

SPECTRUM

3847

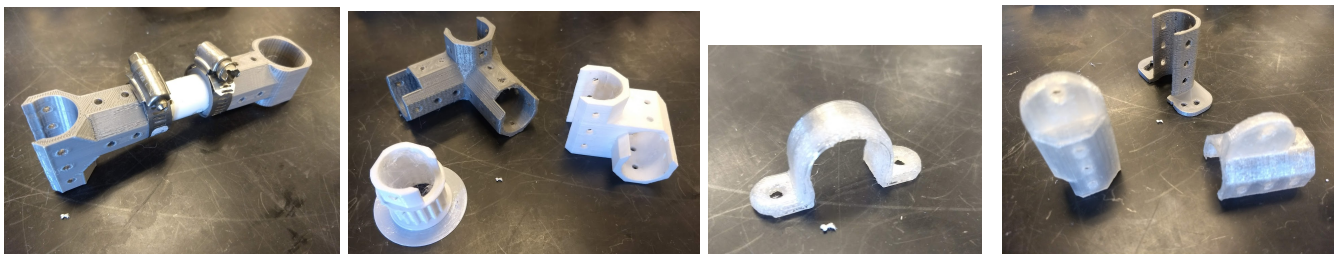
“Protopipe”

Goals

- ▲ Rapid iteration
 - Easy to remove and add parts
 - Easy to reuse parts in the next prototype if needed
- ▲ Inexpensive
 - Try to avoid using expensive parts such as bearings, etc.
 - Use a cheap base material that is locally available
- ▲ Easy adjustment
 - Clamp systems for small adjustments of spacing and belt and chain tensioning
- ▲ As few unique parts as possible in the generic system
- ▲ Easy to make custom parts for each unique application if needed.
- ▲ Able to quickly make rotating parts such as intakes, ball paths, etc.
 - Powered by a hand drill or by a Versaplanetary (or 57 Sport if you like)
- ▲ Able to quickly attach to pneumatic cylinders for making wrists, small arms, catapults, etc.
- ▲ Able to make a rough linear slide system for prototyping stackers / elevators (2015)

Specs

- ▲ 3D Printed Connectors for use with tubing
- ▲ System works best with ½” PVC Pipe but ⅞” tubing also works
- ▲ 5/32” Hole Sizes
- ▲ 1.125” octagon main body, allow for 1.25” hose clamps to work on top of them.
- ▲ Roughly 1.5” of tube is used to connect on each connector



Tools

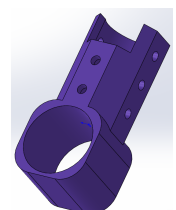
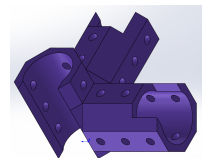
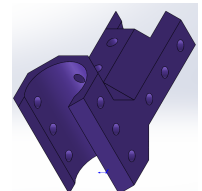
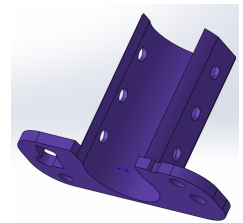
- ▲ 3D printer
 - Or access to one
 - PETG, Nylon or Polycarbonate filament preferred but PLA or ABS may work as well
- ▲ Some way to make sheet parts
 - Laser Cutter or CNC Router or Printed out templates and hand cutting/drilling
- ▲ Cordless Drills, drill bits, and drivers
- ▲ [PVC Cutter \(\\$15\)](#)

3D printed Parts

Grabcad Link to all CAD Files: <https://grabcad.com/library/spectrum-protopipe-1>

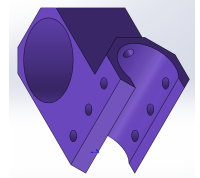
All of these parts are actually a single Solidworks Part with multiple configurations. This makes it very easy to insert them into an assembly and just copy and switch configurations as needed. It also makes it easy to adjust the parts to configure them for your 3D printer if they aren't working for you. You may also need to mirror some of the parts to get the configuration you need for a certain project.

1. Pipe Strap
 - a. Used for mounting flat plates to the pipe or pipe to flat plates. These are also listed in the COTS section but it's probably cheaper to just print your own and you can make sure all the whole patterns and widths are to your liking.
2. 90 Degree Offset
 - a. Used for joining two pipes perpendicular to each other and allowing both of them to pass through the connector. Great for rollers.
3. Pivot Flange
 - a. Mounting wheels, sprockets, pulleys, etc.
 - b. Put through a bearing hole to use a pipe as a shaft, replace it with a bearing for a hex shaft later
 - c. Has a portion of the versa-key system for use with VEX wheels
 - d. Also used as a mounting flange for the tubing, to be able to mount it to a flat plate on its end.
4. 90 Degree End Joint
 - a. Connect two tubes perpendicular to each other. Only one needs to be at its end.
 - b. Use this as a simple pivot by not screwing in the snap on section. Useful for arm, wrists, etc.
5. Corner End Joint
 - a. Connect three tubes at a corner
 - b. one of them can continue through the connector, two must be at their ends.
6. End Bearing Mount
 - a. Put a 1.125" bearing at the end of a tube. Useful for using hex shafts, etc.
 - b. Two bearings can be put into a single mount for making cantilevered axles.
 - c. End bearing mount is the same hole placement as the VEX end bearing gussets so that you can reinforce them if needed.



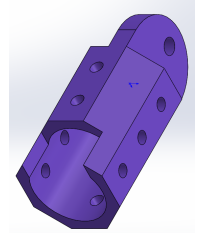
7. Side Bearing Mount

- a. Put a 1.125" bearing on the side of a tube. Useful for using hex shafts as rollers, etc.
- b. Two bearings can be put into a single mount for making cantilevered axles.



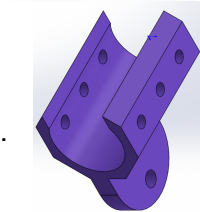
8. End Cap with Pivot

- a. Lets you make angled connections to another pipe either with another "end cap pivot" or with a "snap on side pivot"



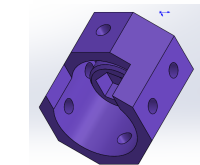
9. Snap on Side Pivot

- a. Lets you make angled connections to another pipe either with a "end cap pivot" or with another "snap on side pivot"
- b. Lets you quickly attach pneumatic actuators to pipes.



10. End Plug

- a. Allows a #10 bolt to be screwed into it from the side
- b. Use in place of standoffs or spacer tubes that would use a press in star nut.
- c. Also has an internal $\frac{3}{8}$ " hex for pushing a bolt in from the inside so that you can drive a shaft with a drill or screw a pipe into a #10 nut.
- d. The internal nut pocket can round out, PLA might work a bit better than PETG here

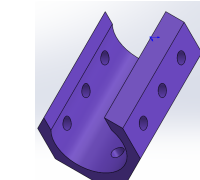


11. Basic Snap on mount

- a. Used as the base for all other parts, not very useful itself
- b. We don't print any of these

12. Side Flange

- a. Used for mounting plates
- b. Also used for making hole drilling jigs
- c. Flange only on one side
- d. Can be used to make sliding mounts across two pipes with a laser cut piece



13. Half Hex to Pipe Bushing

- a. Allows you to put a $\frac{1}{2}$ " Hex shaft into one of the $\frac{1}{2}$ " pipe fittings above. Quick replacement rollers without bearings, etc. Just for testing.

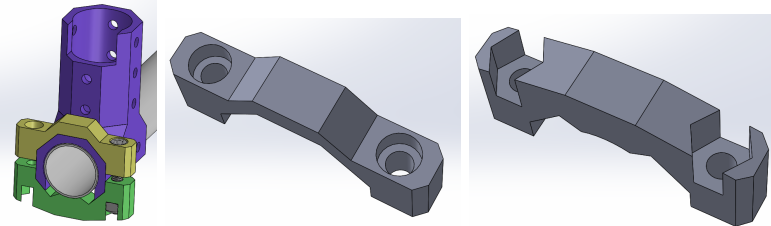


2020 Protopipe Additions

Clamps

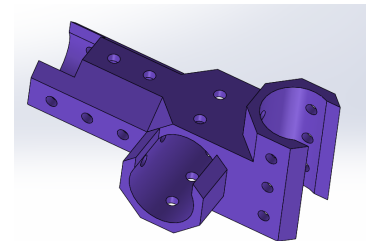
These two piece clamps allow you to securely tighten protopipe to the pipe inserts for quick adjustments and prototypes.

- ▲ Use with 1" Long 8-32 socket head cap screws and nylon lock nuts or jam nuts.
- ▲ Clamps are best printed out of a material that is able to flex without snapping. "Impact Modified PLA" and PETG both work well.



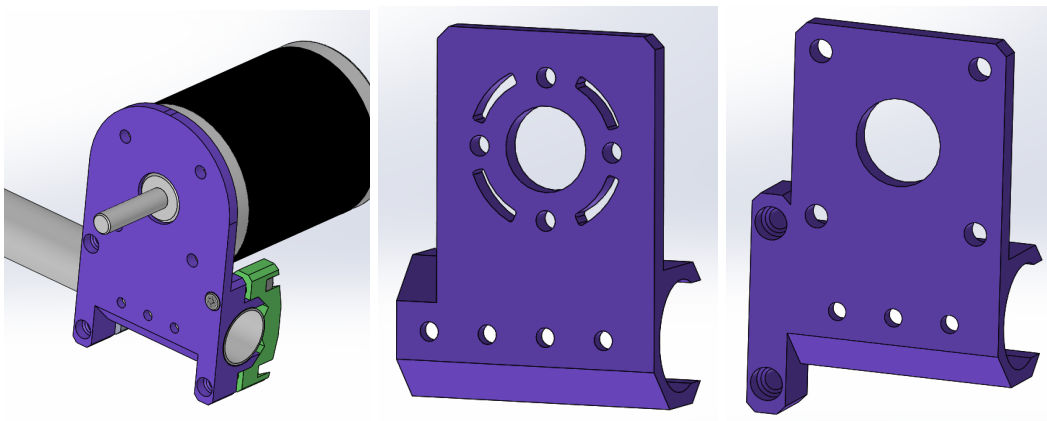
Offset Corner Connector

This connector allows two pipes to pass by each other and one to end mount. This is useful if part of your mechanism needs two degrees of freedom to make adjustments such as adjusting length and height.



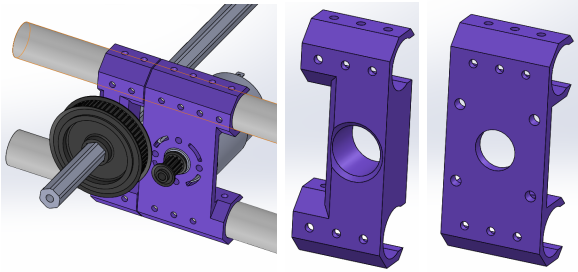
CIM Motor Mount, 775 Motor Mount and Planetary Mount

- ▲ Multiple motor gearbox mounts
 - CIM Mount - Can be used for any motor or gearbox that has a CIM style mount.
 - CIM/MiniCIM/Neo/Falcon 500/Versaplanetary/AM Sport Gearboxes, etc.
 - 775 Mount - Mounts 775 style motors.
 - Planetary Mount - Versaplanetary and AM Sport gearboxes (sport needs spacer)
- ▲ Built In Clamp versions - Has built in clamps, can be mounted with screws as well if you don't want to use the clamps
 - Clamps let you easily slide the motor to tension belts or chain.
- ▲ Regular versions allow normal clamps to be used on the pieces and No Clamp versions allow for tighter fits.



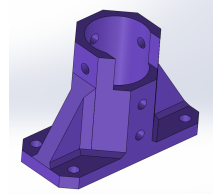
Double Rail 775 mount and thunderhex bushing

- ▲ Double rails give more stability to the prototype.
- ▲ There is also a double rail Planetary mount and a double rail pipe bushing.



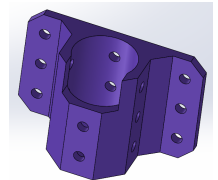
Flange Mount

- ▲ Bottom mount a pipe to a flat surface.



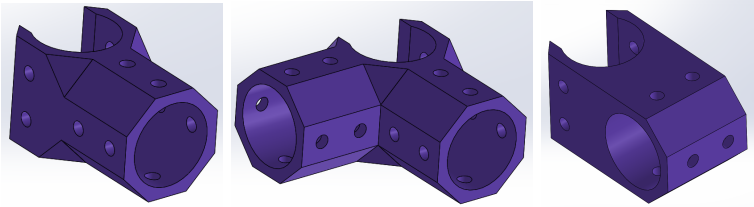
Side Flange Mount

- ▲ Side mount a pipe to a flat surface.
- ▲ There is a regular version that has a bottom for the pipe and thru version that allows the pipe to slide completely through it.



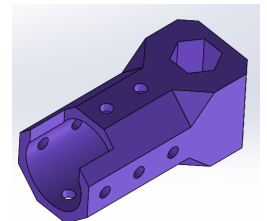
No Clamp Versions

- ▲ We found some of the things we want to build need smaller pieces so we made no clamp versions of several of the parts. These also print faster and need less material.



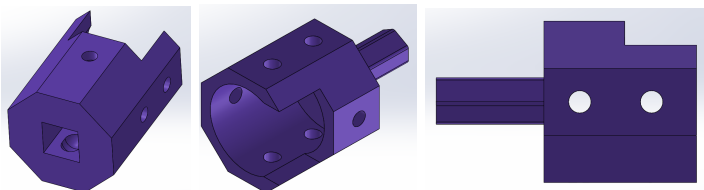
End 500 Hex Mount

- ▲ This is a part developed and suggested by FRC#4926 and Sam Geckler
- ▲ This lets you connect a hex shaft as a rotary joint to the pipe. This could be used for a wrist mechanism or similar.
- ▲ There is also a no clamp version of this part.



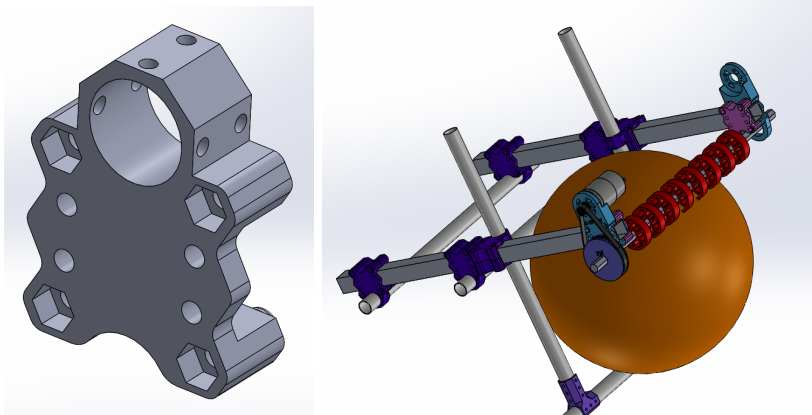
Drill Adapters

- ▲ Allows you to easily spin a pipe with a drill.
- ▲ $\frac{3}{8}$ " Square Socket Drive &
- ▲ Hex Adapter *This part should be printed horizontal with supports enabled.



Protopipe to HYPEblock Converter

- ▲ HYPE Blocks are an awesome resource created by FRC#5254 HYPE
 - <https://www.chiefdelphi.com/t/team-5254-3d-printed-prototyping-resources/335599>
- ▲ This adapter helps you build structures out of protopipe and then have your power transmission be done with the HYPE blocks which are closer to real FRC mechanisms.
- ▲ Example: Shows a simple 2019 Intake prototype.



COTS Items

- ▲ 1/2" PVC Schedule 40 PVC Pipe
 - Optional:
 - 1/2" Schedule 80 PVC for more rigidity (end plugs won't work with this as the ID is too small)
 - [Grainger](#)
 - 7/8" Aluminum tubing
 - Local metal supplier is likely the cheapest
 - DX Engineering: [6063](#) (Probably cheapest online source)
 - McMaster [6063](#) [6061](#) Shipping can be expensive from McMaster
 - Zoro: [6061](#)
 - Boating/Marine supply stores may have this, it's used for some railings and masts
 - 7/8" Wooden Dowel
 - Any 22mm tubing such as Carbon Fiber Tube
- ▲ 1-1/4" Hose Clamps
 - Used for clamping over the 3D printed connector to let you secure them to the pipe without screws and allow them to be adjusted easily.
 - Also used as shaft collars
 - Tighten and loosen with a drill to save time
 - **Sources:** [eBay](#) - [Zoro](#) - [Amazon](#)
- ▲ Keystone 4337 Right Angle Brackets ([973 RAMP Video Link](#) Extremely useful video)
 - Get them from [Mouser](#) or [Digikey](#), buy them in bulk to get them cheaper
 - Used for quickly mounting pneumatics. Double them up to make them stronger.
- ▲ Self drilling wood screws - 1/2" long

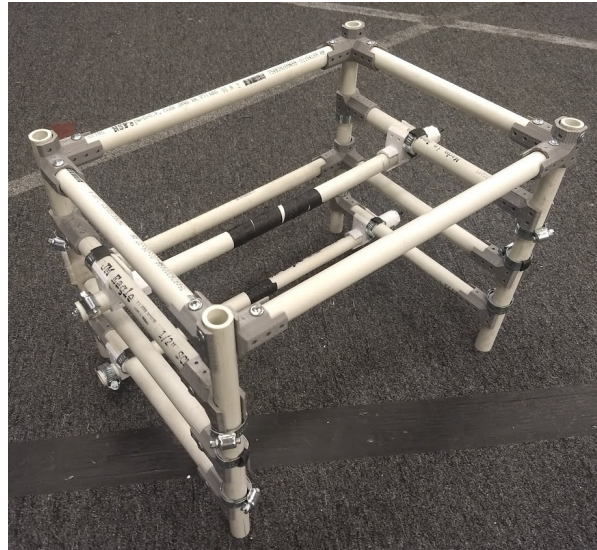
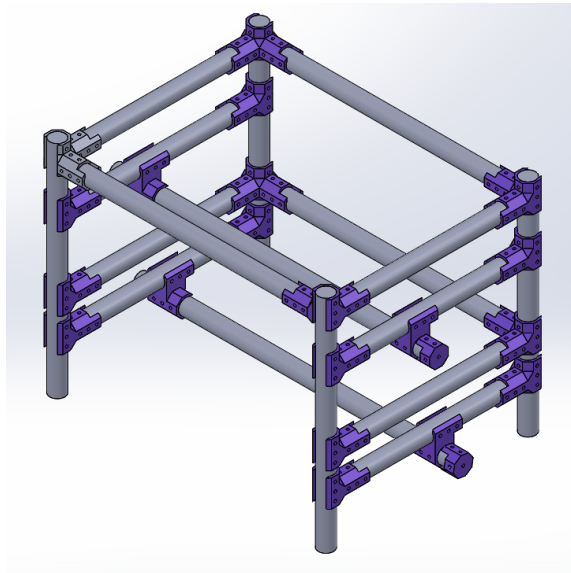
- Used for securing 3D printed parts to pipes
- Use a drill to tighten these quickly
- **Sources:** [Zoro](#) - [Amazon](#) - [Amazon Flat Head](#)
- ▲ #10 x 1" hex head bolt
 - Used in the drill adapter for spinning shafts
 - [10-24 10-32](#) (1-½" long works as well)
 - A fully threaded #10 bolt with a nut turned all the way on to it can be used.
- ▲ Rubber tubing or rubber bands
 - Add them to your pipe clamps and pipe straps to help with adding friction to prevent sliding and rotating of the pipes.
 - Latex surgical tubing works for this
- ▲ PTFE Lubricant
 - used for to make rotating parts work better, since we don't use bearings in lots of places
 - [Amazon Dry Lube](#)

Optional Items

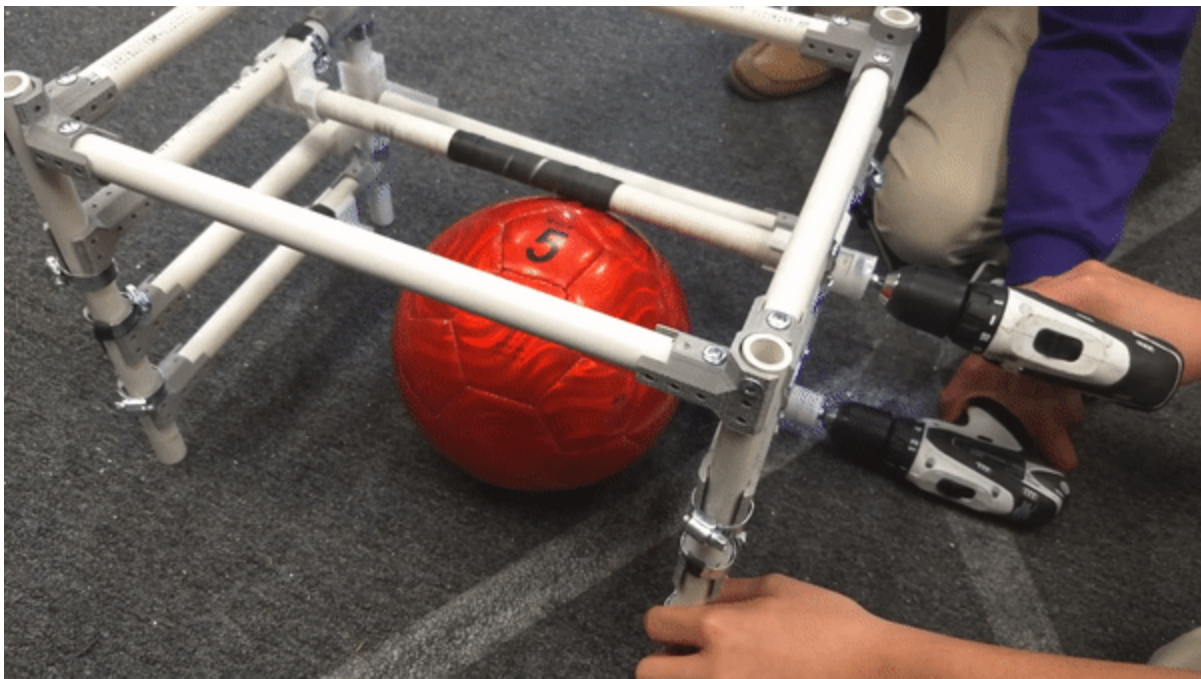
- ▲ Planetary Gearboxes
 - Easily mount motors and change gear ratios
 - We use VPs but 57 sports would work as well.
- ▲ 1-½" ID Aluminum tubing such as VersaRoller tube.
 - A Pivot flange can be inserted into the tube, a pipe can be put through it and all drilled together to get a quickly spinning roller. You can just keep using the hex plugs and hex bearing if you like and mount them with the end bearing mounts or flat plates.
 - 1" PVC has an OD of 1.315" which is only .065" larger than versaroller tubing so it may make a good stand in for prototyping before you buy versaroller tube if you don't have it. Note the ID of 1" PVC is not the same as VersaRoller tube so you will need to make your own adapters for it. The aluminum tubing is definitely preferred for competition robots.
- ▲ 1.125" Bearing mountable wheels, sprockets, gears, etc.
 - Makes it easy to to mount things to the pipe.
 - Hex shaft items clearly aren't big enough.
 - You can print pulleys that can be mounted to the pipe for prototyping
- ▲ Hex shafts, bearing, collars, etc.
 - The end bearing mount does allow for using 1.125" bearings and hex shaft for intakes and systems that need it.
 - You can design in a way to upgrade to a hex shaft after initial testing with the pipe as a shaft is complete.
- ▲ ½" Pipe Straps (Conduit Straps)
 - mounting to flat plates easily
 - Cheaper to just print them but these do work if you need to just buy them.
 - [Home Depot](#) - <https://www.mcmaster.com/3192t51>

Example Prototypes

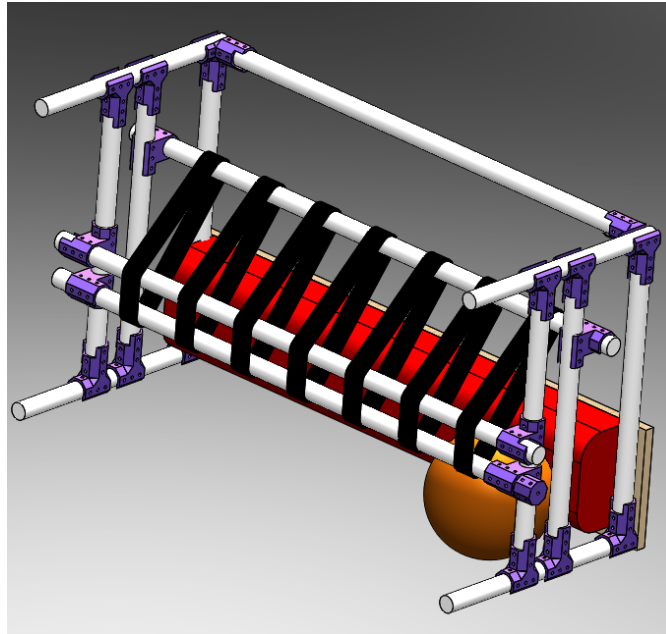
1. 2010 Soccer Ball Pinch Roller



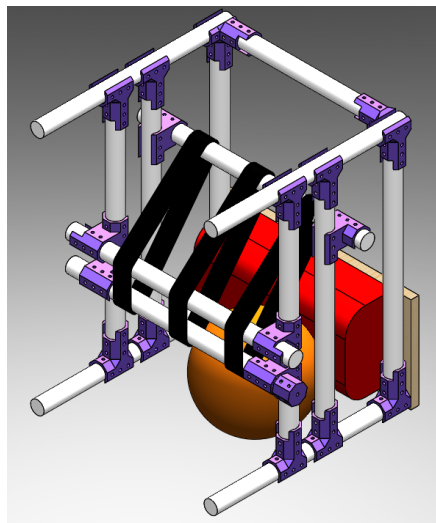
- a. Adjustable Variables: Roller positions, traction material, roller velocities,
- b. Improvements
 - i. Could be mounted to wheels to see how well it holds the ball while simulating driving around the field.



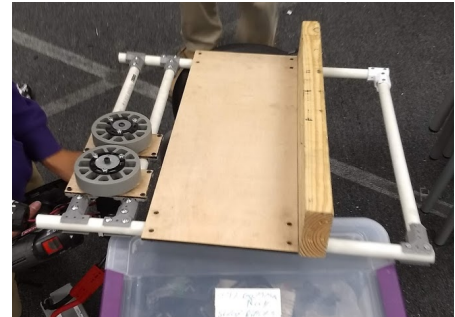
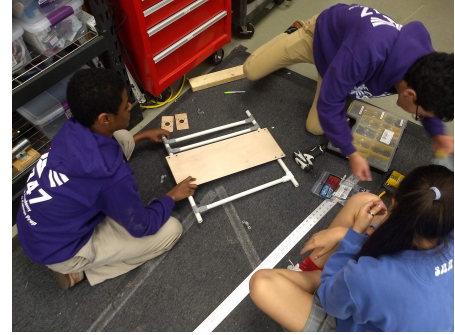
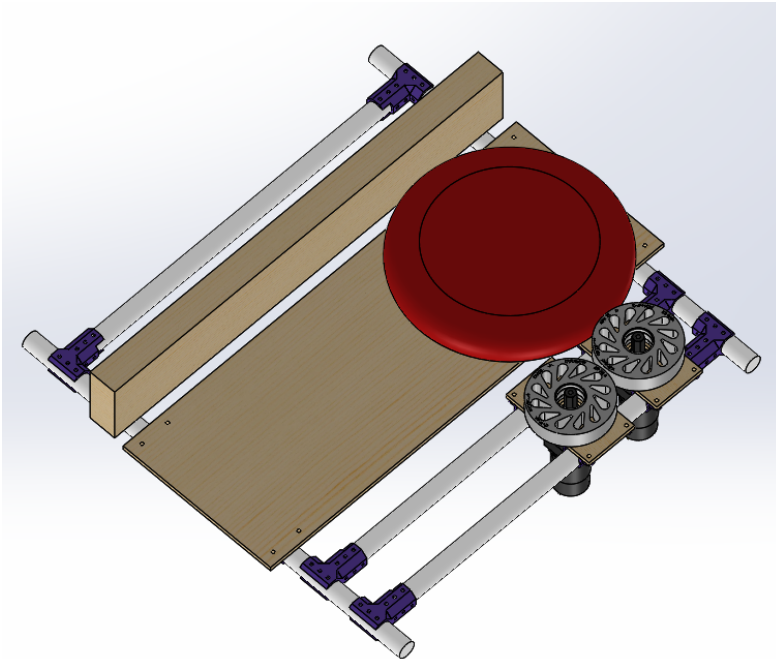
2. 2012 Over the bumper Ball Intake Initial Bench Test



- a. Adjustable Variables - Roller Locations, Bumper Height, Belt Locations / Pattern, Roller Friction Material.
- b. Third roller is a tensioner so you don't have to make multiple belts.
- c. Rollers are able to be adjusted up and down and towards or away from the bumper to learn the optimized belt location to intake the balls over the bumper.
- d. Can be powered by a drill using the end plug or a motor could be mounted to the system and driven by a belt and pulley, etc.
- e. The three rollers would likely be made from $\frac{7}{8}$ " aluminum tubing or the PVC would be reinforced with rods on the inside since the belts would need to be in tension and bending the PVC rollers.
- f. The smaller version on the right is likely enough to get the initial information for roller locations and belt lengths, than a full width version can be created to mount to a chassis for further testing. Widening the prototype just takes making longer PVC sections which is easy.



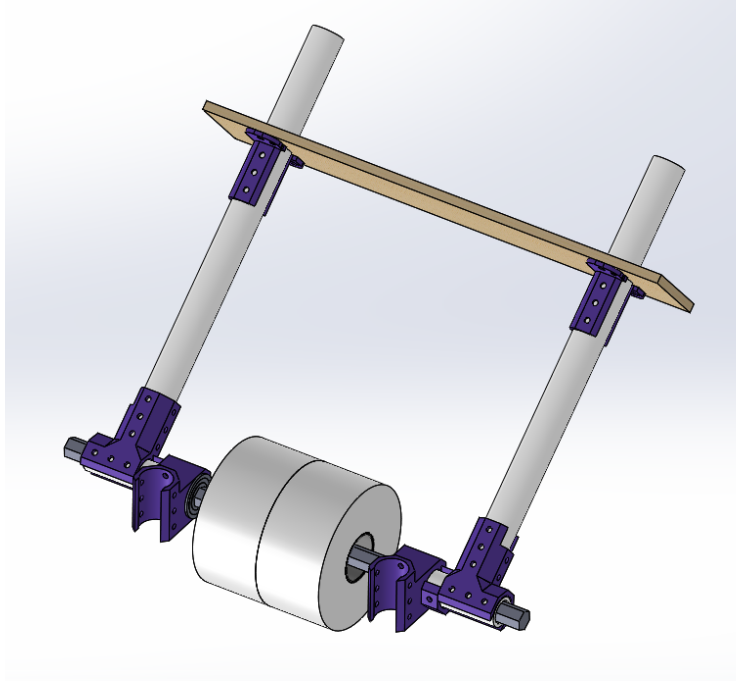
3. 2013 Frisbee Shooter



- a. Adjustable Variables - Shooter Wheel locations, distance to friction wall, friction wall material, wheels, wheel size, gear ratios, motors.
- b. Can add legs that let you adjust the angle
- c. Improvements
 - i. Could add a back stop to the main board for starting the frisbee at the same point.
 - ii. Could add a pneumatic cylinder for consistent frisbee loading



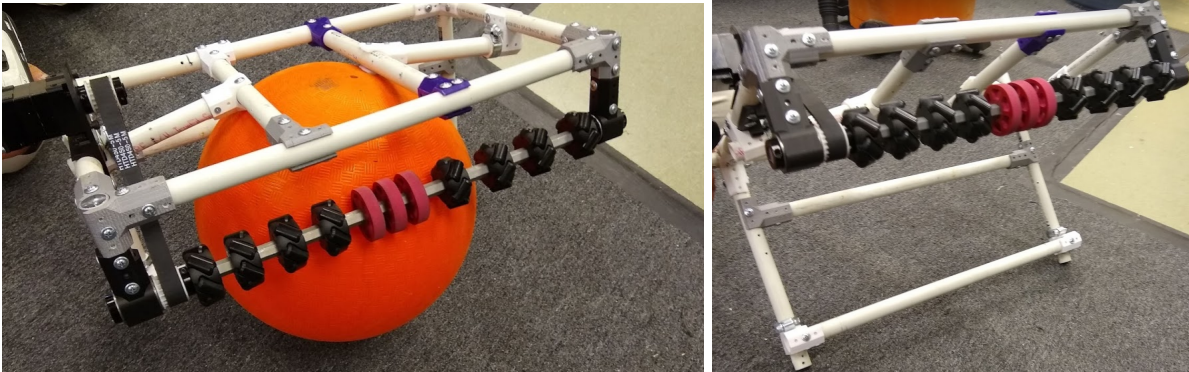
4. Shooter and Adjustable Hood



- a. Adjustable Variables: Shooter compression, angle, wheels, velocity
- b. Utilizes a coaxial hex and pipe setup to allow for the angle to be adjusted on the same axis as the shooter wheels.

5. 2019 Cargo Intake

- a. This was made in the Fall of 2019 to test TheThrifyBot.com Vector Intake Wheels.

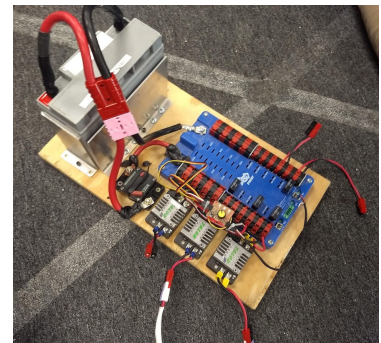


Tips and Notes

- ▲ Use sharpies to write on the tubing to mark measurements, increments for testing, names, etc.
- ▲ Print all the open snap on mounts so the C is printed vertically. Otherwise the snap hinge happens at the layers and they are prone to breaking.
- ▲ If the screws aren't holding for an application, you can remove them and drill all the way through the pipe and use a nut and bolt. #8 work well for this. Washers are encouraged on the 3D printed parts.
- ▲ You can change the ID of the printed parts to change the system to be used with $\frac{3}{4}$ " tube / rod.
- ▲ The pipe or $\frac{7}{8}$ " Tubing can slide inside of $\frac{1}{16}$ " wall 1"x1" aluminum or the 0.4" versatube. This can be useful for joining pre-existing systems, or past robots for prototyping.
- ▲ For longer spans that you need not to bend, using one of the more rigid pipe/tube options is suggested or reinforcing the tube by inserting a rigid core such as a $\frac{1}{2}$ " hex shaft into a $\frac{1}{2}$ " pvc pipe to prevent some flexing.
- ▲ 0.875" OD Bearings fit in the pipe connectors. This would allow for making $\frac{3}{8}$ " thunderhex parts, etc. or for mounting things with $\frac{3}{8}$ " shoulder bolts like in the versaroller system. Not sure exactly how useful it is but it may be cool.
- ▲ If you need to locate an item on shaft quickly but don't have a collar use electrical tape as a replacement, the wheel or gear won't be able to slide past the tape. It works well for tests or quick repairs during playoffs.
- ▲ If needed PVC can be heated and flattened for easier connections to some parts. Example of [FRC#33 using this technique](#).

Other Useful Prototyping Tools

- ▲ Motor Controller Board
 - Use an old Power Distribution Board, main breaker, [servo signal generator](#), and speed controllers to build a control panel that lets you control multiple motors at the same speed.
- ▲ Power-Stick (Modified Drill used to control a motor)
 - Take an old drill or a cheap walmart/harbor freight 12v or 18v drill and remove the motor and gearbox and add wires and Anderson PowerPole connectors (or your favorite quick disconnects). This lets you easily control one motor without needing a battery.
 - [FRC#33 Killer Bees have a guide to build this](#)
 - Ensure it's a brushed drill, and not brushless
- ▲ $\frac{1}{2}$ " HEX turned down to $\frac{3}{8}$ " for small drills.
 - This lets you easily spin $\frac{1}{2}$ " hex bore wheels with a drill to see how they interact with game pieces



Why we didn't choose other options

- **2x4s or other lumber**
 - Prototyping with lumber works but making bearings or slides, etc. takes a long time and you have to manually lay it out and drill the holes, etc. 2x4s are often too large for a lot of tasks. Cutting them requires using the miter saw (chop saw) which is more difficult than a simple manual PVC cutter and harder for new students to use. We will still use them for certain things like structures that require more rigidity, but the pipe is much lighter and faster to work with.
 - Wooden Prototype Examples -
<https://www.chiefdelphi.com/forums/showthread.php?t=160035>
- **VEX Versaframe tube or 1x1 aluminum**
 - Versaframe tube is great but it's not affordable for a lot of fast prototypes. It's harder to snap things on to versaframe tube. Pivots and shafts are also harder.
- **REV extrusion or 80/20**
 - Added benefit of being able to add things in the middle and slide certain things over versaframe tube but definitely more expensive and harder to cut to size than the ½" PVC pipe.

Spectrum Protopipe

