Image A

RufRobot45 was built to apply silicon/caulk on a difficult to access 45° pitched roof

Motivation

Rainwater leaking through a cracked wall in our house caused damage to the paint and the wall, worsens after a heavy rain. After an investigation, I was able to see a gap of 1 to 1.5 cm (around ½ an inch) gap for the length of a section of the roof of 3M/9.8 feet. This space channeled rainwater from the 45° (pitch roof 12/12) roof onto a side panel and down through the cracked wall. See Image 1 below.

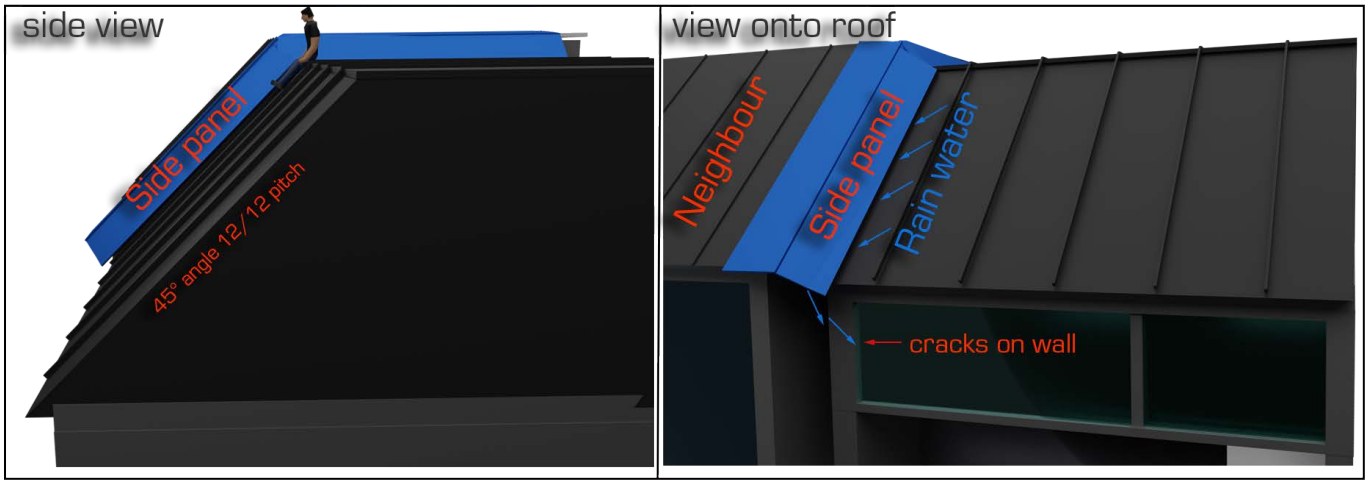

Image 1

I called a few roofers/leakage experts, to get there advice and to assess the cost. The overall cost to repair/stop the leak would be a minimum of $ 1200. The quotes included charges for rigging ropes, safety anchors and insurance to cover the roofer while they inspected and fixed the leak on the difficult to access steep 45°roof.

The estimated cost of $1200 for something as simple as applying Silicone/Caulk of a $20 tube, it was too high, however when you are desperate you would pay the amount to stop the ongoing damage.

Before accepting any of the quotes, I decided to use free time during the Covid 19 lockdown to attempt repair, first of all I had to inspect the roof to see if it's going to be a feasible repair I can do on my own.

Inspection Robot

For the risky inspection, an tether attached RC tank volunteered to go on the steep roof.

The RC tank (Image 2) is a prototype for the final design. Built from old Vex robotic parts (image 3) I had lying around.

Vex 393 motors, tank tread tracks, RC controller and PVC tubes for the chassis to inspect the roof.

Although this Instructable is not about the inspection robot, I have included an image for those who are interested.

Through images from the GoPro a long gap is visible where water could flow towards the side wall. see image 1.

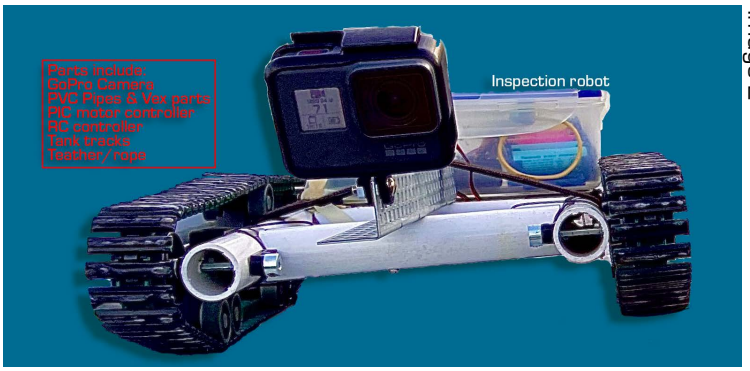

Image 2

Image 3

Automated culking gun design process

This design process could be applied to silicon, glue, or another type of Caulking application that is applied through a tube and nozzle.

Then you need a caulking gun, a simple metal frame to hold the tube and a plunger, a spring to apply pressure, a frame around the tube, then hold the caulking gun and position the tube nozzle against the gap.

Place the nozzle upwards, downwards, rightwards, forwards backwards (axis X, Y, Z) to follow the contour and angle of the gap.

Knowing all this makes it easier to decide what a caulking robot would have to do.

The process was iterative, after many trials, trials and errors, I was able to completely cover the gap and stop the leak.

To better illustrate a design process that others can reproduce I modeled, animated and rendered the robot images with Blender 3D.

Faster rendering was possible by choosing Nvidia Cuda and a 1080TI GPU instead of the CPU on my old system.

Following are the steps in the construction of the robot..

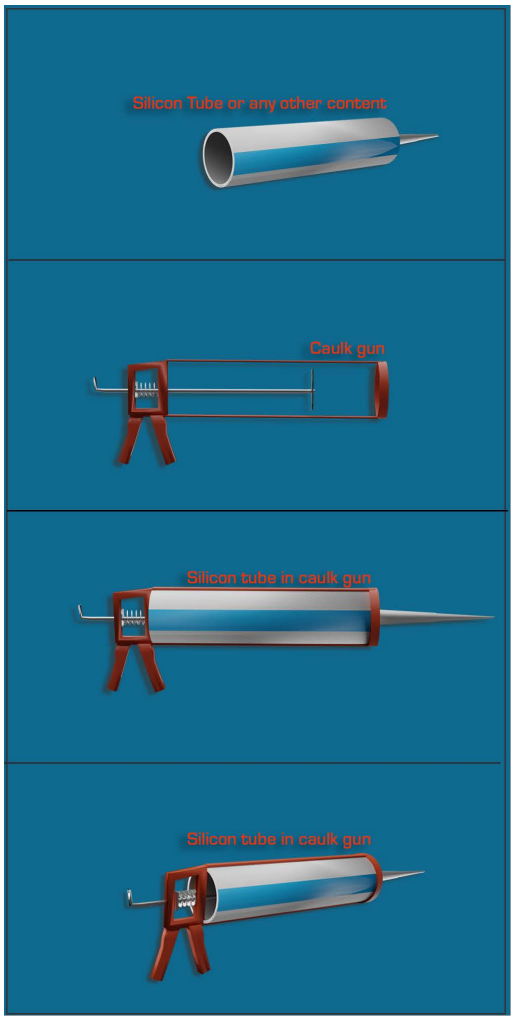

Image 4

Step 1: Motorize the Caulking process

The first step in confirming the vex parts would be enough to reproduce the function of a caulking gun without using the existing caulking gun that would be heavier and more complicated to automate.

The design includes a Vex linear motion kit, 393 motors and various parts to build a type actuator that could push the silicon remotely with the RC controller.

I used the high strength 36 tooth gear to add more torque that is needed to push the plunger into the silicon tube with more force.

The design image is below and the used Vex parts are listed below.

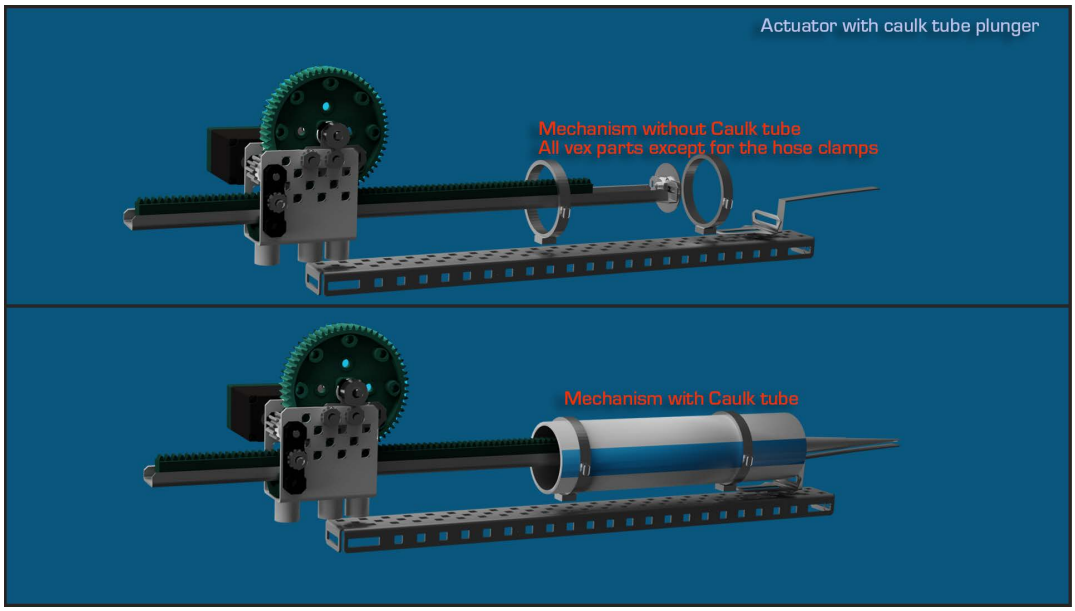

Image 5

Vex parts for Step 1
1x Rail 2x1x25

1x 12" Long Linear Slide Track (for plunger).
1 x linear Slider outer track
4 x Rack Gear sections
2 x Angle Gusset

1 x Vex 393 2 wire Motor and 1 x Motor controller 29
1 x 60 tooth High Strength Gear (2.58 inch diameter)
1 x 12 tooth metal gear
3 x Shaft collar
1 x Rack Gearbox Bracket
2 x High Strength 2 inch shaft
3 x Bearing Flat (Cut one of them into 3 pieces and use them as spacers) 2 x Plus Gusset

3 x .5 inch Nylon Spacers
1 x .375 inch Nylon spacer

Non Vex parts
2 x 4 inch hose clamp(to keep tube in place)

Step 2: Build X,Y, Z positioning mechanisms (Forward Backwards Z axis)

Now that the plunger mechanism works, we can add a forward and backward positioning mechanism to control the location of the silicon tube and plunger, this will help offset the limited movement of the robot tank on the steep roof.

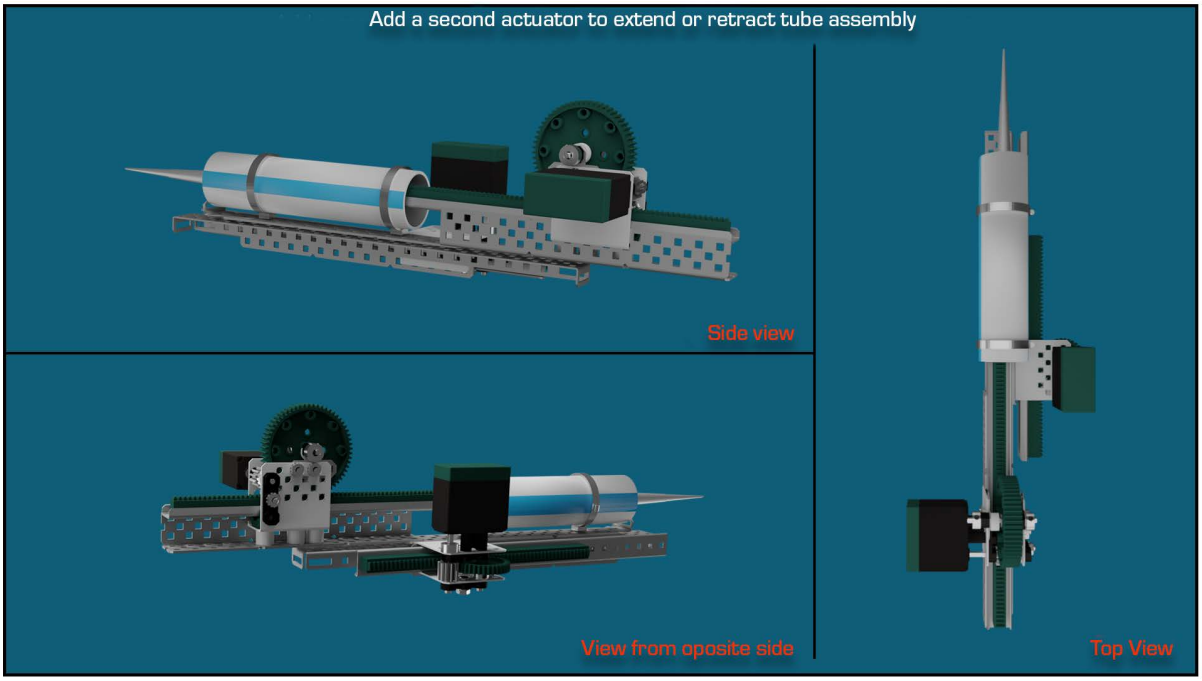

Image 6

Parts for step 2

Vex parts
2 x Angle 2x2x15
1 x Vex 393 2 wire Motor and 1 x Motor controller 29 1 x Worm
Bracket 4 Hole
1 x 12 tooth metal gear
1 x 36 tooth gear
2 x High Strength 2 inch shaft
2 x Shaft collar
1 x 12" Long Linear Slide Track
3 x Rack Gear sections
1 x Linear Sider inner truck
2 x Bearing Flat

Step 3: Build X, Y, Z positioning mechanism (Up or down, Y axis)

In this step, we build the mechanism to move the tube platform up and down that now includes the weight of the silicon tube, two vex motors, two linear motion kits, one to support the plunger, another to provide the forward backward movement.

Other associated parts fundamentally components in step 1 and step 2.

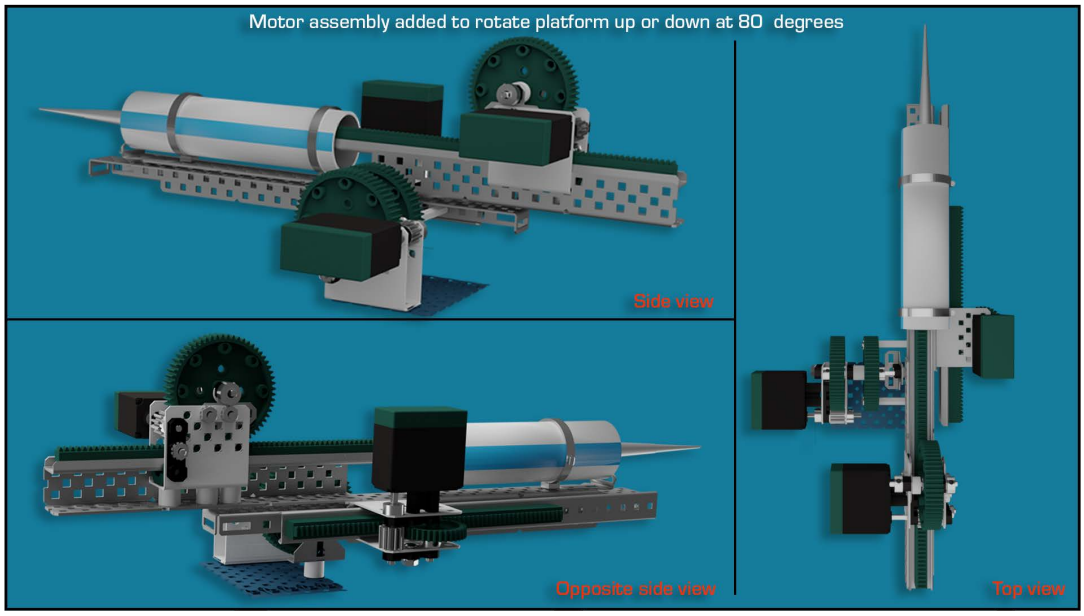

Image 7

Parts for step 3

Vex Parts

1 x steel plate 5x15 (Cut with metal snip or hacksaw to 3.5 x 2.5 inches) This will be the base for the silicon tube assembly.
1 x Vex 393 2 wire Motor and 1 x Motor controller 29
1 x 60 tooth High Strength Gear (2.58 inch diameter)
1 x 12 tooth metal gear
4 x Shaft collar
1 x WormBracket 4 hole
2 x High Strength 2 inch shaft
4 x Bearing Flat
2 x 2 inch standoff
1 x Angle gusset
1 x .5 inch Nylon Spacers

Step 4: Build X, Y, Z positioning mechanism (Left or right, x axis)

The tank bot covers 3 m/9.8 feet on the pitched roof, moving the silicon tube down to inject silicon and up to scrape.

The Vex plastic tank treads have limited traction on the 45˚ incline. The treads provide sufficient control to position the tank slightly to the left or right. Moving the tank upwards and downwards of the roof is possible by a retractable tether (a lockable dog leash).

Once the tank is positioned in place the silicon tube mechanism can slide on a 30cm/12 inch track that is built onto the tank. This means that the bot can cover 30cm sections of caulking at a time before moving the tank via tether to caulk a new area and so on.

Image 8

Parts for step 4

Vex Parts

The image shows a 36 tooth gear, after some testing, this was replaced with a 60 tooth gear to provide more torque needed to push the weight of the silicon tube mechanism up the 45˚ incline.

1 x Vex 393 -2 wire Motor and 1 x Motor controller 29
1 x 60 tooth High Strength Gear (2.58 inch diameter)
1 x 12 tooth metal gear
4 x Shaft collar
1 x Rack Gearbox Bracket
2 x High Strength 2 inch shaft
3 x Bearing Flat (Cut one of them into 3 pieces and use them as spacers)
2 x Plus Gusset
7 x .5 inch Nylon Spacers
2 x Angle 2x2x25 Hole
4 x 1 inch standoffs
1x 17.5" Long Linear Slide Track
2 x linear Slider outer track
5 x Rack Gear sections

1 x Steel C-Channel 2x1x35 or Steel C-Channel 1x5x1x25 (depends on the length of the track).
This C-Channel is attached on the edge side of the track closer to the silicon tube. It support the weight of the tube mechanism. Otherwise the track will tilt out of the plastic linear slider.

Image 9 illustrates positioning of the tank with a tether while controlling horizontal position of the tube.
Image 10 shows a new position for the tank.

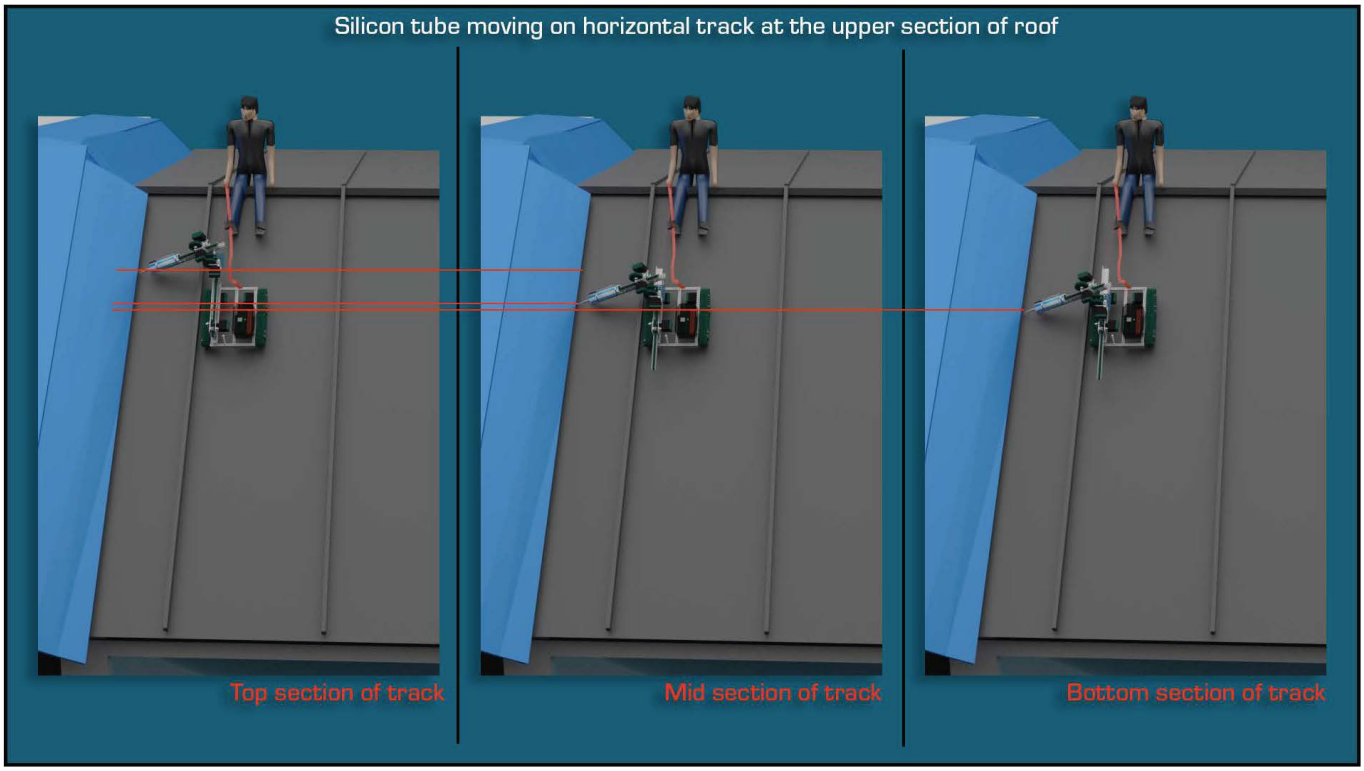

Image 9

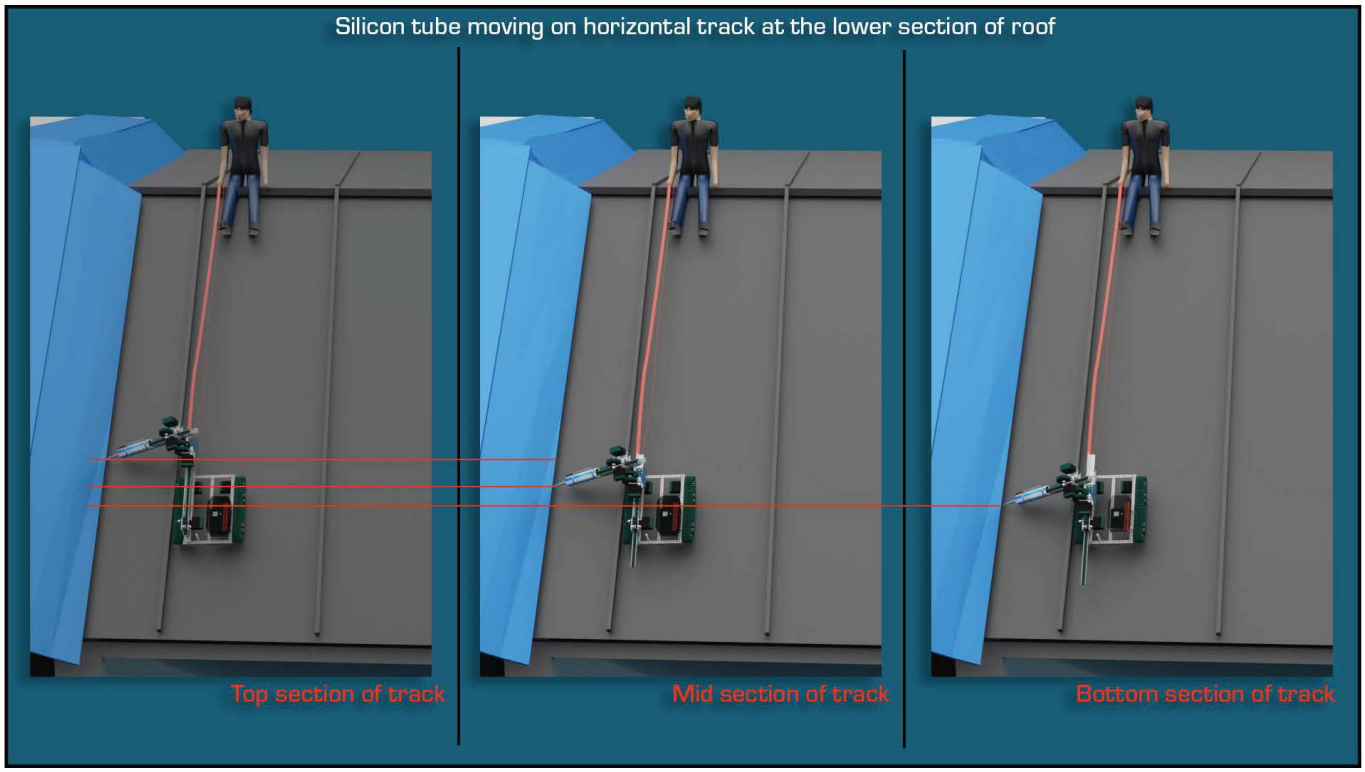

Image 10

Step 5: Build Tank base with controller electronics

I used a tank base vs wheeled because it provides a stable platform with the possibility of some traction, while plastic treads have poor traction its enough for the current design.

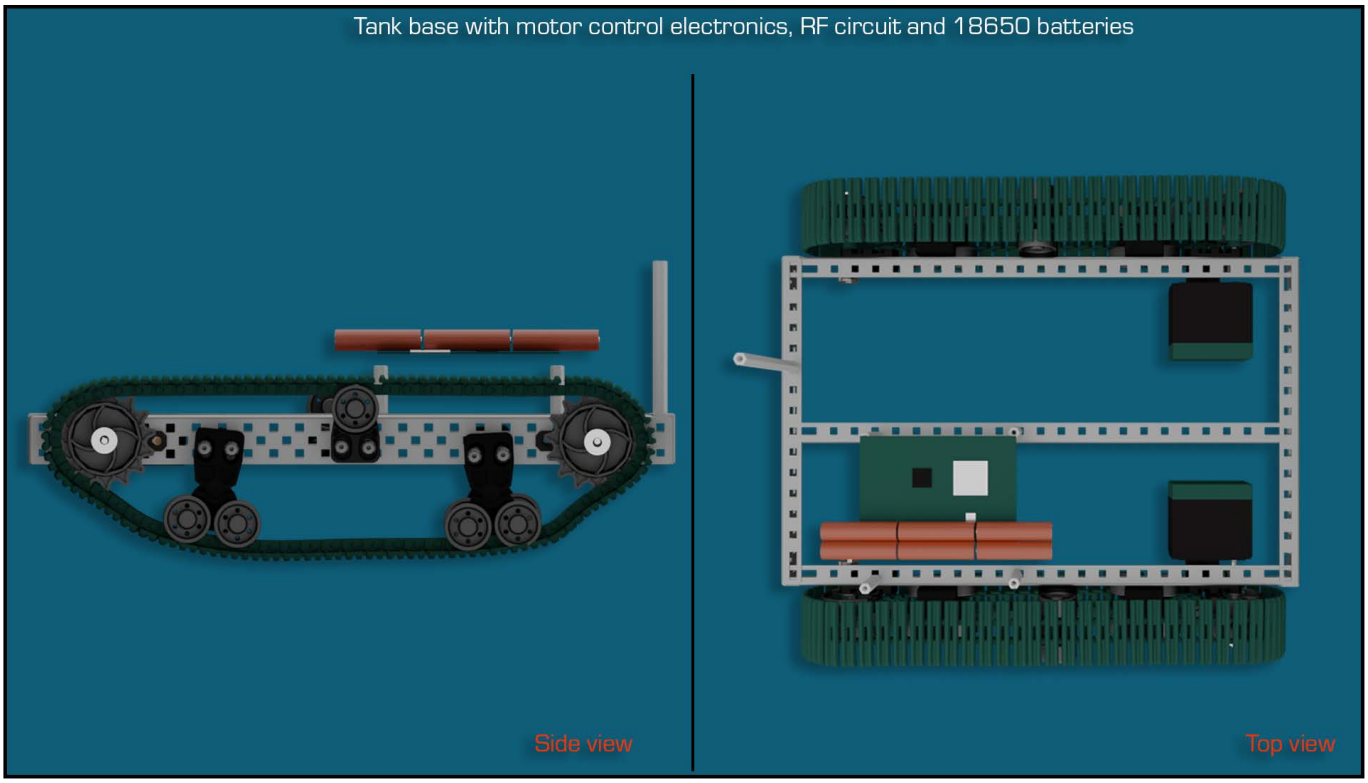

Image 11

Parts for step 5

Vex Parts

2 x Vex 393 2 wire Motor and 1 x Motor controller 29
2 x 3" High Strength Shaft
6 x Bearing Flat
2 x Rail 2 x 1 x 16
2 x Rail 2 x 1 x 25
8 x Shaft collar
1 x Tank tread kit
4 x 1 inch stand offs
1 x Vex Pic Controller

Battery, to power pic controller:
I used the Vex AA 6 battery holder for the PIC controller that provided enough voltage and current during the build out process, however I found that the AA battery pack could not provide the current to power 6 x motors 393 especially when the torque is required to force the plunger into the silicon tube.

To provide appropriate power I connected two 18650GA NCR batteries (3500mAh each) in series to provide ~8volts, with 2 additional batteries wired in parallel for increased current. With this battery setup I have plenty of current to operate the robot covering 3 m of caulking.

I also used an 18650 4 x battery holder as shown in image 14.

Step 6: Attach and connect the tube platform to tank base.

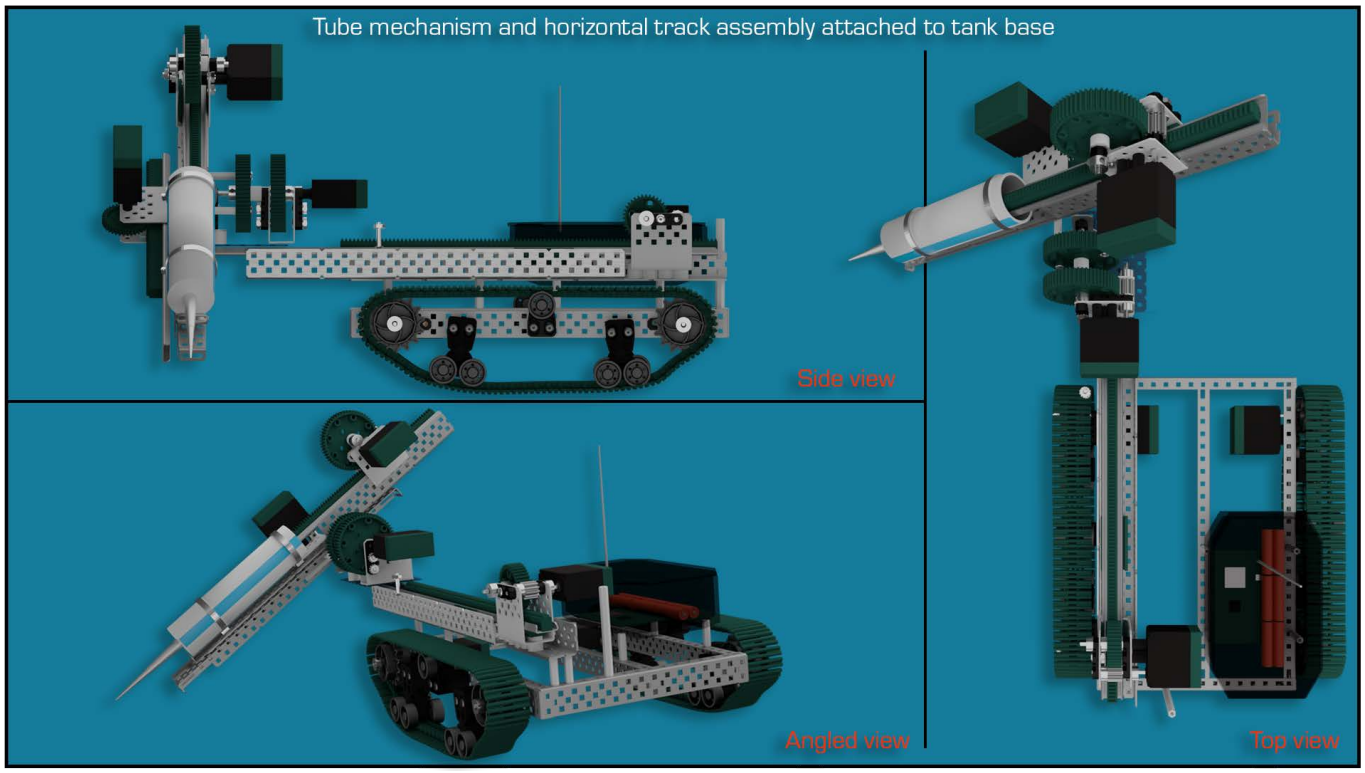

Image 12

The tube platform is fixed to the tank's edge. The edge position provides optimal clearance from the tank tracks, it also provides reachability for the silicon tube.

Adding ballast or any heavy metal object on the opposite side of the tube platform will provide the counterbalance to keep both tank tracks firmly grounded.

Step 7: Connect motors to PIC controller, fine tune RC controller

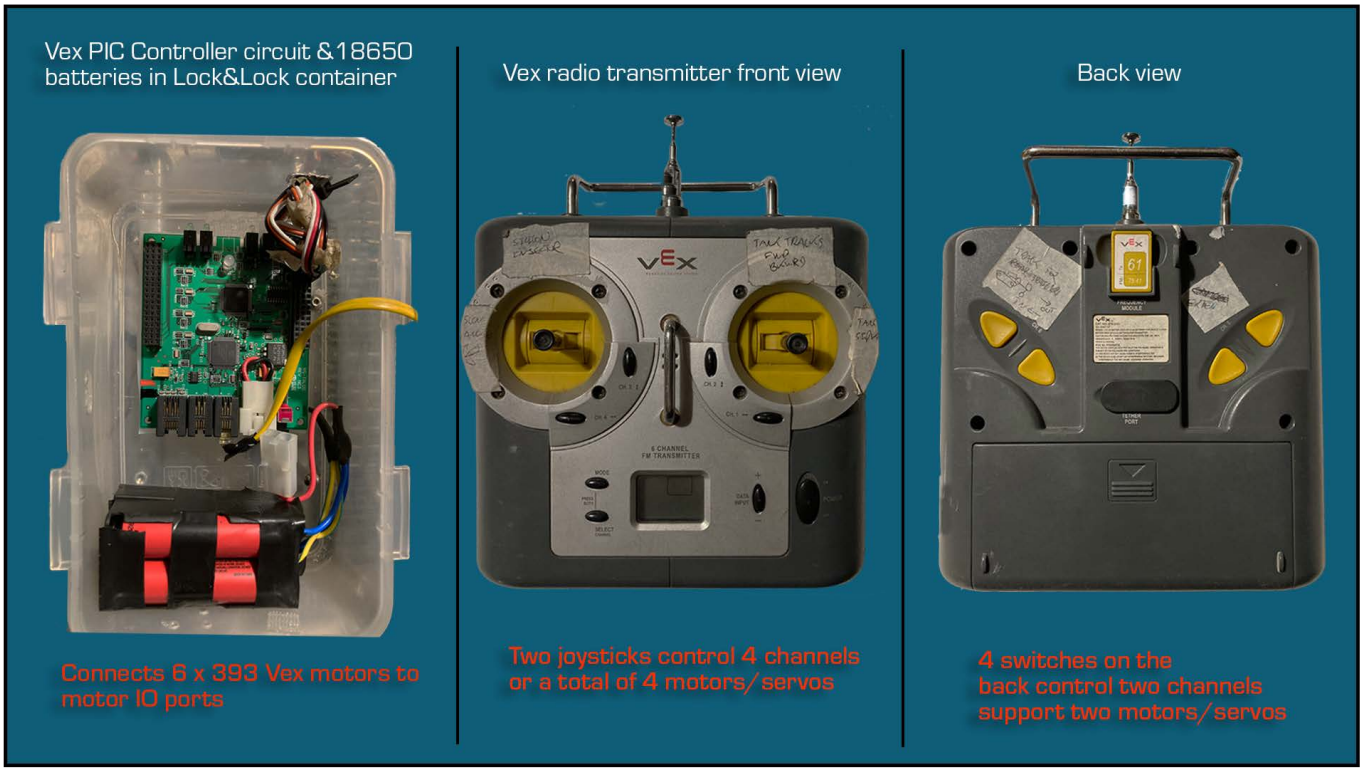

Image 14

In Image 14 the 6 motors are connected to the IO ports on the Pic controller in the Lock&Lock container. Each IO port is mapped on a channel of the transmitter.

For the motors that require finer control such as the horizontal sliding motor as in step 4 and the left right tank tread motors.

A GoPro is fixed and placed on the tube assembly pointing at the nozzle. The camera is there mainly to record the process, and to provide a Point of View back to my iPhone, even though I ended up not using the POV capability, it was easier to sit physically at the edge of the roof so that I could see and control what the robot was doing.

This project can be reproduced using Adruino or another microcontroller, and an appropriate WIFI or radio remote controller.

Vex robotic parts are great and easy to prototype. Newer motors and control system in the Vex V5 range have major improvements, another alternative is ServoCity.com that carry a range of motors, rails, brackets etc everything you need to build the mechanics.

Next is a cleaner and simplified design with sensors and the ability for a tank or device to go beyond the 45 degree angle and up to 90 degrees, delivering silicon on a high wall.
Real images of the robot are attached.

Check again later, I will soon upload videos of the robot.

Image of robot on roof