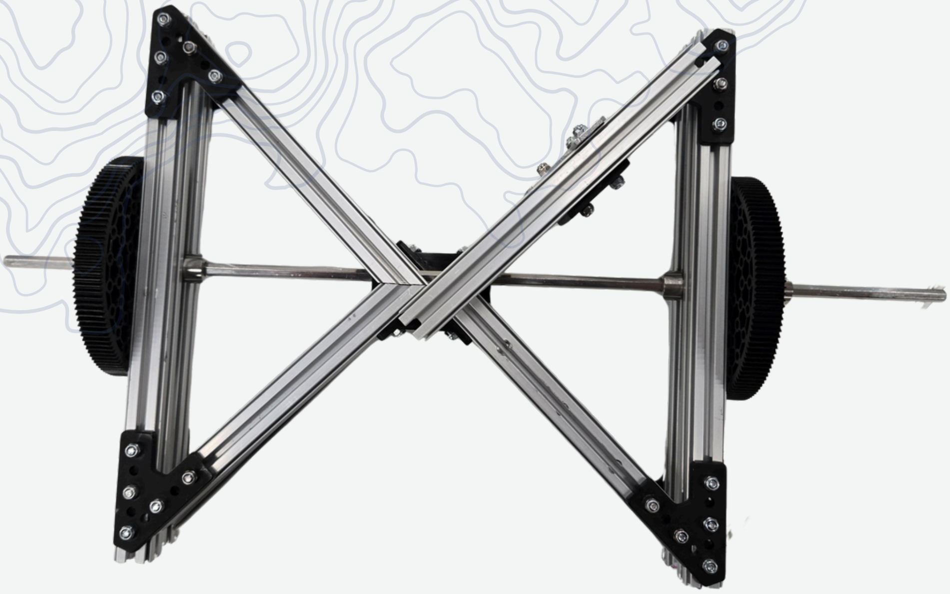
3

In our final version, we added a triangle slope to prevent the robot from tilting and a sliding lock that starts horizontal to guide the rope to the center, then moves vertical to lock it in place securely during the climb.



SPECIFICATION

- Time to grapple rope: 1.2 s
- Time to reach level 3: 3.8 s
- Time to reach level 4: 4.9 s
- Maximum climbing height: 88 cm
- Average climbing speed: 18 cm/s
- Peak climbing speed: 22 cm/s



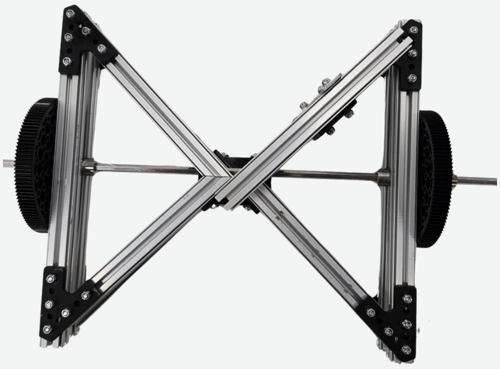
SLIDER LOCK

When the climber is set vertically, the slider slides down and locks onto the rope, securing it for climbing and helping the robot lift smoothly without slipping.

ROPE AUTO ALIGMENT

This automatic alignment system removes the need for precise manual aiming. The geometry of the X-frame and guiding slopes ensure the rope always enters the middle path, allowing quick and reliable locking every time.

X-SHAPE CLIMBER



The climber frame is built forming an X-shaped structure for strength and stability. This design evenly distributes load along both axes, keeping the system rigid during lifting. The central shaft and gears ensure balanced motion on both sides, allowing smooth and aligned climbing.

"Working on this robot showed me how much can be achieved through collaboration - every bolt we tightened brought us closer as a team"

- Mariam

Challenge Lead: Nikoloz Kiladze
Challenge: Write code that balances integrity, complexity, and elegance while maintaining stable functionality of the robot.

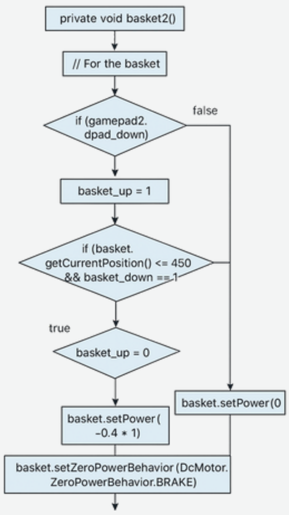
The main goal was to make the code easy to debug and pleasant to read, reflecting cooperation. By dividing it into private functions for each task, it became simple to adjust or rewrite specific parts without wasting time. With a diverse team of coders with different experiences, the structure ensured that, despite being extensive and suited to the robot's needs, everyone could still grasp its logic through pseudocode.

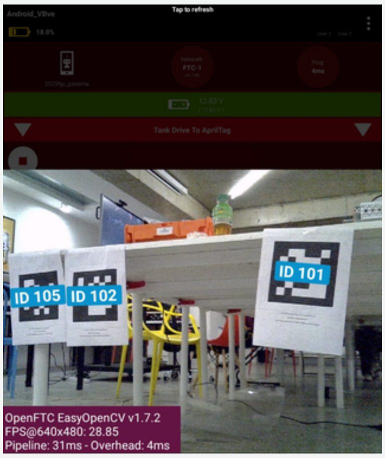
Boolean variables were assigned based on the robot's stage to prevent infinite loops or runtime errors. Encoder feedback from the hex motors controlling the intake height set target positions, stopping the motors when the intake reached the ideal level for collecting balls. Zero-power behavior stabilized the intake base.

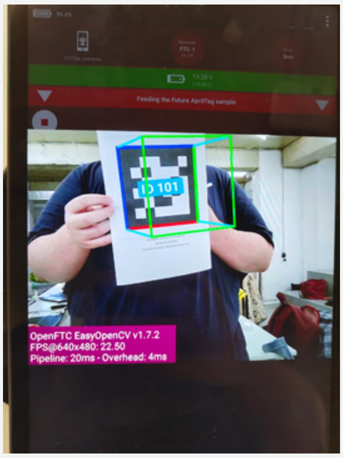
```
private void picker_action() {
    // this is for picker__
    if (gamepad2.a) {
      MooveMyPicker_UP = 1;
    }
    if (gamepad2.b) {
      MooveMyPicker_DOWN = 1;
    }
    if (pickerR.getCurrentPosition() <= 180 && MooveMyPicker_UP == 1) {
      MooveMyPicker_DOWN = 0;
      pickerR.setPower(0.4 * 1);
    } else if (pickerR.getCurrentPosition() >= 5 && MooveMyPicker_DOWN == 1) {
      MooveMyPicker_UP = 0;
      pickerR.setPower(0.4 * -1);
    } else {
      MooveMyPicker_UP = 0;
      MooveMyPicker_DOWN = 0;
      pickerR.setPower(0);
      pickerR.setZeroPowerBehavior(DcMotor.ZeroPowerBehavior.BRAKE); //wout movement
    }
    if (pickerL.getCurrentPosition() <= 180 && MooveMyPicker_UP == 1) {
      MooveMyPicker_DOWN = 0;
      pickerL.setPower(0.4 * 1);
    } else if (pickerL.getCurrentPosition() >= 5 && MooveMyPicker_DOWN == 1) {
      MooveMyPicker_UP = 0;
      pickerL.setPower(0.4 * -1);
    } else {
      MooveMyPicker_UP = 0;
      MooveMyPicker_DOWN = 0;
      pickerL.setPower(0);
      pickerL.setZeroPowerBehavior(DcMotor.ZeroPowerBehavior.BRAKE);
    }
  }
```

```
public class Fgc2025_Project_Editing_the_final extends LinearOpMode {

  private AndroidTextToSpeech androidTextToSpeech;
  private IMU imu_IMU;
  private Servo servoR;
  private Servo servoL;
  private DcMotor pickerL;
  private DcMotor pickerR;
  private DcMotor basket;
  private DcMotor leftAsDcMotor;
  private DcMotor rightAsDcMotor;
  private DcMotor climber;

  int MooveMyPicker_UP;
  int basket_up;
  int MooveMyPicker_DOWN;
  int basket_down;
  float YAW_ang;

private void basket2() {
    // For the basket__
    if (gamepad2.dpad_down) {
      basket_up = 1;
    }
    if (gamepad2.dpad_up) {
      basket_down = 1;
    }
    if (basket.getCurrentPosition() <= 450 && basket_down == 1) {
      basket_up = 0;
      basket.setPower(-0.4 * -1);
    } else if (basket.getCurrentPosition() >= 0 && basket_up == 1) {
      basket_down = 0;
      basket.setPower(-0.4 * 1);
    } else {
      basket.setPower(0);
      basket.setZeroPowerBehavior(DcMotor.ZeroPowerBehavior.BRAKE);
    }
  }
```

Basket contraction and expansion is done in a binary way (either its open or closed). Another version of this basket code is also available that functions similarly (it is capable of contracting and expanding with a unique fixable length that one can set independently by manipulating the joystick).





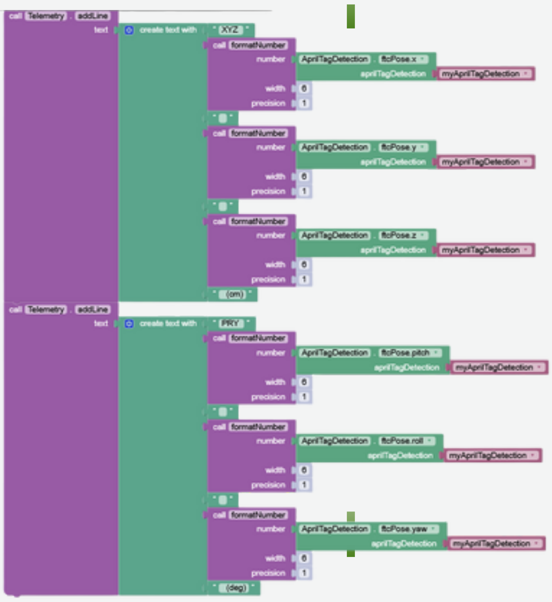


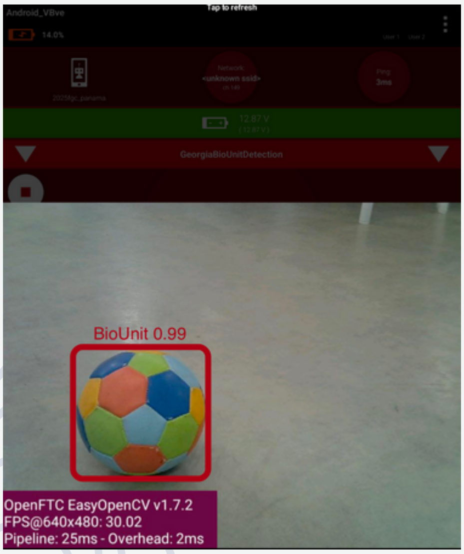
1 Vision-Based Assistance: AprilTag Aim and AI Lock-On

In our robot, we developed two advanced assistive features to improve driver precision and efficiency: **AprilTag Aim-Assist** and **AI Lock-On Biodiversity unit**. These systems use computer vision and sensor fusion to support to make the shooting easier. They allow our robot to react faster and more accurately while staying under driver supervision.

2 APRILTAG AIM-ASSIST

The **AprilTag aim** system helps the robot align perfectly with scoring targets before shooting. When the driver presses the aiming button, the onboard camera searches for a visible AprilTag placed near. Once detected, the system calculates the **relative angle and distance** to the target using the tag's geometric pattern. The robot then automatically adjusts its orientation, using the **IMU** (Inertial Measurement Unit) to stabilize its shooting and compensate for small positional errors. The IMU provides a smooth and precise yaw reading. Once aligned, the shooter adjusts its launch angle based on the calculated distance, ensuring consistent and accurate shots.





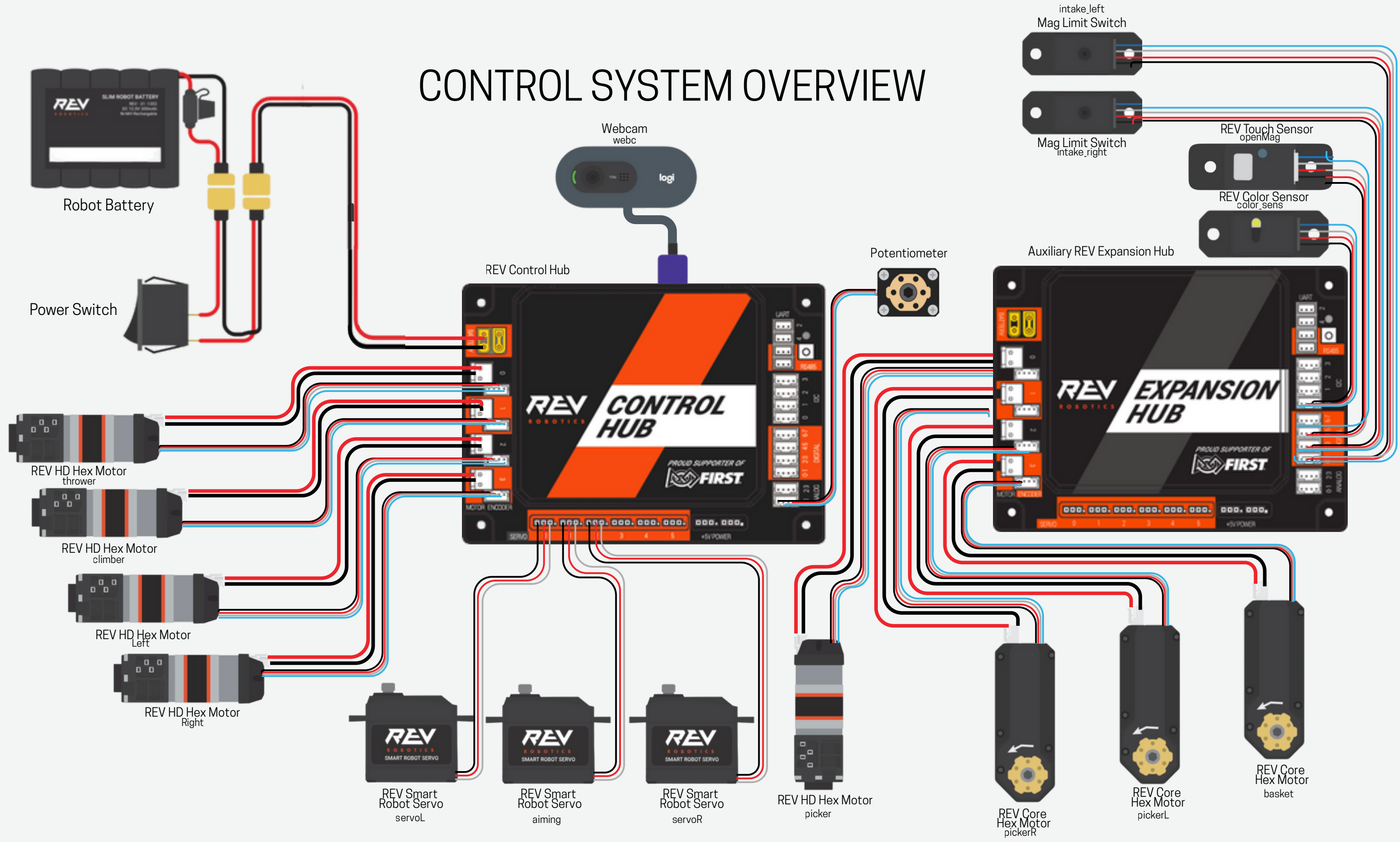
3 AI Lock-On for Biodiversity Collection

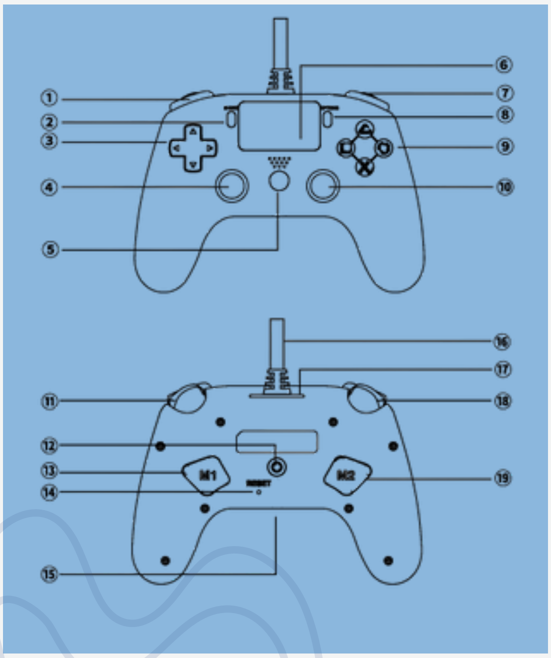
To collect biodiversity units efficiently, we use a **TensorFlow-based object detection model** that recognizes their shapes and colors in real time. When the driver activates the **Lock-On mode**, the robot's camera identifies the closest biodiversity unit and keeps it centered in the frame. The AI continuously updates the object's position, allowing the robot to drive directly toward it for quick intake. The IMU again supports this system by keeping the robot stable and maintaining its heading as the AI corrects the relative position. The combination of **vision feedback and inertial stability** allows the robot to behave smoothly and accurately, even when the field is uneven or lighting conditions vary.

"IMU installation and AprilTag detection allow us to aim the thrower with higher precision – getting more Biodiversity Balls in the Ecosystems."

– Saba Machavariani –

CONTROL SYSTEM OVERVIEW



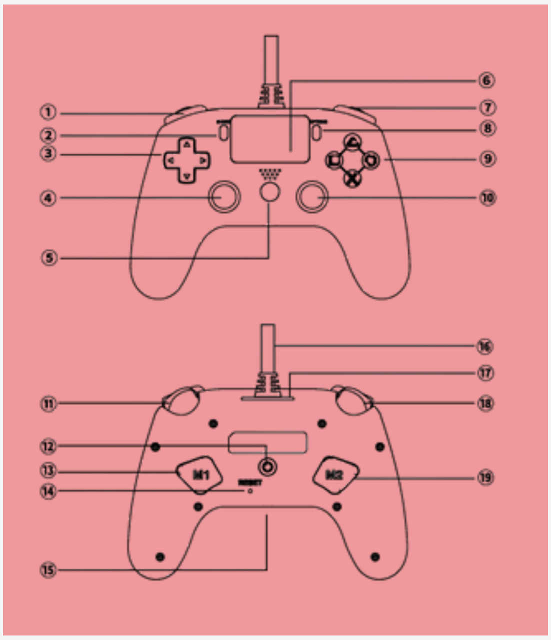


Driver 1 Button Layout

1. ON LOCK ON BIODIVERSITY UNIT
4. LEFT ULTRAPLANETARY MOTOR MOVEMENT
7. OFF LOCK ON BIODIVERSITY UNIT
9. ROTATIONS CLOCKWISE/ANTICLOCKWISE
10. RIGHT ULTRAPLANETARY MOTOR MOVEMENT

Driver 2 Button Layout

1. MOVING UP THE SERVOS USED TO GRAB THE BARRIERS
3. CONTRACTING/EXPANDING BASKET
4. CLIMBER ULTRAPLANETARY MOTOR ROTATIONS
6. MOVING DOWN THE SERVOS TO GRAB THE BARRIERS
9. MOVING UP/DOWN THE PICKER
18. PICKER ROTATION



MEETING WITH UZBEKISTAN

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH ECUADOR

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH SRI LANKA

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH MALAYSIA

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH KAZAKHSTAN

Exchanging Cultures
and cheer each other
before the big week

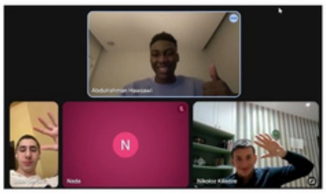
FIRST GLOBAL TEAM GEORGIA

MEETING WITH CANADA

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

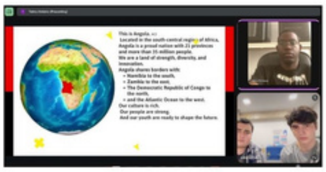
MEETING WITH SAUDI ARABIA



Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH ANGOLA



Exchanging Cultures
and cheer each other
before the big week

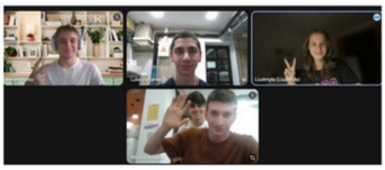
FIRST GLOBAL TEAM GEORGIA

MEETING WITH ESWATINI

Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

MEETING WITH UKRAINE



Exchanging Cultures
and cheer each other
before the big week

FIRST GLOBAL TEAM GEORGIA

Team Reflection

The 2025 *FIRST* Global Challenge, Eco Equilibrium, pushed Team Georgia to design solutions that united engineering precision with environmental purpose. Every subsystem evolved through data-driven iteration, balancing performance, reliability, and maintainability. We learned that true engineering progress is iterative: each prototype, failure, and improvement brought us closer to consistency and control.

Learning Outcomes

Integrating AI-assisted vision and simulation-based driver training marked a major technical milestone. These tools enhanced shooter precision and driver readiness while demonstrating how mechanical and software engineering converge. Documenting each decision taught us that a well-kept engineering notebook is as essential as any mechanical component, preserving knowledge and guiding future refinements.

Outreach & Impact

Beyond competition, our mission was to share the power of STEM. Through outreach events across Georgia, we engaged around 100 students in robotics and sustainability activities. Internationally, we collaborated with teams from 15 countries, exchanging technical ideas and cultural experiences that reflected *FIRST* Global's spirit of cooperation. These initiatives strengthened our belief that innovation grows fastest through openness and shared learning.

Team Growth

Throughout the season, we discovered that collaboration is the core of engineering. Mechanical design, electronics, and coding only succeeded when aligned through communication and trust. Mentorship guided our technical direction, but teamwork built our identity, transforming individual effort into collective capability.

Looking Forward

We leave Eco Equilibrium inspired to continue developing robotics programs that promote sustainability and accessibility in Georgia and beyond. This experience reaffirmed that engineering is not just about building robots-it is about building communities capable of solving real-world challenges together.

"In robotics, success is not built by parts and code - it's built by people"

TEAM GEORGIA

2025

FIRST GLOBAL CHALLENGE 2025
PANAMÁ CITY