ENGINEERDS

WHERE INNOVATION MEETS COMPETITION

BRD | FIRST TECH CHALLENGE ROMANIA | NAȚIE PRIN EDUCAȚIE | INTO THE DEEP

2024-2025 - SEASON #9
SOFTWARE & HARDWARE POSTERS
BUCHAREST TWIN CUP 2025

BTC
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#24478

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"RADU GRECEANU" NATIONAL COLLEGE
SLATINA, OLT, ROMANIA

SOFTWARE

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LOOP TIMES OPTIMIZATIONS

Loop times refer to the frequency at which a loop updates/sec (e.g., a 100Hz loop corresponds to an average of 10ms between iterations).

Problem: Slow loop times cause funky robot movement and delayed response to driver inputs, reducing overall match performance.

Solution: Loop Time Optimizations

POWER & POSITIONAL CACHING

```java
//CheekyMotor
public void setPower(double power) {
        if (Math.abs(power - cachedPower) > threshold){
            motor.setPower(power);
            cachedPower = power;
        }
    }
```

To reduce redundant motor writes, we've created a custom motor class that caches both power and position values. Updates are only sent if the new value differs from the previous one by more than a specified threshold.

SENSOR THROTTLING

```java
//CheekySensor
public double getDistance(){
        if(loopCount % throttleRate == 0)
            cachedDistance = sensor.getDistance(DistanceUnit.MM);
        return cachedDistance;
    }
```

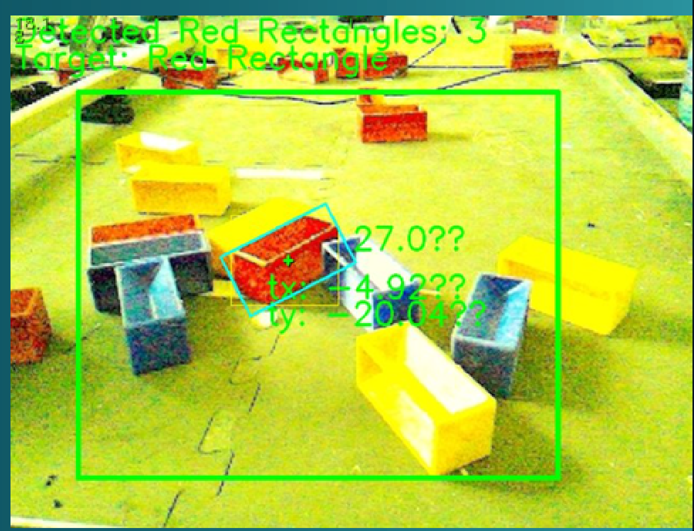
Similarly, we throttle the rate at which our color sensor gets polled. I2C reads on the Control Hub can take around 4ms per call, so reducing the frequency by ½ significantly improves loop times with little cost to responsiveness.

Result: Loop Time Improvements

Thanks to these optimizations, our loop times have significantly improved compared to our previous robot. During the driver-controlled period, we average around 100Hz, while autonomous runs at approximately 70Hz!

CAMERA VISION

Problem: Autonomous routines without vision are limited to only 5 specimens scored, while vision-enabled robots can achieve up to 10 specimens.



Solution: OpenCV Sample Detection Pipeline

We utilize an OpenCV-based computer vision pipeline to detect and analyze samples. First, we threshold the image to isolate red or blue samples based on their HSV color values. We then apply masking to remove unwanted background elements, followed by reverse-masking and Canny edge detection with erosion to clearly separate individual samples from one another. This pipeline also determines each sample's orientation, allowing us to calculate the precise rotation angle needed for our intake claw to grab it properly.

POSITION ESTIMATION & TURRET CONTROL

Once a sample is detected, we estimate its position using the camera's horizontal and vertical offsets. Taking into account the camera's angle, height, and physical offset from the intake, we determine the X and Y displacement of the sample. We then calculate the required turret angle using the arctangent of the X displacement over Y displacement, accounting for the turret's fixed length by subtracting it from the original Y-axis distance measurement.

EXTENSION TARGET CALCULATION

After estimating the sample's distance, we convert it into motor encoder ticks.

Using the known spool radius and the encoder resolution of the motor, we calculate how many ticks correspond to the required extension length. This lets our intake extend to the correct position with little-to-no room for error.

Result: 8-specimen autonomous routine, and driver"Aim-Assist" functionality that dramatically improves sample collection efficiency during TeleOp.

TELE-OP ENHANCEMENTS

AUTOMATED SPECIMEN HANDLING

We make use of the follower during TeleOp in order to automatically pick up & score specimens. The driver resets the Pinpoint's position once the robot touches the wall. After pressing another button, the driver can simply watch how the robot places specimens on its own. This mitigates driver errors and bad movement, whilst also having a high degree of accuracy.

AUTOMATED SAMPLE SORTING

Using a REV Color Sensor V3, the intake automatically spews out wrongly-coloured samples. Otherwise, if a correctly-coloured sample is detected, the robot automatically initiates the transfer sequence.

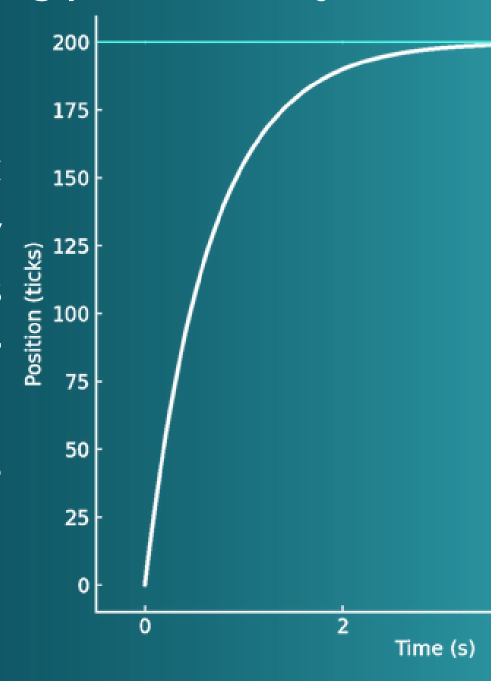
VISION-ASSISTED SAMPLE COLLECTION

Pressing a controller button activates Aim Assist, positioning the turret and extension above the detected sample to reduce driver input and accelerate intake.

Result: Reduced driver workload, eliminated human error, and maximized scoring efficiency throughout the entire TeleOp period.

PID CONTROLLERS

Problem: Motors can vary in their response due to battery voltage, friction, and load changes, causing poor accuracy.



Solution: PID Controllers

Proportional-Integral-Derivative Controllers (PID) are the core of FTC closed-loop control. Simply put, they help the robot maintain target positions by constantly adjusting the motor power level based on encoder feedback. Through PID control, motors can move precisely and reliably

Result: Consistent, precise motor control regardless of varying conditions.

CUSTOM FOLLOWER

Problem: Motion-planning libraries like RoadRunner, while accurate, prioritize time consistency over robot speed and lack customizability.

Solution: Custom PID-Based Follower

During the season, we made use of the RoadRunner 1.0 motion-planning library for our autonomous movement. RoadRunner, while accurate for most use cases, is not the fastest option available. To improve speed and allow for more customization, we developed a custom follower based on a PID-to-Point approach. This system uses three independent PID controllers to manage the robot's position along the x and y axes, as well as its heading angle.

Problem: Abrupt Movement Transitions

Even with adequate PID tuning, the robot stopped and accelerated way too abruptly. This resulted in jerky movement & wheel slippage at the start & end of paths.

Solution: Predictive Deceleration System

Implement a predictive deceleration system into our custom follower.

PREDICTING STOPPAGE DISTANCE

To avoid sudden braking and overshooting, we predict how far the robot would coast if it suddenly stopped applying power: This uses basic physics, applied separately to both axes. We then convert field-relative velocity into robot-relative, apply deceleration constants, then rotate the result back into field-centric.

Result: Smooth, predictable autonomous paths with reduced wheel slip and improved consistency.

BEZIER CURVES

A Bezier curve is a parametric curve defined by a set of control points. It allows for smooth motion. The robot's path & heading are influenced by the position of these points, allowing for greater control.

Problem: Moving along straight-line paths can be inefficient and time-consuming, especially when navigating between distant points on the field.

Solution: Bezier Curve Following

Sometimes it's faster & easier for the robot to move along a smooth curve rather than a series of straight lines (i.e., when going towards the submersible from the basket). We've implemented a Bezier Curve follower that allows our robot to follow curved paths. The follower calculates intermediate target points along the curve, resulting in more fluid and continuous movement.

Result: More efficient autonomous paths with smoother transitions and reduced travel time between key field positions.

HARDWARE

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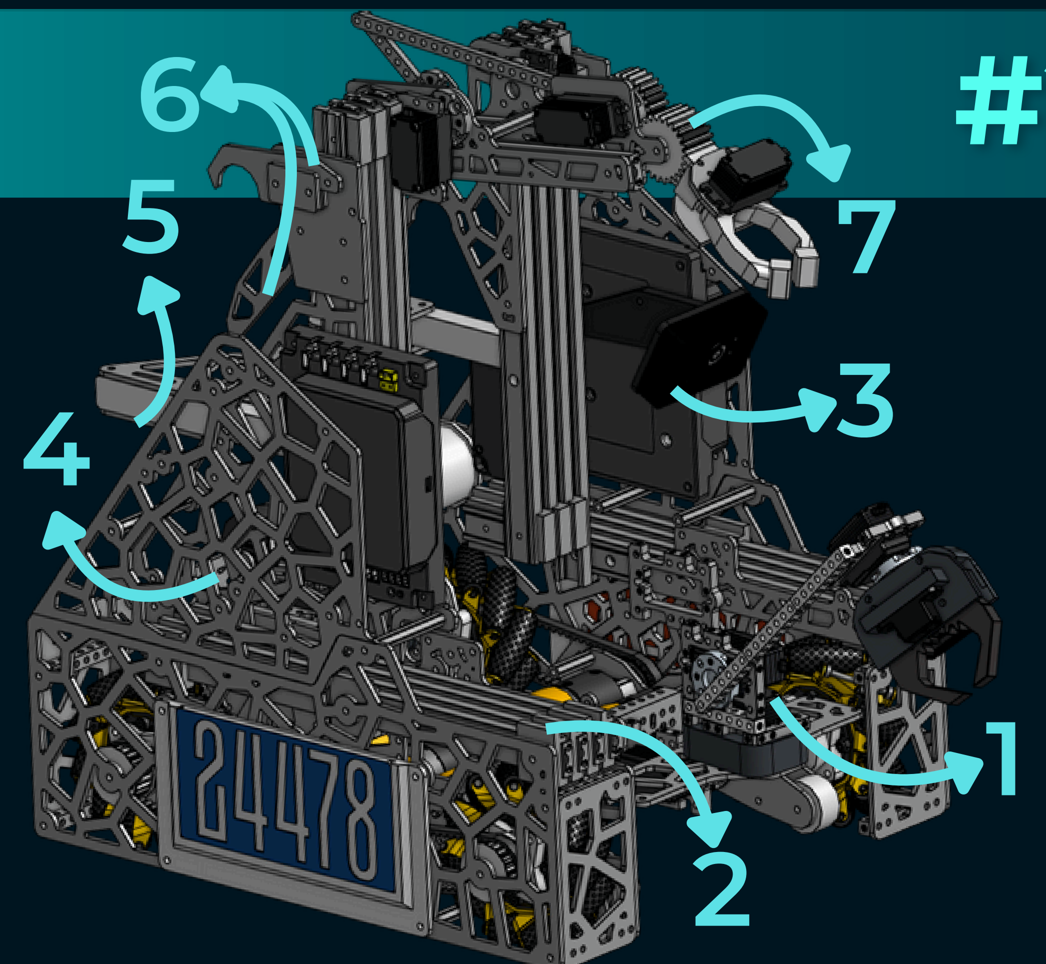
PRESENTING LUX

OUR SMARTEST, FASTEST, AND MOST RELIABLE ROBOT EVER.



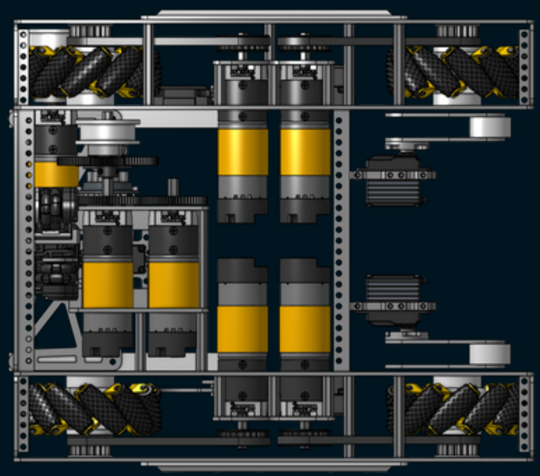
KEY ROBOT PARTS

1. Intake
2. Horizontal slides
3. Limelight 3A
4. Aluminium pocketing => reduce weight
5. Specimen orientor
6. Fixed hooks
7. Outtake

GOALS

- Reach a level 3 ascent
- Good cable management
- Consistent transfer process
- Absorb shocks during collisions
- Compact, as lightweight as possible (to gain more speed), and well-organized
- Resistant, fast, and reliable in actions
- Visually appealing design
- As simple as possible to program, remove points of failure
- Fast & reliable sample collecting & placement

DRIVETRAIN



GOING FASTER

Going from a 24:22 gear ratio to a 24:20 ratio, the new model reaches up to 549 RPM (from 509 RPM), although the risk of power loss still remains.

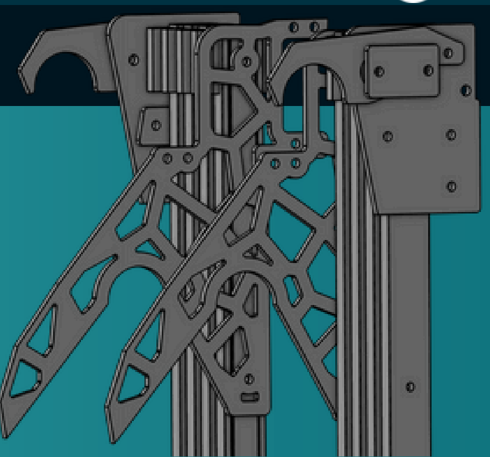
To ensure that the gear ratio was appropriate for the target speed of the drivetrain, we verified the gear ratio using the following calculation:

ASCENT SYSTEM

PROBLEMS ENCOUNTERED IN OUR ITERATIONS

- Two bare motors that power the slides / Metal Hooks, powered by Axon MAX+ servos: not enough power
- PTO: Having so many motors running at the same time caused our robot to have an abnormally high current draw.

SOLUTION = 3 MODULE SYSTEM

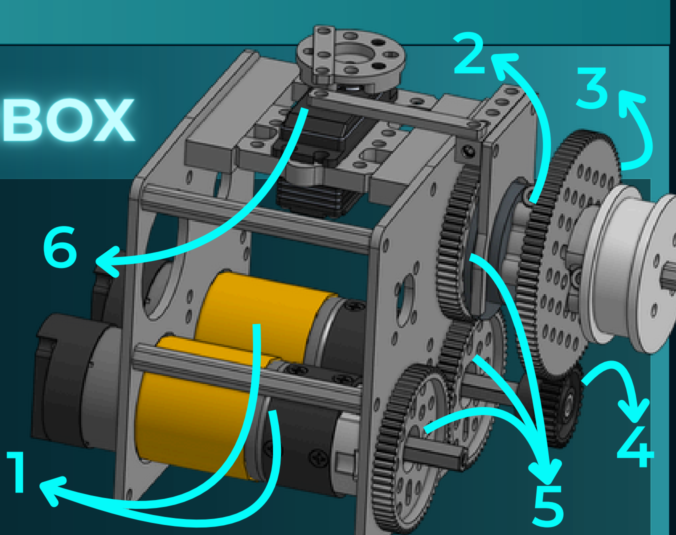


HOOKS

Small Hooks (Cord-Actioned) – These are fixed and positioned at the end of the vertical sliders. They can only move downward, allowing them to pass the first bar and release the larger hooks, which will complete the attachment to the second bar.

Large Hooks – Positioned on the last set of vertical sliders, they enable hooking onto the second bar. After the large hooks attach to the first bar, the small hooks take over the support of the robot on the first bar, allowing the large hooks to complete a level 3 hang.

DESIGN SPOTLIGHT - GEARBOX



KEY POINTS

1. x2 1150 RPM motors
2. Gear shifter
3. 100 tooth gear
4. 20 tooth gear
5. 60 tooth gears
6. Axon MINI+ that actuates the gear shifter through a linkage

We implemented a system that allows the motor input to switch between two different gear outputs. The first gear system, used for vertical extension, has a 1:1 ratio, maintaining the motors' original speed of 1150 RPM. The second system, used for ascent, features a 1:5 gear ratio, which significantly reduces speed but greatly increases torque.

Gobilda Yellow Jacket motor (1150 RPM) generates 7.9 kgf·cm =>

=> The linear slides have 7.9×2=15,8 kgf·cm

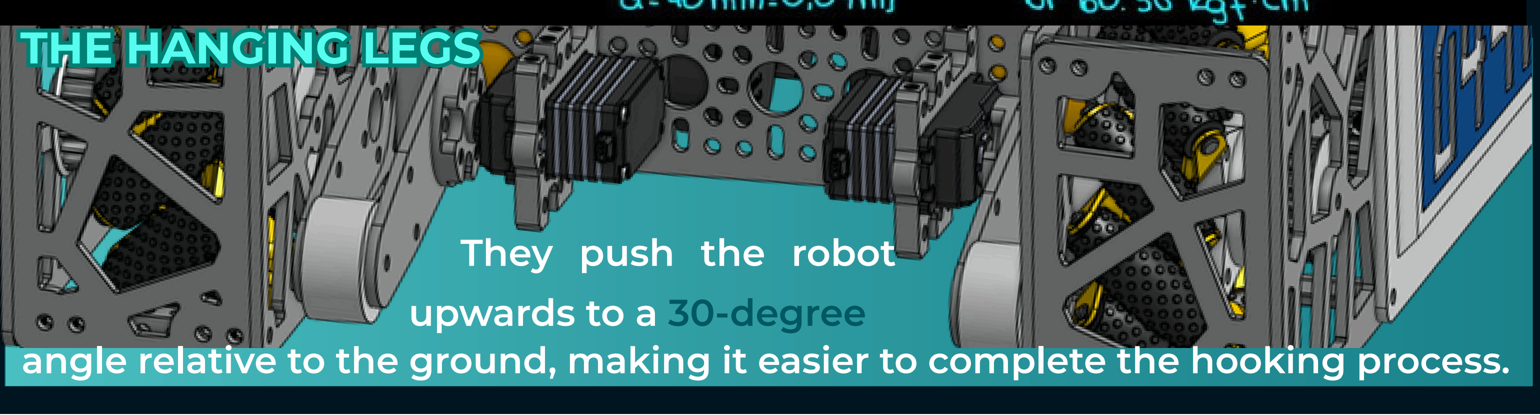
For 1:1 setting : 15,8 kgf·cm / 1150 RPM

For 4:1 Setting : 15,8×4=63,2 kgf·cm / $\frac{1150}{4}$ = 287.5 RPM

The torque needed to lift the robot (t) = Weight force (W) × Spool diameter (d)

$\left.\begin{array}{l} W = \text{robot mass} \times g = 15 \times 9{,}81 = 148.065\ N \\ d = 40\ mm = 0{,}04\ m \end{array}\right\} \Rightarrow t = 148.065 \times 0.04 = 5.922\ N\cdot m$ or 60.38 kgf·cm

THE HANGING LEGS



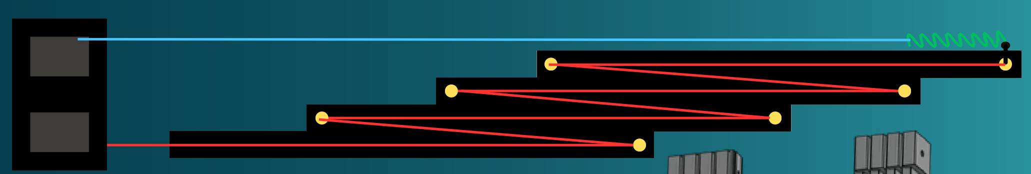
They push the robot upwards to a 30-degree angle relative to the ground, making it easier to complete the hooking process.

EXTENSION SYSTEMS

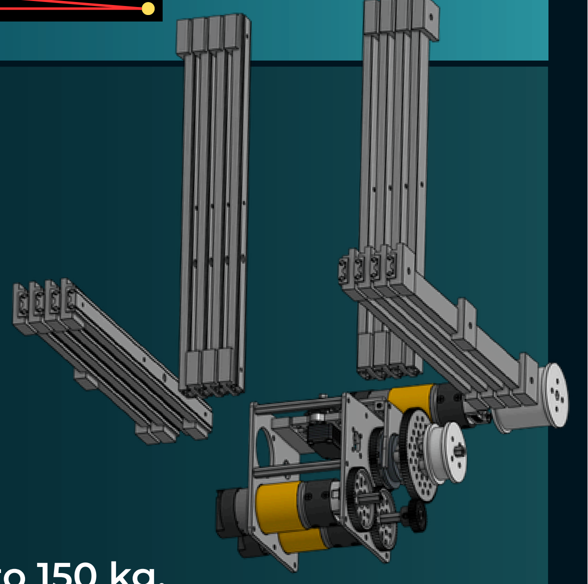
Goal: to achieve a fast and robust extension system that also doesn't occupy too much space between the plates.

HOW DO THEY WORK?

There is a double spool containing both the retraction string and the extension string. The retraction string stretches the spring attached to the last Misumi, while the extension string is pulled onto the spool and then through the pulleys in the inserts, causing the slides to extend. The slides extend in the opposite direction of the retraction process.



PROBLEMS & SOLUTIONS



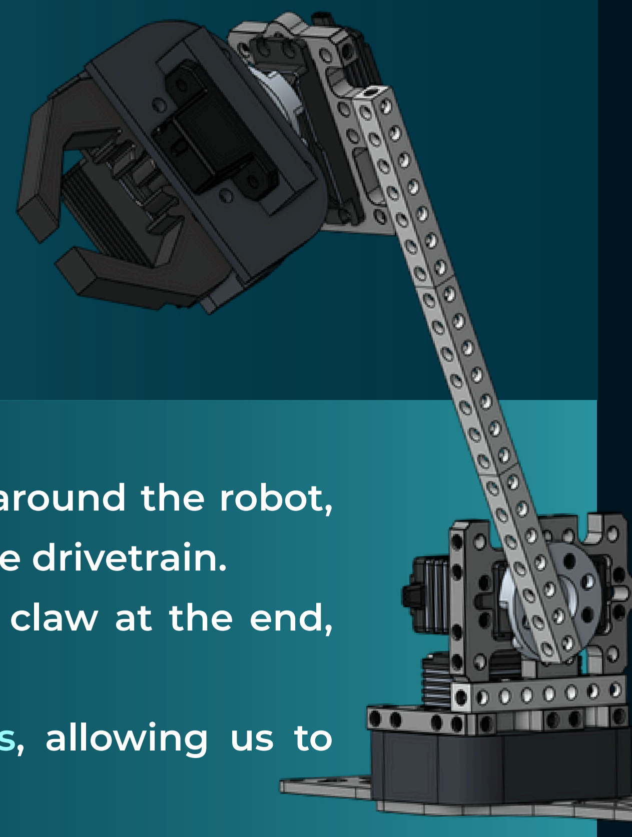
a) Metal Inserts:

To connect the slides, we use metal inserts instead of 3D-printed ones, as previous versions often broke under high pressure. The metal inserts offer significantly greater durability and reliability.

b) String:

Initially, we used a 1 mm fishing line rated for up to 150 kg, but it frequently snapped due to the stress placed on it during operation. To improve durability, we swiched to a stronger 0.9 mm string that supports up to 159 kg.

INTAKE



Goal: picking up samples & deliver them to the human player zone quickly and efficiently.

Problems encontered in the design process

- A fixed claw design = forced us to reposition the whole robot each time. => This would slow down cycle time and make scoring less consistent.

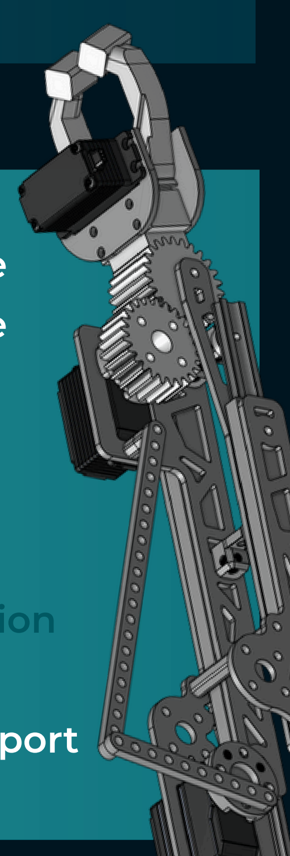
Solution: Pivoting turret claw system:

- The claw is mounted on a turret that rotates around the robot, giving us freedom of motion without moving the drivetrain.
- Attached to the turret is a 10 cm arm with a claw at the end, used to grab samples.
- Once a sample is secured, the turret rotates, allowing us to place it directly into the human player zone.

Result:

- Efficiency: We can rotate instead of driving, saving time.
- Precision: The turret allows accurate placement without constant robot repositioning.

OUTTAKE



How does it work?

- Two Misumi SAR220 slides, placed on a metal support, with the claw attached on top through a quad block. The slides were moved by a linkage-type mechanism.
- Gear system that connects the slides to the claw support.

Key Points:

- Much more efficient system => arm extends based on the task
- The claw's rectangular tip => hook specimens from any orientation
- Reduced the need for such high dexterity from the drivers.
- Enhances the outtake's functionality by making the claw support => much more consistent transfer process.