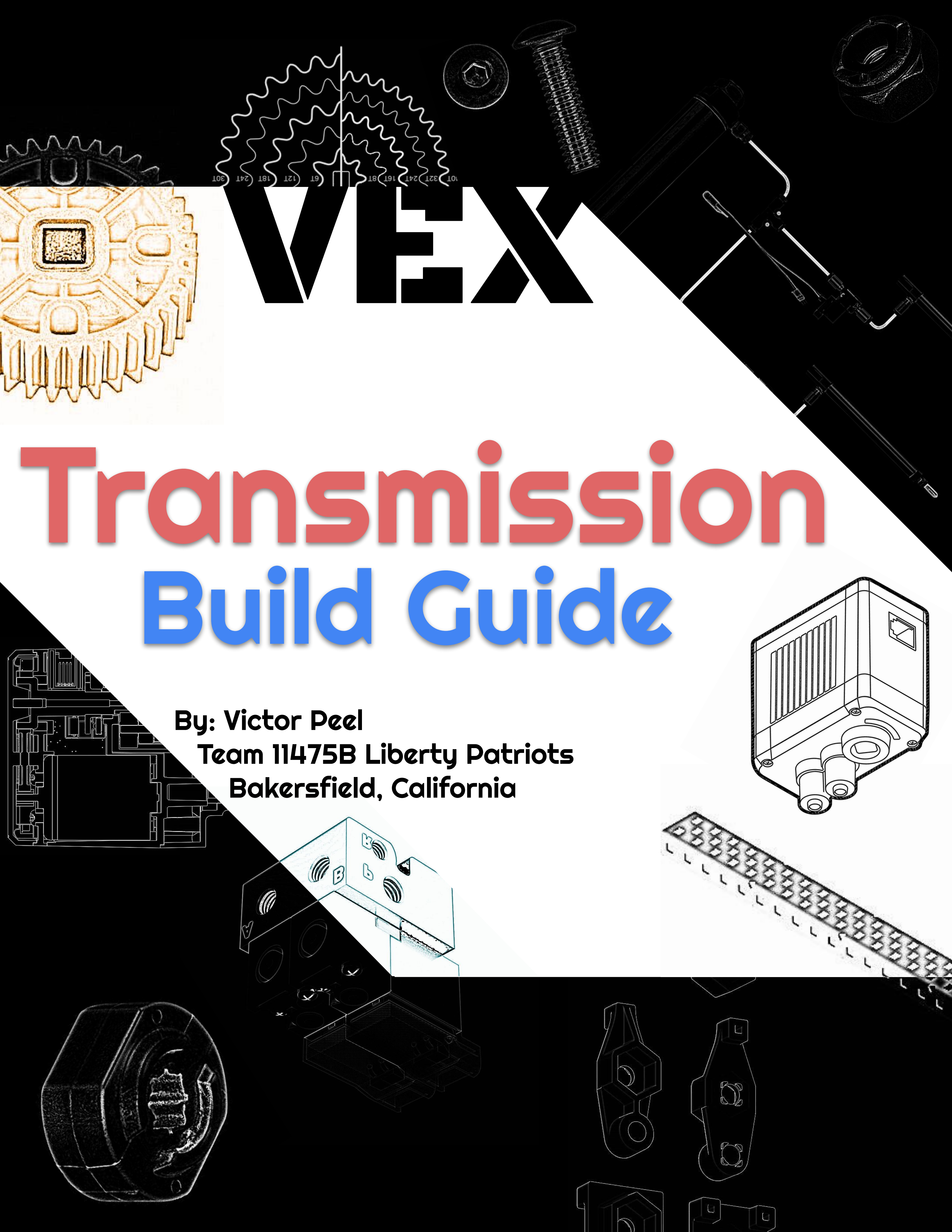

VEX

Transmission Build Guide

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Glossary

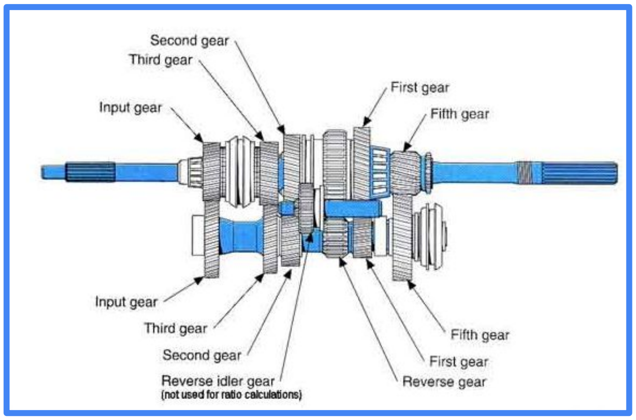
- **Driver gear:** the gear that transmits the power through a gear train, typically hooked up to the motor.
- **Driven gear:** the gear that outputs the power received from the driver gear. This is typically where the mechanism moves
- **Idler gear:** any gear that is between a driver gear and the driven gear. This gear extends the reach of the driver gear towards the driven gear without changing the speed ratio in any way. Idler gears can also be used to change the direction of rotation of the output gear. An odd number of idler gears results in both the input and output gears spinning the same direction, and an even number causes input and output to spin in opposite directions.
- **Transmission:** Any mechanism used to transmit power from one system to another by changing outputs or gear ratio.
- **PTO:** Power-Turn On, a transmission that changes its driven gear.
- Automatic Transmission: Any transmission that performs its actions without input from the user
- **Manual Transmission:** Any transmission that performs its actions with physical input from the user
- **Sequential Transmission:** Any transmission that can be remotely controlled with input from the user. This is separate from the automatic transmission only in programming.
- **Continuously Variable Transmission:** A transmission with infinitely many unique gear ratios.
- **Mechanical Advantage:** The way in which a simple machine (such as a gear train) can alter the force applied to do work
- **Bearing:** An object that supports another object, in this case a slick piece of plastic supporting a drive shaft.
- **Pneumatic Cylinder:** An air-powered piston which enables linear motion
- **PSi:** Pounds per Square Inch, a measure of the distribution of force over an area

Introduction

There are many functions a robot is designed to perform, from driving and sucking in objects to springing out arms to become multiple feet tall. One thing all of these functions have in common is that they need power. A lot of power. Yearning to do more with their robots, many teams turn to alternatives to using up a chunk of that precious 88W of total motor power. They may cut down on weight to reallocate motors away from the drivetrain, utilize pneumatic cylinders for simple operations or maybe, just maybe, implement a transmission into their mechanisms.

Why a transmission?
A transmission allows for the modification of motor power by changing which gears are meshed in a mechanical system. Transmissions are great to use for giving a single mechanism more than one purpose, increasing efficiency. Easy to implement, transmissions are the go-to for many VEX robotics teams of all levels.

You may already know…
Most of today's cars are only capable of transferring the power from the motor to their wheels using a transmission. They are necessary because cars need more torque to start moving than to keep moving, and as a vehicle wants to accelerate it can switch gear to sacrifices wheel torque for speed.



In this guide I will do a brief overview of some of the most common types of transmissions in VRC including:

- Manual
    - Sequential and Automatic, modified manual transmissions
- Power Turn-On

Each design has its own applications, which I will get into on the deep dive of each one.

*__Notice:__ Although these transmission designs are very possible to create using stock VEX parts, it is highly recommended to make the necessary physical modifications to each part to meet the needs of the mechanisms while **maintaining safety**.

Manual Transmission

The **manual transmission** requires input directly from the operator to switch gears and encompasses all sorts of mechanisms, but to keep it simple I will be focusing on **3-speed** and **2-speed** linear manual transmissions.

In terms of practicality, I see the manual transmission as a good design choice for mechanisms that need to pull double-duty between being optimized for torque and for speed. However, because the transmission is manual, this shifting would have to occur outside of a competition match, say to **switch strategies**.

Materials

Below is an **Autodesk Fusion BOM (Bill of Materials)** of the transmission we will be building, refer to the parts list for guidance of what to use before starting.

LS 12T Gear	2
0.500 Torx (Star) Screw (8-32, Steel)	7
LS Shaft v2	3
LS Shaft v2 (1)	1
17 - 2x C-Chan	2
LS 36T Gear	3
LS 60T Gear	2
60T HS Gear (v2)	4
HS Square Insert (Powdered Steel)	2
0.313 OD Spacer, 0.250 (Nylon)	1
0.375 OD Spacer, 0.250 (Nylon)	5
0.375 OD Spacer, 0.500 (Nylon)	2

LS Shaft Collar, Set Screw	3
2.000 Standoff (8-32, Aluminum)	4
Bearing Flat	7
Nylock Nut (8-32, Steel)	9
2.250 Torx (Star) Screw (8-32, Steel)	1
0.375 Torx (Star) Screw (8-32, Steel)	8
V5 Motor (5.5W)	1
8mm Plastic Spacer (276-2019)	6
2.75 Legacy Traction, LS Shaft Insert	1
3.000 Standoff (8-32, Aluminum)	1
LS Shaft Collar	1

Preparation

To ensure smooth operation of the mechanism, **some parts will need to be modified.** Namely the gears, which will need to be rounded at the corners to make them easier to mesh together, like so:

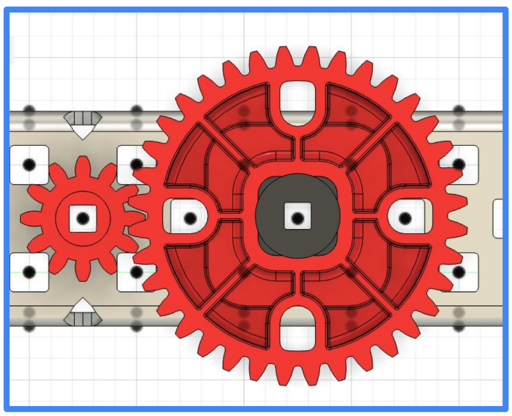
And of course, you will need three tools: a **T-15 screwdriver**, a **T-8 screwdriver** and a **wrench**. This build can also be completed using **5/64** and **3/32** hexagonal drivers and screws as well.

Keep in mind that this is an example transmission, and it is meant to be modified to be used for many applications. **Once you have all the parts listed, you are ready to begin.**

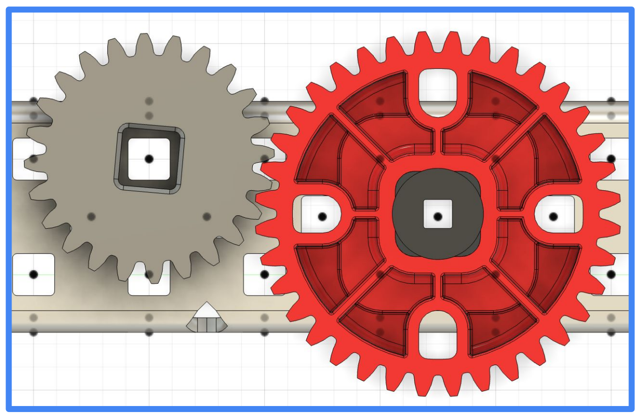
Start!

Begin with your two C-channels. It is important to know how much space you will need for your transmission, so try to **line up the gears** you are planning to use to see how they fit together.

Some gears such as **12T** and **36T** when put together are able to fit on the same row of holes on a **C-channel**. However, when using a **24T** or **48T** gear with a **36T** gear, the gears need to be centered around adjacent rows instead.

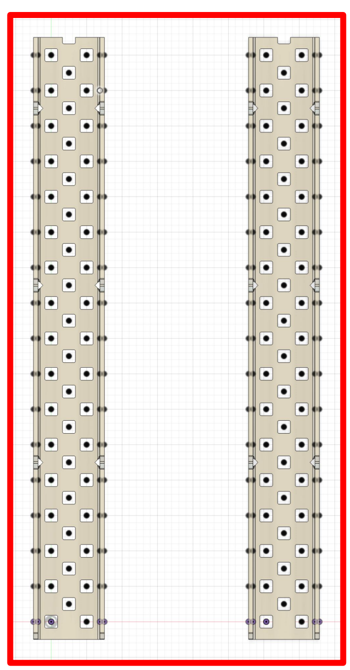


12T with 36T



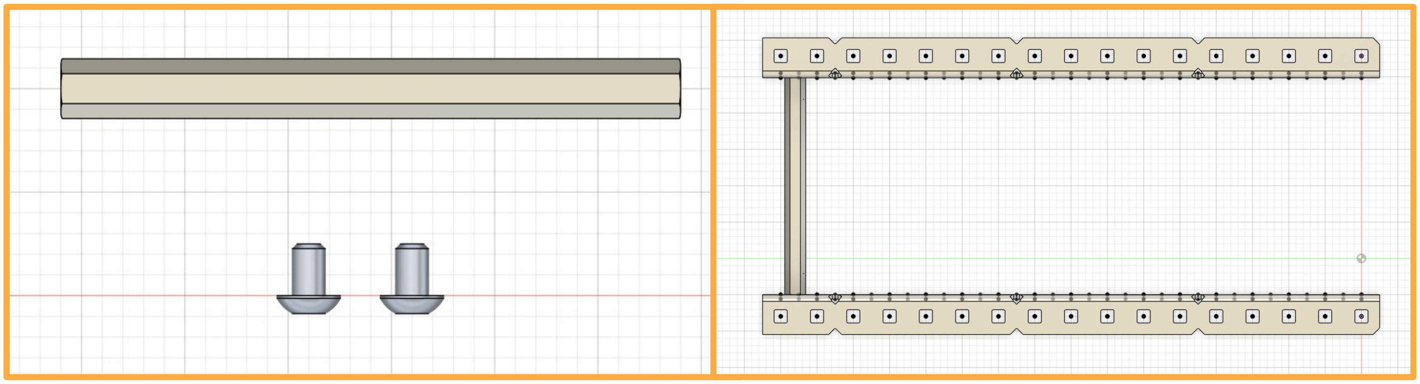
24T with 36T

Here I have two **1x2x1x17** C-channels which will be used for the structural support of the transmission. This can fit three **60T** gears as well as an extra **36T** gear comfortably.

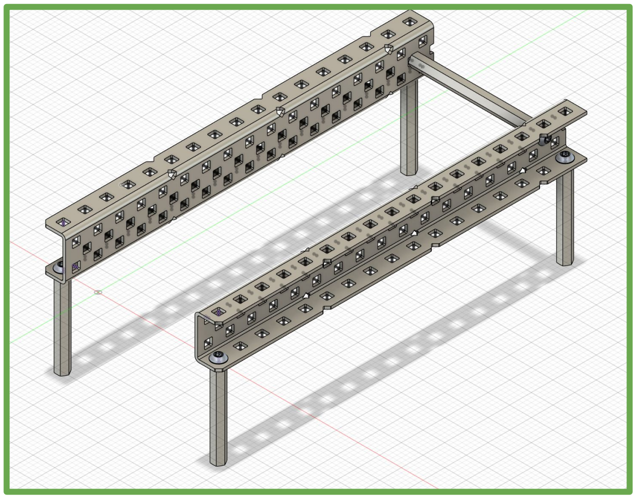


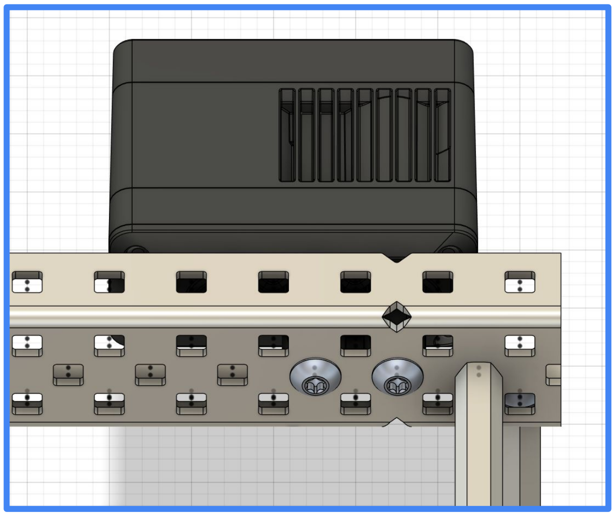
Next, we will connect the two C-channels with a **3" standoff**. When working with moving parts, specifically axles or screws with bearings, it is essential to have everything lined up as perfectly as possible. This reduces friction and can help prevent power issues down the line.

Cross members can provide that structural stability, and in this case we are using a **3" standoff** connected with two **0.25" Torx screws**.



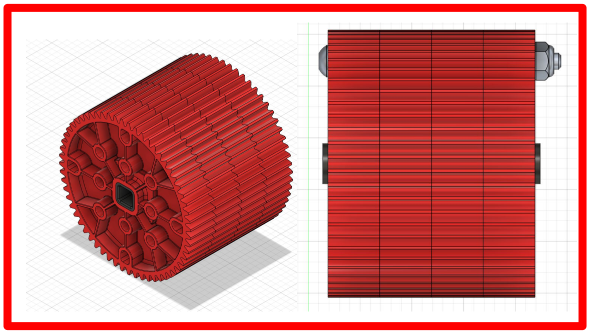
These next standoffs that go on are optional. They simply hold up the mechanism for display, and will likely **not exist on the robot** the transmission is implemented in.

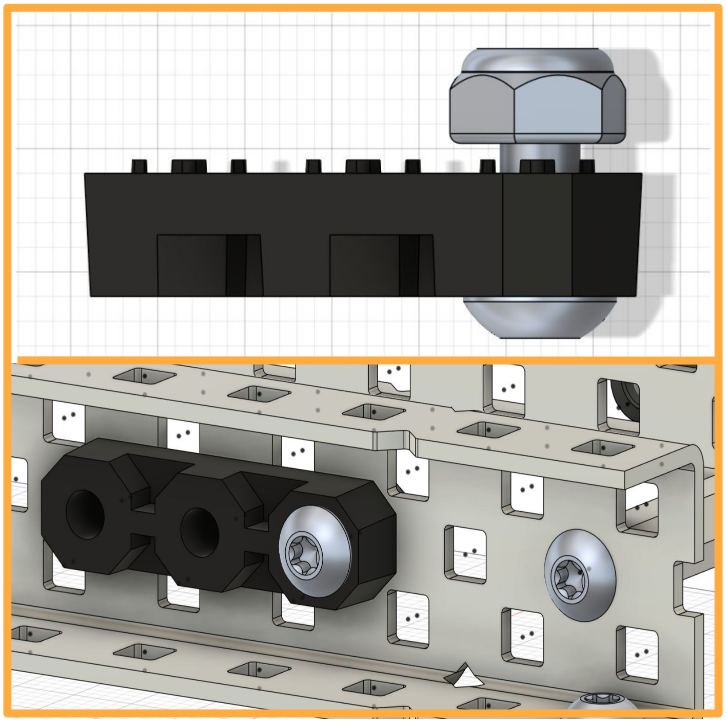




While attaching the motor, be extremely careful not to cross-thread the screws, as this will require you to **replace the threaded inserts**.

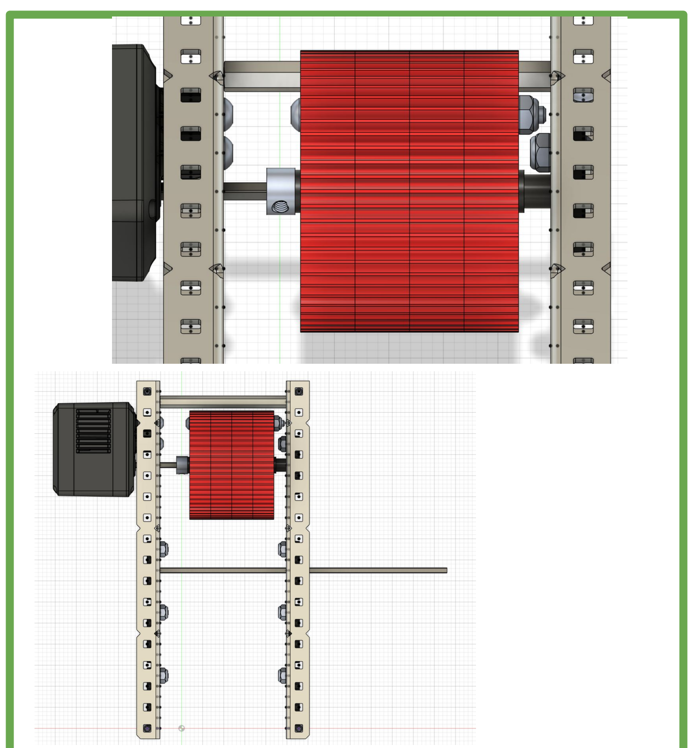
The following step will be to line up four **60T high strength gears,** making sure that the teeth are properly aligned with one another. Connect them with a **2.25" screw** and add a nylock nut at the end to secure it.



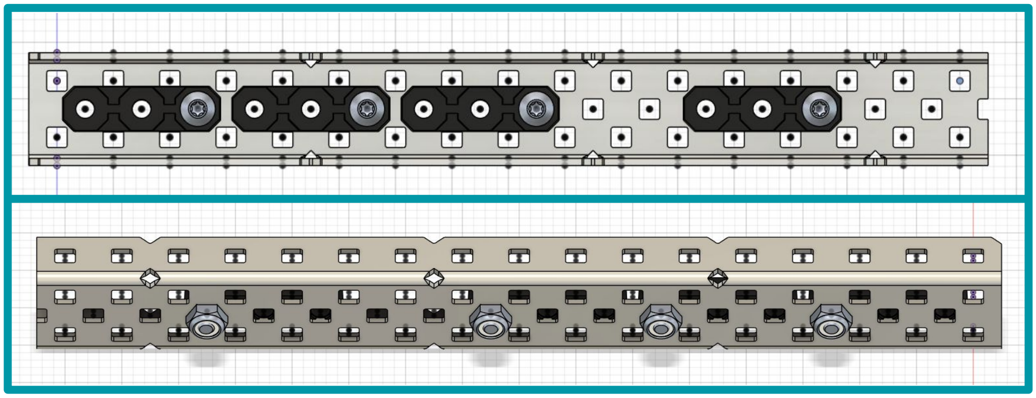


Once this is completed, screw on a **bearing flat** secured with a **.5" screw** and nylock nut, with the center of the bearing directly across from the motor. Make sure you keep a maximum of **two points of contact** when using an axle to both maximize stability and minimize friction. These points of contacts should preferably be a bearing flat along with a motor **or** two bearing flats.

Now that you have a designated area to attach the four **60T gears**, insert a **4-5" axle** through the center of the bearing along with a shaft collar, followed by the four 60T gears with metal gear inserts on either side with a **.25" spacer to finish it off**. Once the axle and all of the components are in place, secure the end of the axle with another shaft collar on the outside of the C-channel.

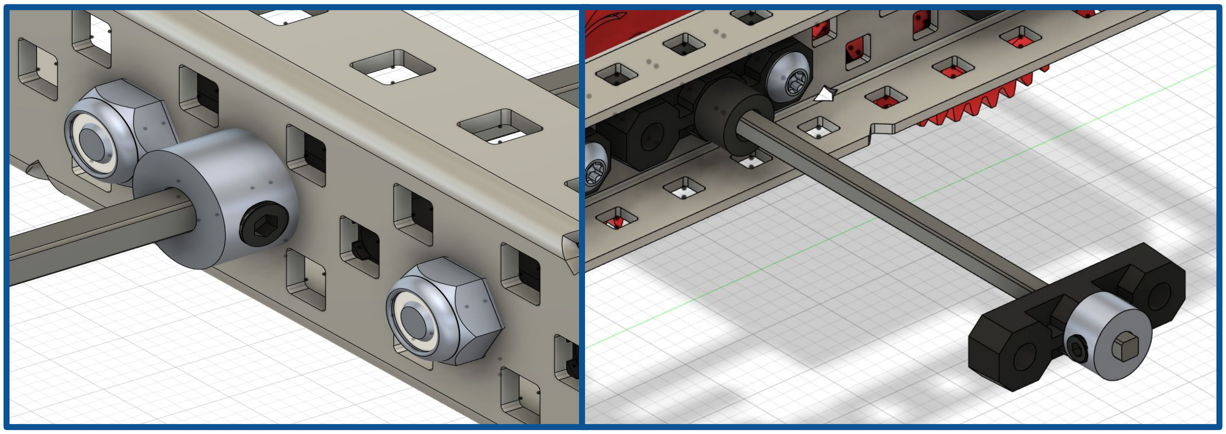


With the motor and high strength gears in place, repeat the process of attaching another three **bearing flats** spaced as shown in the photo below, all connected using a **0.5" screw** and **nylock nut** on all of them. Once the three bearings are properly secured, mirror this process onto the other C-channel directly across each bearing flat.

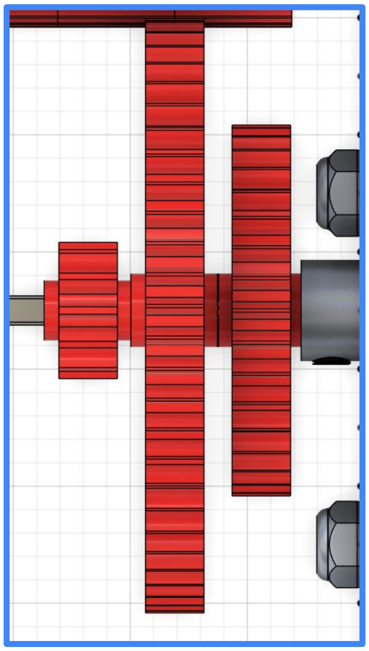


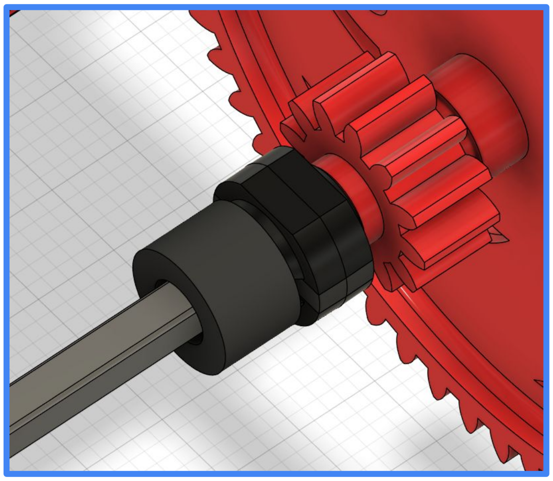
View of the right frame (no motor), the three adjacent bearings are mirrored on the left frame.

Inside of the first bearing away from the motor, insert an axle about **9-10"** in length to serve as a handle for the manual transmission, and in this example I will be using a **bearing flat** for easy handling. Make sure to secure the ends of the axle with **metal shaft collars** but leave one end unsecured for the next step.

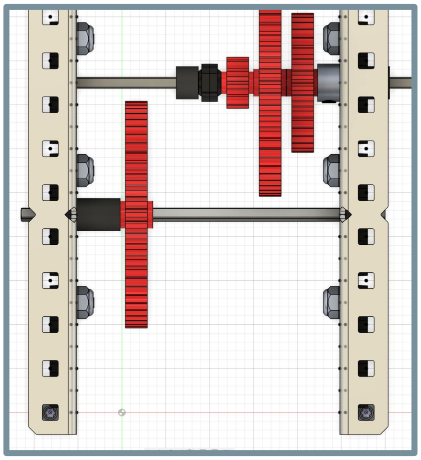


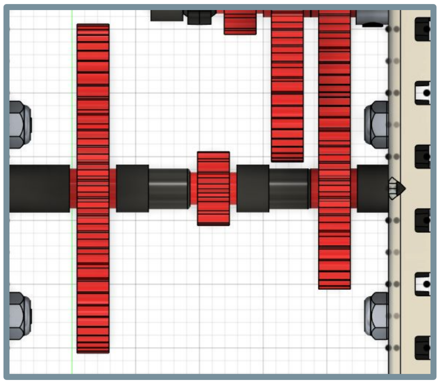
Next, on the newly added axle, attach (from right to left) **36T, 60T, 12T gears**, followed a **rubber shaft collar** and a **.25" spacer**. These gears will be the variables changing when using the transmission to change the gear ratio of the mechanism. **These are the gears with rounded edges mentioned earlier. They will slide much more easily if the edges are ground down a bit.**

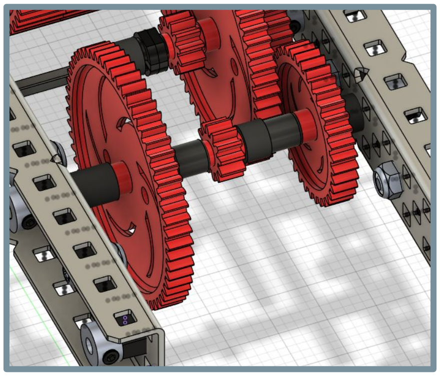


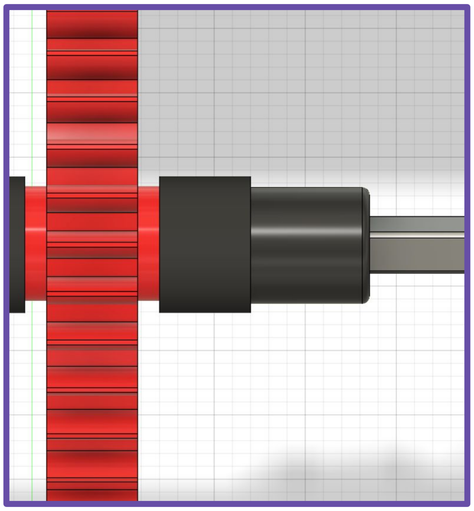


Once the three gears are properly in place, add another axle in the bearing flat directly adjacent to the gears. On this axle add, from left to right, a **0.5" spacer, 60T gear, 0.25" spacer, 8mm spacer, 12T gear, 0.25" spacer,** another **8mm spacer**, a **36T gear,** and one last **0.25" spacer**.



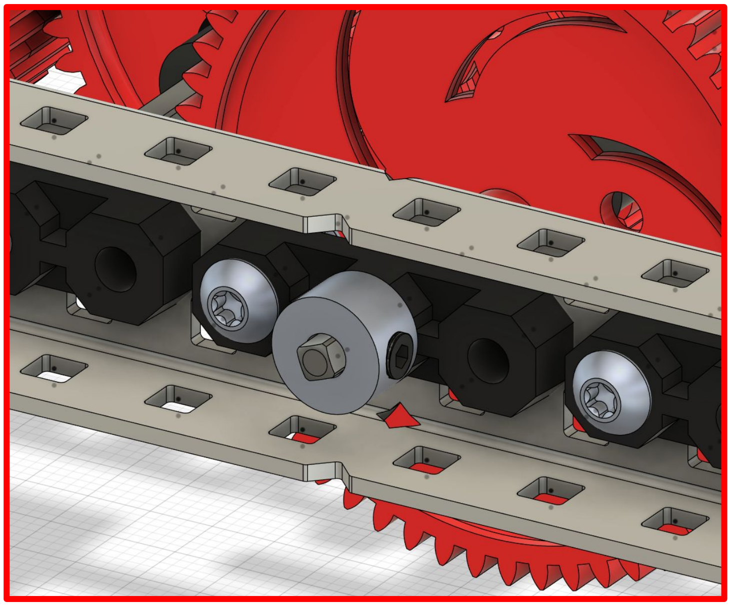


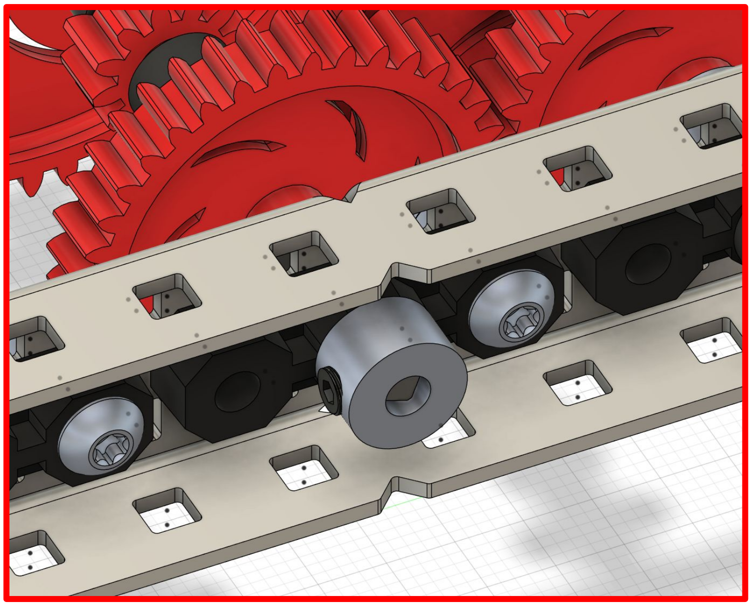




The spacing is very important here as to make sure that only **one set of gears are in contact with another** at a time to keep the whole system from stalling out. Between each of the gears should be exactly 0.25” plus 8mm.

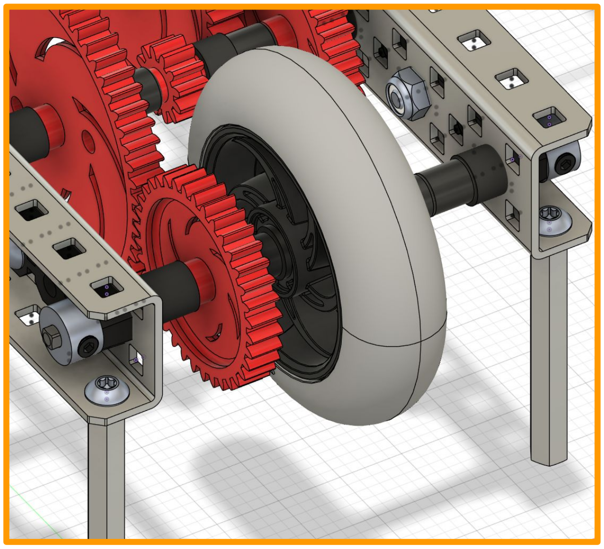
Once the distance between each of the gears is set in place use **two metal shaft collars** on each side of the outside of the C-channels to secure the axle in place as represented in the following images:

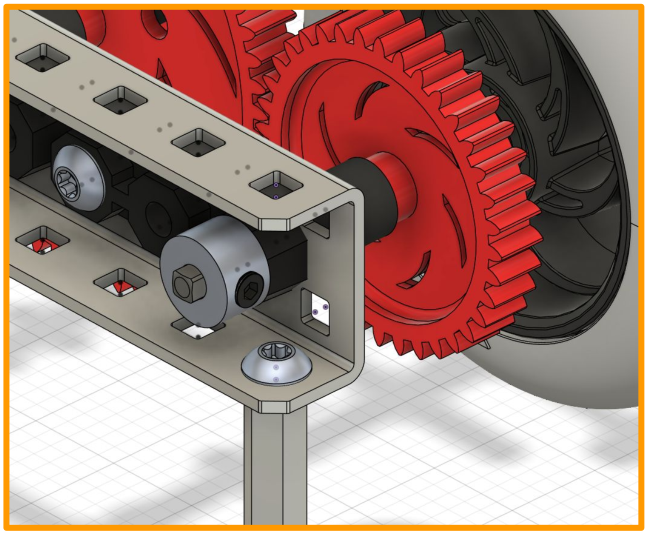




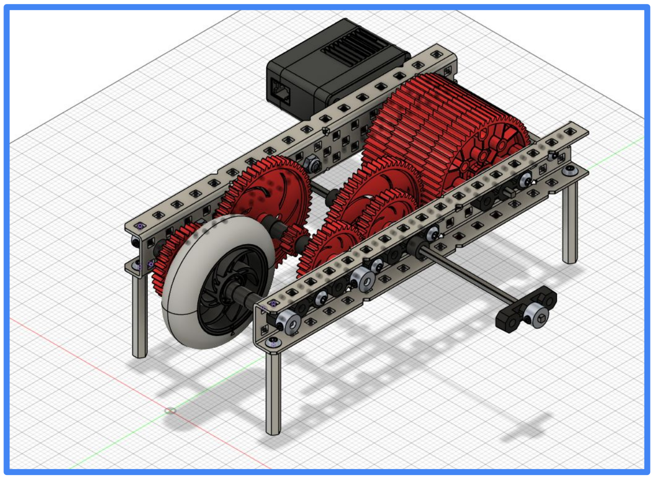
Leave some room to breathe! Do not squeeze the shaft collars on too tightly, or else there will be additional friction.

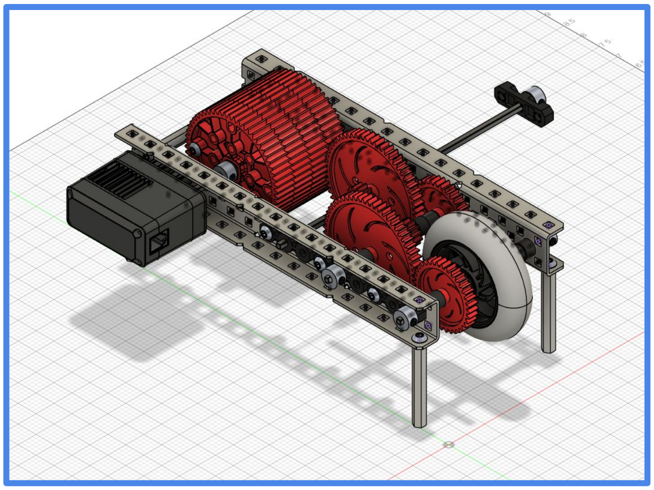
These next steps are optional, but this is where the transmission will actually be applied. In this design I will be using a **2" traction wheel** secured with **metal shaft collars** to show the change in speed and torque as the gear ratio increases and decreases.





THE FINAL PRODUCT!





Congratulations on building your first VEX transmission! With this accomplishment, you now have the experience to create more advanced, in-depth mechanisms for your robot!

Hint: Transmissions such as this are much, much easier to shift gears in when the gears are spinning at higher RPMs.

What to Do...

With this finished product, you can now try one of a few things!

1. Implementation
    a. Try a small project which uses this mechanism to further improve your understanding.
    b. Modify it to try other gear combinations and/or spacing.
2. Improvement
    a. Make it smaller!
    b. Improve manual shifting options.
    c. Make it smoother.
3. Invent!
    a. Put a custom version on a robot mechanism.
    b. Add more speeds.
    c. Or, turn it into an **Automatic Transmission!**

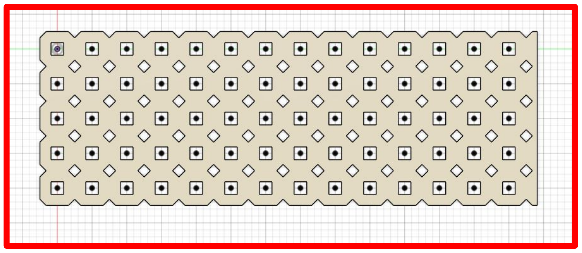
When I see the manual transmission, I see a blank slate. From this baseline, you have whatever you need to build your next advanced transmission.

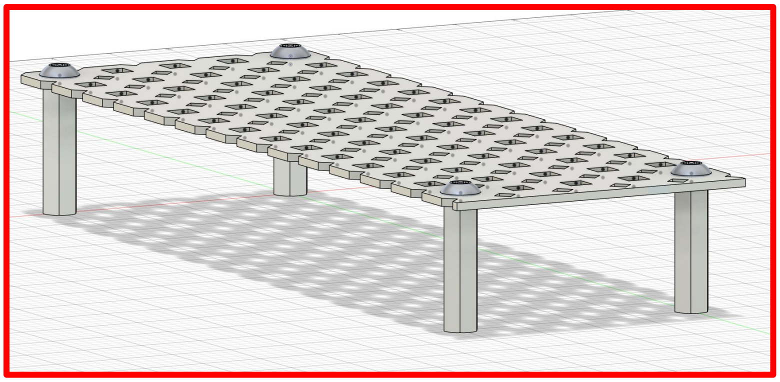
In terms of practicality, a manual transmission is little more than a learning tool, a novelty that I feel most people should experience before any other advanced motion mechanism so they truly understand how these objects interact.

And with that, we are onto a refinement of the manual transmission with all the bells and whistles: the **Two-Speed Automatic Transmission.**

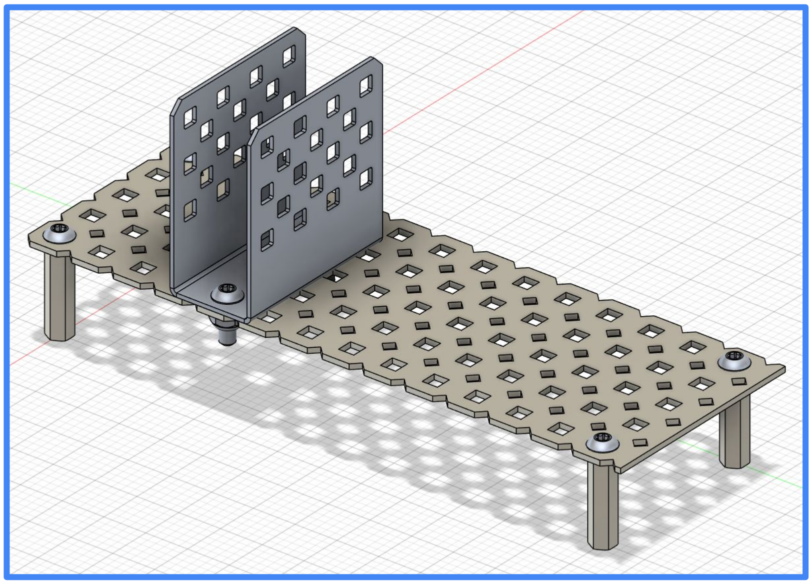
Automatic Transmission

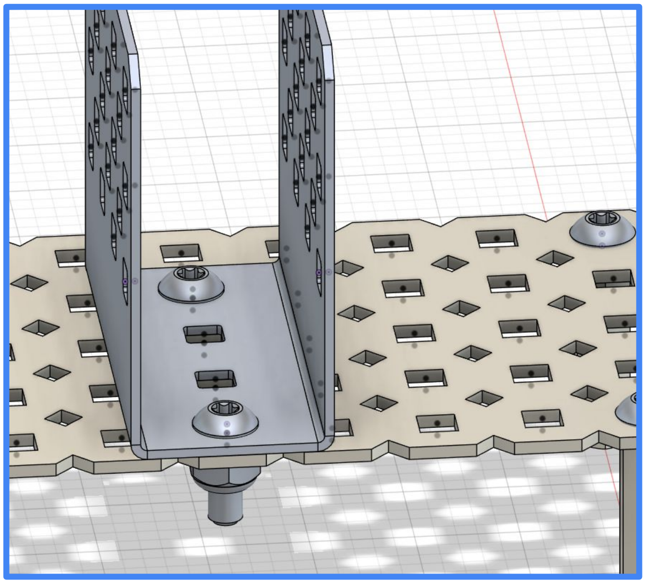
To begin, I am going to use a **12x17** plate to use as a base along with 4 **1" standoffs** to elevate the build.





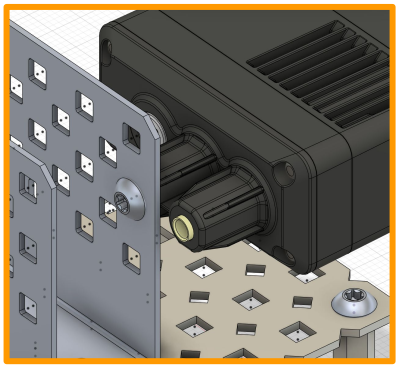
On the aluminum plate, screw on a **rack gearbox bracket** that will be used to house the complex parts of the transmission. **Gearbox brackets** are great tools to use in order to create smaller, more complex gear trains.

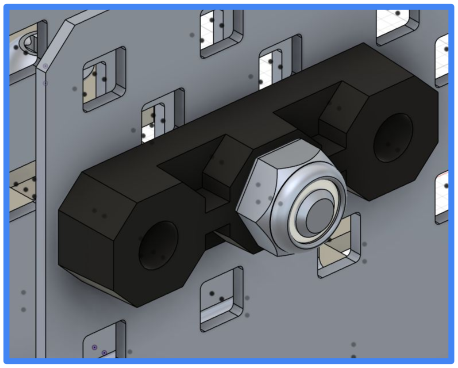


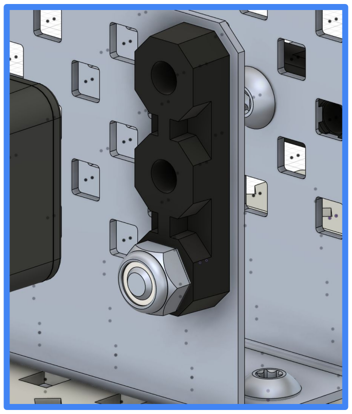


Standoffs can have many different applications besides just holding parallel C-channels together; they can be used for elevation, ratchets, and when used in tandem with shaft collars and **standoff couplers** can provide for abstract support structures.

The next step is to screw a motor onto the gearbox as shown in this photo, **with the slot to insert the axle facing towards the inside of the gearbox.** **Note:** it is always a good idea to secure your Motors with two screws. You may want to modify the gearbox to fit another motor mount!

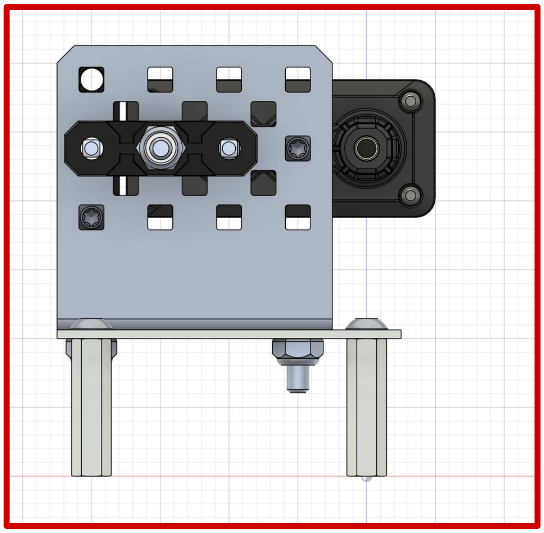


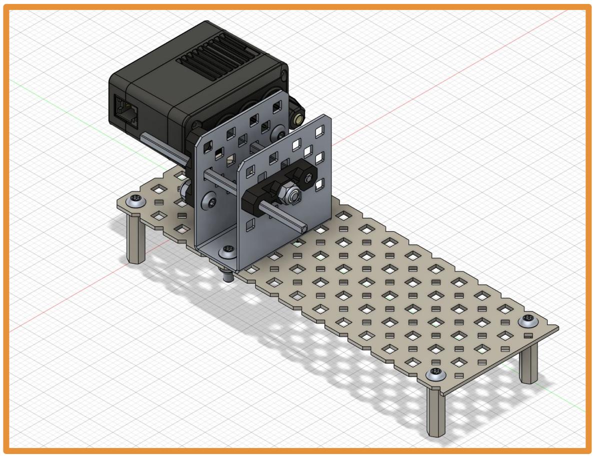




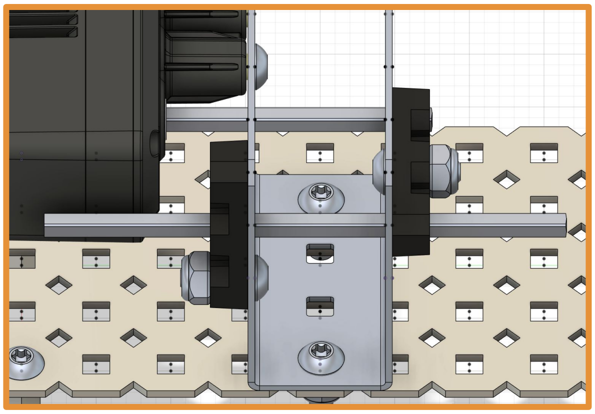
Once the motor is properly secured add two **bearing flats** screwed on using **0.5" screws** and **nylock nuts** as indicated in the photos to the left.

Side view of build up to this point



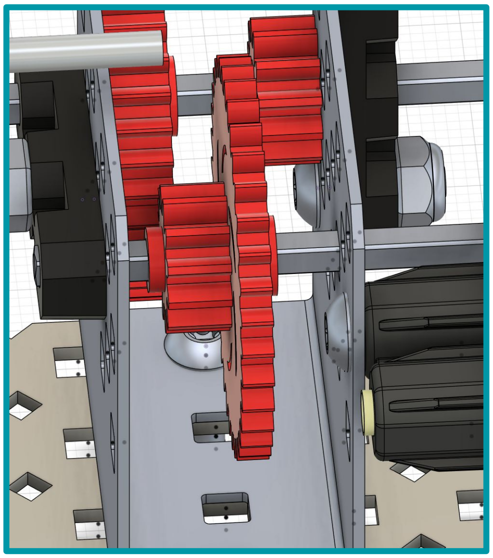


After the bearing flats are in place a **3" axle** into the motor and a **4" axle** going through the two bearing flats as shown to the right.



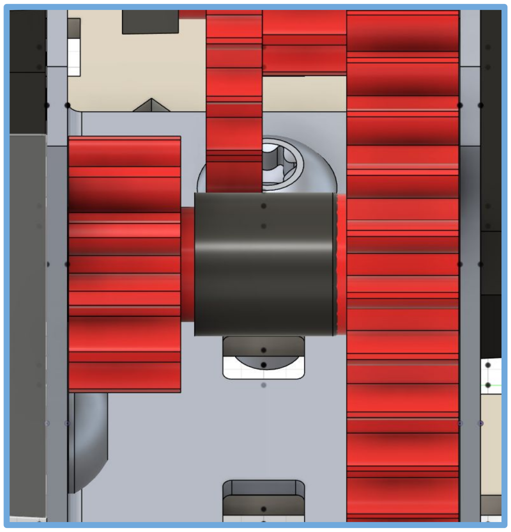
In these following steps the gears are to be modified using sand paper or a rotary tool as follows:

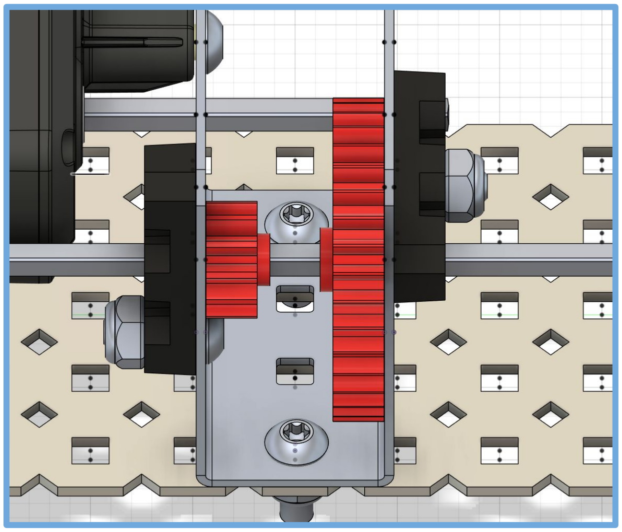
- Two **12T gears** with the small nubs removed on one side
- One **36T gear** with the small nub removed on one side
- One **36T gear** completely cut in half down the center



We thin out these gears in order to make a more **compact mechanism**. Don't be afraid to try something abstract in your builds, as long as those ideas are refined later!
On the axle that was inserted into the motor, add the **36T gear** that was cut in half with the flat side facing the motor and one of the **12T gear** with the sanded end making contact with the sanded end of the 36T gear.

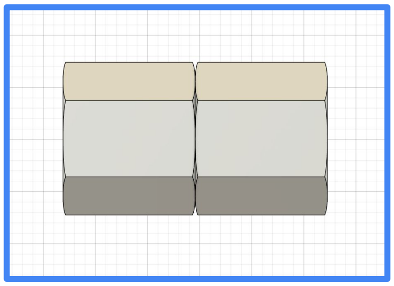
Next, on the axle supported by the two bearing flats, insert the other **12T gear** with the sanded edge closer to the motor. Then add an **8mm spacer** and the **36T gear** with the sanded edge facing outward, away from the motor, as shown.

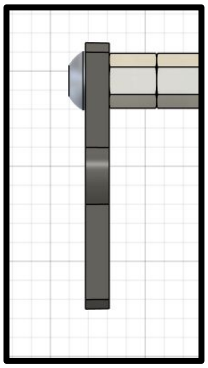




Finally, we will be implementing the **pneumatic cylinder** which enables our gears to shift without us moving them. There are many ways this bracket can be constructed; some people opt for a custom **polycarbonate** shell, while others use **steel lock bars.** In this case, I will be using **plastic lock bars** to force the gears to move.

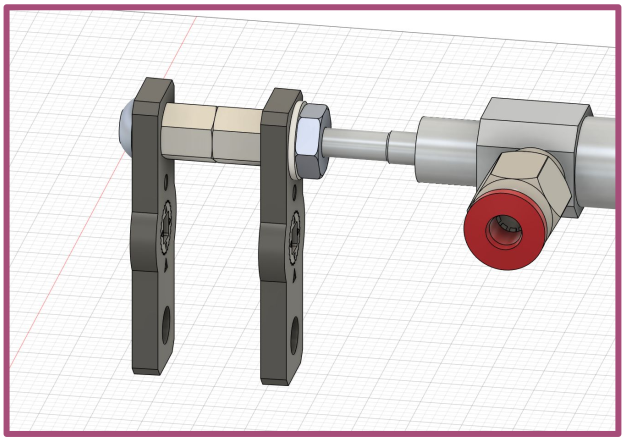
Connecting the two bars will be one **0.5”** standoff. I used two **0.25”** standoffs because they were the next smallest size I had. You can do this substitution as well if you do not have the proper sizing.



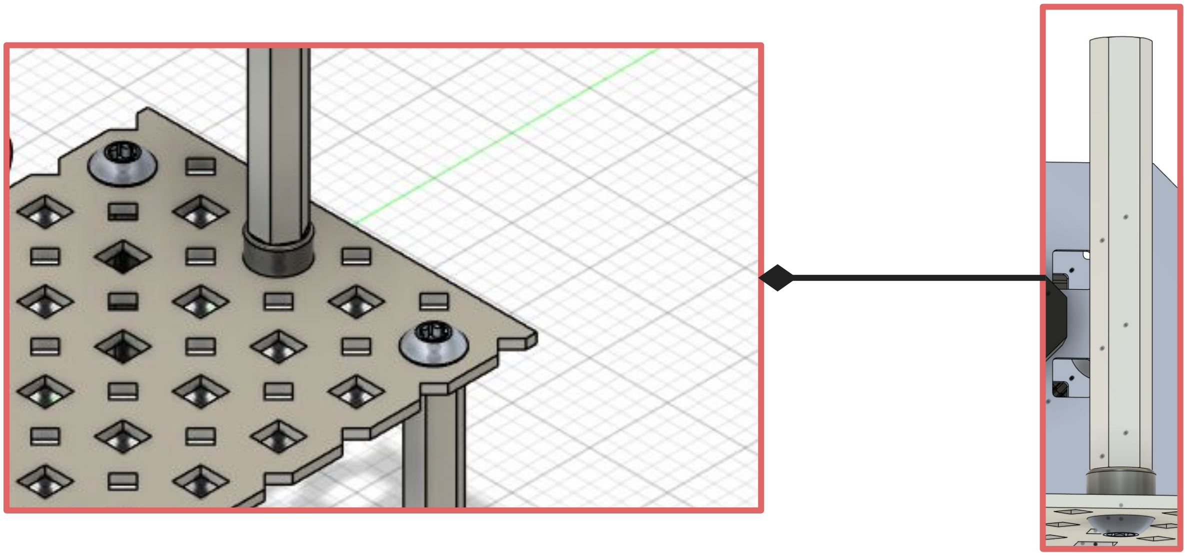


On the left, you will want to insert a **0.25”** Torx screw through one of the holes at the top and bottom of the lockbar, and into the standoff.

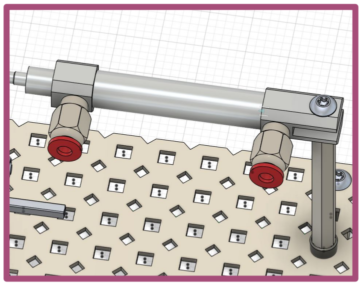
If you look at the end of your **25mm stroke** pneumatic cylinder from the **V5 Pneumatics Kit**, you will see two nuts screwed onto the threaded part. Remove the outermost nut, and store it in a safe place, as they are not the same size as normal VEX nuts. Then screw the cylinder into the other side of the **lock bar bracket** we created.



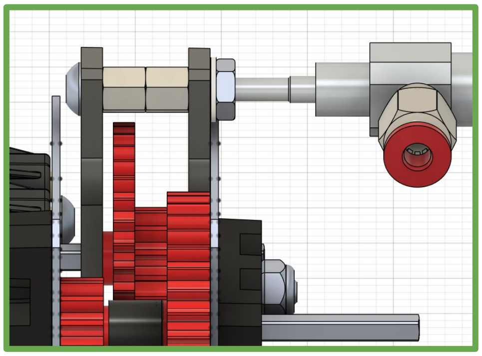
Now we need to create a support for the pneumatic cylinder. We will use a **2"** standoff and a **4mm** spacer, as well as a **0.5"** Torx screw to go through the base. The standoff will be erected on the opposite edge from the gearbox.



Throw a **1"** Torx screw through the top of the **pneumatic cylinder** to attach it to the standoff, and you should be left with this:



And now you will want to slide the lock bar mechanism onto the axle with the ½ **width 36T** gear. Make sure everything is secure, and you're all done!



It’s time to hook up the pneumatic system! You will need parts from your **V5 Pneumatics Kit** to get things working automatically.

You will need a double solenoid, V5 air tank, one valve stem, a straight female fitting, a pressure regulator, eight straight male fittings, three tee fittings and various lengths of 4mm tubing.

For the **air tank**, screw on the **valve stem** and **straight female fitting**. Then, two of the **straight male fittings** will be screwed onto the **pressure regulator,** four onto the **double solenoid** and two onto the **pneumatic cylinder.**

Connect a tube from the air tank to the pressure regulator (left side of the dial), then another tube coming out of the regulator and into the bottom part of a tee fitting. Then, attach a tube onto each of the remaining sides of the tee fitting, each leading into one of the two **adjacent straight male fittings** on the solenoid.

Finally, put two tubes into the open sides of the **solenoid**, and lead them into the pneumatic cylinder.

It is important to note that you will want to turn the pressure regulator down to around 10 PSi by pulling the knob out, turning it counterclockwise, and pushing the know back in. This can prevent damage to the gears due to too much force.

What to Do...

More practical than a manual in almost every sense, an automatic transmission **could feasibly be used in a competition robot.**

Whether changing driving torque to be better matched for pushing or switching between lifting heavy and light objects, an automatic transmission could have many different uses in competition.

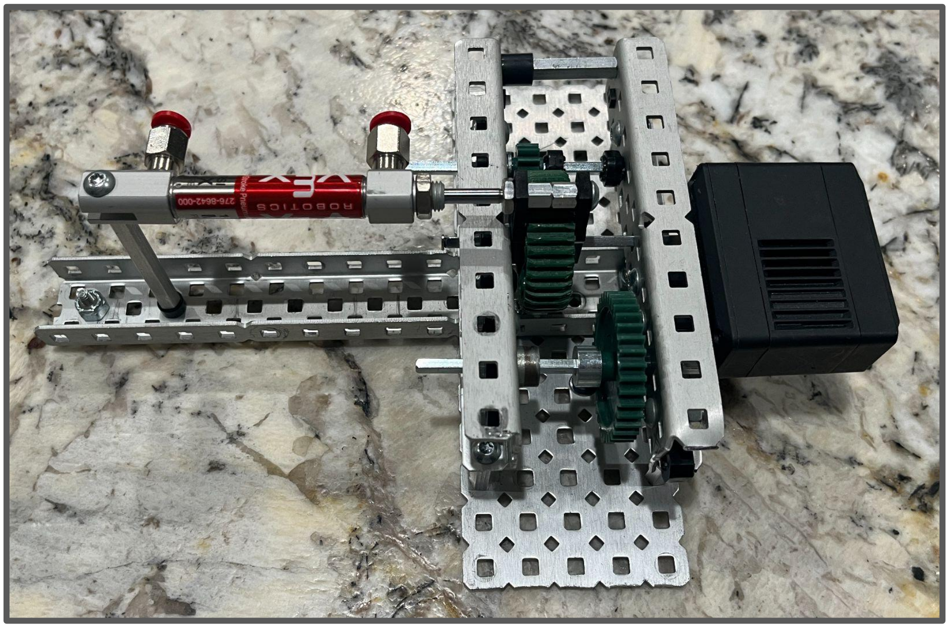
The next step is to program it. Programming a part like this is simple. There are two modes the mechanism could be run in: **sequential** and **automatic**. In **sequential** mode, you would have an “if” statement awaiting a button press from your controller to switch gear. This gives you more control over how the mechanism is operated during a match.

In **automatic** mode, the program can detect changes in power usage and RPM and respond accordingly. This can be useful, as in a match a robot can kite around the field and once it comes across too much resistance, the transmission can kick in high torque mode. Alternatively, although nearly pointless, the robot can begin its acceleration at a lower gear then switch to higher gears. This is much less practical, as the motors are electric and can increase to max RPM much faster than the transmission can keep up.

Now you can take your increased skills and tackle the **Power Turn-On Transmission!** I will not detail *how* to create this mechanism, I will simply show you how it works.

PTO Transmission

Once you are comfortable with the creation, implementation, and modification of different types of transmissions, you can expand your horizons and push your own creative limits and create something new. A **Power Turn On Transmission** is a great next step after the automatic transmission, and in my eyes has the most potential.

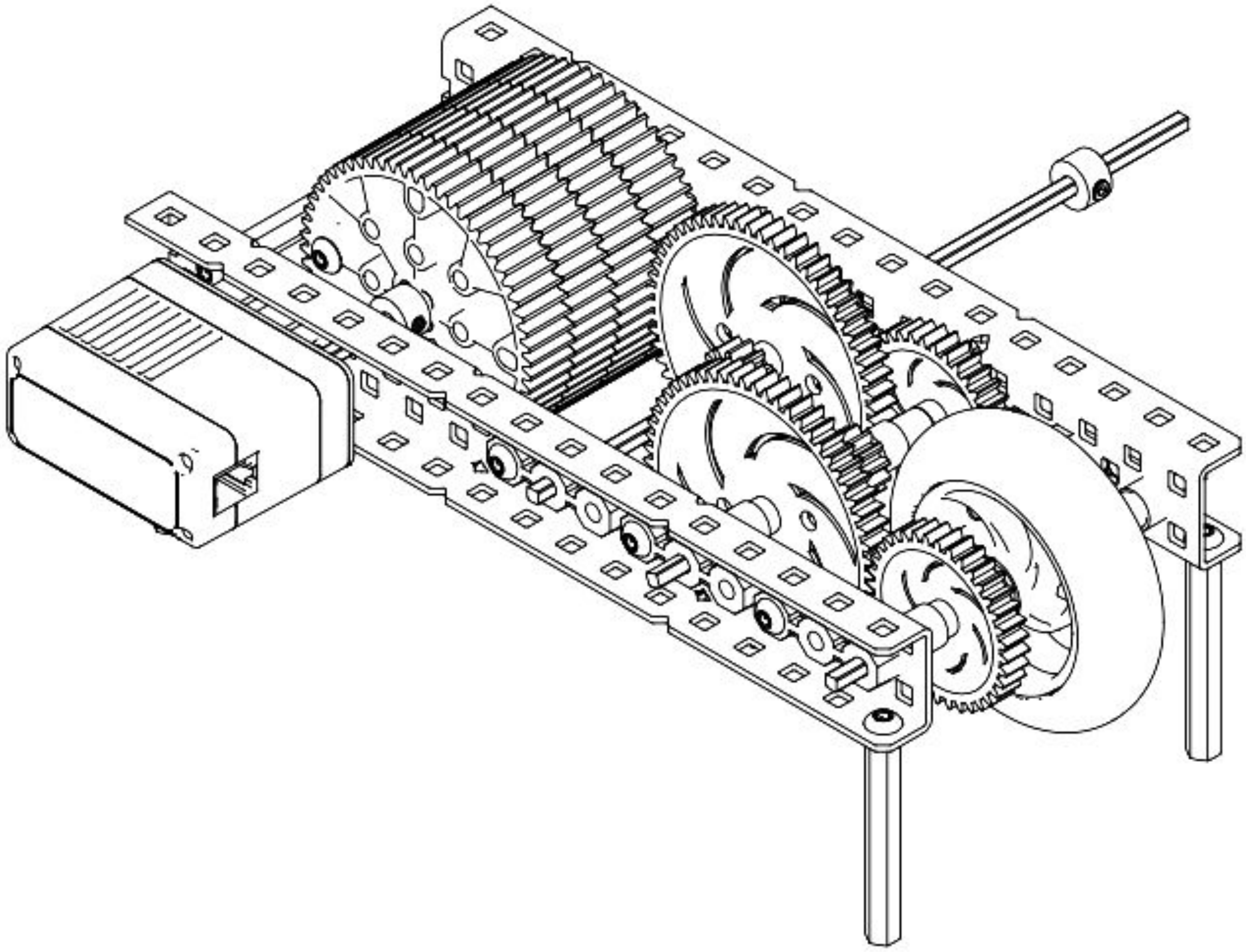


A power turn-on transmission has many applications in a robot. It gets its true reputation from its ability to run **multiple mechanisms** on the robot using the **same set of motors,** allowing for teams to “bypass” the motor limit.

This mechanism is **like** a manual or automatic transmission in the way that it changes gears, **but the gears the driver is meshed with control entirely different mechanisms.**

In last year’s game **Over Under,** many teams were using a PTO transmission in order to use their drivetrain power to pull a winch at the endgame for their climb. **Thanks for reading!**

Isometric View



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	TITLE **Manual3Speed**			
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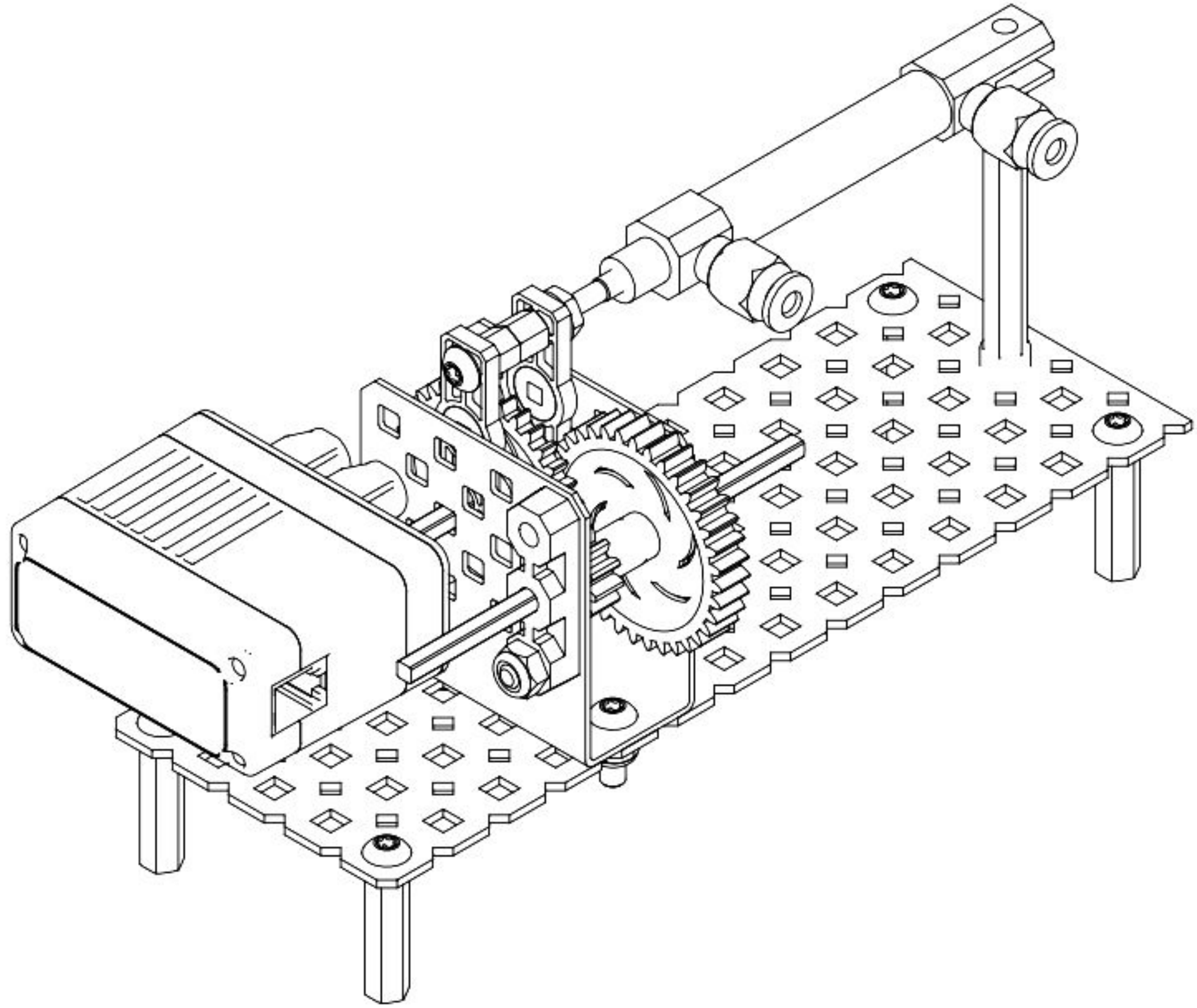
CHECKED	A			
DRAWN Victor Peel 1/23/2025	SCALE 1:1.5	WEIGHT	SHEET 1/1	



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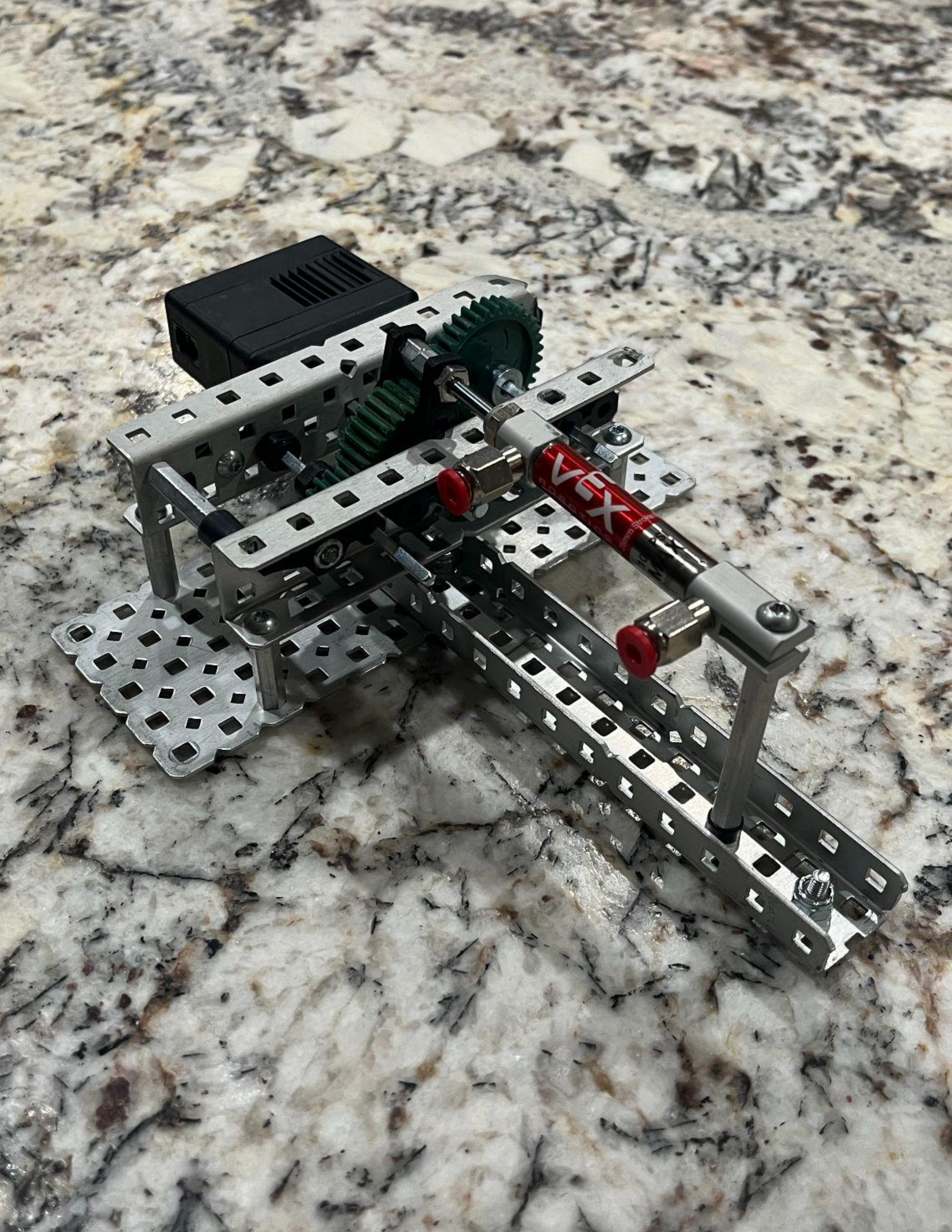
VEX

Sources

A variety of modified images from VEX robotics have been included in this document.

5 speed transmission.png from enginebasics.com

All 3D models have been completed in Autodesk Fusion