ENGR 480 FALL 2020

TEAM 3

TAIKO CANTIL, IVAN SNYDER, ASHER TRUNKEY

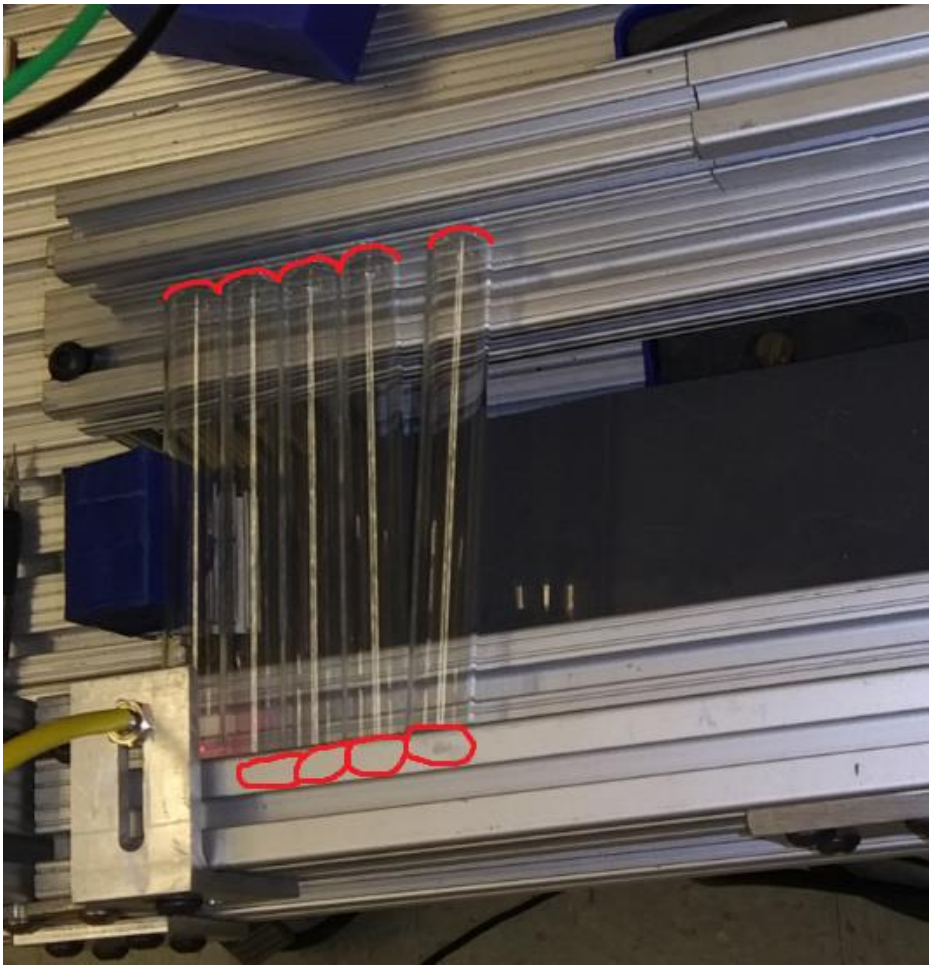
TABLE OF CONTENTS

OPERATING INSTRUCTIONS

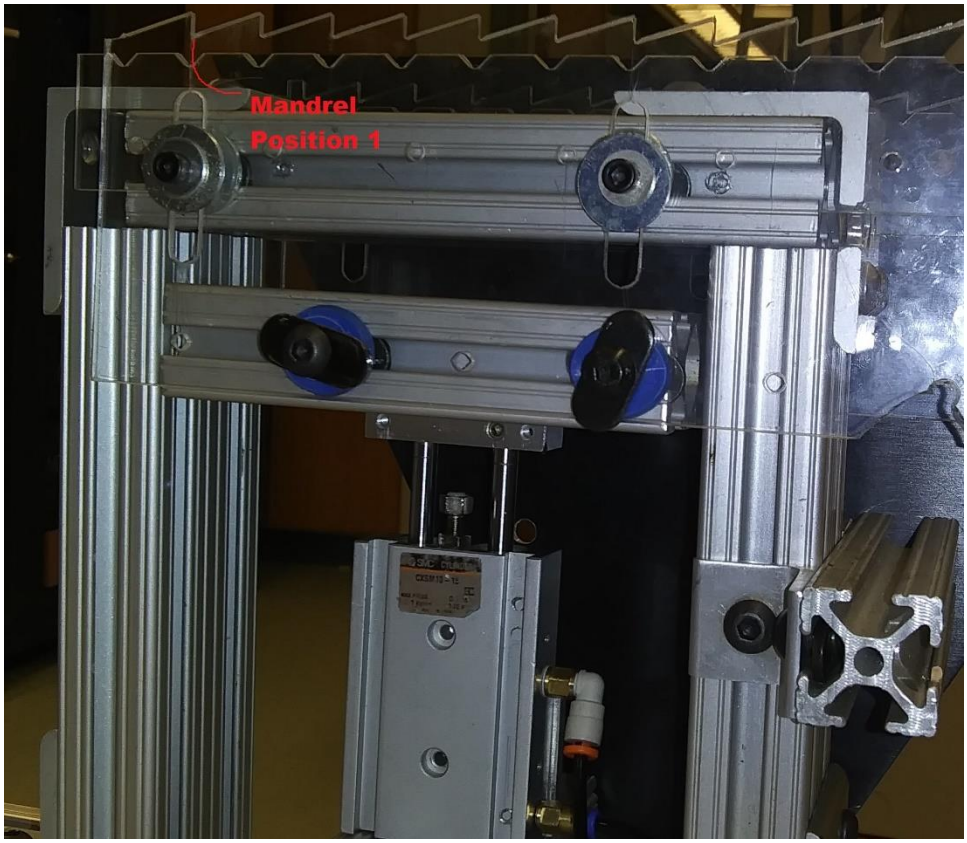
LOADING THE MACHINE

There are 3 main steps to load the machine as there are only 3 main components to the system. First make sure that pressurized air and electricity are connected to the workspace. Also ensure the assembled unit tray is empty.

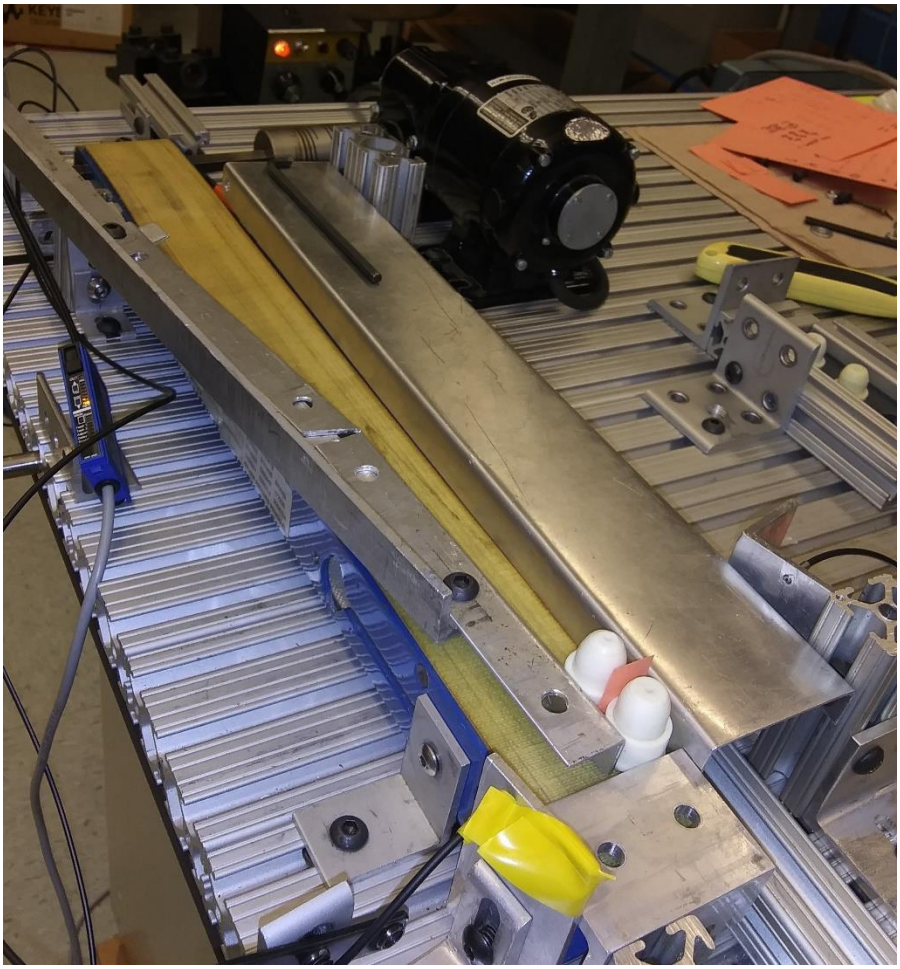
1. Glass Test Tubes: The test tubes must be loaded into the tray with the open end facing away from the robot arm base and towards the outside of the table.



2. <u>The Mandrels</u>: This is the most important item that is getting packaged. Since the mandrel will be holding the graft, it is important that the graft is positioned 5mm from the center of the table end of the mandrel and 15mm from the end of the mandrel end at the edge of the table. The machine is designed specifically to package the items in this orientation. Also note that the mandrels can be placed in any of the notches on the saw-tooth conveyor, but the machine will only take from the first position closest to the test tube rack. Hold down both the “Interlock” and “2” buttons on the robot computer to activate the saw-tooth conveyor. The button combo must be pressed two times with a slight pause in between to fully cycle the conveyor. It goes down and then back up to ready position.



3. The Silicone Caps: The most challenging part to work with are the silicone cap stoppers. These must be positioned on the conveyor 10-15 cm apart. They will move toward one end once the conveyor is turned on. Setting for the conveyor are 0-100 in increments of 10, and the system is designed to be used at the 10 setting.



STARTING THE MACHINE

1. To get the machine running, it is important to make sure that the air hose and table electric power cord are connected if that has not been done already.
2. The switch on the side of the table under the mandrel conveyor needs to be switched to the ON position.
3. Make sure the sensors are working. The sensor has a small processor on it that has teach buttons and also lights that show output. This output light should blink on when the test tubes are place in their proper location. When stoppers are ready to go, the output light on for the photoelectric sensor will turn off which means the stoppers have broken the beam.
4. Pick up the handheld computer for the machine and on the screen click Select Job. This will bring up the list of currently saved jobs, next select the job titled "TEAM_3_WITH_AIR_FINAL".
5. Use controls to move the robot to a position somewhere above the glass test tubes in between it and the saw-tooth conveyor. This is also point 001 in the program.

6. When everything is ready, engage the clutch with left hand on the back of the handheld computer and the press buttons “INTERLOCK” + “TEST START”. This will cycle through the whole program and return back to the ready position.
7. The most likely place for an error is during mandrel placing and test tube placement the first time. The mandrel usually hits the hole in the stopper but that is not 100% guaranteed as any bend in the mandrel can cause variation. Additionally, if the mandrel is successfully inserted but at an angle, it is possible that the free end will be outside the diameter of the test tube. Take care to be aware of this during operation. If necessary, one can release/squeeze the clutch or release the TEST START button to stop the operation of the robot.

TROUBLESHOOTING AND CLEARING JAMS

Below are some of the most common issues in detail and how to solve them.

Location	Symptoms	Cause	Solution
Test Tube Dispenser	Robot stops moving during the tube collection process.	Glass test tube sensor misaligned or the tubes are missing, not in proper place.	Ensure the test tubes are square against blue block and the sensor end is working.
Mandrel Inserting into the Silicone stoppers	Mandrels are not lining up with the holes in the stoppers.	Mandrels are not going far enough into the gripper claw blocks.	Check to make sure the black triangle guard is properly spaced so that the claws have the most mandrel possible.
Conveyor Assembly	The tube is not successfully assembled on the conveyor.	Mandrel is bent. Stopper is not level, hole not centered.	Straighten or replace mandrel. Discard stopper and make/use new one.
Stopper on Conveyor w/ Mandrel Inserted	Mandrel is not within tolerance of the test tube ID.	Cause 1 – Uneven silicone surface. Cause 2 – Angled mandrel hole	Sol. 1 – Discard/fix stopper. Sol. 2 – Discard stopper.

DETAILS AND DESCRIPTIONS

HOW IT ALL WORKS

1. Robot Arm
    a. Test Tube Gripper: The test tube gripper is a pneumatic routed to the robotic arm base station. On the pneumatic, a pair of 3D-printed grippers are used to handle the transportation of the glass culture tube firmly, yet gently.

    b. Mandrel Gripper: This smaller pneumatic cylinder holds two carefully machined aluminum jaws and is routed through the robotic arm to the robotic arm base station. These jaws were designed to tightly secure the mandrels without interfering with the grafts.

2. Glass Tube Dispenser
    a. Gravity: The gravity-fed, glass tube dispenser relies on a very slight angle of inclination to deliver culture tubes safely and repeatably to the singulation area. The slight angling of the dispenser allows the tubes to roll without creating enough kinetic energy to damage the glass. This is possible because the friction factor of glass rolling on aluminum is quite small.

    b. Spring: One of the key elements of the dispenser's singulation function is the spring in the middle of the dispenser. This spring is made out of a flexible plastic and when depressed allows the culture tubes to be collected by the robotic arm.

    c. Proximity Sensor: At the front of the glass tube dispenser, a proximity sits to detect the presence of any loaded glass tubes. The sensor has been taught to output a signal only when a glass tube is ready for transport. If the sensor cannot detect a tube and does not output a signal, the singulation process for the glass tubes will be prevented until a signal is output. This sensor is in place to ensure that every time a stopper is prepared with a mandrel, it can be removed via the tube handling process.

3. Mandrel Saw-Tooth Conveyor
    a. Actuating: The pneumatic is normally extended up when the machine is energized. In order to cycle to the next mandrel, the pneumatic actuator reverses the flow and the pistons contract. This sets the mandrels into the slot since the saw-shaped teeth are now lower and not engaged. When the actuator goes back to original flow, the sawtooth acrylic pieces rise back up and then hold the mandrels in the ready position.
    b. Design: The system has simple pins and slots that align the two acrylic conveyor parts. There is also the main ∏ shaped frame that is attached to the table. The acrylic piece that only has slots is attached to the main frame. The sawtooth acrylic piece is guided by slots up and down on this main frame but is also connected to another block of 80/20 that is connected to the pneumatics.

4. Conveyor
    a. Guidance Walls: Along the sides of the conveyor are stopper guide walls. These walls are intended prevent jamming and create repeatable location for the silicone stopper caps to wait for the mandrel and culture tubes to be assembled.

    b. Photoelectric Sensor: These sensors are in place to detect if a stopper has reached the required insertion location. A beam of light is passed from one sensor to a reciprocating sensor and emits a signal. If the light is blocked, by say, a stopper crossing the threshold, then the signal is turned off. The robotic arm will not insert a mandrel if no stopper is within the threshold.

    c. Stopper Movement: Stopper caps are placed in onto the conveyor in an upward facing direction and allowed to move to the end of the conveyor for assembly. The speed of the conveyor can be controlled using the attached motor controller. For best results use a slow speed of 11-12 rpm with the directional control set to reverse.

5. Placement Tray
    a. Concept: The placement tray marks the end of the assembly process and is the starting location for delivery/shipping or further processing. This part can be changed out as needed for the desired post-processing applications.

MAINTENANCE

- Glass Tube Dispenser
    - Spring Replacements: While no tests have been conducted regarding the longevity of the dispenser's spring, it had been observed that (over a span of a few weeks) the spring had deformed slightly. In the future, it may be necessary to replace the spring when it no longer behaves as intended. To improve the life of the spring, it should be supported on the free end when not in use.

    - Slope Adjustments: Depending on the method of loading the glass tubes, it may be necessary to increase the angle of inclination to ensure repeatable tube processing. This can be done easily by adjusting the brackets on the sides of the dispenser.

- Saw-tooth Conveyor
    - Triangle Mandrel Guide: It should be periodically checked that the mandrels are properly being positioned so that there is 5mm available for the robot to grasp.
    - Connections: Screws that hold the guides together may come loose over time; they should be occasionally checked to be sure they are properly tightened.

- Silicone Cap Conveyor
    - Guides: The guides for the caps should be checked often to be sure that they are properly aligned and position the caps correctly.

- Sensors: The through beam sensor must be checked often to be sure it is correctly positioned to detect if caps are present.

FUTURE IMPROVEMENTS

1. Stoppers: One obvious improvement would be the creation of specialized caps that would allow for more repeatable insertions. These caps could have something like a funnel built into the insertion area to guide the mandrels into the correct position better.

2. Conveyor System: It has been observed that caps occasionally fall when the assembled package is lifted off the conveyor belt. A device to hold incoming caps back could prevent this from occurring.

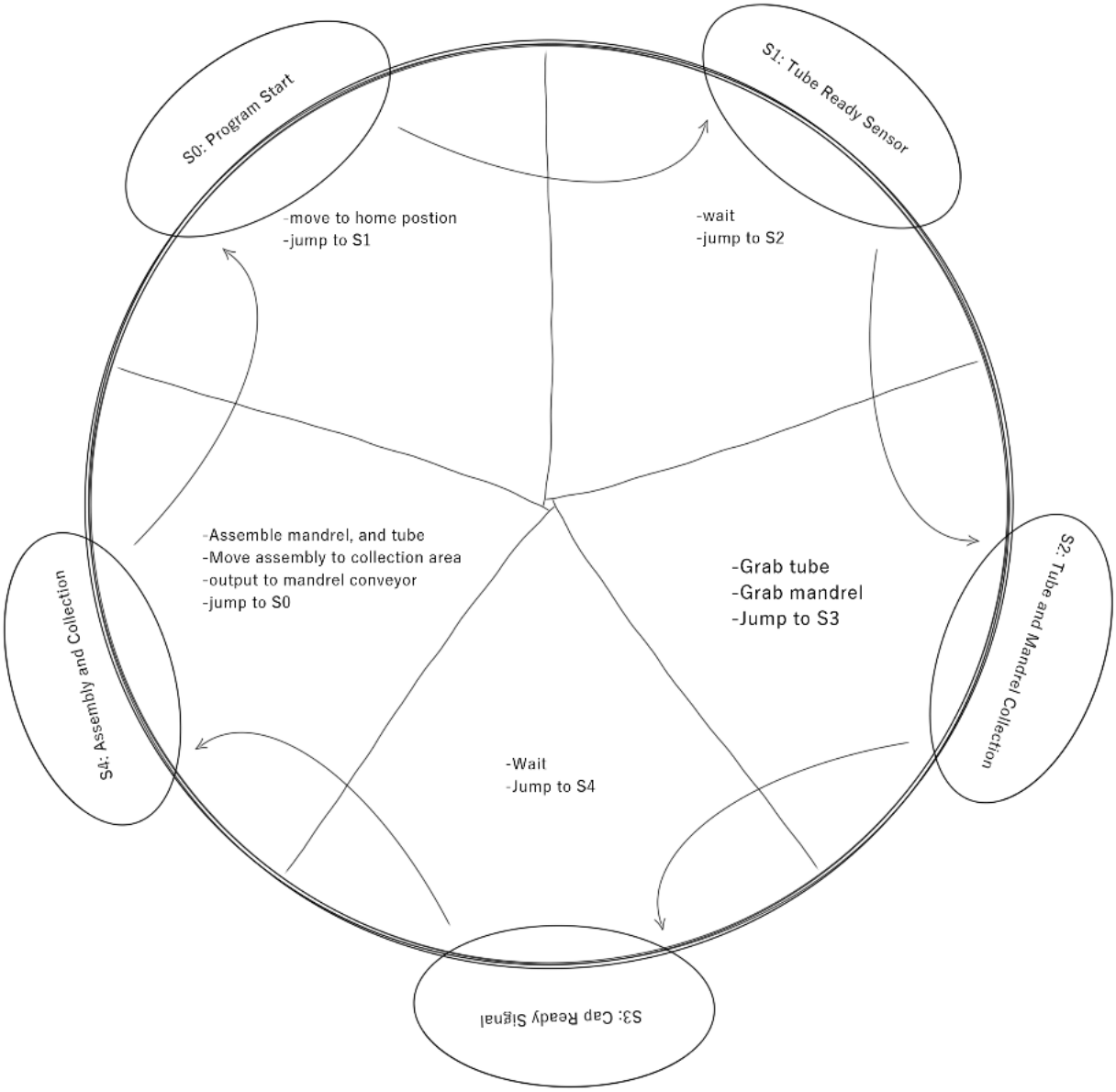
3. Final Delivery Position: Currently, there is only one programmed point of final delivery, which does not match the placement tray layout. More points could be manually added to the program, or a new delivery container could be designed so that the drop off point is always an empty, consistent location.

PERFORMANCE DATA

- Currently runs through process in about 46 seconds.
- 70%-90% accuracy (90% when desired packaging conditions are met, 60% default conditions).
- Roughly 78 processes ran per hour.
- Estimated 47 completed assemblies per hour (default).
- Estimated 31 failures per hour (default).

DIAGRAMS AND FIGURES

STAGE DIAGRAM



S0: Program start

This is the start of the robot's program, the robot moves to the home position between the culture tubes and the mandrels, just above the spring retention for the tubes. At this point the program jumps to stage 1

S1: Tube ready signal

In this stage the robot is given a wait signal from the proximity sensor. If there is not a tube currently available, the robot continues to wait. Once signaled that a tube is ready, robot moves to stage 2.

S2: Tube and Mandrel collection

Once there is a tube available the robot opens the jaws, moves down, and closes the jaws, gripping the tube before then moving through then next part of the program where the robot then moves to mandrel tray, opens the mandrel jaws, and grabs the mandrel before moving on to a position above where the caps are waiting and on to State 3.

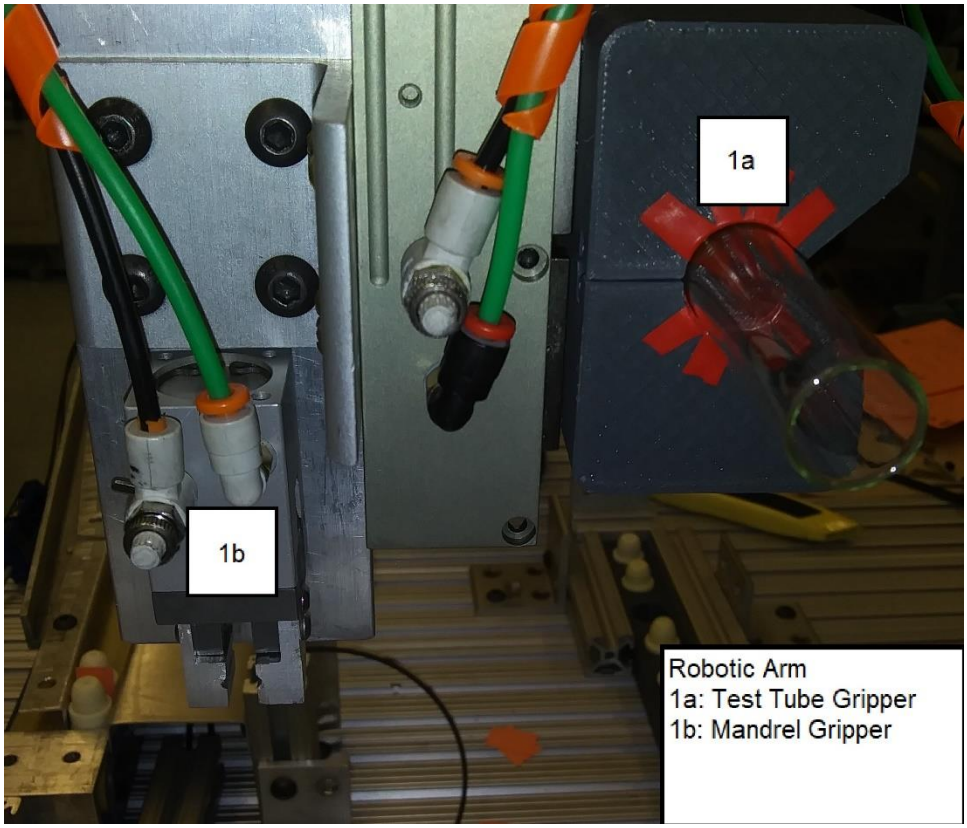
S3: Cap ready signal

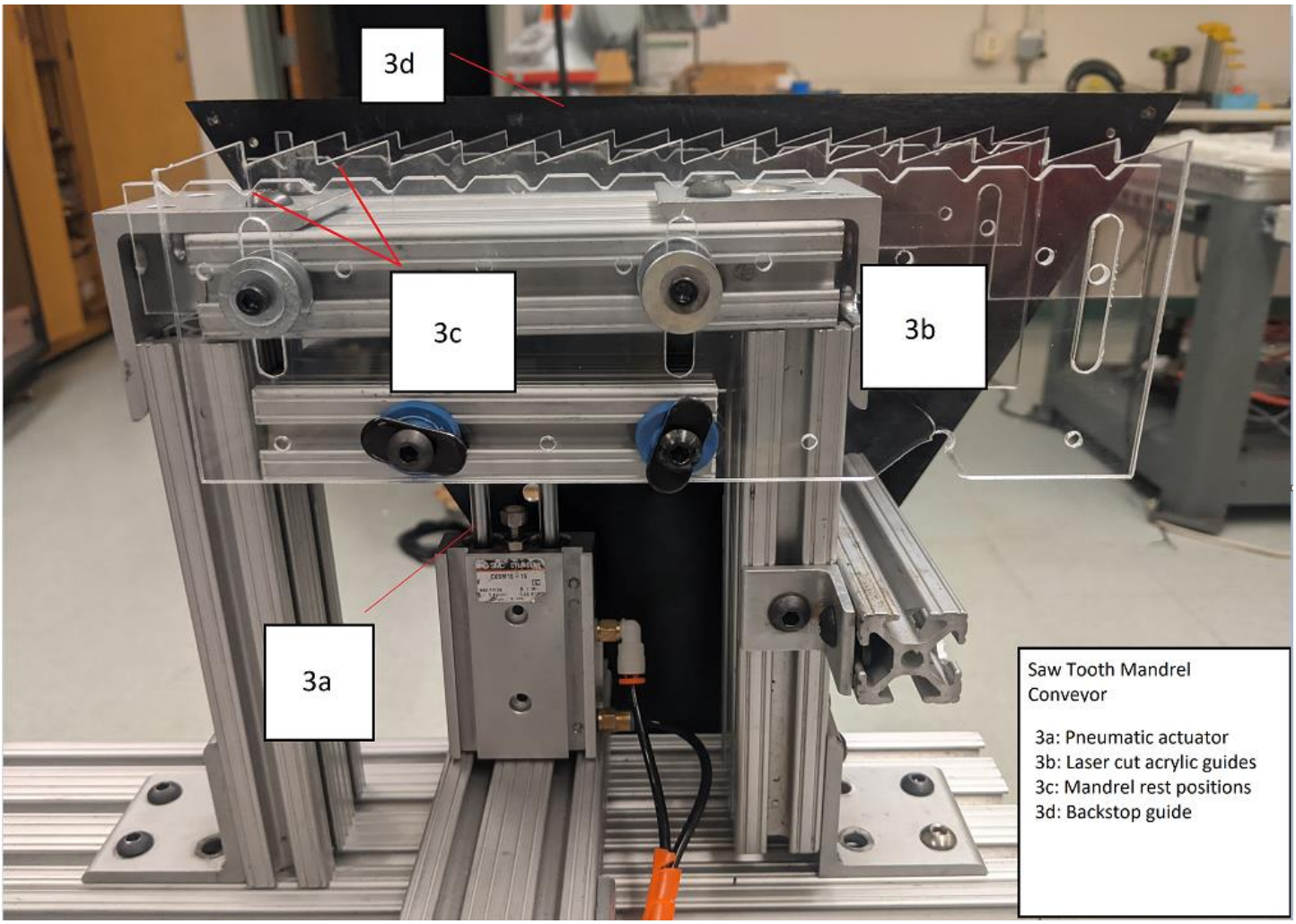
In this stage the robot is again given a wait signal, this time from a through beam sensor. In the event that there are no caps available the robot will hold its position and wait until it receives a signal from the through beam sensor that there is a cap in the ready position, at this point the robot will move onto stage 4 for assembly.

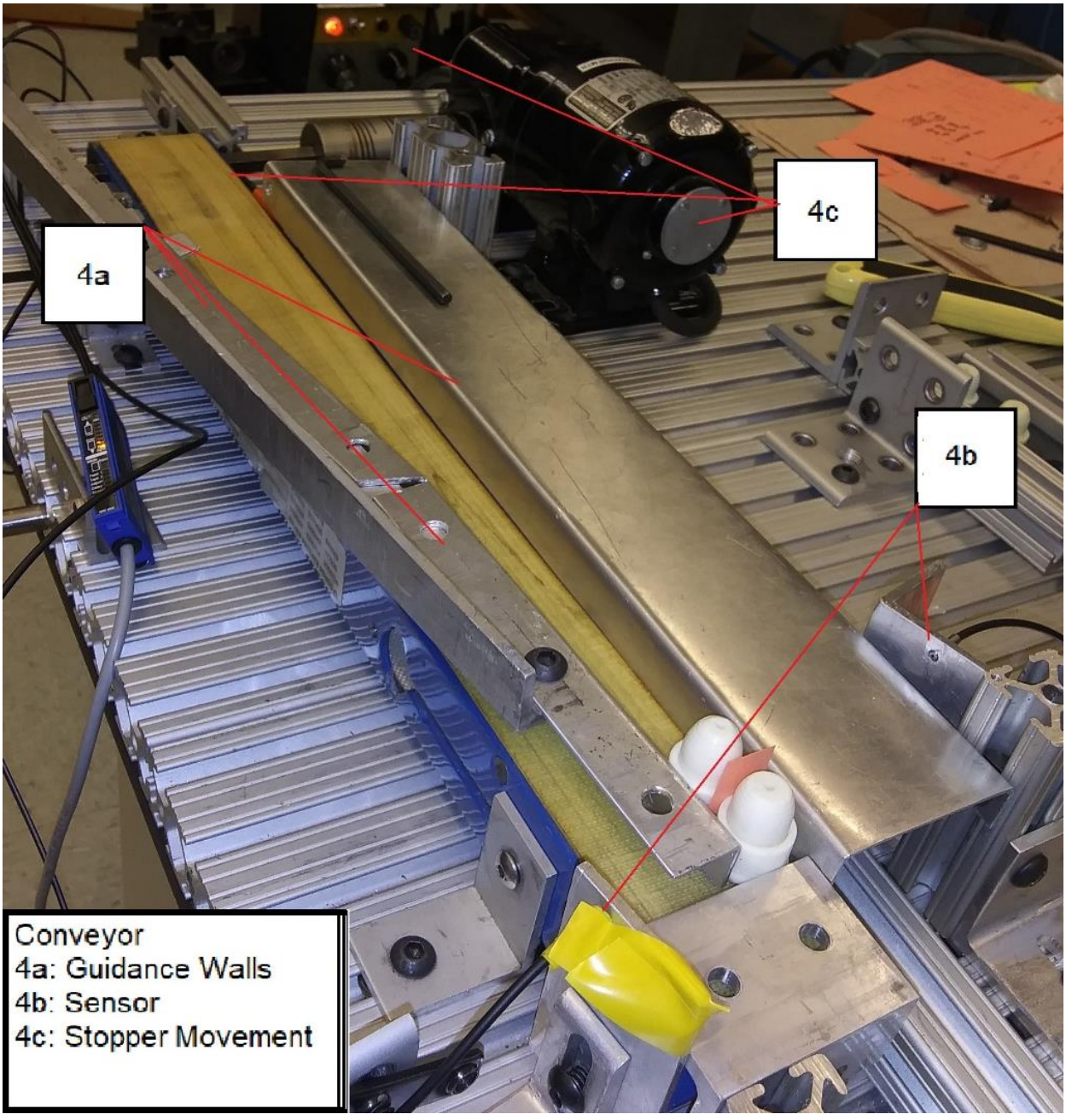
S4: Assembly and collection

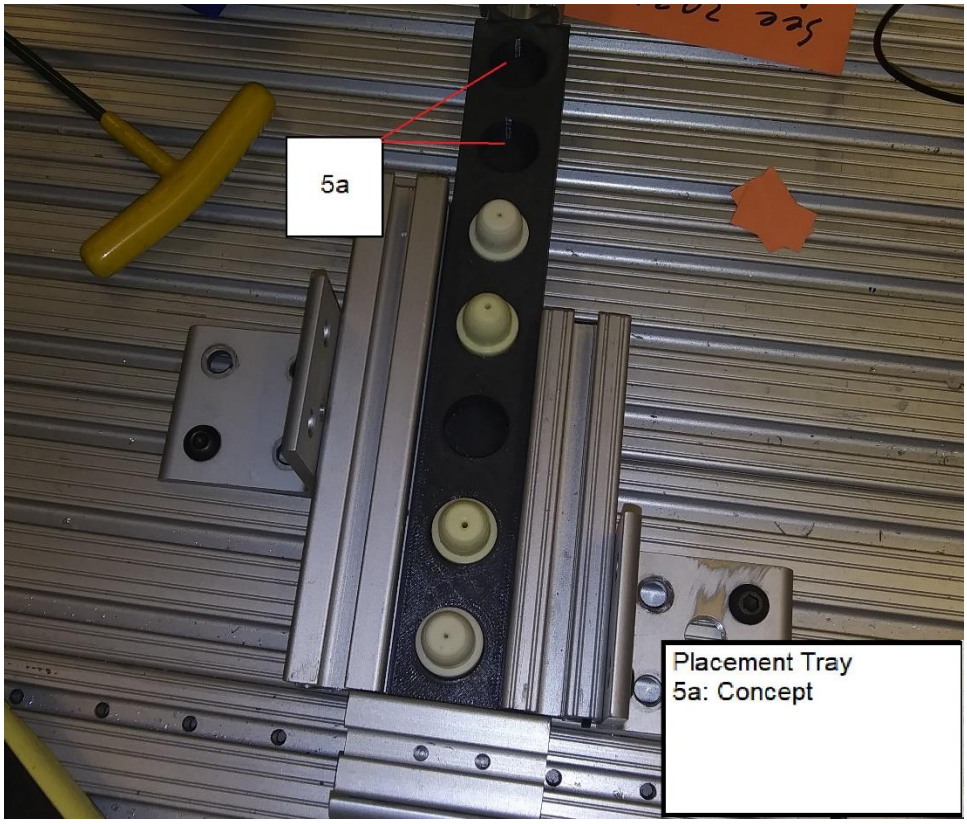
Once given the signal that a cap is available the robot will lower from its position, inserting the mandrel into the cap and then open the mandrel grips allowing the arm to move up, rotate around and then lower the culture tube over the mandrel and down onto the waiting cap. At this point the mandrel, cap and tube are all assembled and there is a strong seal between the cap and tube, allowing the robot to raise from its position and progress through the program to where the assembled product is deposited in the collection tray. Once the assembly is placed into the collection tray the program issues a command to the mandrel conveyor to move the mandrels forward one position. While this is happening, the robot is moving back to its home position, ready to begin again at state 0.

FIGURES

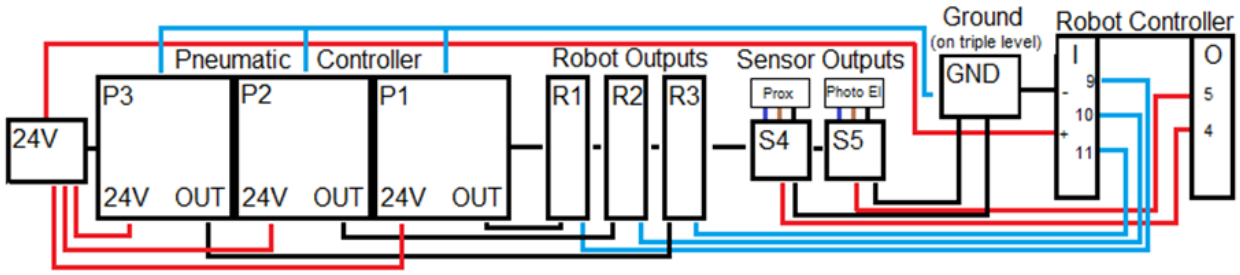



3d
3c
3b
3a
Saw Tooth Mandrel Convevor
3a: Pneumatic actuator
3b: Laser cut acrylic guides
3c: Mandrel rest positions
3d: Backstop guide


4a
4c
4b
Conveyor
4a: Guidance Walls
4b: Sensor
4c: Stopper Movement

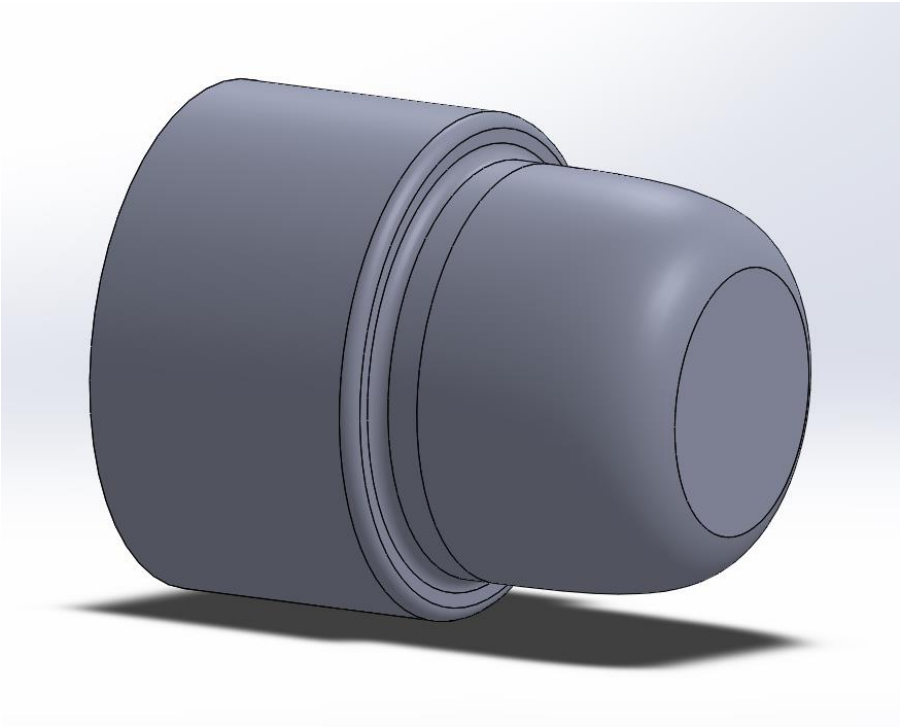


Wiring Diagram

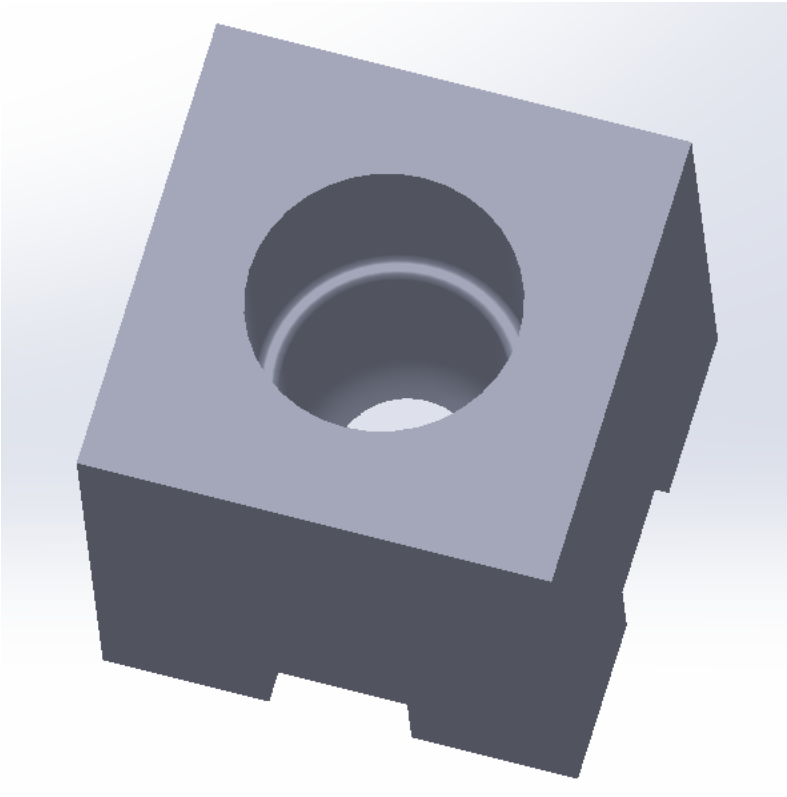


CAD MODEL DESIGNS

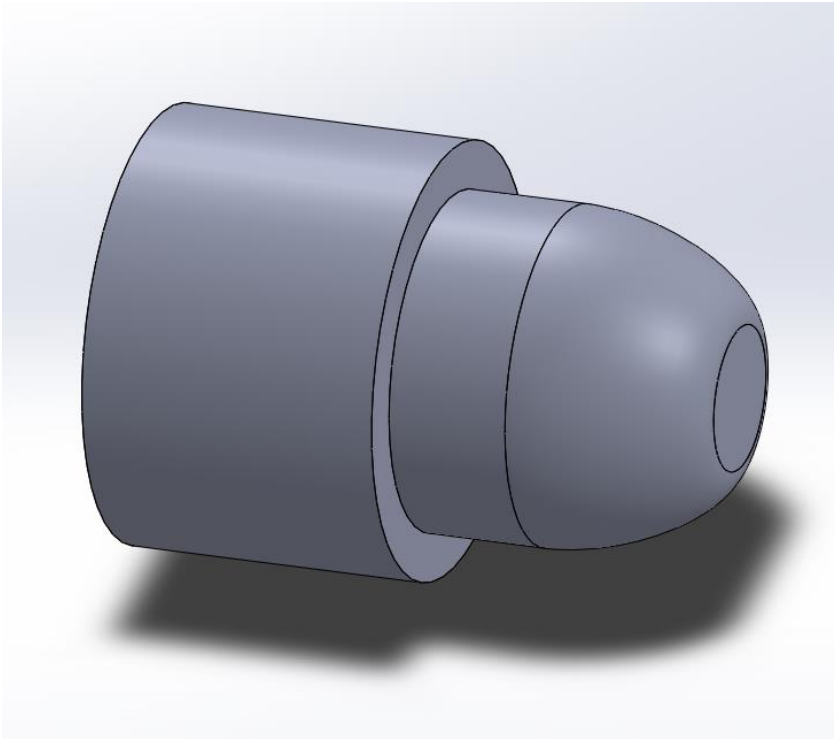
Original Silicone Stopper Design (Below)



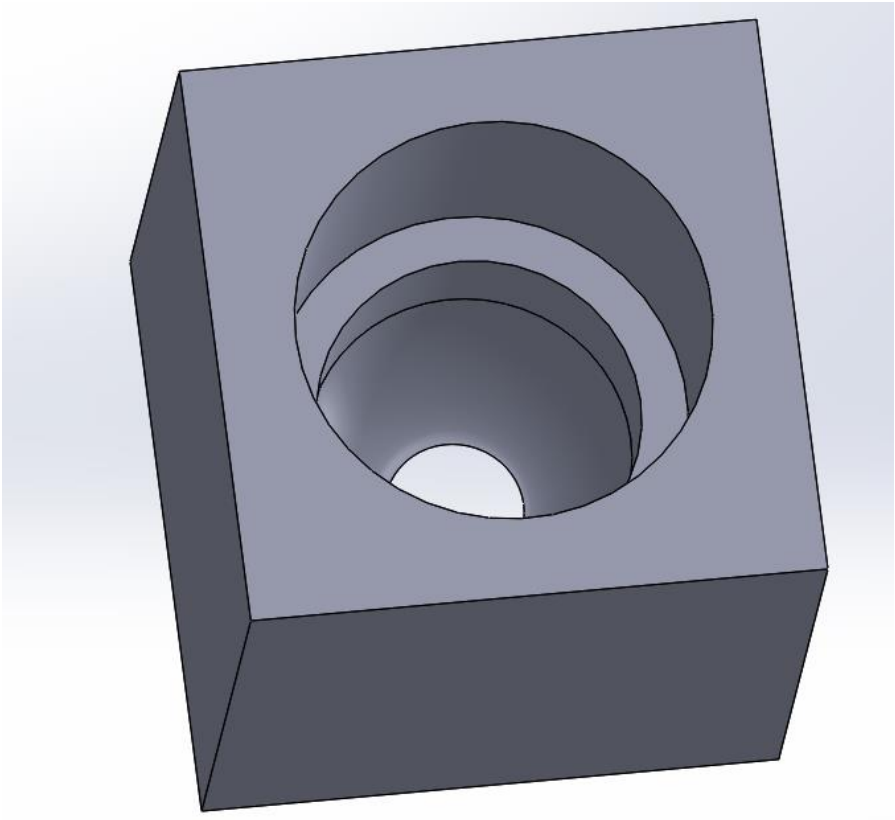
Original Stopper Mold Design (Below)



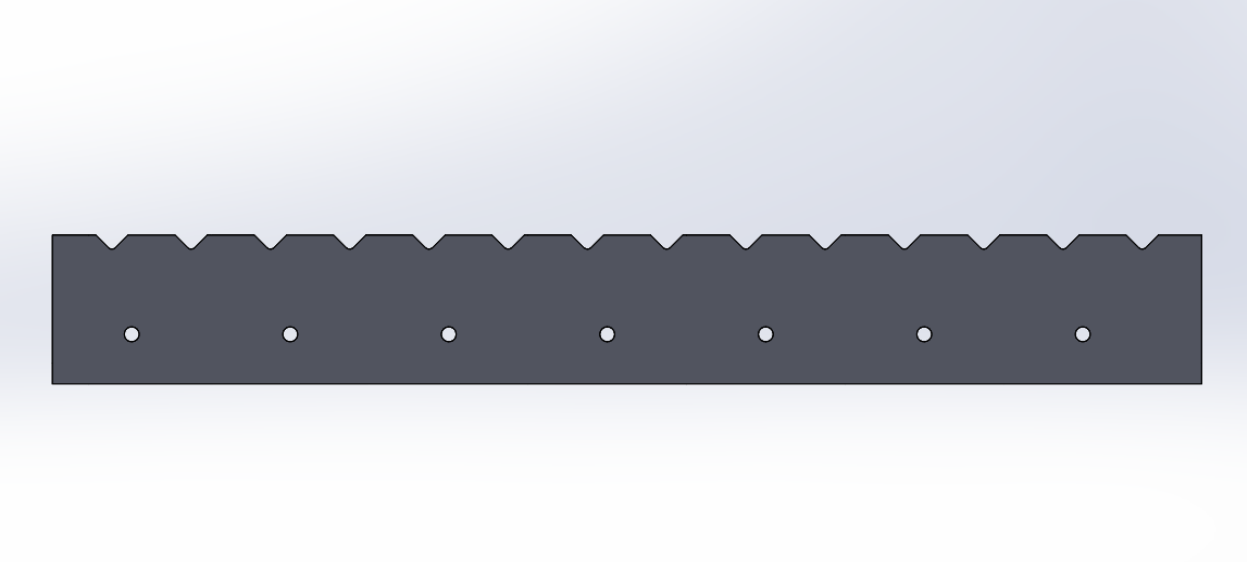
Modified Silicone Stopper Design (Below)



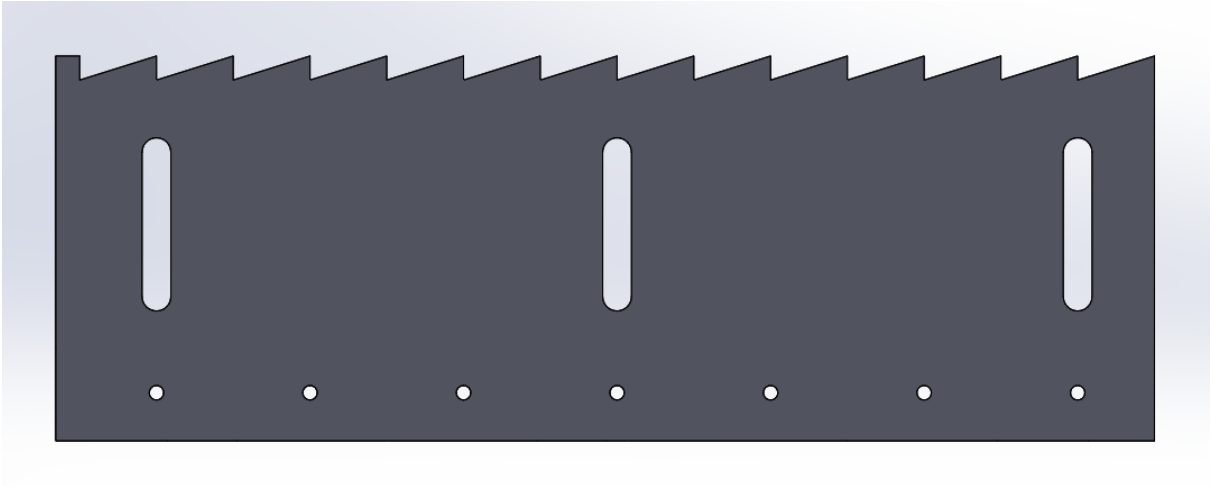
Modified Silicone Stopper Mold (Below)



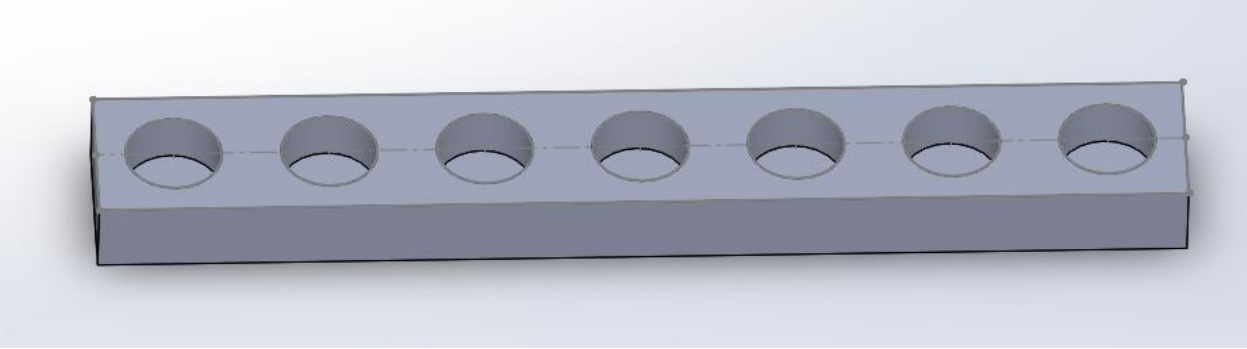
Sawtooth Conveyor Part A (Below)



Sawtooth Conveyor Part B (Below)



Collection Tray (Below)



ROBOTIC CODE

```
/JOB
//NAME TEAM_3_WITH_AIR_FINAL
//POS
///NPOS 30,0,0,0,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
C00000=53800,41476,-58523,49931,72860,-60288
C00001=54490,51505,-58539,48772,76314,-57145
C00002=54490,69346,-55132,48306,81282,-52967
C00003=54490,58389,-57214,48600,78219,-55533
C00004=54490,49771,-58746,48862,75781,-57599
C00005=53799,35426,-58647,50540,70806,-62163
C00006=28237,49199,-24107,68444,70910,-73861
C00007=36749,50027,-19319,64971,66794,-75067
C00008=36969,50844,-18579,64882,66684,-75092
C00009=38362,51452,-17619,64301,66046,-75168
C00010=38433,47518,-16969,65146,65091,-76915
C00011=38433,47518,-16969,65146,65089,-76912
C00012=14404,38581,-29030,75590,75700,-76264
C00013=27477,36836,-22417,166900,44179,-76631
C00014=34103,59095,-38734,164155,18739,-79385
C00015=34103,64579,-37920,164205,16016,-79418
C00016=34543,58909,-40068,165291,17204,-80202
C00017=33490,60504,-14691,164591,34626,-79302
C00018=33312,75416,-13105,164779,26766,-79377
C00019=33268,79690,-11916,164835,25044,-79404
C00020=33268,82905,-11106,164890,23687,-79441
C00021=33268,70832,-13461,164705,29272,-79308
C00022=49503,51571,-49818,165457,15003,-103127
C00023=49701,73227,-45864,168840,4800,-105365
C00024=49701,77030,-44756,171088,3314,-106785
```

C00025=49702,46209,-50320,165208,17885,-103043

C00026=49701,26585,-49225,164672,30531,-102670

C00027=55362,32847,-36622,164583,35916,-104771

C00028=47892,37754,-49398,55111,69222,-65535

C00029=53802,41476,-58523,49932,72853,-60289

//INST

///DATE 2020/11/23 17:47

///ATTR SC,RW

///GROUP1 RB1

NOP

MOVJ C00000 VJ=3.00

MOVJ C00001 VJ=3.00

WAIT IN#(4)=ON

DOUT OT#(9) ON

MOVJ C00002 VJ=1.49

WAIT IN#(1)=ON T=0.35

DOUT OT#(9) OFF

WAIT IN#(1)=ON T=1.00

MOVJ C00003 VJ=1.00

MOVJ C00004 VJ=3.00

MOVJ C00005 VJ=3.00

MOVJ C00006 VJ=3.90

MOVJ C00007 VJ=2.00

MOVJ C00008 VJ=0.25

DOUT OT#(10) ON

MOVJ C00009 VJ=0.25

DOUT OT#(10) OFF

WAIT IN#(1)=ON T=0.75

MOVJ C00010 VJ=1.00

MOVJ C00011 VJ=3.90

MOVJ C00012 VJ=4.50

MOVJ C00013 VJ=8.00

MOVJ C00014 VJ=2.50

```
WAIT IN#(5)=OFF
MOVJ C00015 VJ=0.45
DOUT OT#(10) ON
MOVJ C00016 VJ=0.78
DOUT OT#(10) OFF
MOVJ C00017 VJ=2.50
MOVJ C00018 VJ=0.78
MOVJ C00019 VJ=0.78
MOVJ C00020 VJ=0.78
WAIT IN#(1)=ON T=0.50
MOVJ C00021 VJ=1.50
MOVJ C00022 VJ=3.50
MOVJ C00023 VJ=2.00
MOVJ C00024 VJ=0.78
WAIT IN#(1)=ON T=0.50
DOUT OT#(9) ON
DOUT OT#(11) ON
MOVJ C00025 VJ=5.00
MOVJ C00026 VJ=5.00
DOUT OT#(9) OFF
DOUT OT#(11) OFF
MOVJ C00027 VJ=5.00
MOVJ C00028 VJ=8.00
MOVJ C00029 VJ=2.50
END
```