Hyperloop: VEX in the Real World

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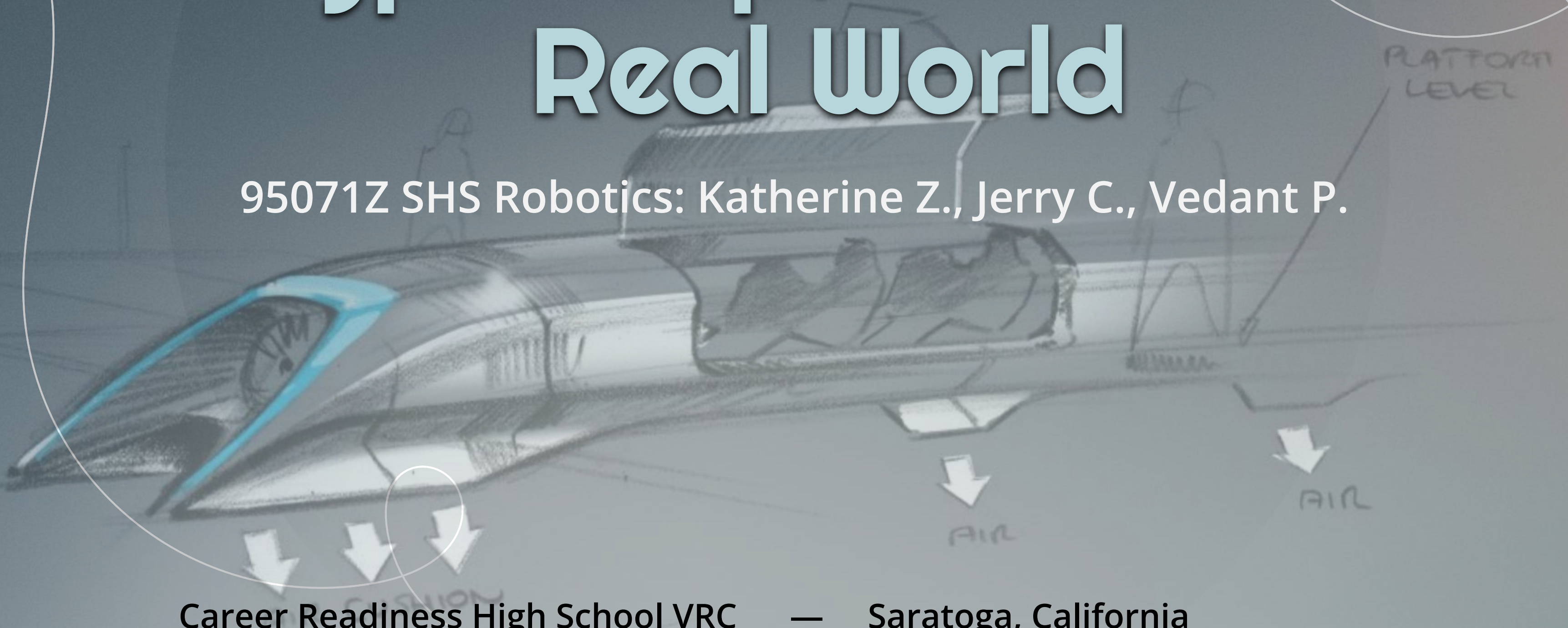

Career Readiness High School VRC — Saratoga, California

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Why Hyperloop?

"I think life on Earth is more about solving problems…It's got to be inspiring, even if it's vicarious"

—Elon Musk

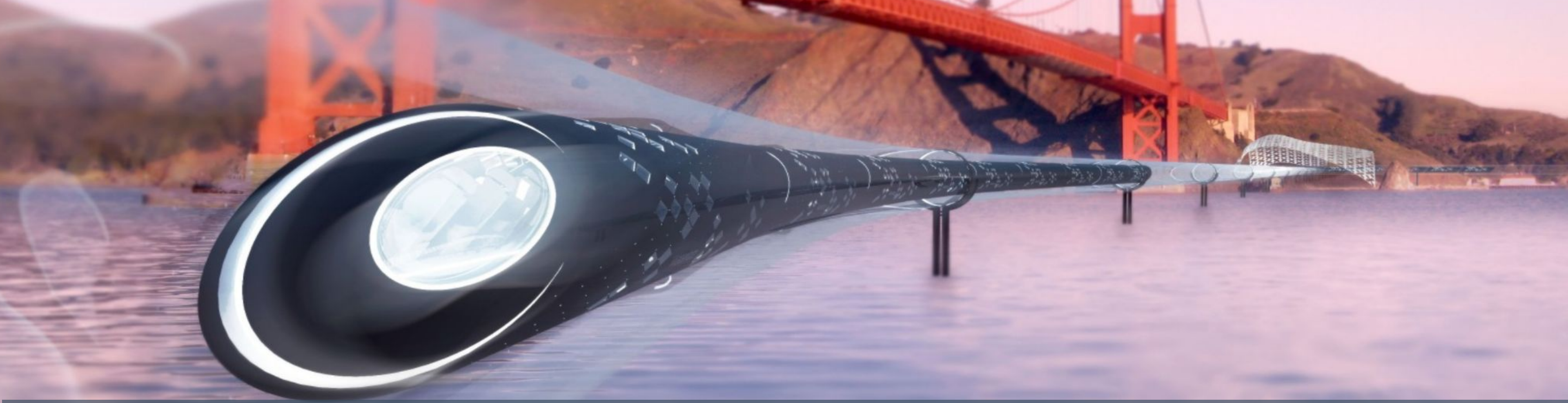


Figure 1: Waterloop, a competition organization in the Hyperloop competitions

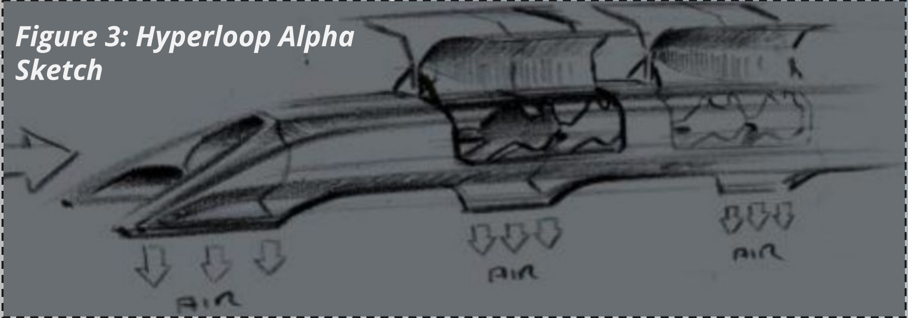
Hyperloop

- **Hyperloop** is a proposed **high-speed transportation system** for people and goods.
- In 2012, Tesla and SpaceX founder and CEO **Elon Musk** revealed the idea of hyperloop.
- In 2008, California High-speed Rails were approved for construction, but Musk grew **disappointed in current transportation technology**.
- In turn, he proposed an alternate design to **shorten hours of travel into mere minutes—Hyperloop.**
- We recently had an opportunity to interview one of Elon Musk's subordinates, **Besei Song**, about the processes Hyperloop workers go through and how it relates to VEX as a whole.

Figure 2: Elon Musk

In the original design, Musk proposed elevating a **pod** (or capsule in a tube), using **low-pressure air to move the pod** and having a **cushion of air** at the bottom of the tube for **support**. These air bearings are **controlled with aerodynamic lift** and a compressed air reservoir, similar to those used in VEX.

Figure 3: Hyperloop Alpha Sketch



The tube itself would be made of steel and supported by pylons. **Solar arrays** would cover the top of the tube so the system's **self-powering** and **ecosystem-friendly**.

Figure 4: Energy Production Graph

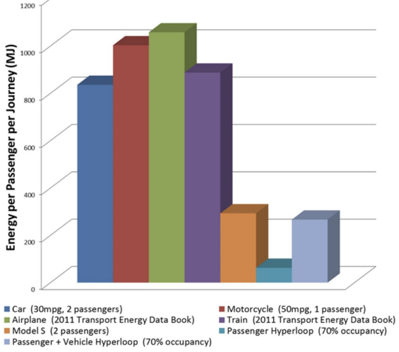
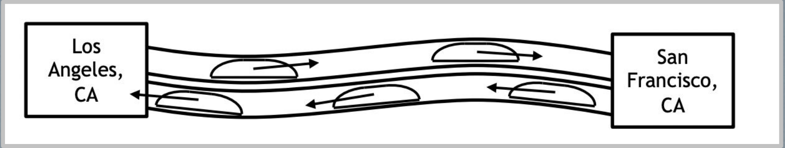


Figure 5: L.A. to S.F. Route



However, there were **many issues** to this design, such as **overcoming the Kantrowitz limit** or the ratio limit of pod to open space. Methods to overcome air resistance were also modeled, as this is the **most expensive** and requires the **most power** in the whole system. The **speeds** of the hyperloop train also needs to be adjusted to its location between cities. For example, Los Angeles and San Francisco are two highly-populated cities that requires winding trails to navigate through. In a Hyperloop capsule, passengers should feel comfort and no sudden movements, so many factors would be adjusted in each turn to account for this.

In the end, Musk decided that it would be **too difficult to complete** a design as ambitious as the Hyperloop train. Instead, he encouraged engineers around the world to innovate a promising solution.

Why Hyperloop?

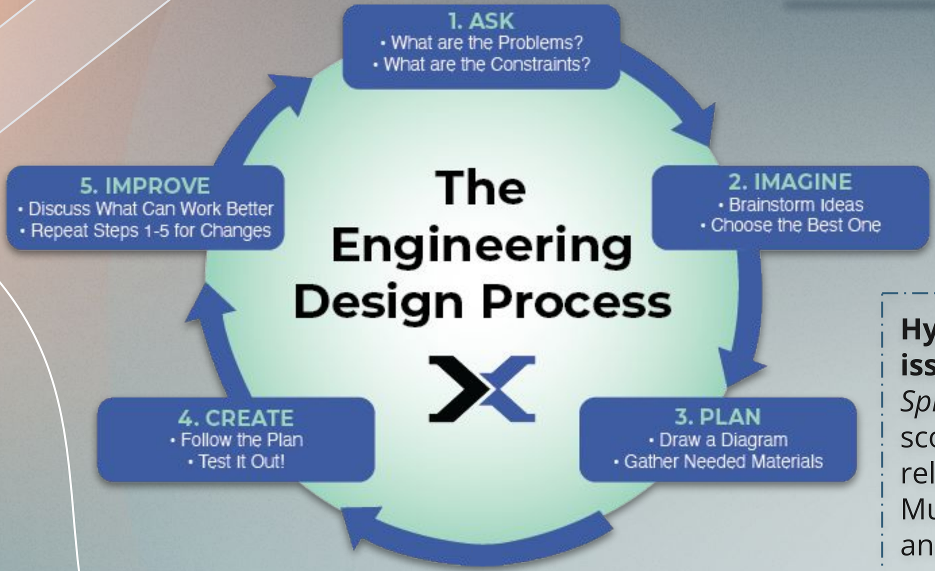


Figure 6: Design Process

Hyperloop is very similar to VEX, as there are **issues awaiting to be solved**. In VRC's 2022-2023 *Spin Up,* teams are tasked to tackle a problem of scoring the most points in any way. Hyperloop relates this factor into the real world when Elon Musk introduced an new era of travel to ambitious and curious engineers. These **engineers** face many of the same problems we do, and their way of **problem solving are almost identical to us** like going through the **Design Process**. The Design Process consists of several stages: Ask, Imagine, Plan, Create, and Improve.

02

Design Process

Analyzing VEX

Finding Criteria and Constraints

Spin Up consists of 4 ways of scoring.

SCORING METHOD	SHOOT DISKS INTO HIGH GOAL	SHOOT/PUSH DISKS INTO LOW GOAL	CHANGE ROLLER TO YOUR COLOR	EXPAND ROBOT ACROSS TILES
POINTS	5 PER DISK	1 PER DISK	10 PER ROLLER	3 PER TILE
DIFFICULTY	4/5	1/5	2/5	3/5

Aside from VEX's constraints, we came up with the following criteria and constraints to set ourselves up for success:

1. **Efficiency**
   a. We strive to score disks and turn rollers as fast as possible.
2. **Sustainability**
   a. Our robot should be robust.
3. **Cost Effective**
   a. The design should be affordable.
4. **Accuracy**
   b. Shoot disks with precision and expand in the right direction.

Analyzing Hyperloop

Finding Criteria and Constraints

Elon Musk also created a rough criteria and constraint list for Hyperloop. All of these comparisons are to modern trains and land vehicles.

1. Safer
2. Faster
3. Lower cost
4. More convenient
5. Immune to weather
6. Sustainably Self-Powering
7. Resistant to Earthquakes
8. Not disruptive to those along the route

As shown above, there are many similarities and crossovers between the criteria and constraints of Hyperloop companies to our criteria for Spin Up. All engineers start with this same process when starting to problem solve. Besei Song describes the design process as “Define the scope, the main objective, and tasks. Then, decide the timeline for each task.” **A project’s success relies heavily on how it is approached**, as demonstrated by both VEX and Hyperloop.

Imagine: VEX

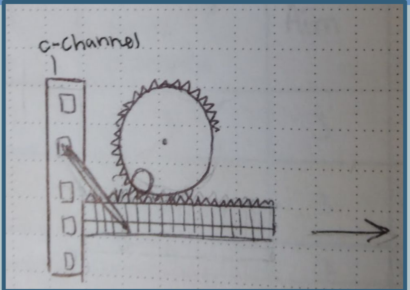
Brainstorming Ideas

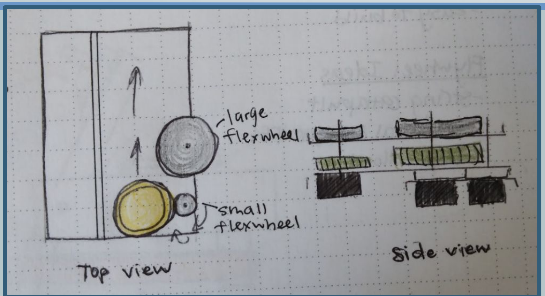
	Scale		
4	3	2	1
Best	Good	Fine	Not so good

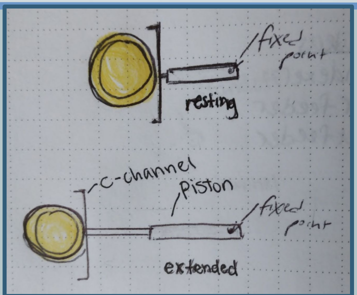
Design	Simple Build	Speed	Practicality	Resources	Total
Puncher	2.40	3.60	3.60	3.25	12.85
Indexer	3.40	2.40	2.00	2.60	10.40
Feeder	3.60	3.40	3.80	3.60	14.40

In VEX, we first **researched and brainstormed designs** for all the mechanisms we could use. Using our criteria and constraints, we came up with 3 main shooter mechanism designs reflected **above**. We roughly sketched our designs and everyone ranked each mechanism functionality in the design matrix. **This method is how we decided on a design that fits our criteria the best.**

Figure 7: Our Brainstorming Sketches







Imagine: Hyperloop

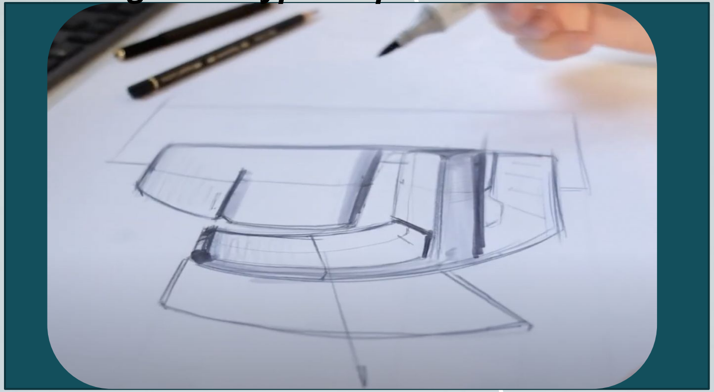
Brainstorming Ideas

Figure 8: Virgin Hyperloop One Maglev

There are many **companies** competing to develop the first successful hyperloop system. In 2013, Musk first sent out the proposal, suggesting the use of fans to create an “air bearing” to hold up the train with air force. However, after reiterations of designs, **Virgin Hyperloop One** decided **magnetic levitation** to elevate and move the pod off the tracks with considerable speed is the best method.

Another competing company, **Hyperloop TT**, uses **linear electric motors** to power the pods forward. Both companies isolate their pod in a **low-pressure tube** to **reduce air resistance and friction**. All of these factors are the results a comparing and contrasting designs and brainstorming.

Figure 9: Hyperloop TT Sketch



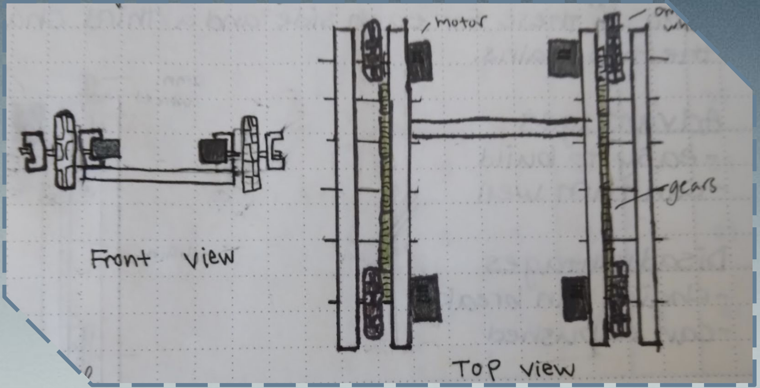
Plan: VEX

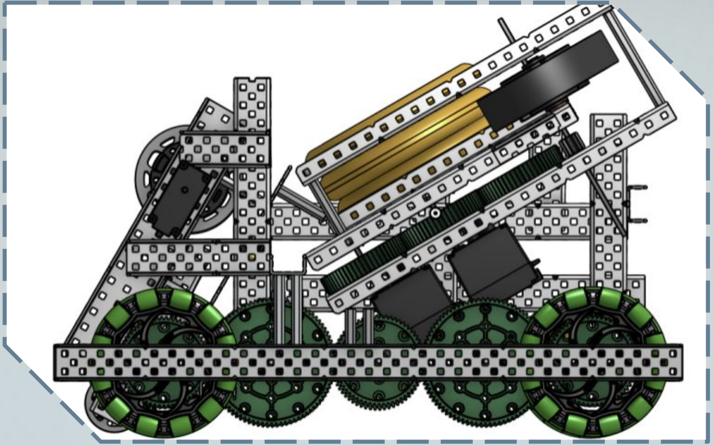
Making Preparations, Modeling

In our team, we use **Onshape** to CAD our robot before each rebuild, and also **more detailed sketch designs** out in multiple perspectives in our notebook. All members contribute to the planning, so we have as much ideas to work with as possible.

Our sketches consist of multiple views of the designs, each giving more insight on the construction and capability. The CAD model can give us a more accurate description of how to construct our robot once we have finalized the design.

Figure 10: Our sketches and Onshape CAD



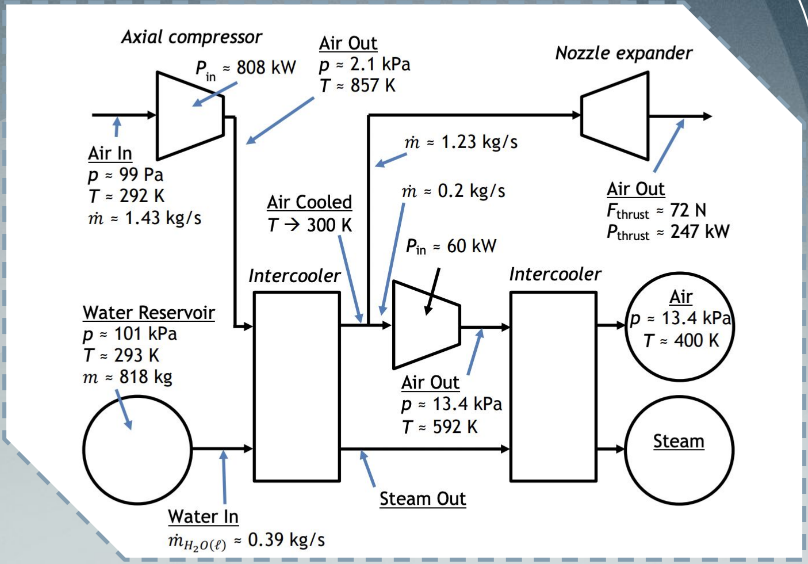


Plan: Hyperloop

Making Preparations, Modeling

IN BOTH VEX AND HYPERLOOP COMPANIES, innovation is born from models and ideas on paper. Success is much more likely using multiple methods of thinking and accurate planning.

Figure 12: Sketches (from Musk)



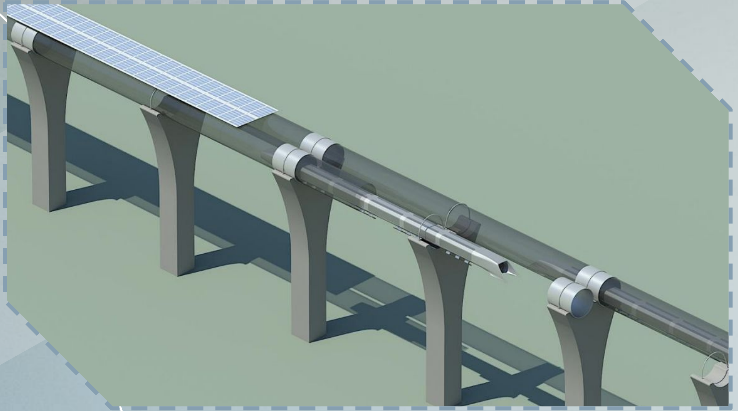


Figure 11: 3D Model (from Musk)

IN THE HYPERLOOP ALPHA DOCUMENT originally released by Elon Musk, it included many 3D models like the one shown left and sketches like the one shown above.

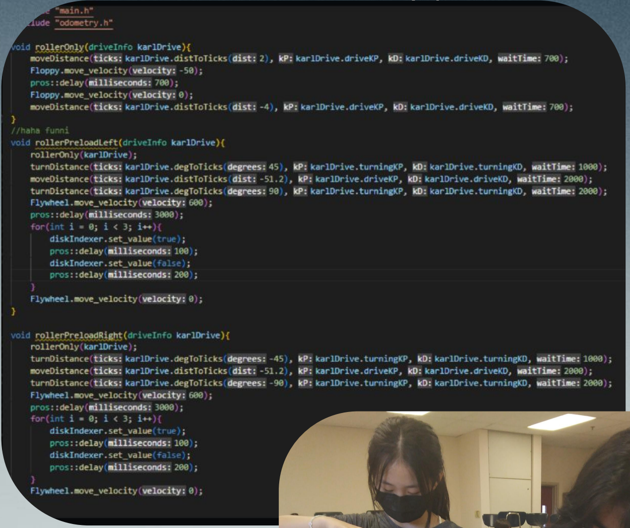
Create: VEX

Building, Coding, Testing

"ANYTHING'S POSSIBLE IF YOU'VE GOT ENOUGH NERVE." – J.K. ROWLING

We start by building our drive train, which serves as a base and allows the robot to move around the field. Next, we move on to the intake, which can bring in disks to our robot. Then, we build the flywheel, allowing us to shoot said disks into high goals and execute our main strategy. Finally, we attach the roller and our expansion mechanism, which are also necessary to earn extra points and gain an advantage. Along the way, we will code each mechanism to make sure everything runs smoothly.

Figure 13: Our Code



```
e "main.h"
lude "odometry.h"

void rollerOnly(driveInfo karlDrive){
    moveDistance(ticks: karlDrive.distToTicks(dist: 2), kP: karlDrive.driveKP, kD: karlDrive.driveKD, waitTime: 700);
    Floppy.move_velocity(velocity: -50);
    pros::delay(milliseconds: 700);
    Floppy.move_velocity(velocity: 0);
    moveDistance(ticks: karlDrive.distToTicks(dist: -4), kP: karlDrive.driveKP, kD: karlDrive.driveKD, waitTime: 700);
}
//haha funni
void rollerPreloadLeft(driveInfo karlDrive){
    rollerOnly(karlDrive);
    turnDistance(ticks: karlDrive.degToTicks(degrees: 45), kP: karlDrive.turningKP, kD: karlDrive.turningKD, waitTime: 1000);
    moveDistance(ticks: karlDrive.distToTicks(dist: -51.2), kP: karlDrive.driveKP, kD: karlDrive.driveKD, waitTime: 2000);
    turnDistance(ticks: karlDrive.degToTicks(degrees: 90), kP: karlDrive.turningKP, kD: karlDrive.turningKD, waitTime: 2000);
    Flywheel.move_velocity(velocity: 600);
    pros::delay(milliseconds: 3000);
    for(int i = 0; i < 3; i++){
        diskIndexer.set_value(true);
        pros::delay(milliseconds: 100);
        diskIndexer.set_value(false);
        pros::delay(milliseconds: 200);
    }
    Flywheel.move_velocity(velocity: 0);
}

void rollerPreloadRight(driveInfo karlDrive){
    rollerOnly(karlDrive);
    turnDistance(ticks: karlDrive.degToTicks(degrees: -45), kP: karlDrive.turningKP, kD: karlDrive.turningKD, waitTime: 1000);
    moveDistance(ticks: karlDrive.distToTicks(dist: -51.2), kP: karlDrive.driveKP, kD: karlDrive.driveKD, waitTime: 2000);
    turnDistance(ticks: karlDrive.degToTicks(degrees: -90), kP: karlDrive.turningKP, kD: karlDrive.turningKD, waitTime: 2000);
    Flywheel.move_velocity(velocity: 600);
    pros::delay(milliseconds: 3000);
    for(int i = 0; i < 3; i++){
        diskIndexer.set_value(true);
        pros::delay(milliseconds: 100);
        diskIndexer.set_value(false);
        pros::delay(milliseconds: 200);
    }
    Flywheel.move_velocity(velocity: 0);
```

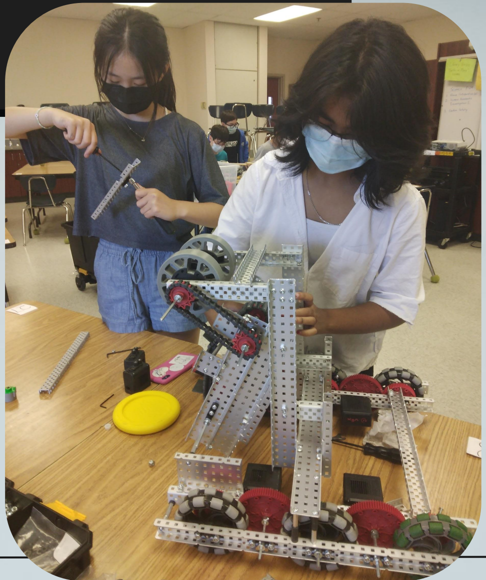


Figure 14: Building our Robot

Create: Hyperloop

Building, Coding, Testing

VIRGIN HYPERLOOP started testing for their interpretation of the hyperloop. It took place in a 500 meter track built in the Nevada desert.

Figure 15: Virgin Hyperloop Track (outside of Las Vegas, NV)

Figure 16: Frontal View of the Virgin Hyperloop

The system is controlled by advanced software that guarantees almost unnoticeable acceleration and deceleration while inside the passenger pods.

They started off by building the necessary structure for magnetic levitation, a mechanism already used in monorails. Using two sets of magnets, it allows the passenger pods to be lifted upwards and float in order to move at extremely high speeds with little to no friction.
Next, a low pressure, vacuum sealed tube system was created to allow testing regardless of climate and weather conditions.

Improve: VEX

Reviewing & Analyze Problems

After testing, **there's always room to improve**: expansion covering more tiles, flywheel shooting more efficiently, and drivetrain running smoother with minimum friction. **During competitions**, our robots are put to the test against others. **We get feedback on our designs** and reach out to other teams to solve our flaws. A robot's successfulness can easily be determined by our rankings in the competition, and overall performance.

Figure 17: Our Team at Placer Competition

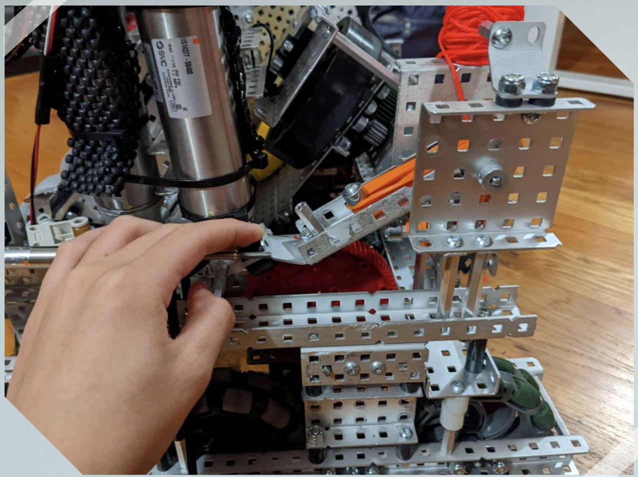


Figure 18: Working on the Expansion

We also do **match analysis** after competitions to ensure that everyone is on the same page to **improve our robot before the next competitions**. For every match, we list what happened, what went well and didn't, and lessons learned so that we cover every detail and ensure that our new criteria and constraints list is as accurate as possible.

Improve: Hyperloop

Reviewing, Analyze Problems

Figure 19: New Cargo Transport Designs

NOVEMBER 8TH, 2020

Virgin Hyperloop launched the **first transportation test** with 2 people in its pod. However, the pod still is unable to turn at corners, and the passengers experienced heavy motion sickness. In response to this, Virgin Hyperloop adjusted their **focus to transport cargo instead**, since issues involving transporting people wouldn't be necessary to address. The results of this test showed that **there's still many problems with the design**.

Song explains in our interview: "All projects are ongoing: improvement never stops. We will always continue to improve it, see what issues come up during project, and resolve issues. There is no defined completion date."

Hyperloop and VEX are again very similar. **Improvement never stops because innovation has no limits.**

“The greatest glory in living lies not in never falling, but in rising every time we fall.”

–Nelson Mandela

03

Career Readiness

“Robots are related to everything” – Song

VEX involves **all of the necessary skills to be successful in a STEM career**. Whether it’s the engineering or collaboration experiences, all of it prepares a student for their future.

In a VEX Robotics team, students learn to collaborate with peers to engineer and program a robot. Everyone has different designated roles and effectively designs a robot suitable for the challenge together. This is similar to Hyperloop companies, who manage their workers to foster collaboration. **Working in groups fully prepares STEM students for a professional environment**.

Every student brainstorms the most beneficial design for a robot, and undergoes the design process. Our team uses **decision matrixes** to rank our different mechanisms, and document everything within our **engineering notebook**. All team members **communicate** on a Discord group chat to give live updates, ask questions, or simply hang out with each other online. In **STEM careers, individuals utilize these managing skills to complete tasks successfully and efficiently.**

Throughout the season, we **track expenses and create budgets with donations on a spreadsheet** shared with everyone in the Robotics Club. When managing the club, we create **weekly checklists** to ensure we mimic a deadline-like scenario. These skills help us **adapt** and form **a habit of planning ahead.**

Aside from planning, organization, and teamwork skills, VEX also prepares us for a STEM career with **first-hand experience in programming, hardware, and 3D Modeling**. Song has many experiences working with Elon Musk, saying "Even for tesla's car, it is basically a whole robot, with a hardware and software portion."

In VEX, we develop our skills in **C++** for programming. Using VScode, we integrate motors, pistons, and sensors into our bot to make it function more smoothly. In our bot, we **custom developed a cubic function** to increase speeds of our motors using the internal sensors of our drivetrain motors. We are also implementing **odomentry** to track our robot's position with the most accuracy. For example, turning and shooting discs. While going through the many iterations of the robot, proficient coding skills are also developed while in a VEX team.

In addition, we have **first-hand experience in designing and building robots.** Throughout the season, a team goes through many designs and iterations, adjusting from feedback through competitions. Robots are built, taken apart, and repeated. Hardware and mechanical skills are sharpened, and these **technical skills** can be **leveraged in STEM fields** to create new and better technology.

These **fundamental skills** are very useful for a student pursuing a career in STEM. Programming and hardware will be **essential in the future**, particularly in a projects like the Hyperloop. Song says that "Hyperloop is a high-speed train; both hardware and software together to make it work."

In VEX Robotics, students experience their robot creations come to life. From metal and screws and V5 motors, they can see their robot performing to the highest caliber of accomplishing the yearly game's challenge. Innovation is inspiring and alongside friends, it becomes more of a passion than a hobby. The greatest thing we believe that VEX does for students is that VEX develops students from the ground up with knowledge on engineering and programming principles, making them competent in their future STEM careers in fascinating yet enjoyable way.

Thank You! - 95071Z SHS Robotics

Citations

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