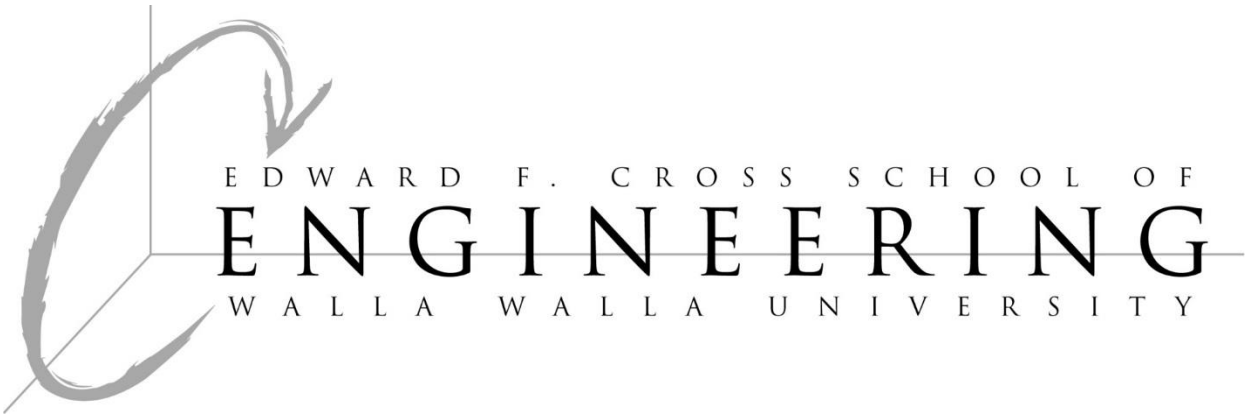

Documentation for Yoyo Assembly Station

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June 11, 2014

Instructor:
Ralph Stirling

Table of Contents

Table of Figures

1 Introduction and Objectives

This year for ENGR 480, our objective was to design and build a station capable of assembling a yo-yo without any human interaction other than to press that start button. This goal was a very large task requiring that we all learn how to manufacture our own fixtures, learn how to program logic using ladder diagrams and state space, as well as integrating the PLC controls with sensors and pneumatics. Our solutions to each step of the assembly process changed drastically throughout the quarter, but we believe we have come up with relatively efficient methods of assembling the given yo-yo components.

The yo-yo that we will be working with was designed and machined by Ralph Stirling using our in-house CNC mill and lathe. After a final yo-yo design was settled upon, we began to plan each step of the assembly process by determining what sort of fixturing will be necessary as well as how simple can each task be completed to reduce complexity and the waste of time and space. We of course wanted to make the whole process as streamlined as possible to reduce human interaction and therefore increase productivity.

However, time constraints lead to an incomplete overall design and we were unable to complete the entire process. Our progress thus far has taught all of us vast amounts of knowledge about the process of automation and each group members has valuable input about future work that remains with respect to the stations in which they were directly involved.

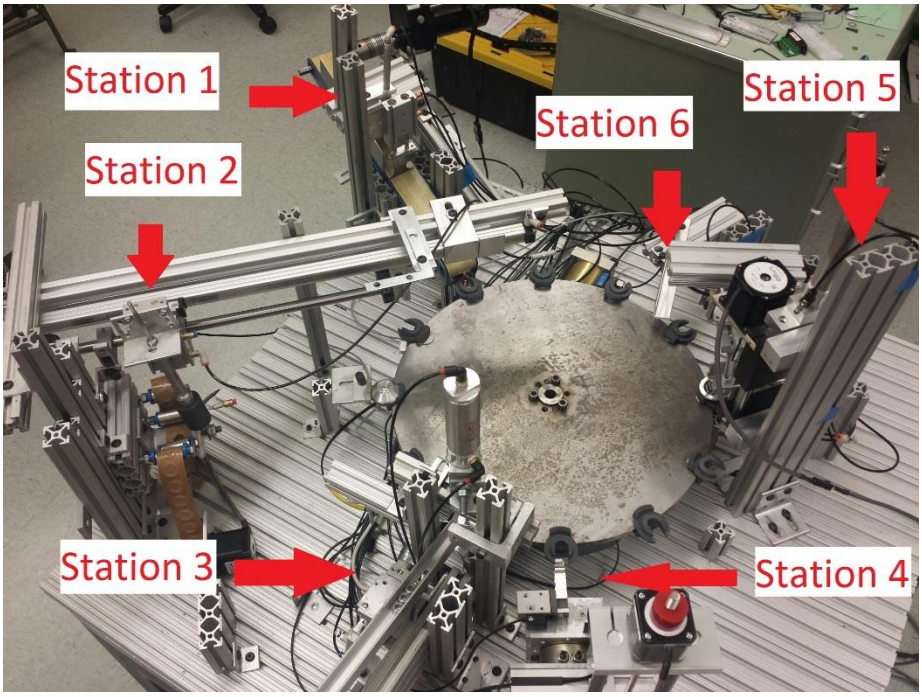


Figure 1. *Complete Station Setup*

2 Loading the Machine and Pre-Operation Checks

2.1 Loading the Machine

In order to load the machine, each station must be checked so that all the necessary components are stocked and ready for operation. These parts include the following which can be seen the picture below.

- **Yo-yo halves**
  - Verify that there are twice as many halves ready as the amount of yo-yo's you want at the end of the assembly process.
- **O-rings**
  - Make sure the roll is tight and the first o-ring is positioned properly above the relief hole.
- **Bearings**
  - Load as many bearings as possible, just make sure there are enough for the amount of yo-yo's you are planning to assemble.
- **Set screws**
  - Load as many set screws as possible, just make sure there are enough for the amount of yo-yo's you are planning to assemble.

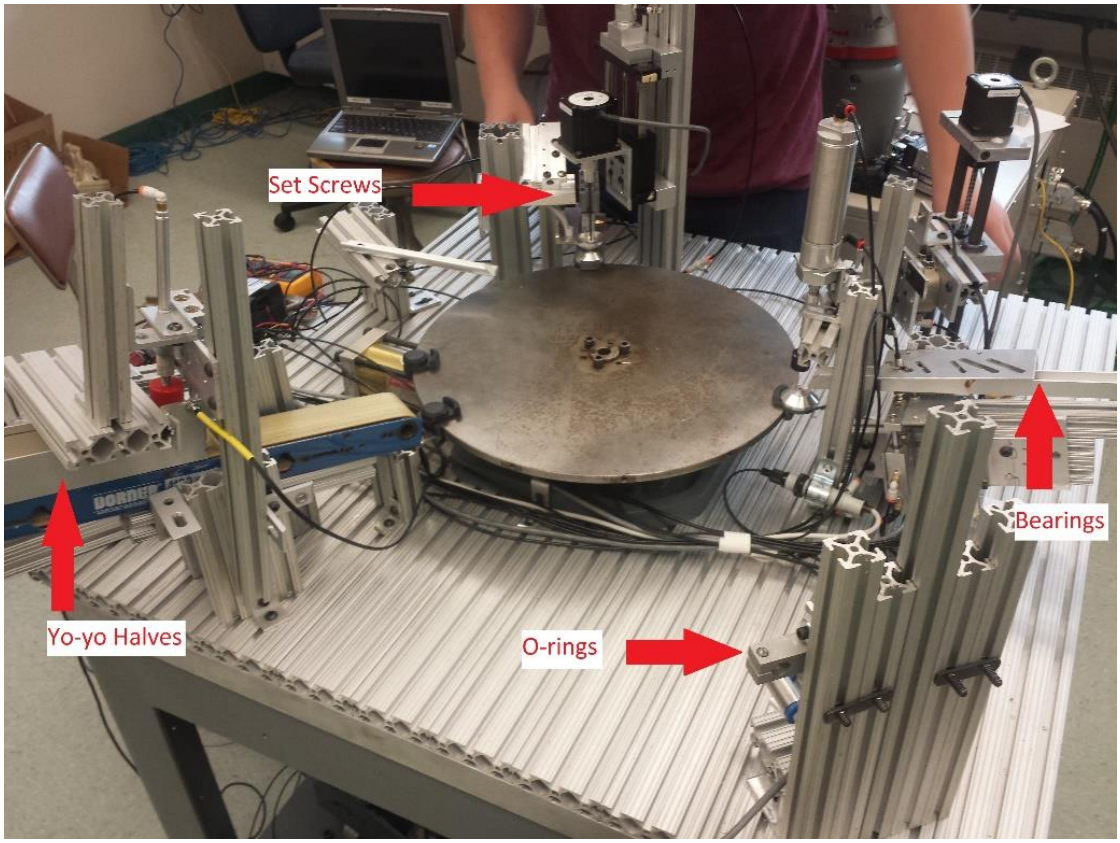


Figure 2. *Necessary Components to Stock before Operation*

2.2 Pre-Operational Checks

In order to insure success, you must make sure that the entire setup is ready to function properly before pressing the start button. This includes checking to make sure everything is stocked, but it also includes verifying that all the sensors are powered and functioning properly as well as making sure there nothing will get caught as the turret rotates and all sensitive items are removed from pinching and crushing points. In order to safely operate the machine, please make sure all surrounding members' hand are free from any devices before operating the machine.

3 Assembly Processes

3.1 Turret – Moving the Yo-yos

This is the rotor, it holds all the yo-yos and moves them around from station to station. A part was designed and 3D printed for holding the yo-yo halves.

The yo-yo holder was designed to keep the yo-yo in position, while allowing the yo-yo half to slide on easily, and with room for the gripper to grab the lip of the yo-yo.

Step 1: Attach the yo-yo holders in all stations.

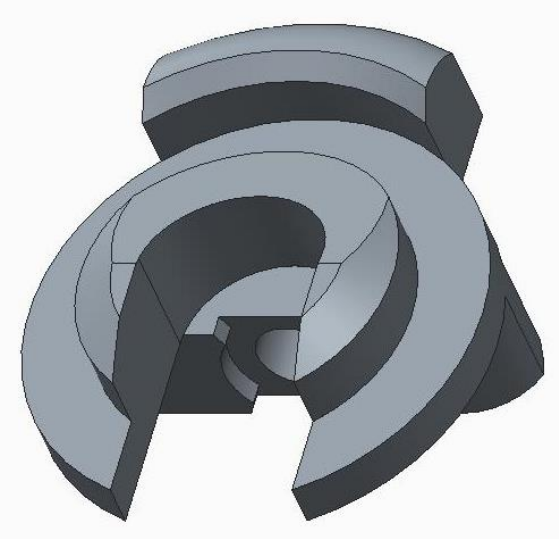


Figure 3. *Part holder*

3.2 Station 1 - Placing the Yo-yo Halves

The first step towards assembling a yo-yo using the given turret setup is to place the yo-yo halves into the fixture in which the rest of the automated assembly processes will be completed. The method we incorporated to precisely place the halves in the correct position involves a belt conveyor, a singulating mechanism, and gravity. The belt conveyor runs continuously while the assembly mechanism is in process as the singulating gates open and close in the precise order to place a single yo-yo half in the locating fixture. The yo-yo halves are guided as they approach the locating fixture which ensures the half will fall into the correct position each time. Below is a list of the necessary procedures incorporating into our operational logic to automate this part of the overall process.

Step 1: As the loaded conveyor moves, the singulating plunger will lower between the first and second yo-yo halves, separating each and allowing the first half to move freely.

Step 2: Raise the second singulating actuator which will allow the half to travel down the conveyor towards the locating fixture.

Step 3: The half will then fall into the locating fixture.

Step 4: Once the yo-yo has been properly seated into the locating fixture, the turret will now turn once the rest of the stations have completed their assembly tasks.

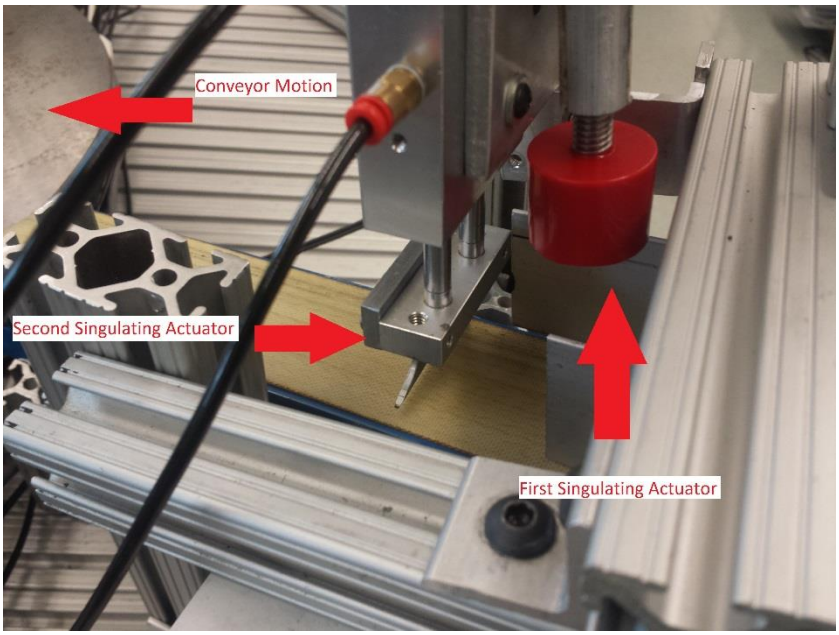


Figure 3. *Singulating Mechanism of Station 1*

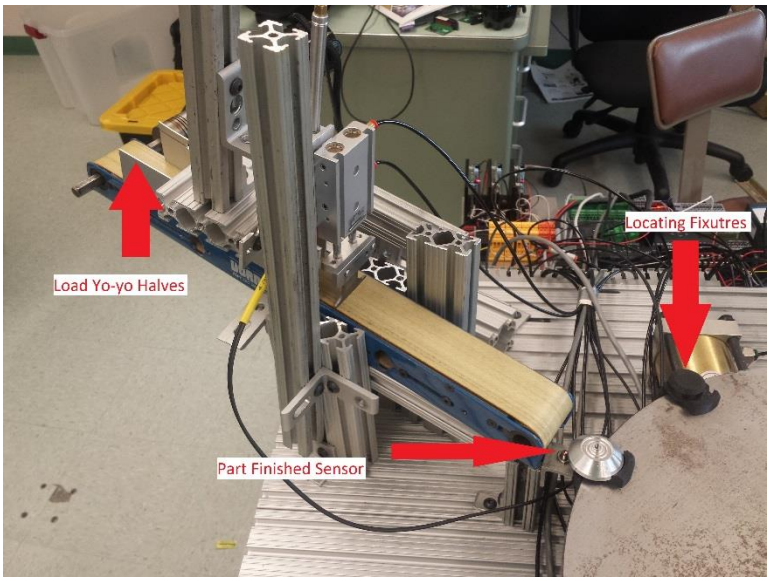


Figure 4. *Station 1 Setup*

3.3 Station 2 – Placing the O-ring

At station 2 the objective was to find a method to punch the center of the o ring out, take the o ring away from the tape, and properly place it onto the yo yo halves. The method chosen to approach this problem involved designing a 3D printed piece that could use a combination of suction and dislodgement to remove the o rings from the tape. As it can be noted on the figure 5, the assembly of 3D printed parts involves an outer casing that will trap the o ring inside, and an inner part that is responsible for punching the center of the rings out, applying suction, and centering the o ring on the yo yo half by having the little tip go through the inner hole of the yo yo.

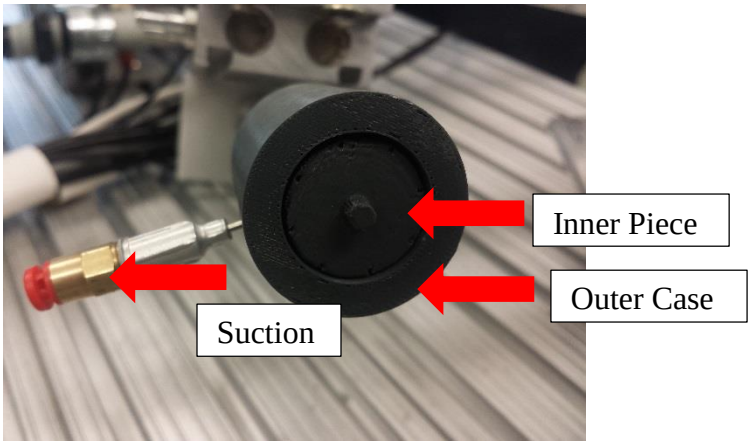


Figure 5. *3D Printed Assembly Station 2*

A separate pneumatic system is also needed to get the o ring to the location where the yo-yo halves can be found. The steps behind the mechanism are as follows:

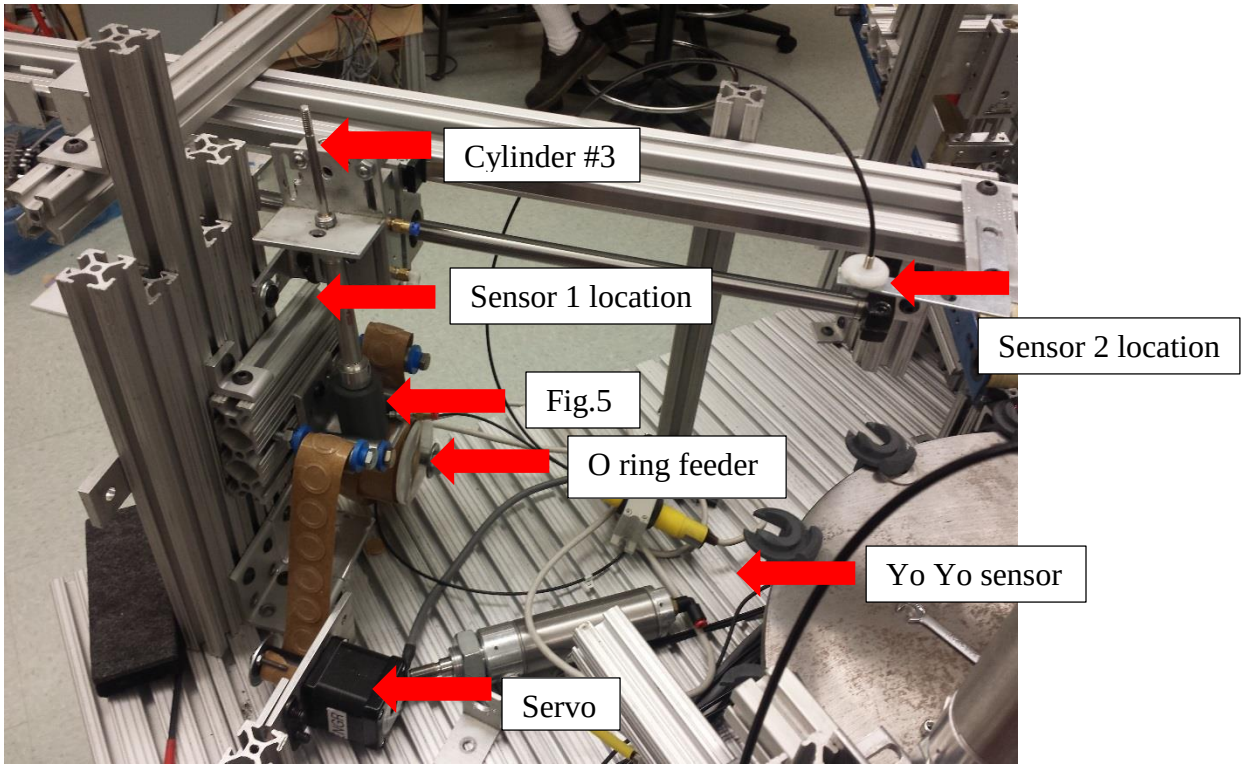


Figure 6. *Overall Station 2 Assembly*

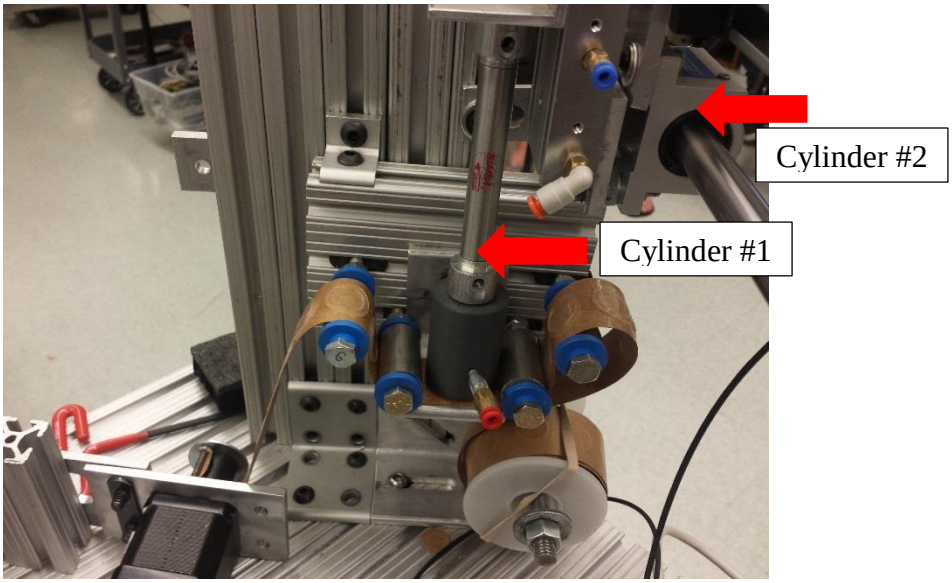


Figure 7. Cylinder action

Step 1: The yo-yo sensor informs station 2 that the yo-yo is in place and that it can now begin working.

Step 2: Cylinder 1 and cylinder 3 close up onto the o ring and wait for servo to pull.

Step 3: When servo starts pulling suction goes on once the o ring has dislodged from the tape cylinder 3 followed by cylinder 2 goes up until sensor 1 picks up that they are on the proper position.

Step 4: Once sensor 1 triggers, this lets cylinder 3 to slide the part with o ring and suction until it triggers sensor 2.

Step 5: Cylinder 1 followed by cylinder 3 moves the o ring into the proper position and turns off suction.

Step 6: Cylinders 1 and 3 go back up triggering sensor 2 of which sends the command to slide the assembly back to idle position.

3.4 Station 3 – Placing the Bearing

At station 3, the bearing would need to be singulated, then properly placed on every other yo-yo half then punched into place. In order to complete these tasks, we devised a relatively simple method for completing this task in as few steps as possible. Below is a step by step process through which this station proceeds.

Step 1: Once the yo-yo half has arrived and the go command has been received, the release actuator will let the bearing slide down the rail into the proper position.

Step 2: When the bearing is properly placed, a sensor will allow the punching actuator to properly seat the bearing on the yo-yo half.

Step 3: As the punch presses the bearing on the yo-yo half, the singulator will also release letting another bearing into position for the next bearing placement procedure.

Step 4: Since the bearings only need to be placed on every other yo-yo half, the program will enter a wait state. When the next yo-yo half has passed, the state will begin with step 1.

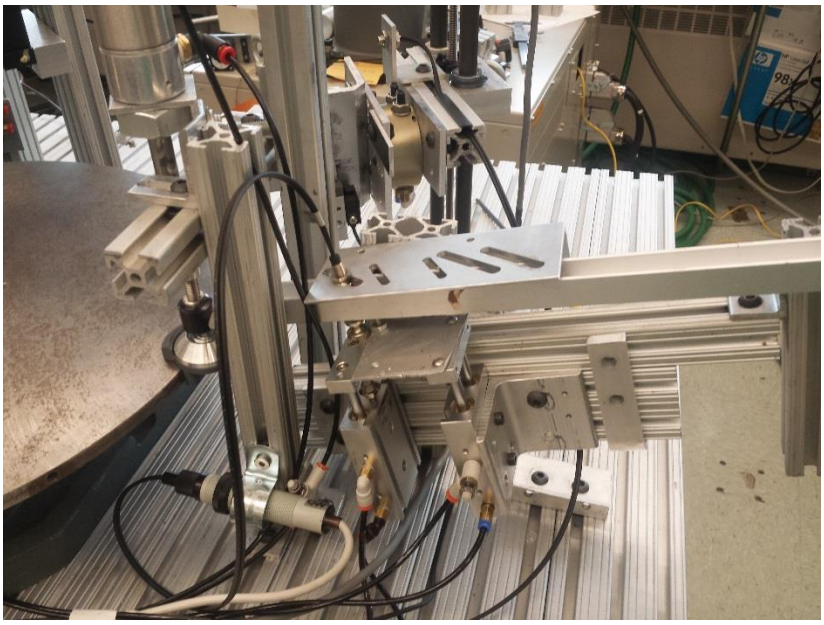


Figure 6. *Station 3 Setup*

Figure 7. *Bearing Punch above Yo-yo Half*

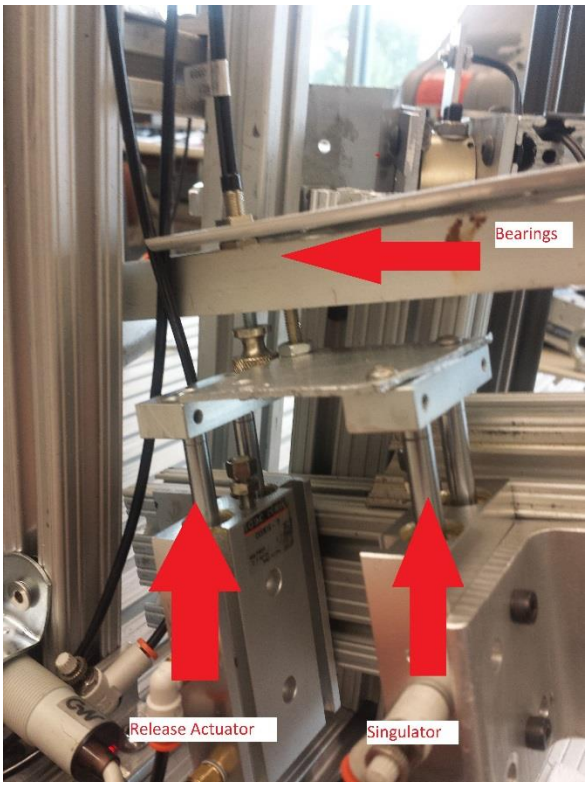


Figure 8. *Bearing Singulator Mechanism*

3.5 Station 4 – Flipping a Yo-yo Half

This station flips the yo-yo onto another yo-yo half, but one without a bearing. This takes two rotations to complete.

Step 1: Once the yo-yo, with bearing, moves into position, stepper motor will raise the grippers into position to pick up the yo-yo.

Stem 2: Once in position, the jaws will close, this will send a signal to the PLC that this action has been completed.

Stem 3: Once grabbed, the stepper motor will move up, high enough so that the yo-yo as well as the rotating mechanism will have enough room to rotate 180 degrees. After the flipped signal has been sent, the stepper will lower. Once the stepper profile for this is completed, this station will send the "complete" signal to the PLC and wait for the next part.

Step 4: With a new yo-yo half, with bearing, has moved into position, the stepper motor will lower the half it is holding into position.

Step 5: … and release.

Step 6: After the gripper sends the released signal, another stepper motor profile will start, moving the apparatus up out of the way of the moving part holders. Once there it will rotate again.

Step 7: The flipping mechanism will send a flipped signal and send the “completed” signal again.

Step 8: Listening for when the part holder starts moving again, the stepper motor will lower the grippers to the bottom, low enough for the grippers to pick up the next yo-yo. Once in position, the go command will be sent again, and this time, it repeats.

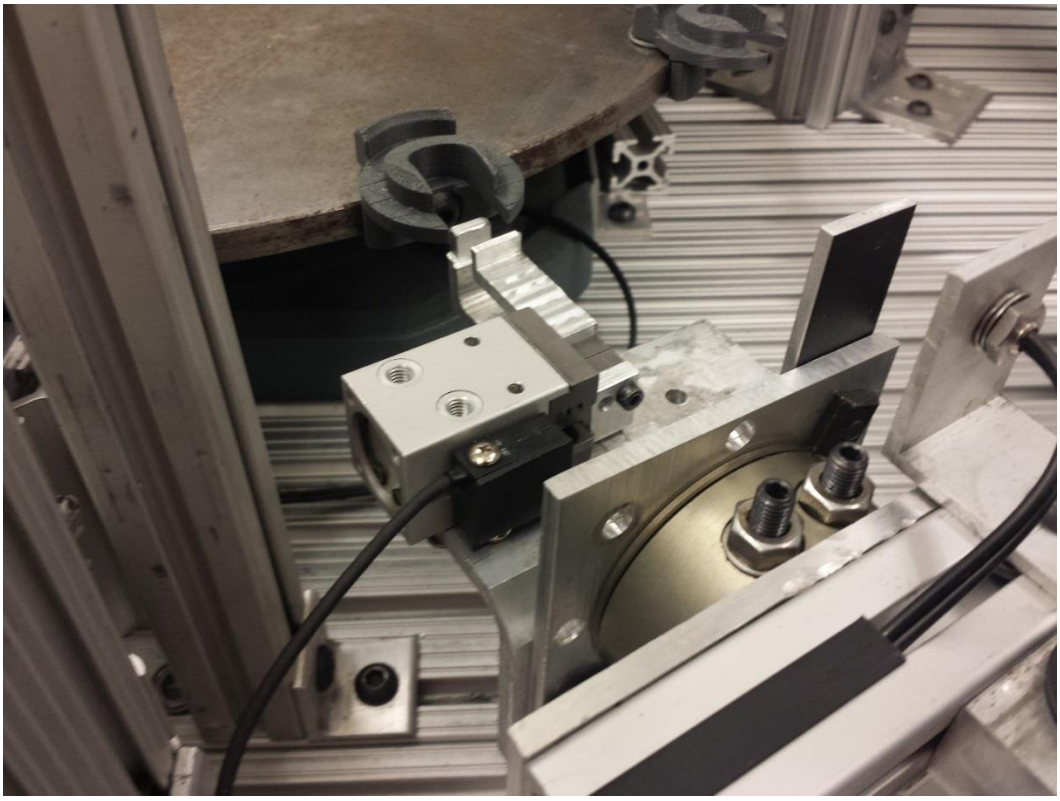


Figure 8. *Yo-yo flipping mechansim*

3.6 Station 5 – Placing the Set Screw

This station feeds the setscrew into the correct position. It is then screwed through the yo-yo assembly. The setscrews are loaded into a tray that in a particular arrangement. An air cylinder actuates, pushing the set screw down a ramp, into position. Then the stepper motor turns on and is lowered down, screwing the yo-yo halves together. The

Step 1: Plunger extends to keep yo-yo from moving in the holder

Step 2: Feeder extends to push setscrew down ramp, into location. Feeder retracts and next setscrew falls into the loading station.

Step 3: Stepper motor mount lowers the stepper motor down till the Allen wrench makes contact with the screw.

Step 4: Stepper motor turns on and screws the setscrew through the yo-yo.

Step 5: Cylinder 3 retracts, raising the stepper motor/Allen wrench assembly away from yo-yo.

Step 6: Cylinder 1 retracts.

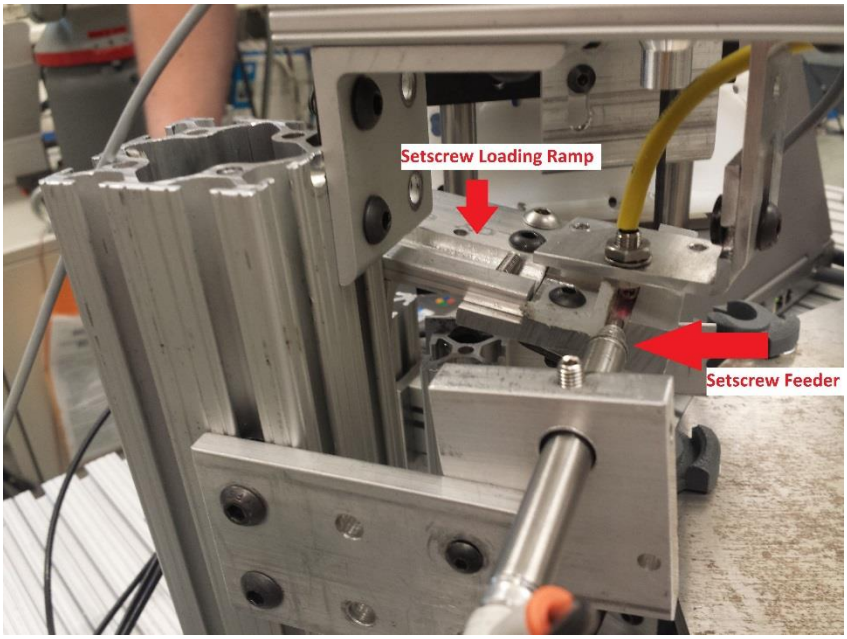


***Figure 9**. Setscrew Feeder*

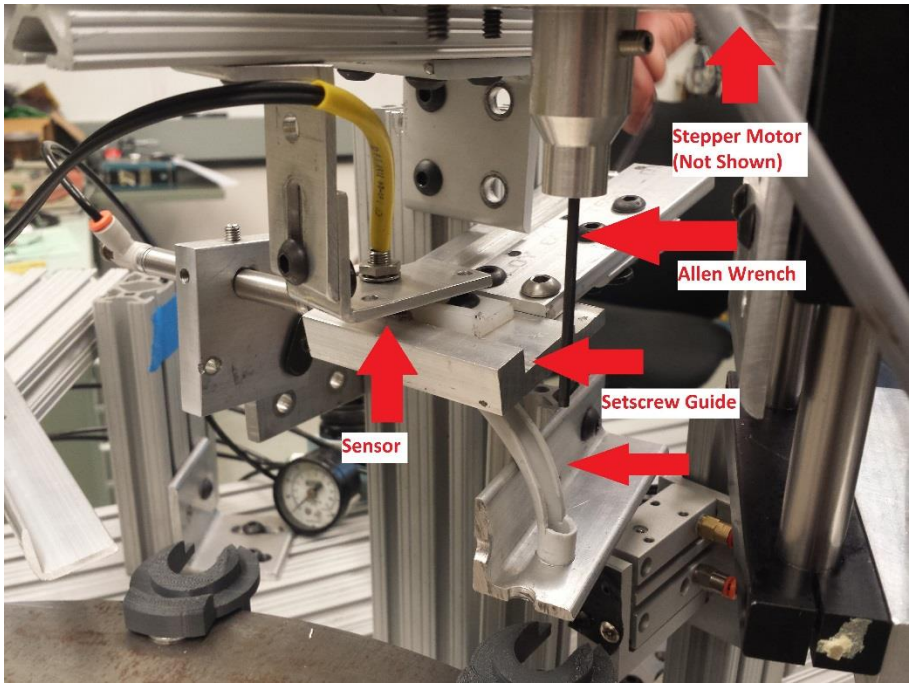


***Figure 10**. Setscrew Station*

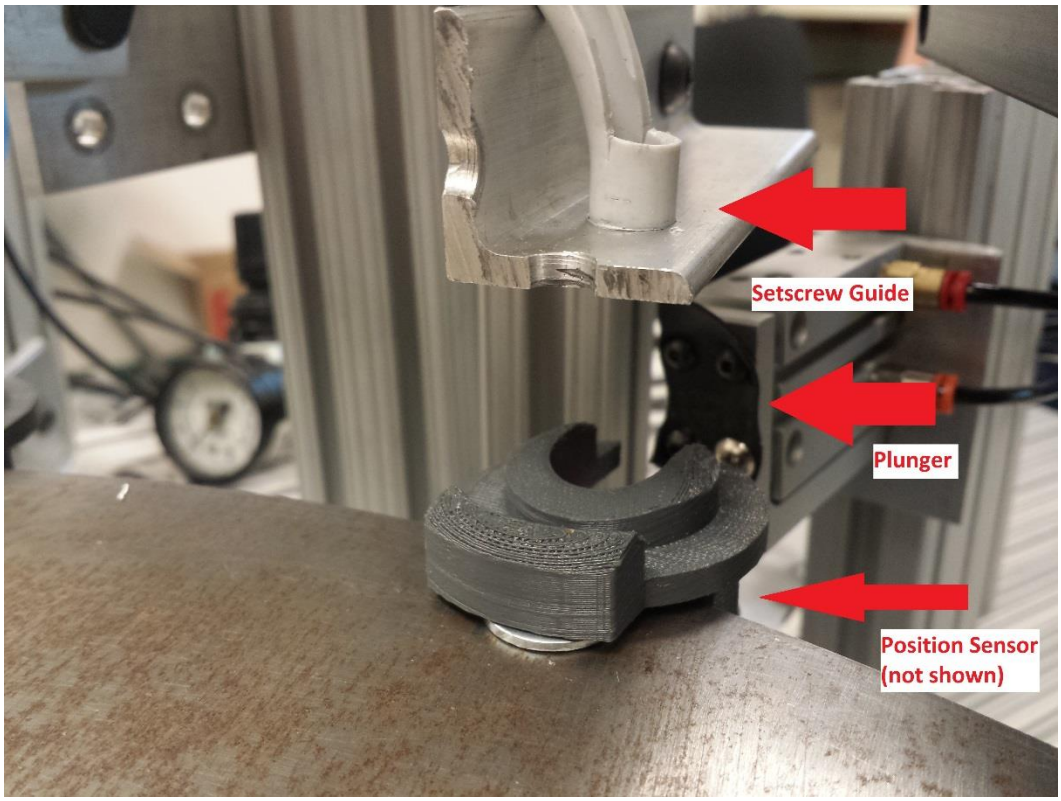


Figure 11. *Close-up View of Setscrew Guide*

3.7 Station 6 – Removing the Completed Yo-yo

Our final station is the most simple of all by incorporating no moving parts and requires no controls. It is a purely passive system that simply pulls the yo-yo off the locating fixture as the turret rotates. Below is a simple outline of the process.

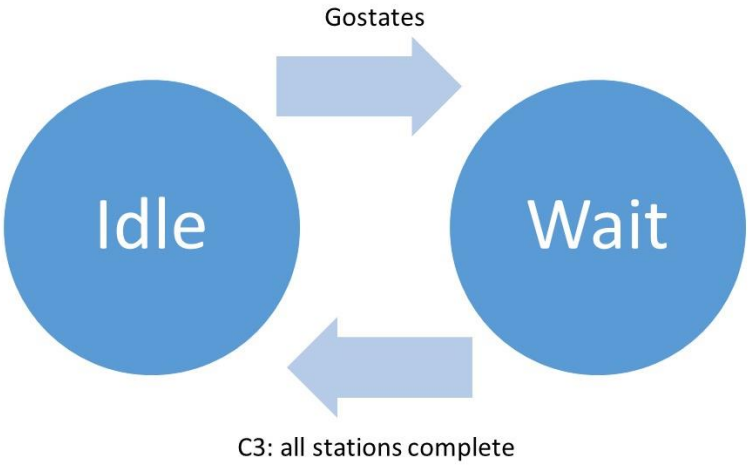
Step 1: As the finished yo-yo rotates away from station 5, it approached the removal bar.

Step 2: As the yo-yo moves past the removal bar, the natural geometry of the yo-yo will lift itself from the locating fixture and will then allow itself to fall into a collection basket.

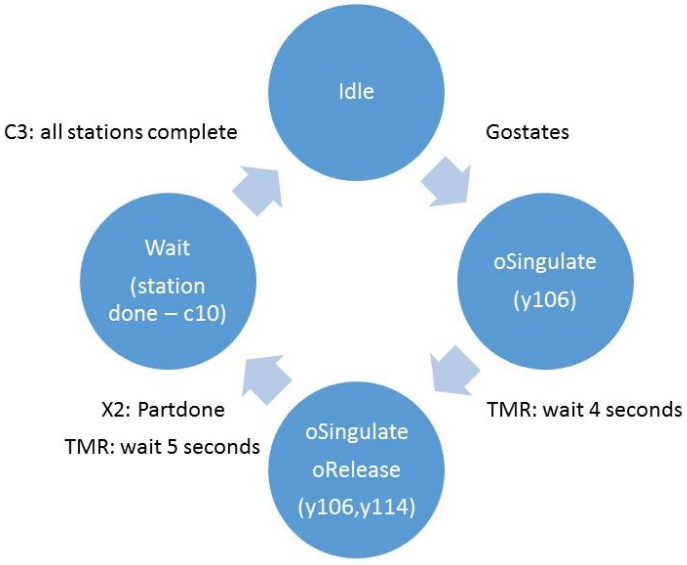
4 Station States and Logic

One of the major tasks with automating a process is to determine the order in which simple tasks need to be completed in order to work in unison with other operations to complete a complex overall task. The method of sorting out the steps involved in each station is to incorporate ladder logic. This form of logic is can be easily represented using states which encompass the processes completed within each station as well as the overall process.

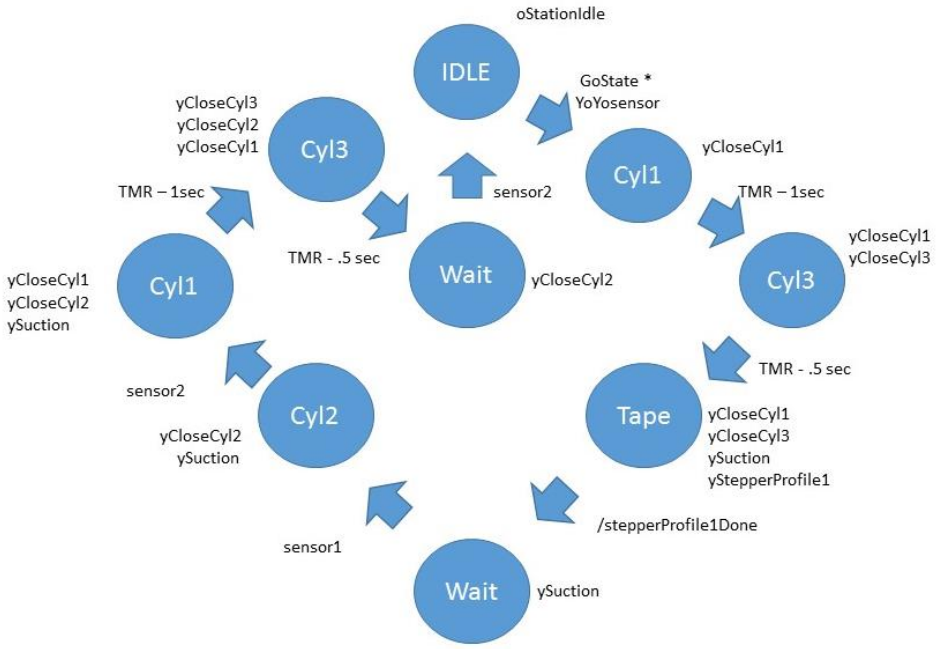
4.1 Turret State



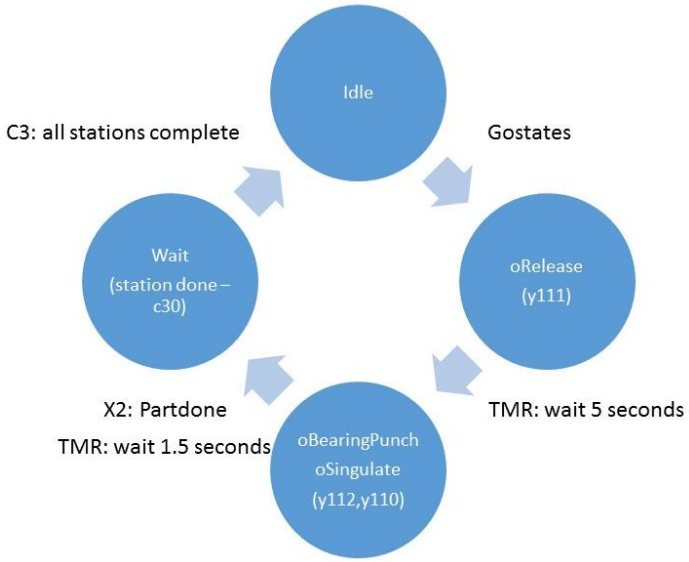
4.2 Station 1 State



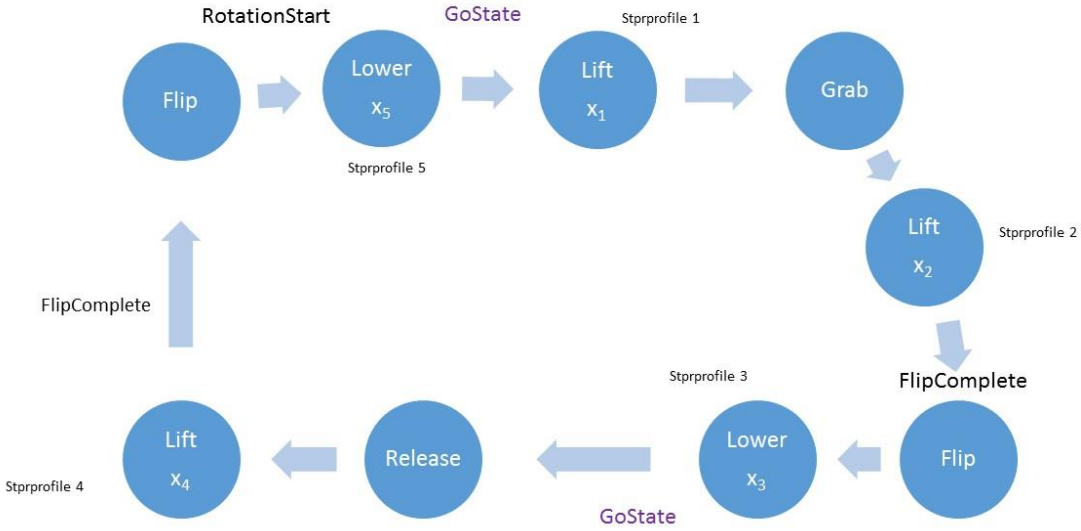
4.3 Station 2 State



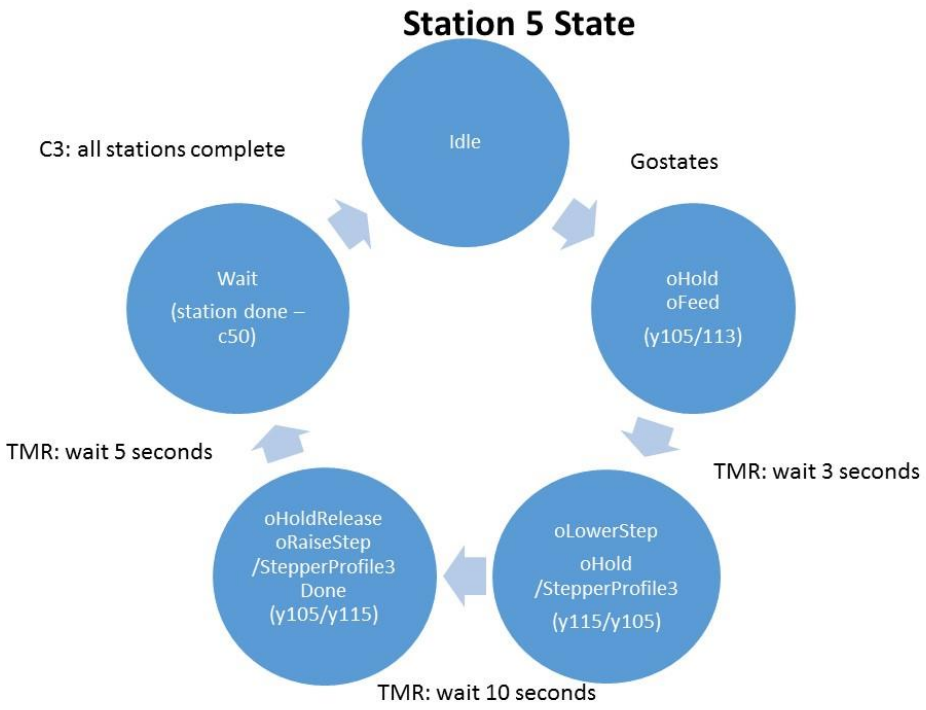
4.4 Station 3 State



4.5 Station 4 State



4.6 Station 5 State



5 Future Work

In order to complete all the tasks that were originally assigned, a significant amount of future work will need to take place in order to finish the stations that we were unable to complete. Below is a list of how each station may be improved upon to efficiently and repetitively assembly yo-yo's.

Turret: No future work is needed.

Station 1: This station is quite different from the original design but functions fairly well. However, there are still some flaws that would need to be addressed. The singulating function works quite well, but the guiding system can be bumped quite easily which means the yo-yo half will not land in the locating fixture properly. A better guidance system will need to be incorporated. Sensors that tell the program when parts are ready and when parts are not ready will also need to be incorporated in the future.

Station 2: For the near future in order to get this station working a few modifications need to be made. Primarily, on the 3D printed assembly part shown on Figure 5, there needs to be a small inward extrusion around the center pin so that the yo-yo can fit almost perfectly in line with the assembly as well as having the assembly be able to go all the way in and apply some pressure on the o ring. Also, evidently we ended weak on the programming end of things as we need to set up the servo and all the sensors accordingly. Another improvement would be to find a method to get the vacuum inside the part to be connected to a higher pressure air without damaging or having to re-calibrate the other stations. Finally, there weren't sufficient sensors and pneumatic tube fittings of the proper size to make this fully functional. Despite all that the concept is solid and it would function otherwise.

Station 3: Station 3 functions very well, however, the main problem is that the bearing will not always land in the proper location before being pressed onto the yo-yo half. A better guidance system will need to be incorporated along with sensors that are capable of determining the supply of bearing as well as when the bearing has properly been seated on the yo-yo half.

Station 4: This station needs rubbers on the gripper, so that the yo-yo can be held sufficiently. Also motor profiles are needed. When working on the motor profiles, moving down the grabber into the "home" position needs to be done while the plate is rotating, so timing will need to be worked out.

Station 5: To improve this design, a better setscrew alignment part is needed. The accuracy of the plastic tubing that is currently used is not consistent enough. A custom 3D printed part would be more effective. Also the stepper motor should be properly aligned and programmed to make sure the setscrew is screwed properly each time.

Station 6: No necessary modifications will need to be made to station 6 in order to make the station function more efficiently. However, sensors could be incorporated to insure that the completed yo-yo was actually removed from the turret before allowing it to rotate again.

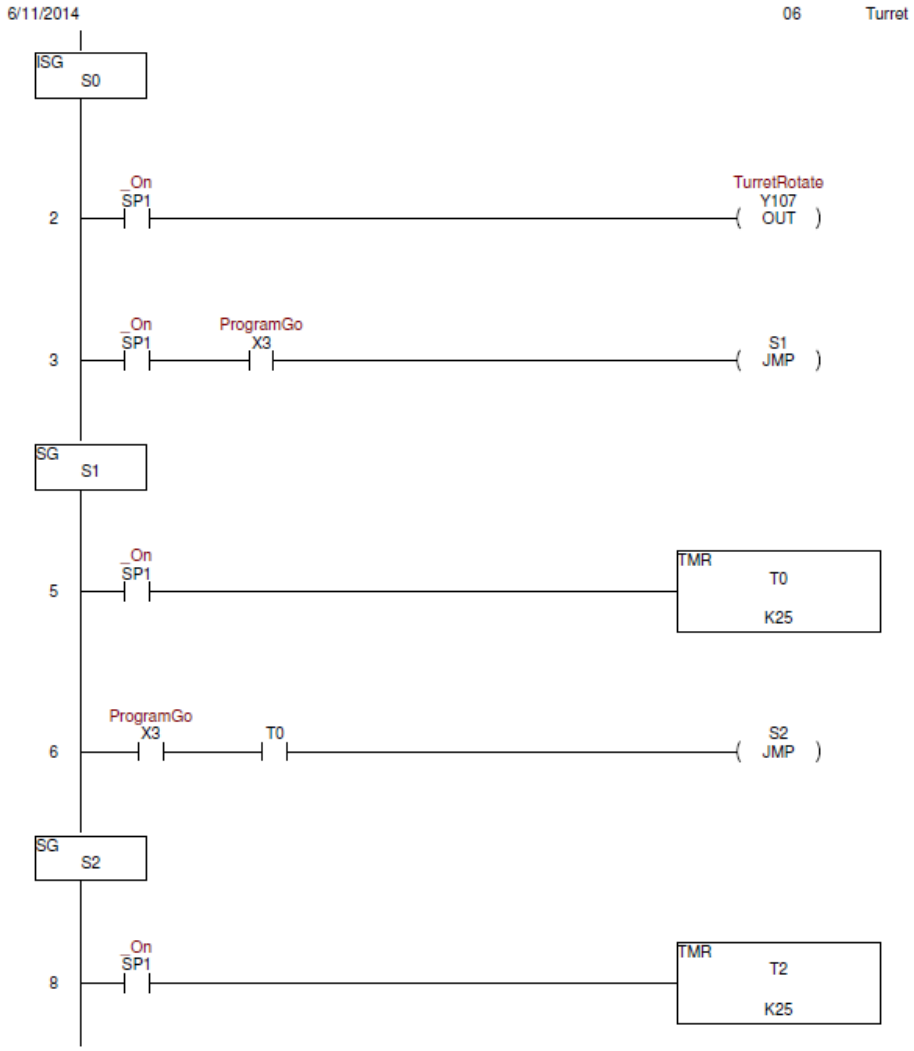
6 Conclusion

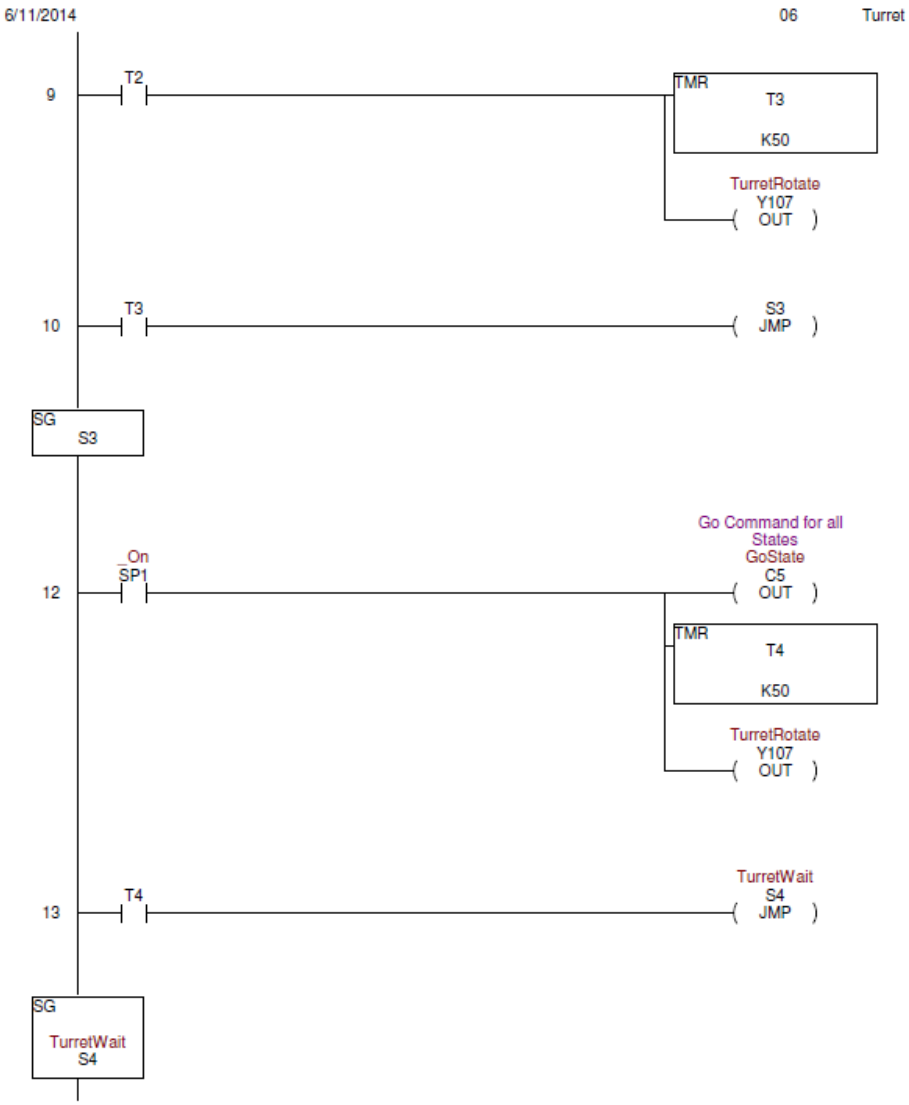
Overall, this project has taught us about many of the complications that arise when trying to automate a given process. Sometimes a function may appear to be simple when assembling the device with your hands, but trying to make fixturing and then control the process safely using PLC can get very complicated in a hurry. In conclusion, we were unable to fully automate the yo-yo assembly process, but we were able to get a significant portion of the setup completed within the allotted time. In the future, many improvements could be made to make the process more efficient and robust. This project has been a major learning event for all of our team

7 Wiring Diagram

Wiring Table		
	Output	**Input**
Turret	Y107	
Station 1		
Cylinder 1	Y106	
Cylinder 2	Y114	
sensor		X3
Station 2		
Track	Y101	
Cylinder 1	Y102	
Suction	Y100	
Stepper motor	Slot 2	
Sensor		X6
Station 3		
Cylinder 1	Y112	
Cylinder 2	Y111	
Cylinder 3	Y110	
sensor		X4
Station 4		
rotor	Y103	
gripper	Y103	
Stepper	Slot 3	
Sensor		X7
Station 5		
Cylinder 1	Y105	
Cylinder 2	Y113	
Cylinder 3	Y115	
Stepper	Slot 1	
Sensor		X5

8 PLC Ladder Logic

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TMR
T3
K50
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T3
S3
JMP
SG
S3
Go Command for all
States
GoState
C5
OUT
12
_On
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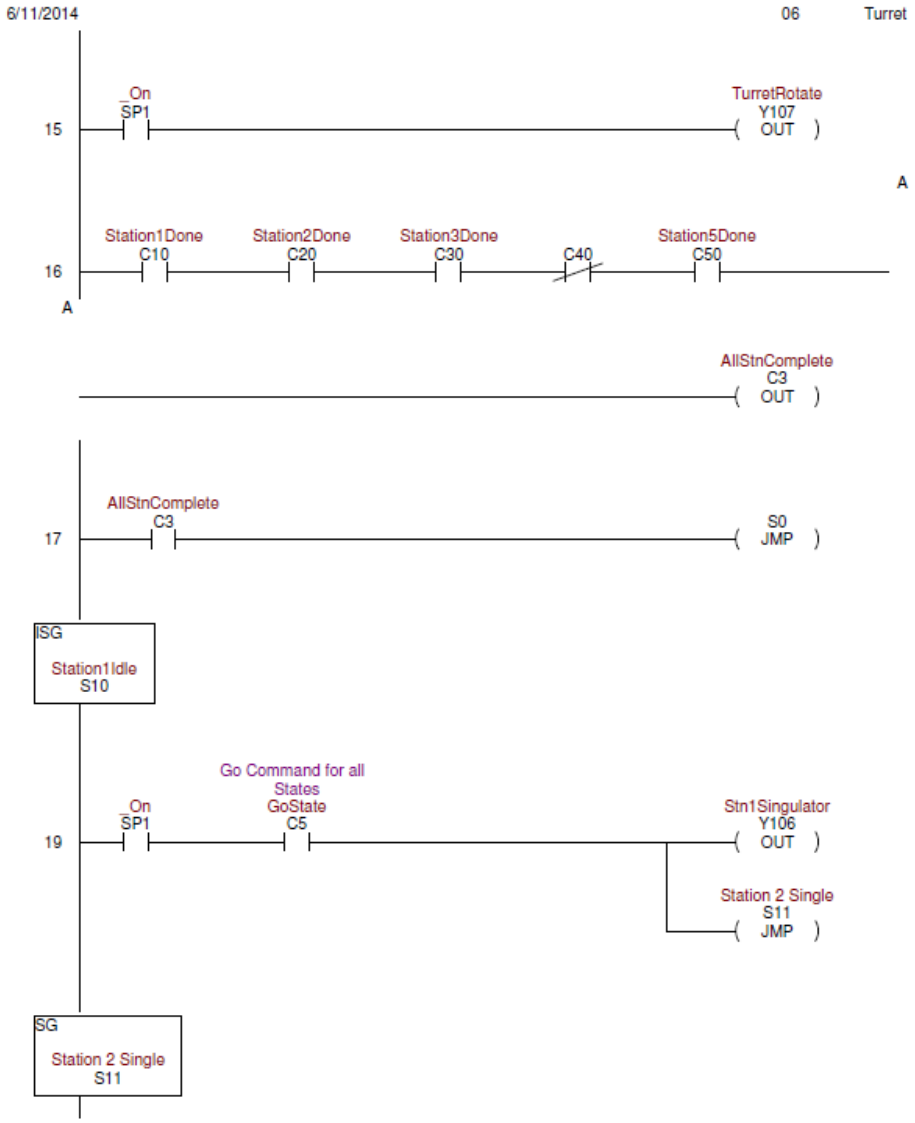
OUT
TurretWait
S4
JMP
13
T4
SG
TurretWait
S4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C30
C40
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A
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C3
OUT
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AllStnComplete
C3
S0
JMP
ISG
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S10
19
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Station 2 Single
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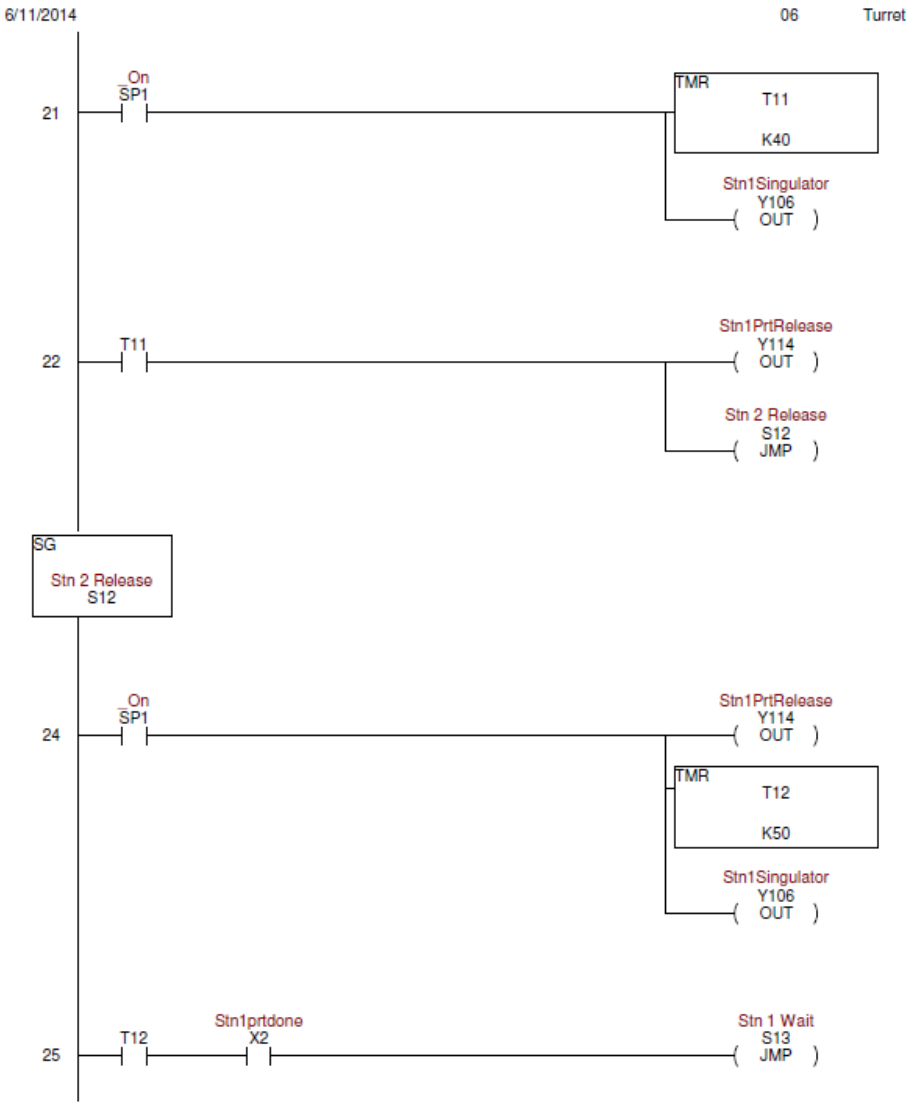
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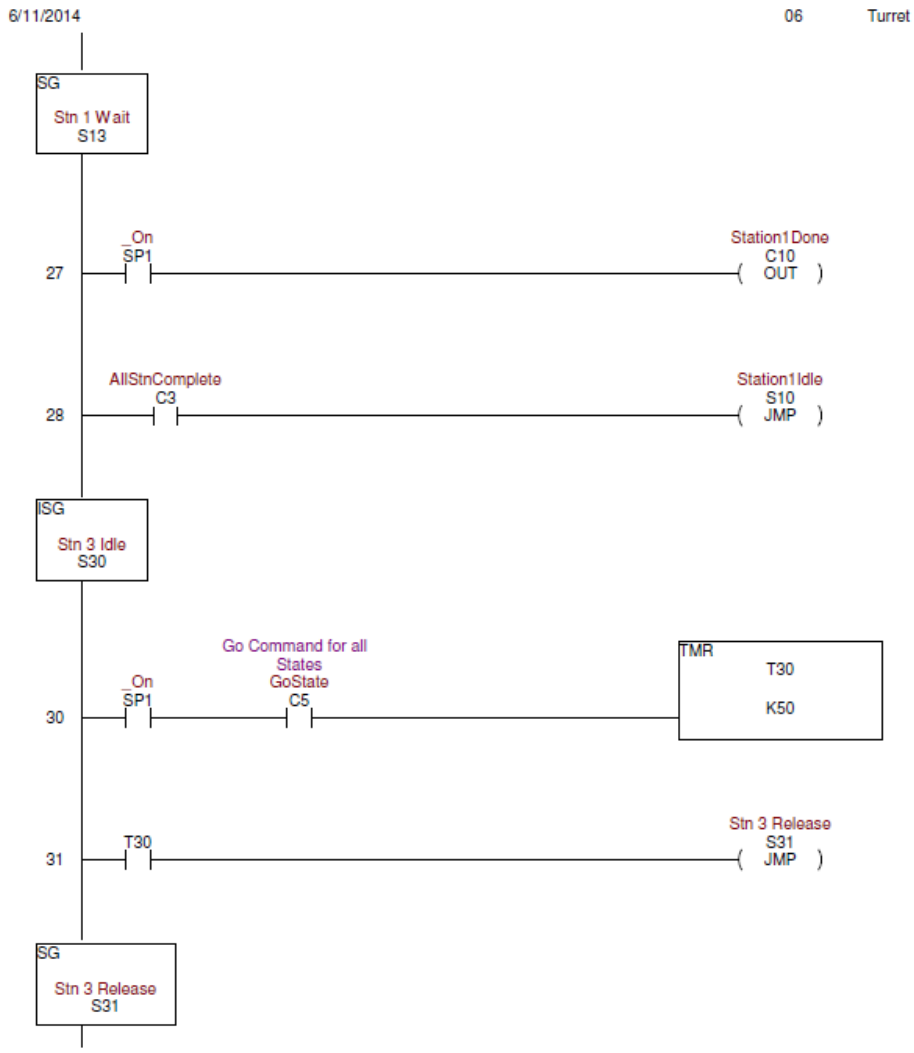
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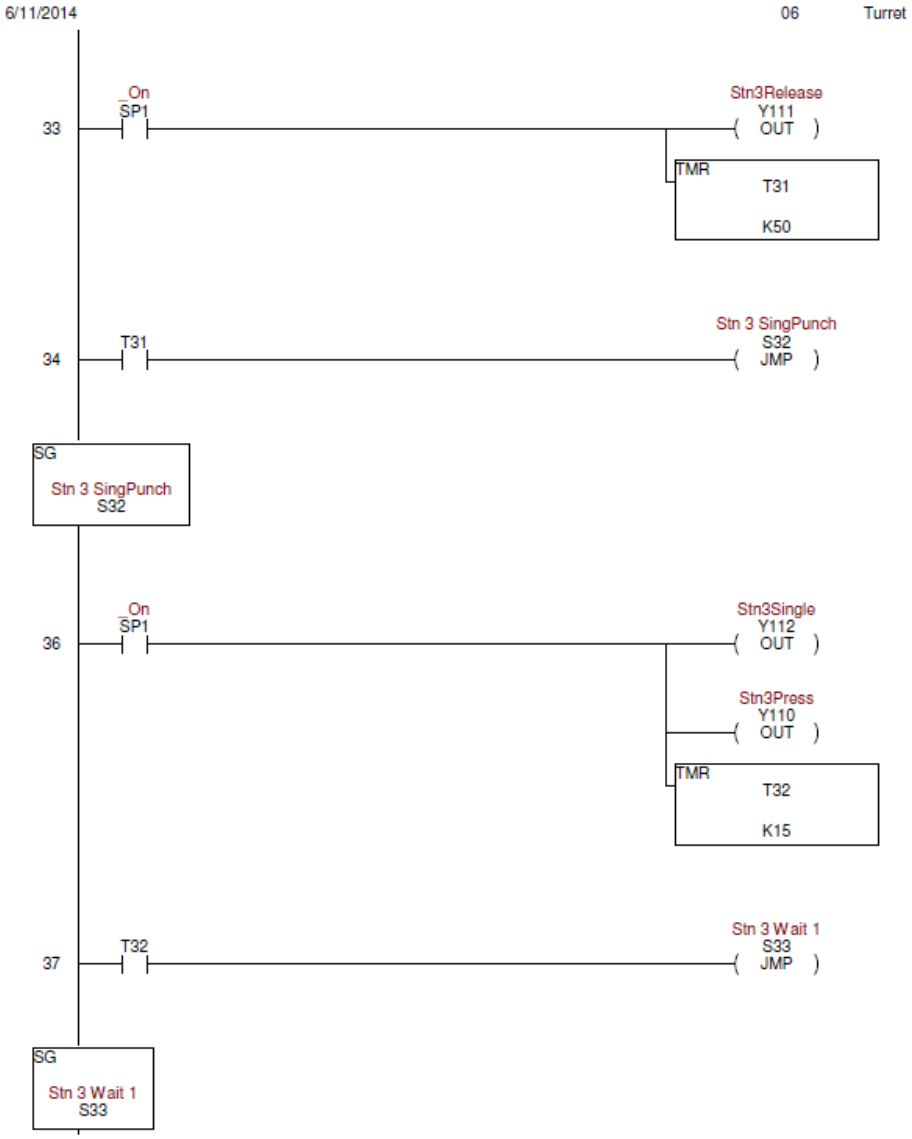
S31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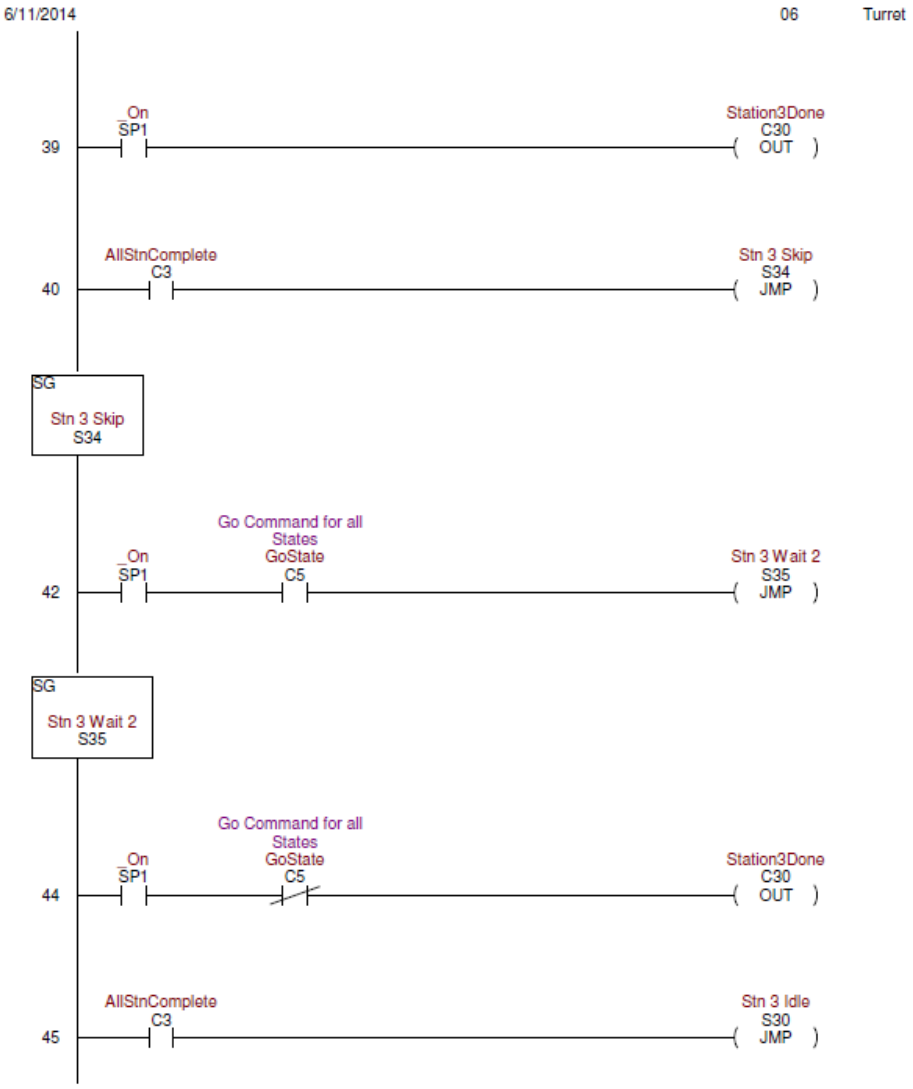
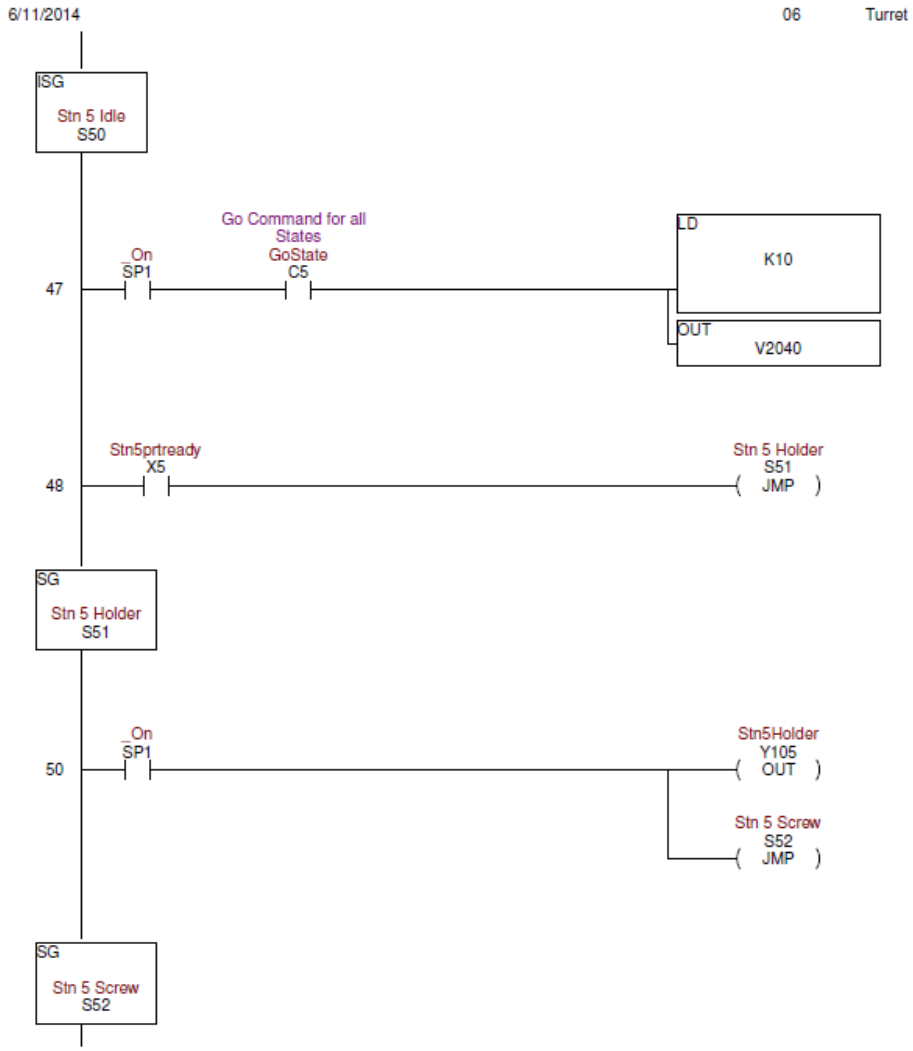
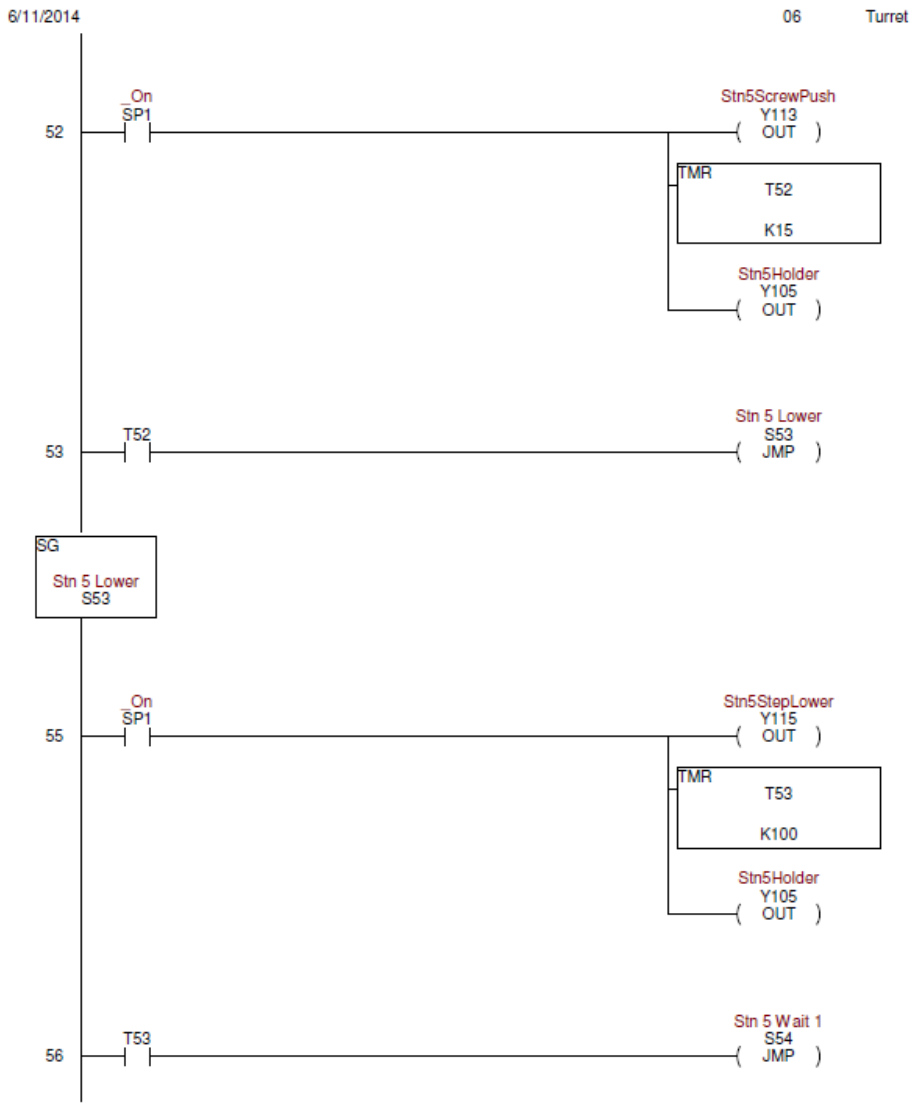
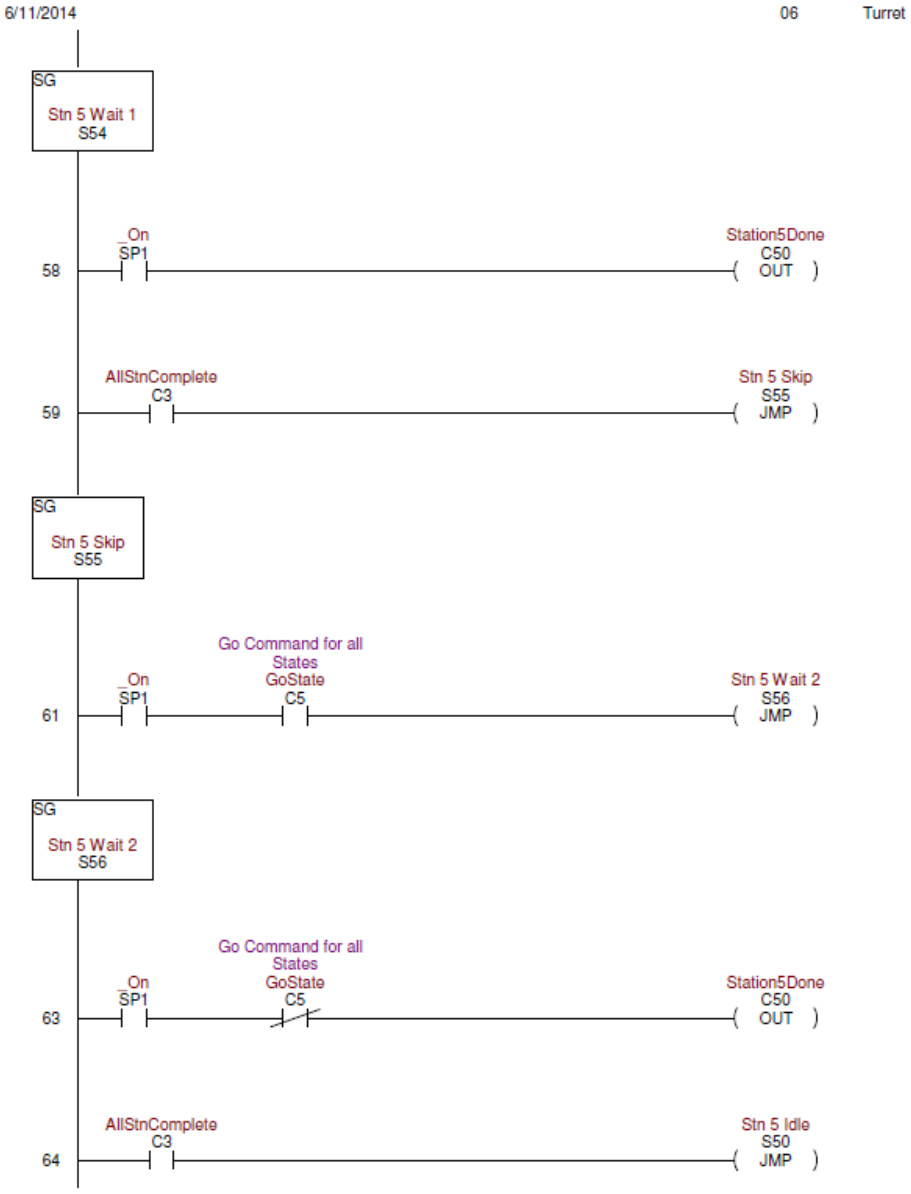
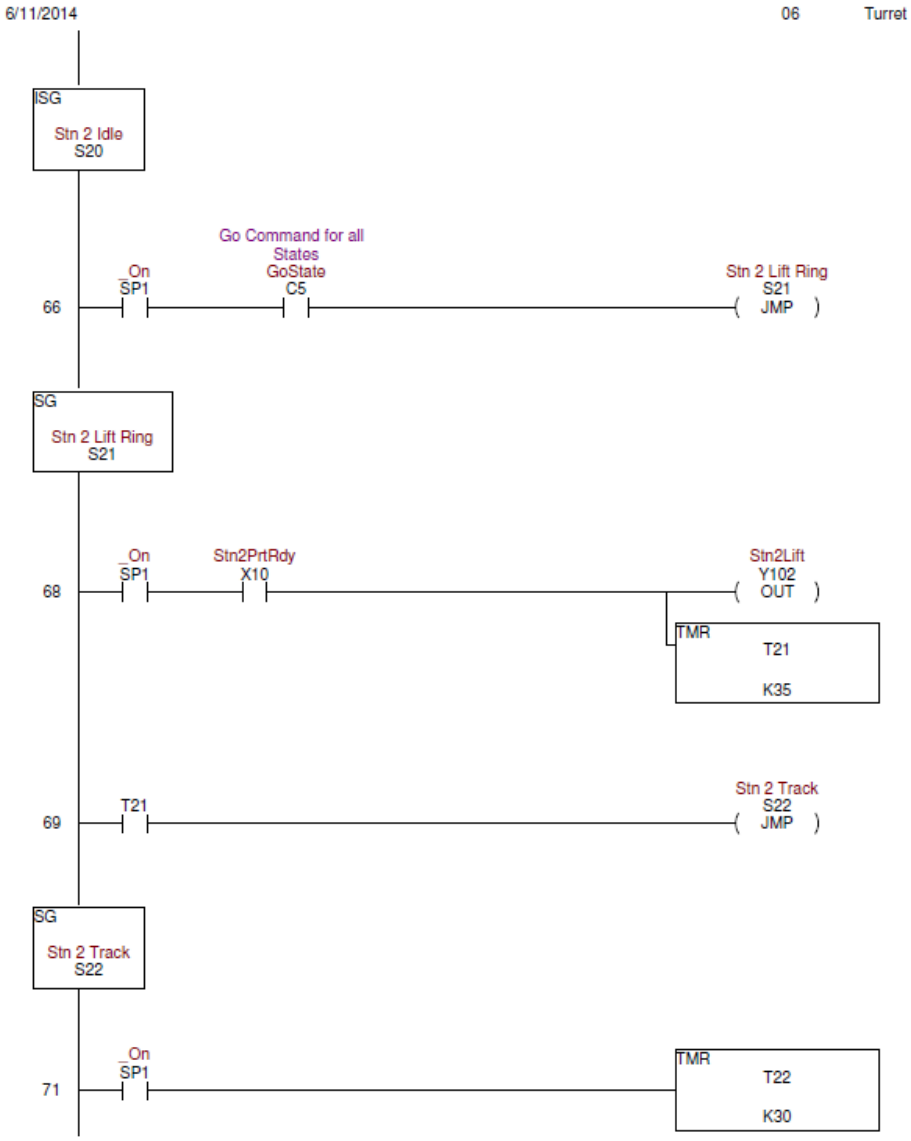
S33
JMP
SG
Stn 3 Wait 1
S33

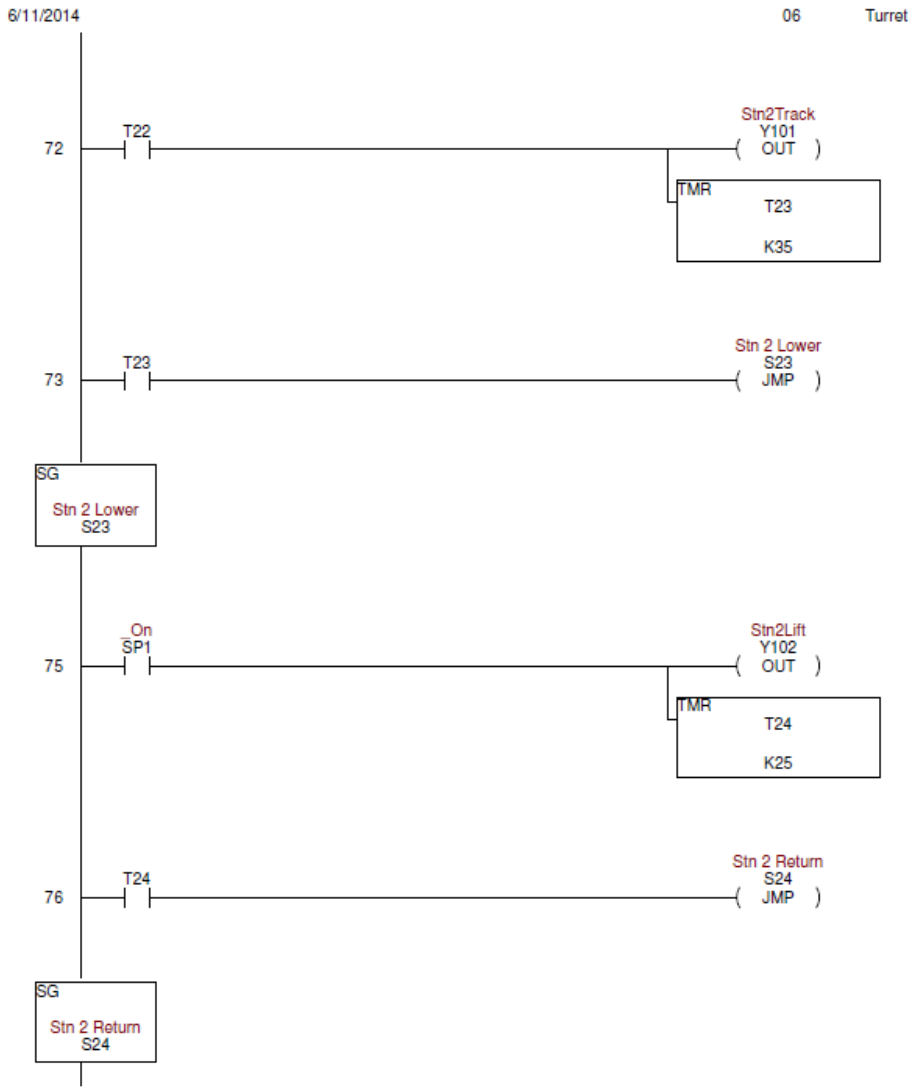

6/11/2014
06
Turret
39
_On
SP1
Station3Done
C30
OUT
40
AllStnComplete
C3
Stn 3 Skip
S34
JMP
SG
Stn 3 Skip
S34
42
Go Command for all States
GoState
C5
_On
SP1
Stn 3 Wait 2
S35
JMP
SG
Stn 3 Wait 2
S35
44
Go Command for all States
GoState
C5
_On
SP1
Station3Done
C30
OUT
45
AllStnComplete
C3
Stn 3 Idle
S30
JMP

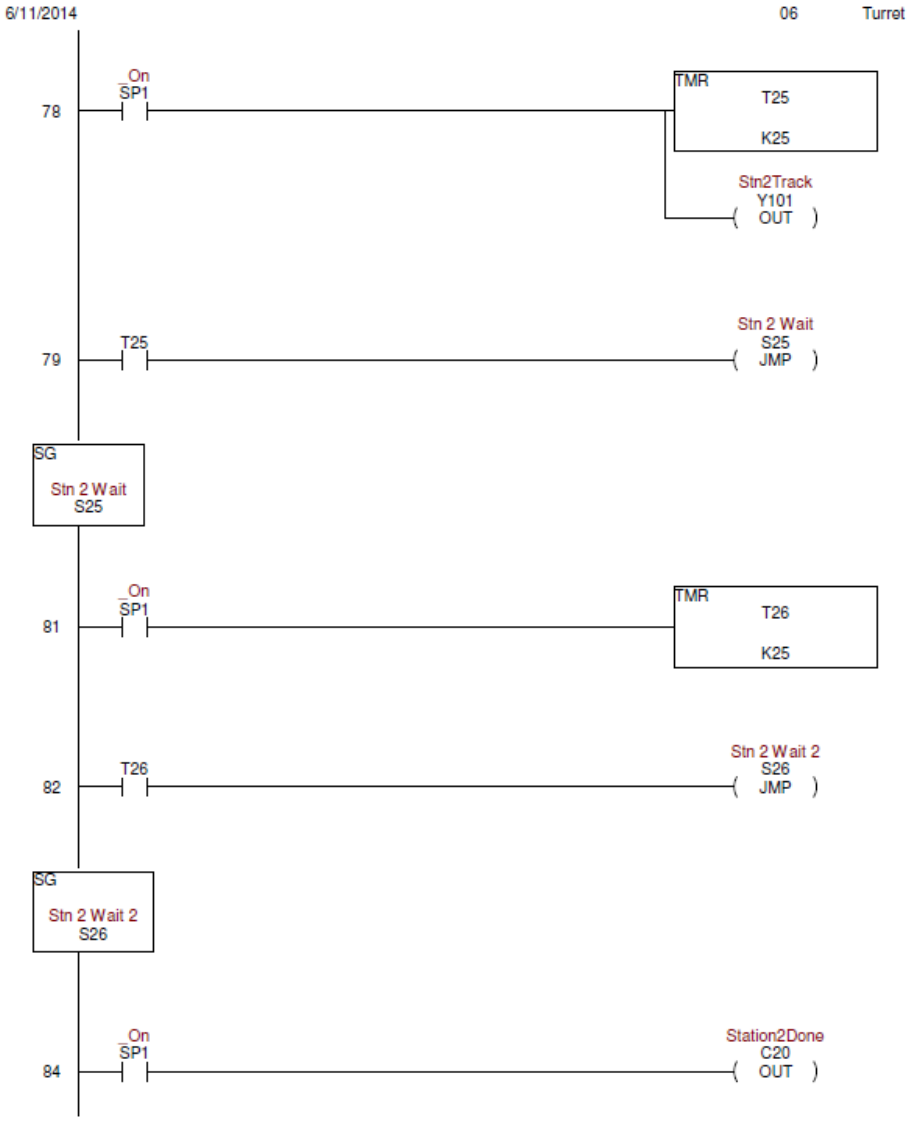

6/11/2014
06
Turret
ISG
Stn 5 Idle
S50
47
_On
SP1
Go Command for all
States
GoState
C5
LD
K10
OUT
V2040
48
Stn5prtready
X5
Stn 5 Holder
S51
JMP
SG
Stn 5 Holder
S51
50
_On
SP1
Stn5Holder
Y105
OUT
Stn 5 Screw
S52
JMP
SG
Stn 5 Screw
S52

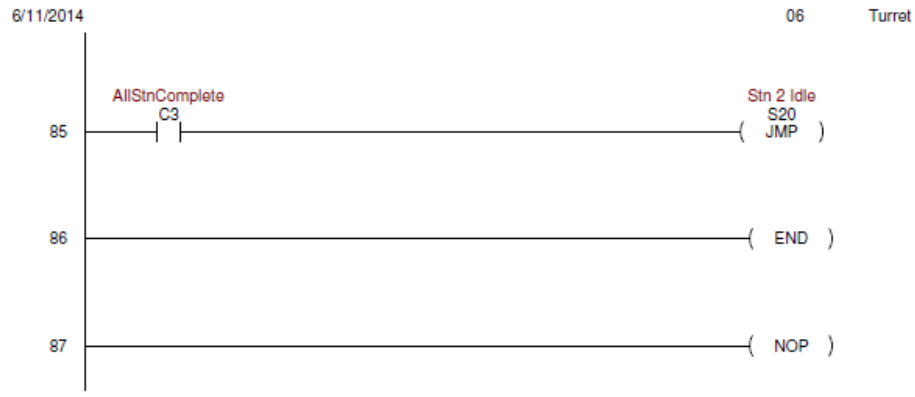

6/11/2014
06
Turret
52
_On
SP1
Stn5ScrewPush
Y113
OUT
TMR
T52
K15
Stn5Holder
Y105
OUT
53
T52
Stn 5 Lower
S53
JMP
SG
Stn 5 Lower
S53
55
_On
SP1
Stn5StepLower
Y115
OUT
TMR
T53
K100
Stn5Holder
Y105
OUT
56
T53
Stn 5 Wait 1
S54
JMP


6/11/2014
06
Turret
SG
Stn 5 Wait 1
S54
58
_On
SP1
Station5Done
C50
OUT
59
AllStnComplete
C3
Stn 5 Skip
S55
JMP
SG
Stn 5 Skip
S55
61
Go Command for all States
GoState
C5
Stn 5 Wait 2
S56
SG
Stn 5 Wait 2
S56
63
64
Stn 5 Idle
S50


6/11/2014
06
Turret
ISG
Stn 2 Idle
S20
Go Command for all States
GoState
C5
_On
SP1
66
Stn 2 Lift Ring
S21
JMP
SG
Stn 2 Lift Ring
S21
_On
SP1
Stn2PrtRdy
X10
68
Stn2Lift
Y102
OUT
TMR
T21
K35
T21
69
Stn 2 Track
S22
JMP
SG
Stn 2 Track
S22
_On
SP1
71
TMR
T22
K30


6/11/2014
06
Turret
72
T22
Stn2Track
Y101
OUT
TMR
T23
K35
73
T23
Stn 2 Lower
S23
JMP
SG
Stn 2 Lower
S23
75
On
SP1
Stn2Lift
Y102
OUT
TMR
T24
K25
76
T24
Stn 2 Return
S24
JMP
SG
Stn 2 Return
S24


6/11/2014
06
Turret
78
_On
SP1
TMR
T25
K25
Stn2Track
Y101
OUT
79
T25
Stn 2 Wait
S25
JMP
SG
Stn 2 Wait
S25
81
_On
SP1
TMR
T26
K25
82
T26
Stn 2 Wait 2
S26
JMP
SG
Stn 2 Wait 2
S26
84
_On
SP1
Station2Done
C20
OUT


6/11/2014
06
Turret
85
AllStnComplete
C3
Stn 2 Idle
S20
JMP
86
END
87
NOP