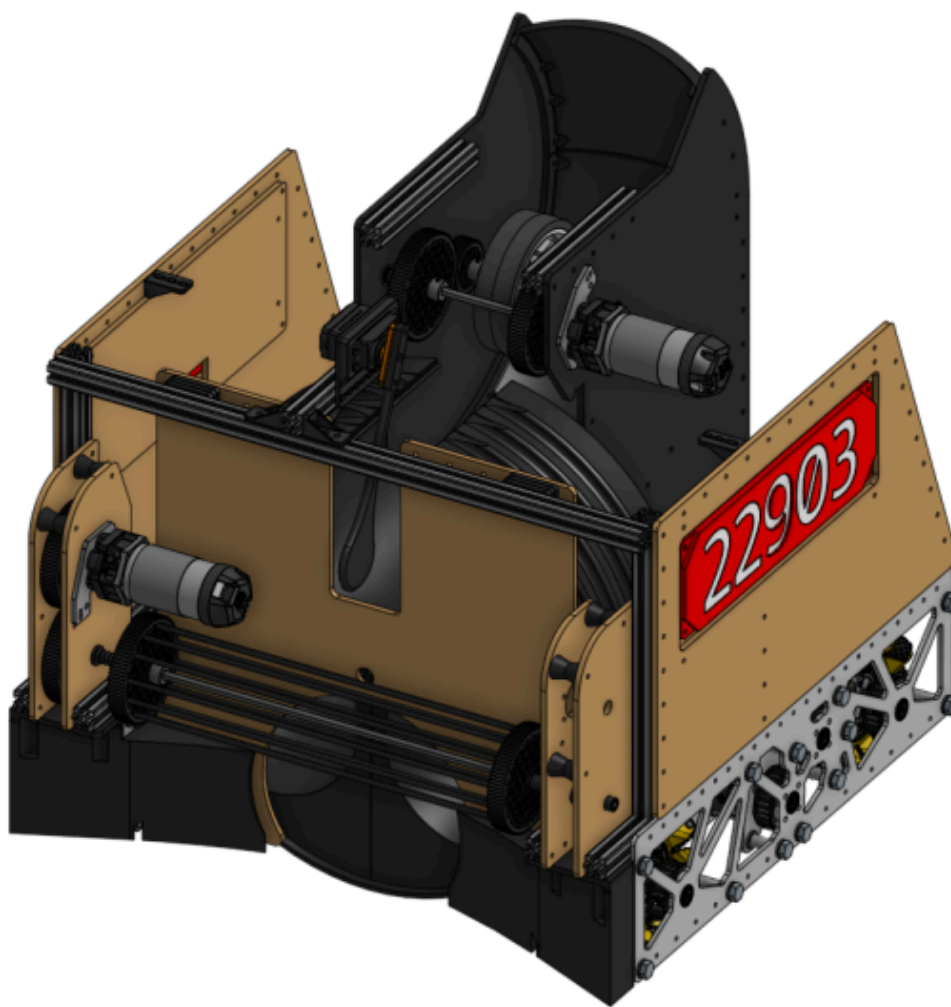


#22903 VegaMind

*"The Automaton"*  
Robot Portfolio



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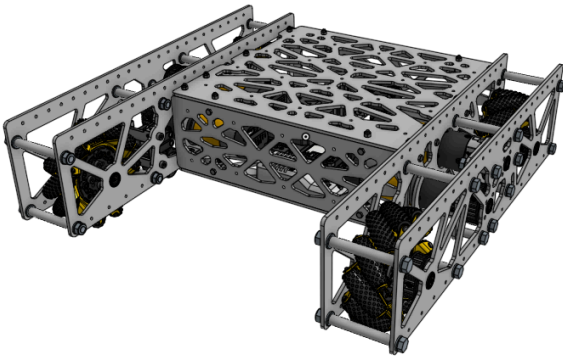
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## About Us

We, **#22903 VegaMind**, are a team from a small European country called **Slovenia**. We are the “**senior**” team of the two teams that we, as **FIRST Slovenia**, are split into. Our team consists of a couple of high school students who are dedicated to sharing and bringing **STEAM** to the youth.

The other team is our “**sister**” team, **#28080 VegaTech**, with whom we love to do FTC and other projects. We usually join forces for the FGC season, but split up again for the FTC season.

# Design Timeline



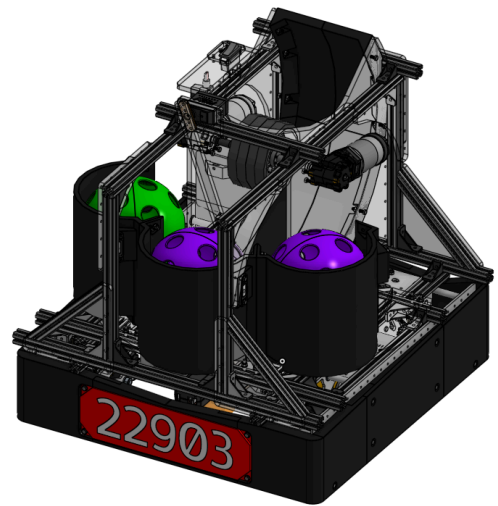
## RI3D (Robot In Three Days)

At the start of this season, we participated in the RI3D challenge, during which we created our **drivetrain** and a conceptual **shooter** capable of manually launching artifacts. The drivetrain was adapted as a part of our **Project Strand** (A project that aims to standardise robot parts for FTC). We have also decided we will use an **iterative design process** (as written in the “*Design Flow*” Section of this Chapter).

## Pre-Oberkochen

The Pre-Oberkochen period took place during the time we spent designing our robot before participating in the **Oberkochen Scrimmage**.

The robot design in this period was much more basic and lacked an intake. Due to our failure in designing a suitable intake, we made a design that used **three separate storage compartments**, mounted on a **rotating platter**, which was able to move and position the correct compartment in front of the **shooter**. Making use of **gravity**, the shooter would unblock the path, allowing the **artifact** to roll into the shooter and launch it.



This design was sound on paper, but had critical flaws. First, due to the lack of an intake, it **relied on a human player**. Second, the artifacts we were using to test the robot were **not standard** and were a few hundred **microns too big**. As a result, the actual artifacts we got at the scrimmage **failed to launch**. We tried compensating with scotch tape, but the root issue wasn't fixed, and the **shooter worked unreliably**.

## Post-Oberkochen

After the Oberkochen failure, we performed a deep analysis of what we did right and what we did wrong. As a result, we learned a lot of lessons from our mistakes and made many improvements, as detailed in the chapter “*Robot Design*”.

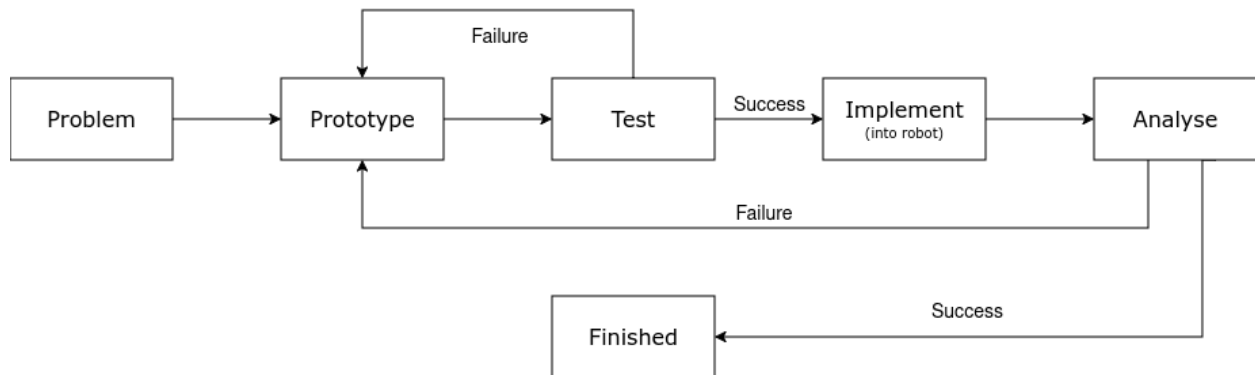
We **identified** the following issues that contributed to our failure in Oberkochen that we **addressed** in our new design:

- Do **not** rely on a human player. This adds extra complexity to the game and allows for less time for **scoring artifacts**.
- Do **not** rely on gravity to score artifacts. Our Oberkochen design relied on it to pull the artifacts into the shooter, and as such, made it prone to fire failures, misfeeds and just not falling into the shooter. This hindered our scoring significantly
- If at all possible, do **not** use 3D-printed artifacts to test a robot. 3D printing, although very accurate, still produces microtolerances that can make weeks of designing and calibration for naught. Use **official** artifact samples.
- Use a **flywheel** on the shooter. A flywheel allows you to **store inertia**, making the shooter **much more powerful**.

Armed with this new knowledge, we decided to **scrap** a majority of our Pre-Oberkochen design and start anew.

## Design Flow

Our robot development follows an **iterative engineering design cycle**, where mechanisms are prototyped, tested, and improved until reliable performance is achieved. Failures are analysed and fed back into the design stage, allowing us to refine systems before final implementation rapidly.



# Robot Design

## Introduction

This design for our robot, nicknamed “*The Automaton*”, was engineered to address the shortcomings of the **Pre-Oberkochen** design, detailed in the chapter “*Lessons Learned*”. This design was made by keeping the **functional drivetrain** (modular by design) and **completely redesigning** the **entire** top part of the robot.

A major decision we made was to **scrap the electronics compartment** and **widen the drivetrain**. Although it **forced** us to **remove** the previously mounted **servo hub**, this decision allowed us to fit a new **vertical spindexer**, basing our design around it. Additionally, widening our drivetrain also **improved** our robot’s **stability**.

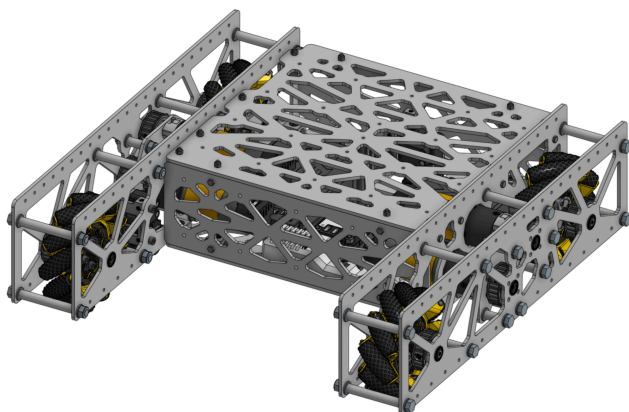
## Project Strand

Project Strand is an effort made by our organisation to **standardise** as many **parts** of the robot as we can. It is fully **free** and **open-source**. Standardised parts are fully modular and may be reused by other designs in the future. This project is an ongoing effort by **both VegaMind and VegaTech** to enable any team to reuse existing and working designs that are compatible with their own designs, due to its modular nature.

Project Strand **reduces rebuild time** for existing robots and **reduces** the “**boilerplate**” period of every season (time spent building repetitive and non-changing modules).

## The Drivetrain (“Gestell”)

As part of our **Project Strand**, the Drivetrain was **our biggest innovation** during this season. Designed by our now-alumni member, in cooperation with our sister team, the Drivetrain



features a **fully-standardised** and **modular** design.

We opted for a **fully laser-cut aluminium chassis**, using the **goBILDA** system of **Mecanum Wheels, Motors and Odometry Pods** (modifying it to **use any other system** is **still possible**).

The Odometry System is used to **allow exact pinpointing** of the robot’s position **at all times**.

Additionally, we implemented a **servo power module** into our Drivetrain,

since we had noticed a lack of speed and power in the servos during our previous seasons. This change **boosted our servo power dramatically**.

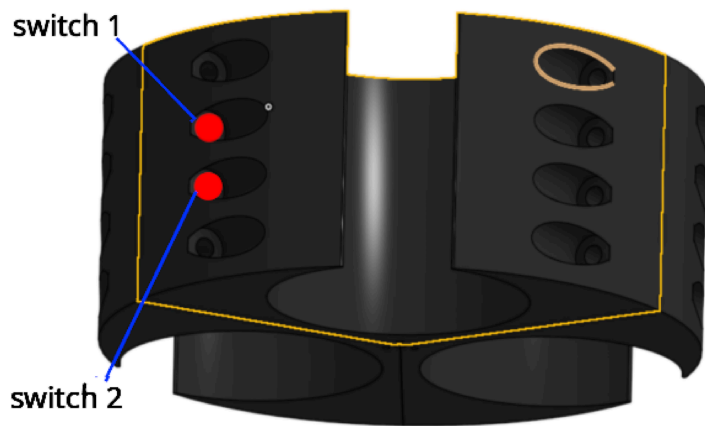
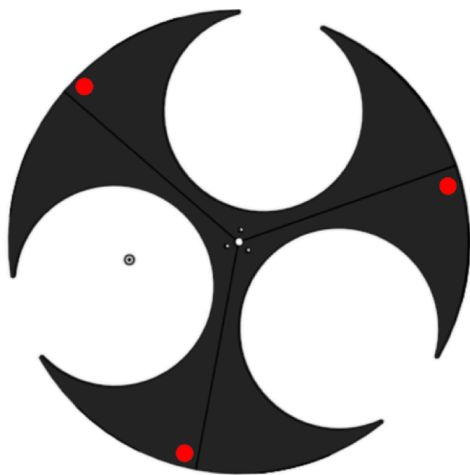
The choice of chassis material mostly landed on cost and strength, and aluminium seemed to be a good **middle ground**.

To prevent scratching and absorb shocks, we designed a simple **bumper system** with screw-in license plate slots. The bumpers are **3D printed**, as it allows us to quickly prototype, and the weakness of the bumpers allows them to absorb more energy into themselves instead of transferring it onto the Drivetrain, thus protecting it further.



## Storage / Magazine

Our storage system (the “**Magazine**”) is designed as a **vertical revolving spindexer**, and allows us to store all three artifacts **simultaneously** and deposit them to the **upper shooter**. The spindexer is powered by an **Ultraplanetary motor**, connected via a **chain drive**. Due to the motor’s slack and mechanical imprecision of the attached gearboxes, we opted to **use magnets** (see image) and **limit switches** to track the spindexer’s position, along with an **attached encoder** to measure motor steps and **eliminate slack**.



*Magnet position indicated by red dots*

The spindexer has **six valid positions** (three at the bottom and three at the top), and these positions **mount these magnets**. **Magnetic limit switches** detect these magnets passing, and combined with an externally mounted **encoder**, we always **know** if our **position** is **valid**.

The magnetic switches have become more of a **redundancy**, as the introduction of the external encoder proved to solve all of our problems. Now they serve more of a fallback role.

However, we still weighed the pros and cons of each approach:

	Magnetic Limit Switch	External Encoder
Pros	<ul style="list-style-type: none"> <li>- Reliable</li> <li>- Quick trigger</li> <li>- Absolute</li> </ul>	<ul style="list-style-type: none"> <li>- Accurate</li> <li>- Position known at all times</li> </ul>
Cons	<ul style="list-style-type: none"> <li>- High tolerance range</li> <li>- Requires more calibration to find bounds</li> </ul>	<ul style="list-style-type: none"> <li>- They are not absolute → the magazine must be aligned before each startup for the position to be known</li> <li>- Takes up space</li> </ul>

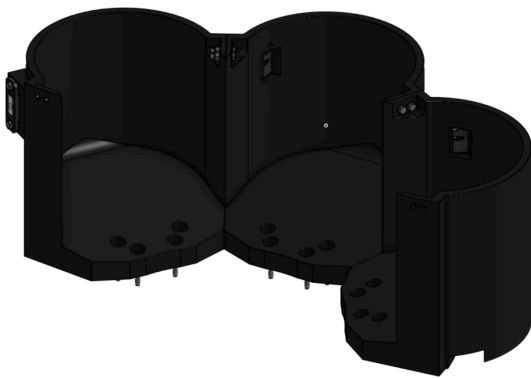
Implementing a **hybrid system** ended up being the best for our use case, using the **external encoder** as our **main** pinpointing system and the **magnetic limit switches** to quickly detect the rough position of our Magazine if the encoder is unavailable.

An **integrated camera** at the bottom of the spindexer (opposite to the intake) allows us to **keep track** of the colour of the artifacts in **each slot** (with testing it has been shown that the colour sensor has subpar reliability).

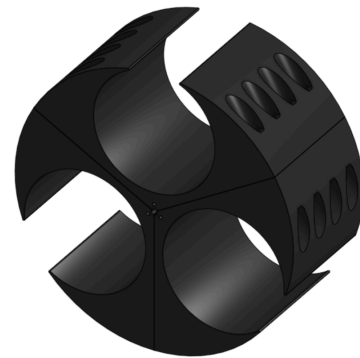
A gear ratio of **1 : 25** on the motor allows quick-response movements of the spindexer, while our **sensors and encoders** ensure mechanical precision.

The Magazine is a **simple and elegant** solution that balances **speed, precision**, and, with the combined software, **shoots correct colour patterns** as defined by the Obelisk.

This design was **massively modified** from our Pre-Oberkochen design of revolving compartments, as seen below (“Before” on Left, “Current” on Right).



*Revolving Compartment Design*



*Magazine Design*

## Shooter

Our Shooter features a **Rubber Flywheel-based** design, with an added **machined steel disc** for **extra inertia**. Although this requires more time for windup/winddown, it was a **necessary tradeoff** for gaining **more inertia dramatically, increasing output power**. We can calculate the inertia as such:

$$I = \frac{1}{2}mR^2 = \frac{187g \times (3.55cm)^2}{2} = 1178.33g \cdot cm^2$$

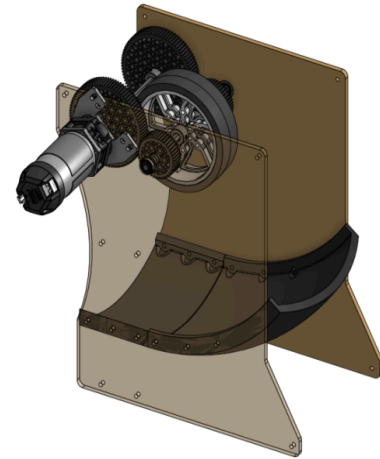
It contains an **upward ramp** and a **fast-spinning launch flywheel** (REV's 90mm Grip Wheel).

The weight of the machined disc was determined through **experimental analysis**. We tried shooting the artifacts with different weights attached and measured their distance. We then **plotted** the data on a **graph** and interpolated the optimal weight between the data points. This method proved to be **successful** as our shooter can reach farther than before.

To use the shooter, it must first reach the **required RPM** (which we measured as ~3100 RPM), which takes a couple of seconds. Once the Magazine is **aligned with the ramp**, we can use the **Servo Stick** that's mounted to the Shooter (see image) to **push the artifact** out of the Magazine and onto the ramp. The artifact then rolls down the ramp towards the Flywheel, where the Flywheel then **transfers** its **rotational energy** onto the artifact, launching it out of the ramp into the air.

The motor has an attached **3 : 1 gearbox**, while the transfer gears have a ratio of **1 : 2**, totalling a ratio of **3 : 2**. This achieves a **theoretical speed of ~4000 RPM**, although the actual realised speed is lower.

The Shooter system is **simple** and can be **disassembled** and **integrated** into **other designs** with relative ease. We iterated through many different ramp lengths and angles but settled on a 55-degree incline, which provided the **optimal** ratio between **altitude gain** and **distance**.



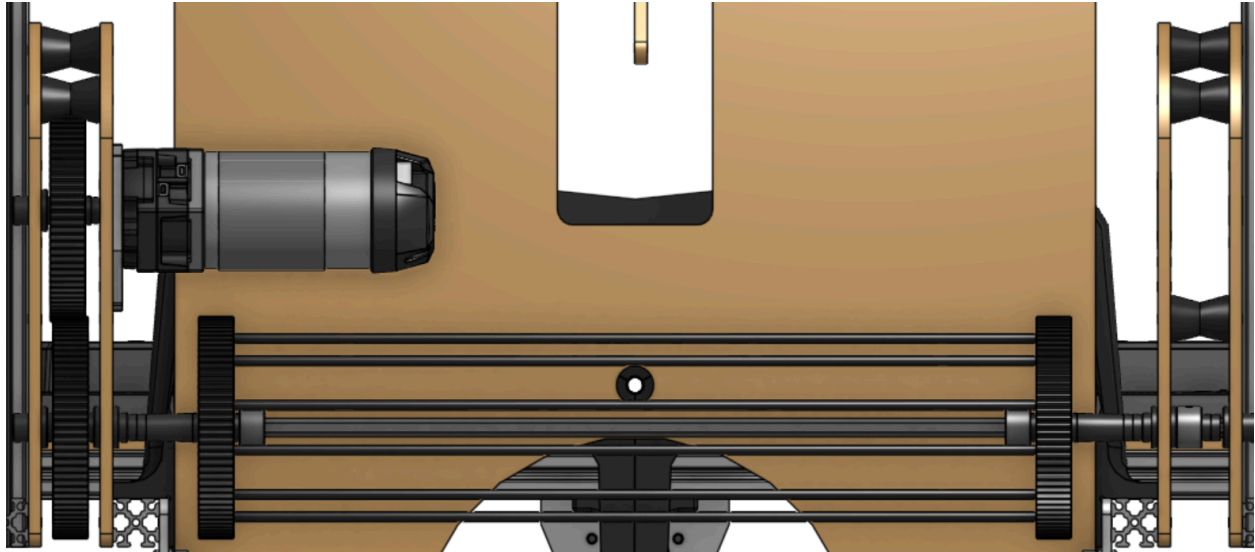
## Intake

The Intake for this season is an **Artifact Intake Roller** (see image on next page) mechanism that uses **spinning rubber tubes** to grab and push artifacts into the **Magazine**. We iterated and tested many designs for the Intake, and we landed on this design, since it provided the best results.

The core part is a sequence of **two gears**, with **tied rubber tubes** under tension. It spins towards the Magazine and makes use of **friction** to manipulate the artifacts.

It uses the standard **Ultraplanetary motor** with a **3 : 1** gear ratio. Size constraints forced us to seat the motor **on top** and use a **1 : 1 gear transfer**. It spins fast since we don't need high torque to drive it.

As such, it is a **simple part**, with relatively **few moving parts**, which can be **easily swapped** for alternative options and can be **adapted for other robot designs**.



# Software

## VSCF – The Visual Spectrum Communication Framework

**VSCF (Visual Spectrum Communication Framework)** is an **experimental robot-to-robot communication system currently undergoing field validation**. The system enables **wireless data exchange using visible or infrared light**, allowing communication **without using radio channels**, and therefore **remaining fully FTC-rules compliant** (confirmed on the FTC Q&A forums).

Each robot is equipped with a **camera and a visible LED matrix display**. The display transmits **encoded data packets using light**, while the partner robot's camera detects and decodes the information.

Data is transmitted using **QR-encoded packets**, chosen for their **high error tolerance and resilience in noisy visual environments**. Initial testing shows **reliable identification of transmitted data even under variable lighting conditions and match-level visual noise**.

While the system is still under development, the **proof-of-concept has been successfully demonstrated**, and we are continuing **field testing and refinement during competition practice**.

## Potential Applications

The system enables several forms of **cooperative robot coordination**, including:

- **Artifact sequence communication** between alliance robots
- **Robot position sharing** for safer and more efficient path planning
- **Inter-robot coordination**, reducing interference during scoring cycles
- **Coopertition strategies**, enabling non-allied robots to avoid path conflicts

By leveraging **machine vision and optical communication**, VSCF explores **an alternative coordination channel that does not rely on traditional wireless protocols**.

## Machine Vision

To maximise autonomous performance, we implemented a **machine-vision system for real-time artifact detection and field awareness**.

Using **OpenCV**, we developed a pipeline that performs **colour filtering and noise smoothing** to detect **purple and green artifacts**. For performance reasons, the system **alternates between colour detection passes**, allowing us to maintain a **stable refresh rate without sacrificing detection reliability**.

Once an artifact is detected, the system calculates its **precise position on the field**. This is done by combining:

- The **robot's odometry-derived position**
- The **camera's orientation and mounting geometry**
- **Lens distortion calibration**

Using these parameters, we compute the ray projection from the camera to the detected artifact, allowing the robot to map artifact locations onto an internal field model.

By continuously scanning the field, the robot maintains a **dynamic artifact map**, which enables:

- **Adaptive autonomous path planning**
- **Efficient artifact collection**
- **Real-time adjustment to changing field conditions**

Machine vision is also used to **read the Obelisk April Tag**, which determines the required artifact stacking sequence. Once the correct tag has been detected and validated, the **AprilTag pipeline is disabled to reduce computational load**, allowing the robot to prioritise artifact detection during the remainder of the match.

This system enables the robot to **transition from purely scripted autonomous routines to a perception-driven strategy**, allowing it to **adapt dynamically to the state of the game field**.

## Autonomous

The Autonomous is split into two algorithms: The **Red** Autonomous and the **Blue** Autonomous (depending on the alliance you're playing as). The algorithm uses **Machine Vision-based Pathfinding** combined with **Static Positioning** to navigate the field.

The Autonomous sequence defines **4 preset** positions, the **Shooting Position** and **3 Scouting Positions**. Shooting and other processes are done similarly to the processes defined in the bottom "**TeleOp**" section. It follows a sequence as such:

1. Read the **April Tag** on the **Obelisk**
2. Go to the **Shooting Position** and shoot every artifact in the **preload** (by alternating the magazine according to the read **pattern**)
3. Move to **Scouting Position 1** and detect the closest artifact row
4. Move to said artifact row and pick them up with the intake, and by rotating the magazine
5. Move to the **Shooting Position** and shoot out the loaded artifacts
6. **JUMP TO STEP 3** (Scouting Position 2 and 3 respectively) **AND REPEAT**
7. Finish by moving out of the **Launch Zone**.

## TeleOp

Even during the manual operation of the robot, we try to utilise **machine vision** as much as possible. During high-stress games, when there are a lot of things happening, drivers often make mistakes.

To mitigate that and **alleviate** the driver's **mental load**, we try to operate the robot as autonomously as possible, even during the manual phase of the match. We do this by having the driver input **macros** telling the robot what it should do. Essentially, the driver can give the robot an input to take the most optimal path and collect the artifacts or go into a shooting position and dispense the artifacts.

We also have a **manual override**, which can be triggered either by the driver or by the robot automatically if it detects an obstruction to **ensure the safety** of all the participants and their robots. The manual override immediately stops the robot and gives the full explicit control to the drivers to handle the interruption as they see fit.

## Processes

All of the **software components** are split up into **separate processes**. After testing, we decided to ensure **minimal latency** for each component (examples of a component being a shooter, the magazine, vision manager, etc.) by putting them into **separate threads**.

**Multithreading** allows us to process multiple things in parallel and **drop latency** by a **margin of several times over** compared to our previous single-threaded architecture. This also allows us to push many more **concurrent tasks** at once, without sacrificing latency and performance.

This allows for better **robustness**, as if any part fails, it can simply be restarted and handled appropriately **without disrupting** other components. It also forces the entire system to have a more **modular** design. All in all, it improves the **reaction speed** of our robot greatly, allowing for more complex processing (better yielding pathfinding, more frequent **camera pipeline** activation, etc. ).

## Magazine

The Magazine is controlled by a **PID Drive** and a **Magnet Sensor system**. The Magazine employs **switching controls**, which allow the player to **switch between pre-set positions** easily. These **six positions** are defined to perfectly position the Magazine into the correct **Intake feed points** and the **Shooter ejection points**.

By keeping **track** of which **colour** is fed into the Magazine by the Intake with a **camera** (either in **Autonomous or Manual**), we can also ensure that we feed the Shooter with the **correct colour pattern**, as denoted by the **Obelisk April Tag**.

## Shooter

The Shooter uses a **state machine** to follow a simple series of steps, as described below in the list:

- Spin up the Flywheel (Spindex)
- Nudge the artifact with a servo motor
- Spin down the Flywheel (Spindex)

While simple in theory, it carries a bit of nuance. First, we **can't rely on the player** to determine the appropriate speed of the **Shooter Flywheel**. We fix this by **tracking the approximate speed**, counting the encoder steps, and time passed. Not only does this allow us to calculate the RPM, but it also allows us to **change it on the fly**. As we know the robot's relative

position to the baskets, we can use this position to change our target RPM, so that the artifact will reach the baskets.

To avoid wasting time between shots, we have a **wait period** before spinning down the Flywheel, as immediately doing so would cause **wasted time** for sequential shots.

## Intake

The Intake code is written to be very efficient. We move the Magazine to a **valid position** for intaking an artifact, **spin the Intake** and **push an artifact** into the Magazine.

The Intake motor can be spun up and down **as needed** with a **toggle switch**. We also have a "**safety servo**" that blocks the intake when it's not actively used, so artifacts that don't fall out or block the spindexter from spinning.

## Drivetrain

Due to our use of **Mecanum Wheels**, we have a lot of freedom with our movement. For our movement, we use the **Pedro Pathing TeleOp Drive**, allowing us to **continuously track** the robot's **position**, without adding any extra expensive computation from processing **April Tags**. We also have the aforementioned distance sensors mounted on the side of it, **preventing** any accidental **collisions**, only stopping in the case of an **unexpected** obstacle. Because we know the field layout, we can differentiate between preset elements and actual obstacles that are in our way.

# Social Media and Outreach

This year was fueled by further and consistent growth. Our Instagram account **grew ~30%**, with our older and **shared “FIRST Slovenia”** account **gaining ~25%**. We have driven to become more well-known and grow as a team to expand the FTC/*FIRST* scene in Slovenia.

As members of **FIRST Slovenia**, we also **represent FIRST** and **FTC** at **FLL** tournaments with over **200+ attendees**, where we **advertise and promote** our teams to middle schoolers and high schoolers alike. Our team was present at **two regional competitions** and **one national competition**, where we allowed people to **pilot** our robots and presented them with how the robots work.

Additionally, we had a stand at the **MOS Fair**, an event **known** and **anticipated country-wide**, with some of the **biggest firms** presenting themselves there, where we advertised the FTC and FGC competitions and the *FIRST* scene as a whole.

Similarly, we also presented our team at our high school **technology fair**, successfully recruiting new people. We take steps to **train** our **new** and **old** team members to get comfortable by using their **existing skills** or by **growing new skills** (e.g. software development, hardware design, laser cutting, teaching 3D printing, etc.). Our goal is to ensure every member of our organisation learns **new** and **valuable** skills and that everyone is kept up to date on the **newest technologies**, and for that, we host lessons for our members on laser-cutting, 3D-printing and other **useful skills**. With our sessions, **we have grown our teams by ~30%**.

Our efforts have brought us to win the **1st Place Control Award** in Stuttgart 2026, for extensive use of **sensors** and **detection technology** in our robot, automating many elements of operation on our robot.

All of our **mentors** are **alumni** team members, so there is always someone willing to help, as they want to keep **participating** and **engaging** with *FIRST*, as some of them are even **FIRST volunteers**. We make sure to keep the tasks that the newer members are assigned proportional to their skills, so they never feel overwhelmed while still challenging them, allowing a **clear progression of skills and abilities**.

The mentors step in when needed/asked for help, **allowing** us to **progress** when we are stuck, but also give us breathing room to **innovate** and **plan** on our own. We also make sure to set **clear milestones**. Each fully completed iteration of the robot has to be done a week before each scrimmage, and we use a task board (Trello) to track and manage all the specific deadlines.

Our general goal is to **grow our presence** in Slovenia and get even more people interested in *FIRST* and robotics / STEAM in general. As such, our **current goal** is to grow FTC in Slovenia to the point where we can **host our own FTC tournament** domestically and invite foreign teams to join us. This way, we can not only grow domestic presence but also **global awareness of FIRST**.

Our mission to **grow FIRST in Slovenia** has led us to the idea of starting a “New Team Starter-Kit” where, with **Sponsorship**, we allow **new teams to get curated starter kits for lower prices** and allow them to enter the world of *FIRST*. Additionally, with our **mentoring process**, we, *FIRST* Slovenia, as seasoned members, can provide **guides and resources to new teams**.

# Financial Sustainability and Sponsors

Financial sustainability is a big part of our planning, especially since our long-term goal is to **expand** our presence **country-wide** with the assistance of a **government grant**.

As such, we **seek sponsors** and **financial backing** for our seasons aggressively, with the **Mentors** helping with the **management of funds**, while we try to **budget, spend efficiently**, and **reuse** as many components as we can, without compromising quality, from previous seasons. Additionally, we also make **extensive use of 3D Printing technology**, as it allows **rapid** and **inexpensive** prototyping.

As such, we have seasonal **budget plans** to try to **minimise unpredictable spending**. We also try to **acquire sponsors** that can **help** us more **directly**, for example, Plastika Trček is able to provide us with free 3D printing filament instead of financially supporting us, saving everyone money.

Another way we entice sponsors is by doing custom projects for them. For instance, we built a custom drawing robot (Project "Pajk"; eng. "Spider") for a custom apparel shop, strengthening our relationship and spreading our team by word of mouth. This also helps the sponsors feel like they are investing in something great and makes them feel like we also appreciate them.

Additionally, we would like to thank all of our sponsors for supporting us and allowing us to compete. In order of appearance, top-to-bottom, left-to-right:

- Vegova Ljubljana
- Zavod 404 / Institute 404
- Zavarovalnica Triglav d. d.
- MOL
- Delavska hranilnica d. d.
- Plastika Trček d. o. o.
- 1Home Solutions GmbH



ELEKTROTEHNIŠKO-RAČUNALNIŠKA  
STROKOVNA ŠOLA IN GIMNAZIJA  
LJUBLJANA



Mestna občina  
Ljubljana

