Robotic Flashlight Assembler Instruction Manual

ENGR 480 Manufacturing

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Operation Instructions

This section includes instructions for starting, loading, clearing jams, and shutting down the flashlight assembly machine. This includes the robotic arm, part feeding stations, PLC controller, and air system.

Starting

1. Ensure parts are loaded in all eight part stations
    1.1. Part stations include: Flashlight noses, big o-rings, on/off switch rings, small o-rings, heat sinks, snap rings, flashlight bodies, and batteries. (See loading description below)
2. Ensure nose o-ring guide is in place at the central assembly station
3. Power on the robotic arm and controller
    3.1. Turn the large knob style switch on the side of the robot controller to 'ON'
    3.2. Wait for the boot cycle in the robot control pendant to complete
        3.2.1. When complete the control pendant will display 'Please select a Main Menu'
    3.3. Ensure the key at the top left of the control pendant is switched to 'PLAY'
    3.4. Ensure the E-stop at the top right of the control pendant is off
4. Power on the PLC
    4.1. Plug the orange extension cord into a standard wall power outlet
    4.2. Ensure the 3-way switch at the bottom right of the PLC is switched to 'RUN'
5. Turn on system air
    5.1. Switch the air valve mounted next to the PLC to 'C-2'
        5.1.1. You should hear a small release of air when switching from the off position (labeled 'N') to the on position (labeled 'C-2') or vice versa
6. Select and start the job 'HELLIETEAM' in the robot control pendant
    6.1. Using the touch screen on the control pendant select 'JOB' -> 'SELECT JOB'
    6.2. Using the arrow buttons scroll to 'HELLIETEAM' and push the 'SELECT' button
    6.3. Push the 'SERVO ON READY' button and then the green 'START' button
7. Start the machine by pushing the green button mounted next to the PLC

Loading

Eight stations will be loaded with flashlight parts. One assembly tool station will be loaded with the nose o-ring guide tool.

1. Flashlight nose – Located at the bottom of Tower 4 these roll down a white plastic tray with the threaded end pointing up and away from the center of the table.
2. Big o-rings – Located at the top of Tower 4 these roll on end (like a car tire) in a narrow track.
3. On/Off switch rings – Located at the top of Tower 4 these slide on their side down a ramp where they are stopped by two button head screws.
4. Small o-rings – Located at the bottom of Tower 4 these roll on end (like a car tire) in a narrow track.
5. Heat sinks – Located at the top of Tower 3 these slide spring first down a PVC tube. Insert heat sinks slowly to avoid excessive speed as they slide down the PVC tube.
6. Snap rings – Located between Towers 3 and 4 these are stacked (like a roll of quarters) in a clear plastic tube.

7. Flashlight bodies – Located at the bottom of Tower 3 these roll on their side with the closed end facing away from the tower.
8. Batteries – Located in the middle of Tower 3 these roll on their side with the negative end facing away from the tower.

Clearing Part Jams

Flashlight part loading station jams – Jams occurring in the loading stations for the flashlight nose, big o-rings, small o-rings, heat sinks, flashlight bodies, or batteries can be cleared by tapping the tower where the jam occurred to cause a small vibration in the tower.

O-ring jams – O-ring jams are the most common and are cleared with a small vibration in the tower.

Flashlight nose and heat sink jams – These are less common and sometimes require a slightly larger vibration to clear than o-ring jams.

Flashlight body and battery jams – These are uncommon, but can still be cleared with a, relatively speaking, large vibration in the tower.

Other jams – For any other jams occurring with the robotic arm, in the central assembly station, in the final assembly threading station, in the snap ring loading station, or in the on/off ring loading station do the following:

1. Push the E-stop on the robot control pendant and turn the switch at the bottom right of the PLC to 'STOP'
2. Clear any jams manually if possible. If the jam involves the robotic arm see "Clearing Jams Involving the Robotic Arm" below
3. After a jam occurs the robotic arm will need to be reset. See "Resetting the Robotic Arm after a Jam"

Clearing Jams Involving the Robotic Arm

1. Decide which direction or directions will be safest to move the robotic arm out of the position in which it is jammed
2. Move the robotic arm to a cleared position away from the jam
   2.1. Turn the key at the top left of the control pendant to 'TEACH'
   2.2. Release the E-stop on the control pendant
   2.3. The robotic arm controller will probably be aware it was involved in a jam and will be displaying an error message. Push 'RESET' on the touch screen to exit the error message
   2.4. Using the 'COORD' button select a coordinate system in which to move
   2.5. Push the 'SERVO ON READY' button on the control pendant
   2.6. Squeeze the black trigger on the back of the control pendant under your left hand to its half way position
   2.7. While holding the trigger in its half way position use the movement buttons on the control pendant to move the robotic arm in the direction decided upon in step 1 to a clear position away from the jam
3. Reset the robotic arm by following the steps below in "Resetting the Robotic Arm after a Jam"

Resetting the Robotic Arm after a Jam

1. Turn the key at the top left of the control pendant to 'TEACH'
2. Release the E-stop on the control pendant
3. If any error messages are displayed on the control pendant clear them by pushing 'RESET' on the touch screen
4. Move the robotic arm near its home position
   4.1. Using the 'COORD' button select a coordinate system in which to move
   4.2. Push the 'SERVO ON READY' button on the control pendant
   4.3. Squeeze the black trigger on the back of the control pendant under your left hand to its half way position
   4.4. While holding the trigger in its half way position use the movement buttons on the control pendant to move each joint of the robotic arm to its zero position except for the first joint at the base of the robotic arm. The first joint should be rotated about ninety degrees counter clockwise so the robotic arm is pointing toward the final assembly threading station.

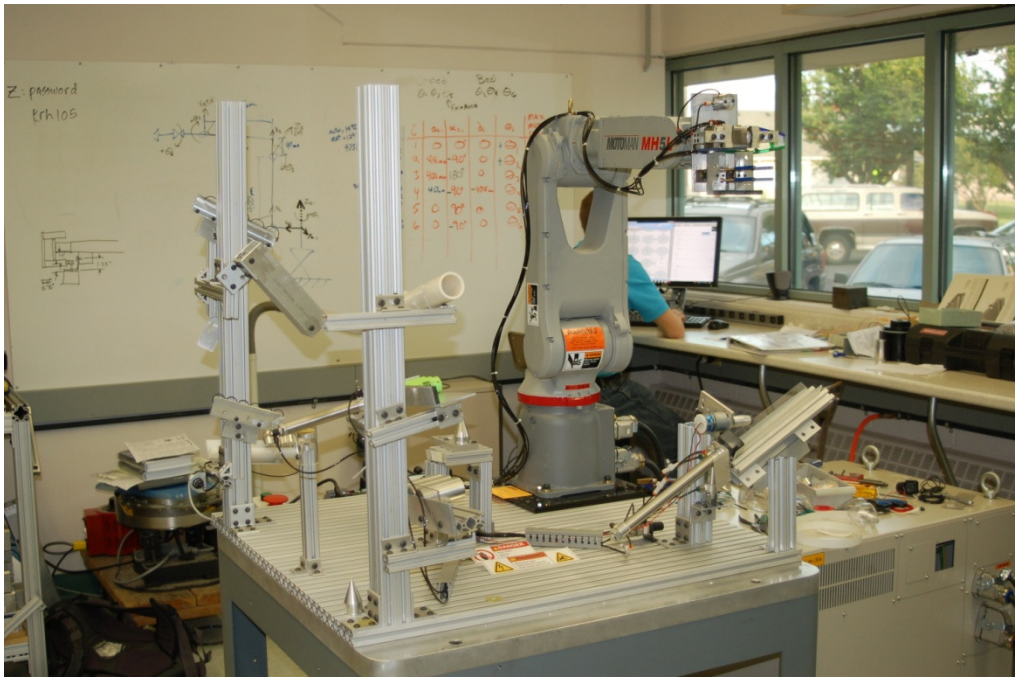


Figure 1: Robotic Arm Reset Position

5. Go to the "Starting" section above. Note that many steps in this section will already be complete

Shutting Down

1. Wait until a finished flashlight has been ejected from the final assembly threading tray
2. Press the E-stop on the robot control pendant
3. Put the switch at the bottom right of the PLC to the 'STOP' position
4. Power down the robotic arm and controller
   4.1. Turn the large knob style switch on the side of the robot controller to 'OFF'
5. Power down the PLC

5.1. Unplug the orange extension cord powering the PLC
6. Turn off system air
   6.1. Switch the air valve mounted next to the PLC to 'N'

Diagrams

PLC Ladder Logic

The logic controlling the PLC was very simple due to the handshake pattern that occurred between the Motoman and the PLC. We decided to control every action with the PLC instead of having the Motoman control the end effecters. The reason we did this breaks down to our knowledge of PLC digital logic versus the digital logic language of the robot. Since our logic is so linear and patterned it is very straight forward.

The idle state has two inputs: Start Button and Nose Ready sensor. If both of these requirements are complete it moves into the next state. Wait for Ready 1 is the next state where we make sure that the robot is not performing a task. When the robot is ready it will jump to the next rung and begin the trigger cycle and the first motion of the robot, R1. The rest is just a pattern that only changes a bit when an additional action needs to happen between states. For instance between R1 and R2 the soft gripper needs to close onto the nose cone. This is accomplished by sending and additional output y112, in this case, to tell the grippers to close. This pattern continues throughout even until the assembled nose cone is ready to be placed for final assembly. Please refer to Appendix A for detailed ladder logic diagram.

State Machine

The state machine for flashlight assembly is based on a pattern of handshaking between the PLC and robotic arm. When the robotic arm is not moving it outputs a ready signal to the PLC while the PLC actuates any necessary air cylinders, motors, or grippers. When the PLC has finished it sends a trigger signal to the robotic arm at which point the arm turns off the ready signal it was sending to the PLC and moves to the next point in space. While the arm is moving the PLC waits for the arm to turn a ready signal on again before actuating anything. When the arm reaches its destination it turns a ready signal to the PLC on again and the process repeats.

This pattern is convenient for listing all the points in space the robotic arm will travel through and separating each movement of the arm between cylinder, gripper, or motor actuations. Each movement is labeled R1, R2, R3, etc. and corresponds to the state diagram labels as well as the jobs listed in the robot control pendant. See appendix B for the state diagram, sequential list of points the robotic arm passes through, and the movement labels such as R1, R2, etc.

CNC Programs

The flashlight body, nose cone, on/off ring, and o-ring guide were machined on the Mori Seiki CNC lathe. The platform that holds the nose and o-ring guide at the central assembly station was machined on the Haas CNC mill. See appendix C for CNC g-code.

Wiring Diagrams

PLC Inputs		PLC Outputs	
X0	Start Button	Y0	Trigger
X1	Nose Ready	Y111	Vacuum
X2	Robot Ready	Y112	Soft Gripper
		Y113	Hard Gripper
		Y114	Battery Air Cylinder
		Y115	Motor/Air Cylinder
		Y116	Eject Air Cylinder

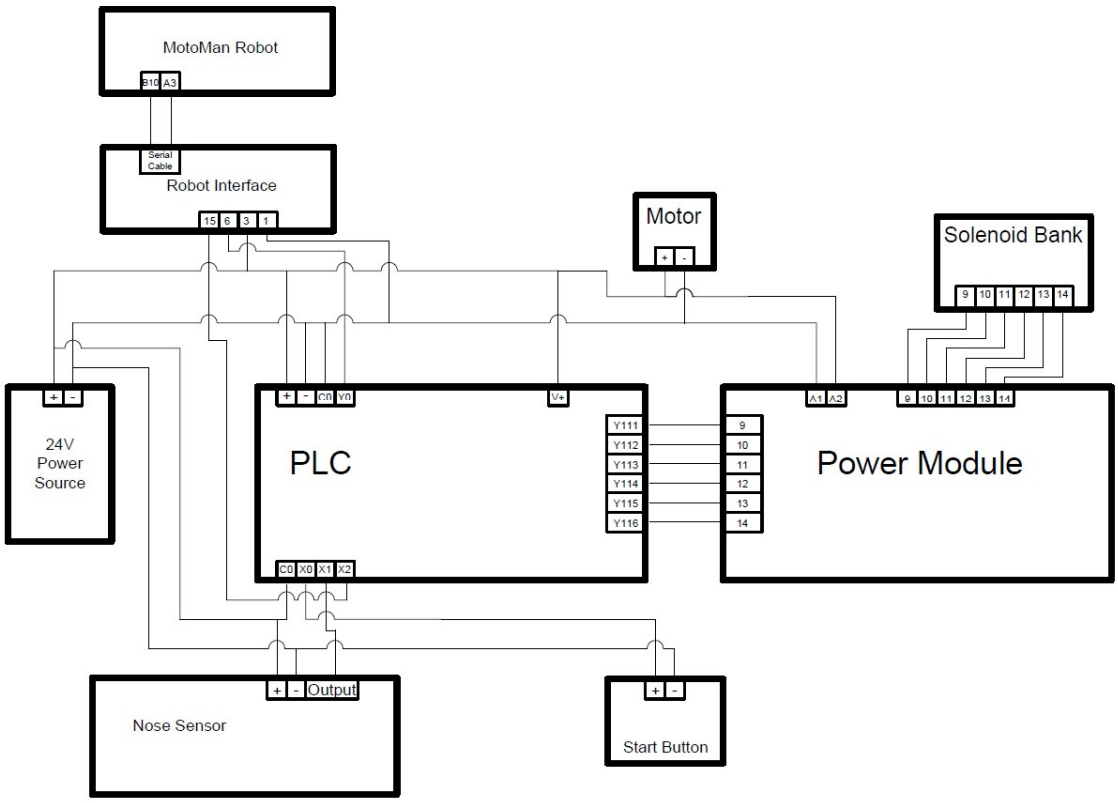


Figure 2: PLC Wiring Diagram

System Parts & Functions

System Outline

We are assembling flashlights with the Motoman MH5L robot. The benefits of this method are repeatability and consistency. This method is very linear, meaning that the robot can perform one task at a time where as the hard automation method allows many things to happen at one time to maximize efficiency. The positions for each part supply station were carefully placed at a relatively uniform distance from the robots range of motion. The first tower, tower 3, is comprised of the body station, battery station and heat sink station. The second tower, tower 4, is comprised of the large o-ring station, small o-ring station, on-off ring station, and nose cone station as seen below. The snap ring station is isolated so that the end effecter can properly reach it. Please see Appendix D for Motoman runs and points.

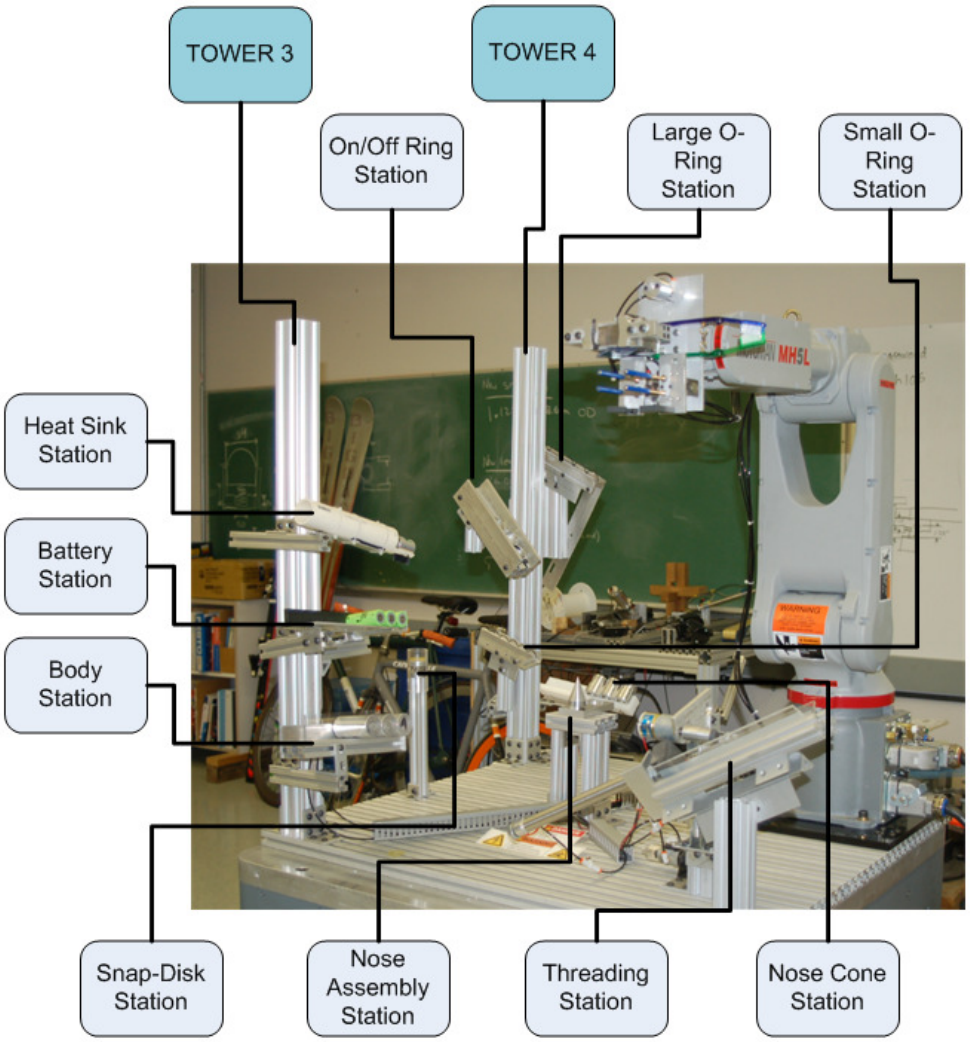


Figure 3: Flashlight Assembly Factory

Central Assembly Station

This station is where parts for the nose cone assembly are brought and assembled. The centralized location of this station makes it an ideal spot for bringing parts that are relatively equidistant from it and assembling them within conservative bounds for the Motoman robot. This station consists of two major areas. The first is the area where the nose cone is brought and pieces are added to it. The second is to hold our nose o-ring guide (see O-ring Guide). This station was constructed with 80/20 beam topped with a milled aluminum platform. This platform has a milled spot for the nose cone as well as a milled spot for the o-ring guide. The order of operations for this station is:

1. Nose cone is brought over and set down on the central assembly station.
2. The o-ring guide is picked up and set into the nose cone.
3. The first large o-ring is brought and placed loosely on the o-ring guide.
4. The first brush cycle is done (see Brush Cycle).
5. On-Off ring is placed onto the nose cone.
6. The second large o-ring is brought and placed loosely on the o-ring guide.
7. The second brush cycle is done.
8. O-ring guide is removed and put back in its holder.
9. Small o-ring is dropped loosely into the nose cone.
10. Alignment of small o-ring is performed using o-ring guide (see Small O-ring Alignment).
11. Heat sink is dropped in.
12. Snap ring is pressed in.
13. Finally the nose is taken and delivered for threading (see Final Assembly Threading Station)

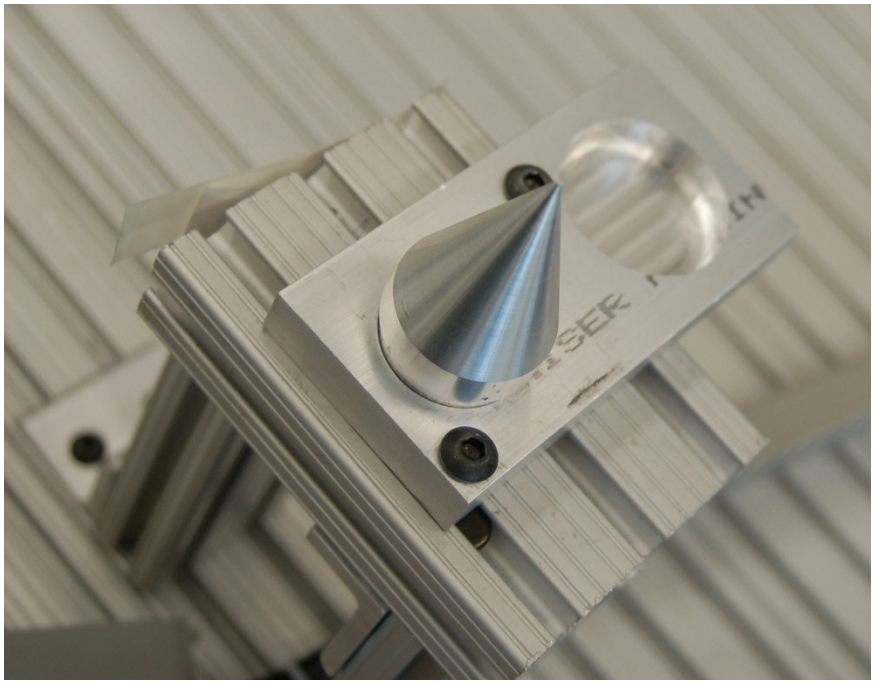


Figure 4: Central Assembly Station

Final Assembly Threading Station

All the final assembly and product ejection is performed at the final assembly threading station. This is the last step in the flashlight assembly process. This station is comprised of a threading tray, rubber threading motor, rubber stopper, and ejection piston. The order of operations is:

1. Assembled nose cone is placed onto the threading tray and slides down to the rubber stopper.
2. Then the assembled body is placed behind the assembled nose on the threading tray.
3. The rubber threading motor is lowered until the body begins spinning.
4. The body is spun until threaded completely.
5. When threading is complete the flashlight is ejected via the ejection piston.

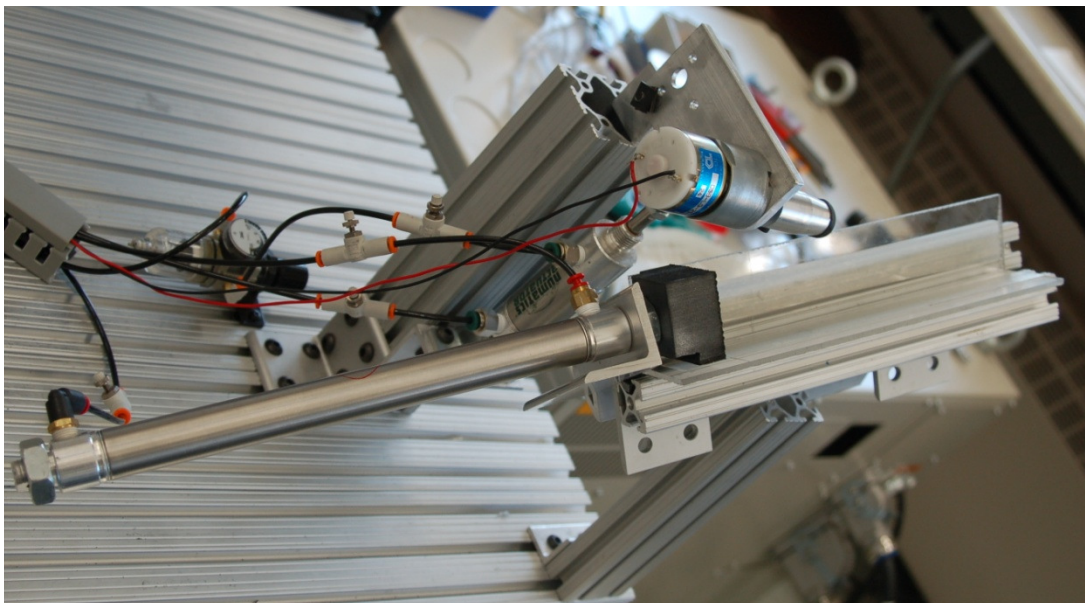


Figure 5: Final Threading Assembly Station

O-ring Guide

The o-ring guide was a clever tool implemented in our design process to aid in the simple alignment of the large o-ring. Rather than come up with a complex o-ring dispenser we decided to use a cone shaped guide. The large o-ring is placed onto the o-ring guide and a brush cycle is performed to set the o-ring in the proper position.

Figure 6: O-ring Guide

Nose Cone Station

The nose cone station is located on tower 4. This is a gravity fed part input station. There is a sensor here telling whether a nose cone is present to begin assembly. This is the first part to be placed in the assembly order. It is constructed of a milled piece of plastic that allows the nose cones to roll down and gently stop above the sensor ready for pick up by the Motoman robot.

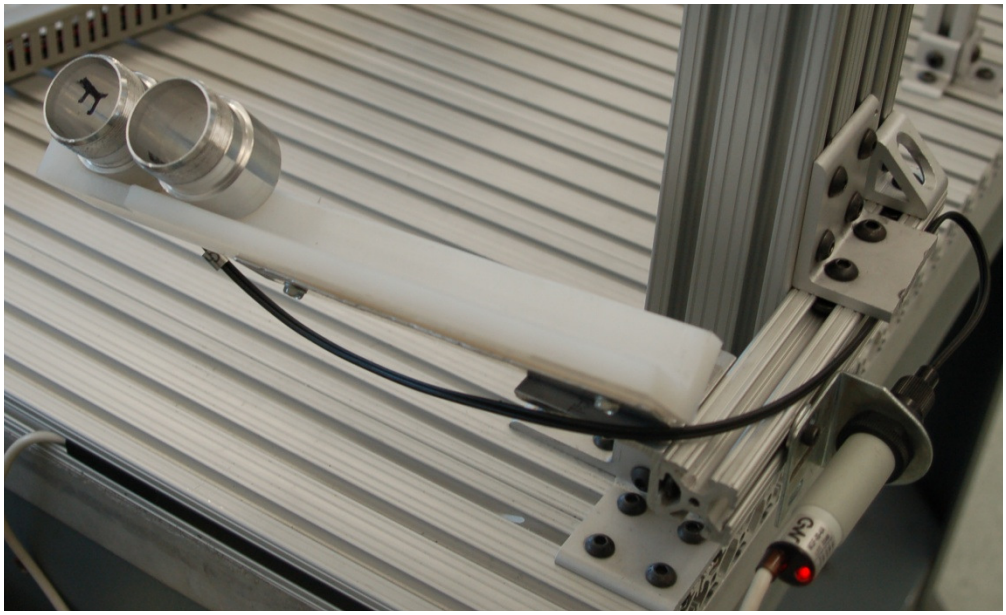


Figure 7: Nose Cone Station

Large O-ring Station

The large o-ring station is located on tower 4. This station is gravity fed and allows the o-rings to gently roll down a slot and stop at the end where it waits to be picked up by the Motoman robot. It is made of milled aluminum plates and mounted to the 80/20. This station would be easily supplied with a vibration singlution bowl.

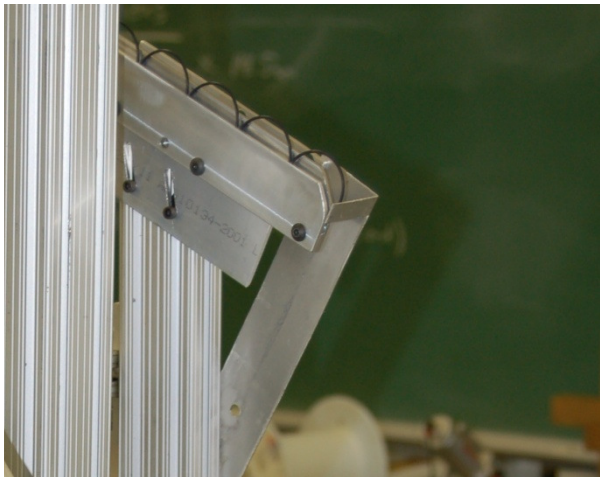


Figure 8: Large O-ring Station

Small O-ring Station

Similar to the large o-ring station; also located on tower 4. This gravity fed slot allows the singulated o-rings to roll down to the stopper where they are ready for pick up. The construction is of milled aluminum plates and an aluminum stopper mounted to the end.

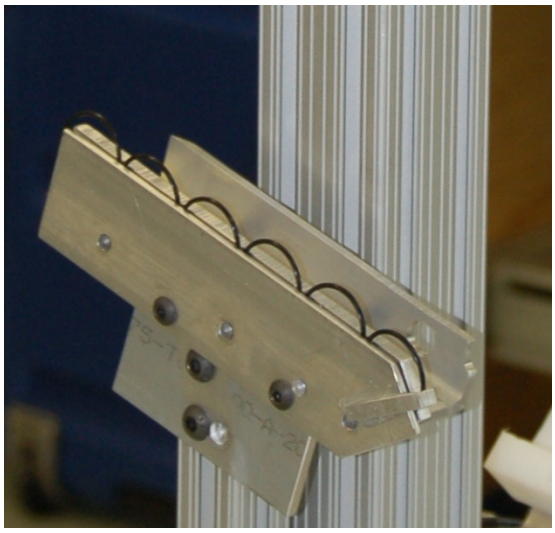


Figure 9: Small O-ring Station

On-Off Ring Station

This station is the last one mounted to tower 4. This is gravity fed and allows the singulated on-off rings to slide down a tray until they are held in the proper position by two ¼ 20 bolts. This station is explicitly designed to work with our soft gripper end effecter. It is made of a double 80/20 beam and 2 aluminum plates that keep the on-off rings from falling out.

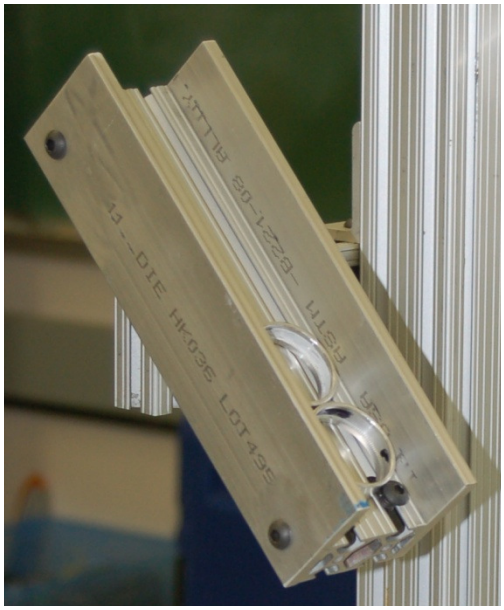


Figure 10: On/Off Ring Station

Heat Sink Station

The heat sink station is where the assembled heat sinks are prepared for pick up. It is located on tower 3. It is made of a PVC pipe that has been milled open to allow for the soft grippers to easily grab them. The heat sinks are singulated and slid down spring first until a stopper gently rests them in the position for grabbing. The reason the heat sinks are slid spring first is that we need them to load into the nose cone lens first. By gripping towards the rear we solve this dilemma.

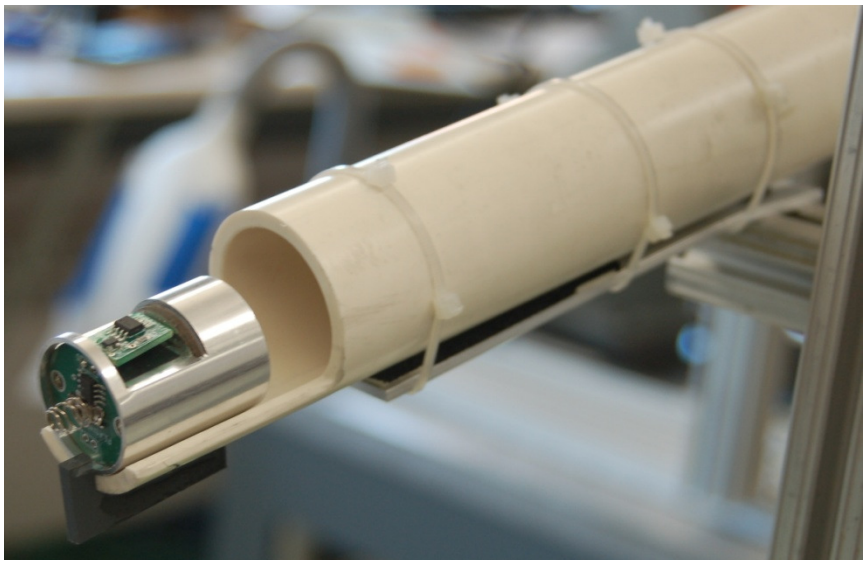


Figure 11: Heat Sink Station

Snap Ring Station

This is the station where the snap rings are singulated and brought into the work space. This station is the only non-gravity fed station. The snap rings are stacked and placed into a vertical hopper that is spring loaded. The snap ring end effecter lowers into the hopper and the vacuum is turned on. This operation picks a snap ring up and then presses it into the nose cone. This station is built with 1 ½ inch acrylic tubing with 2 aluminum caps with a spring between them. The spring lowers to give snap ring end effecter room to make the proper suction to pick up a snap ring. This way the same suction can be implemented no matter if there are 1-50 snap rings in place.

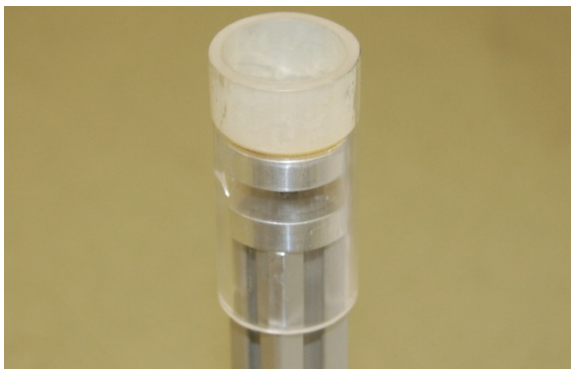


Figure 12: Snap Ring Station

Body Station

The body station is located on tower 3. The body station is gravity fed and allows the parts to roll into their grabbing position. The body is grabbed with the hard jaws. This station is built with an 80/20 base with an aluminum plate to stop them from rolling out. This also aligns them perfectly to allow for consistent picking.

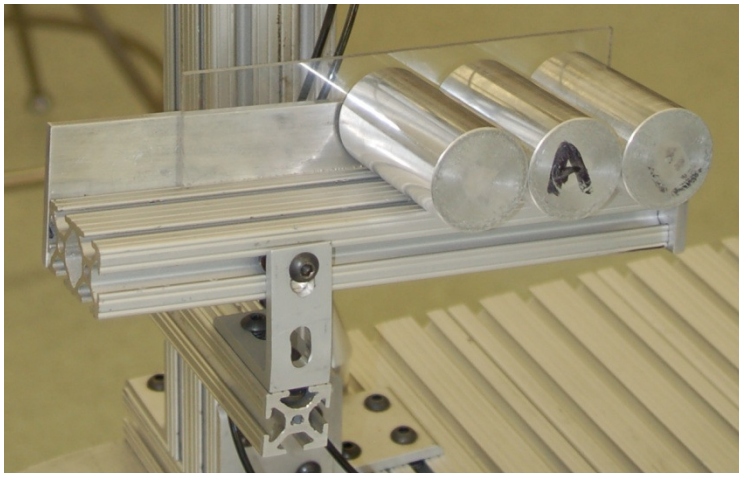


Figure 13: Body Station

Battery Station

The battery station is located on tower 3. This gravity fed station allows for the batteries to roll down to the ready position. They only need to be loaded in the correct orientation. The minus side would point away from tower 3. This would ensure that the magnet in the hard gripper end effecter can properly hold both the body and battery for final assembly. This station is built with an aluminum base and a plastic backing plate that keeps them in alignment. A hole is milled out of the side to allow an air cylinder to eject the battery into the body when a body is present. The battery is held in the body by magnetism.

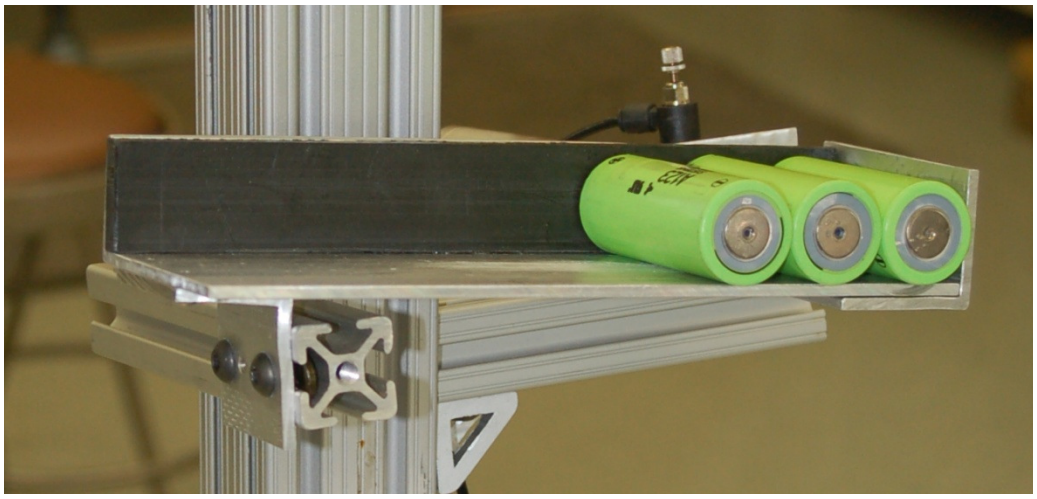


Figure 14: Battery Station

End Effecters

One of the challenging things about using a robotic arm to do the part manipulation is that you need to have all your end effecters attached and have enough room around them so that they operate properly. Our end effectors are strategically placed on the end effecter plate. The main effecter is the soft grippers. This tool picks and places most of the parts including the nose cone, the o-ring guide, the on-off ring and heat sink. The soft grippers also have an o-ring gripper attached to them to pick and place each o-ring. The hard grippers are used for the body and battery pick and place. The snap-ring tool is a cylindrical suction device that grabs each snap ring via a vacuum. The aluminum body of this tool is used to press the snap ring into place.

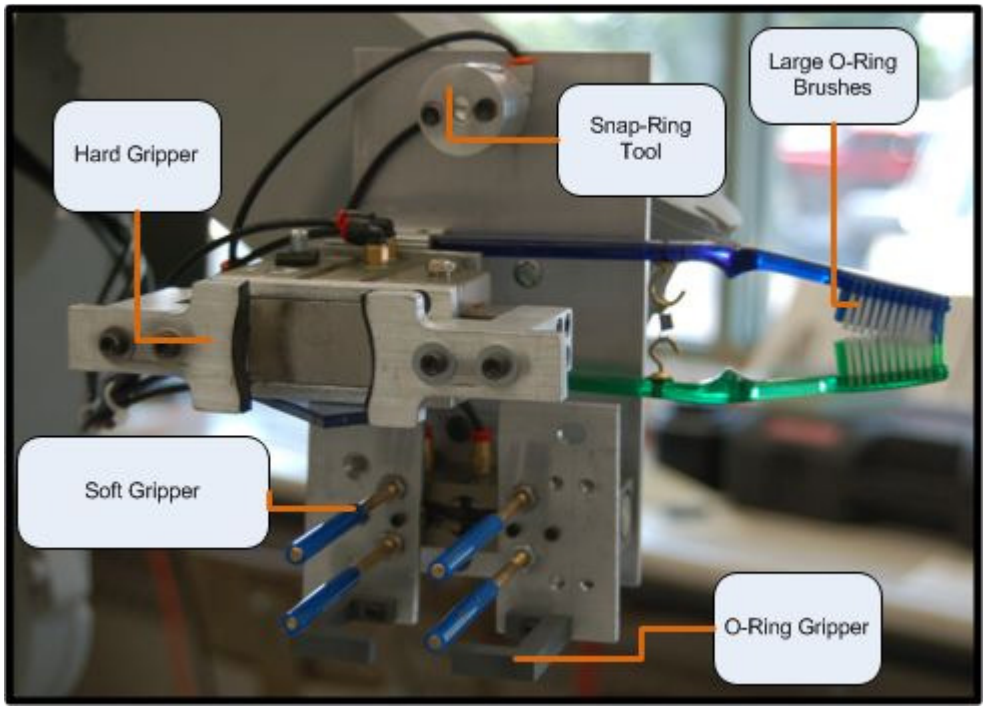


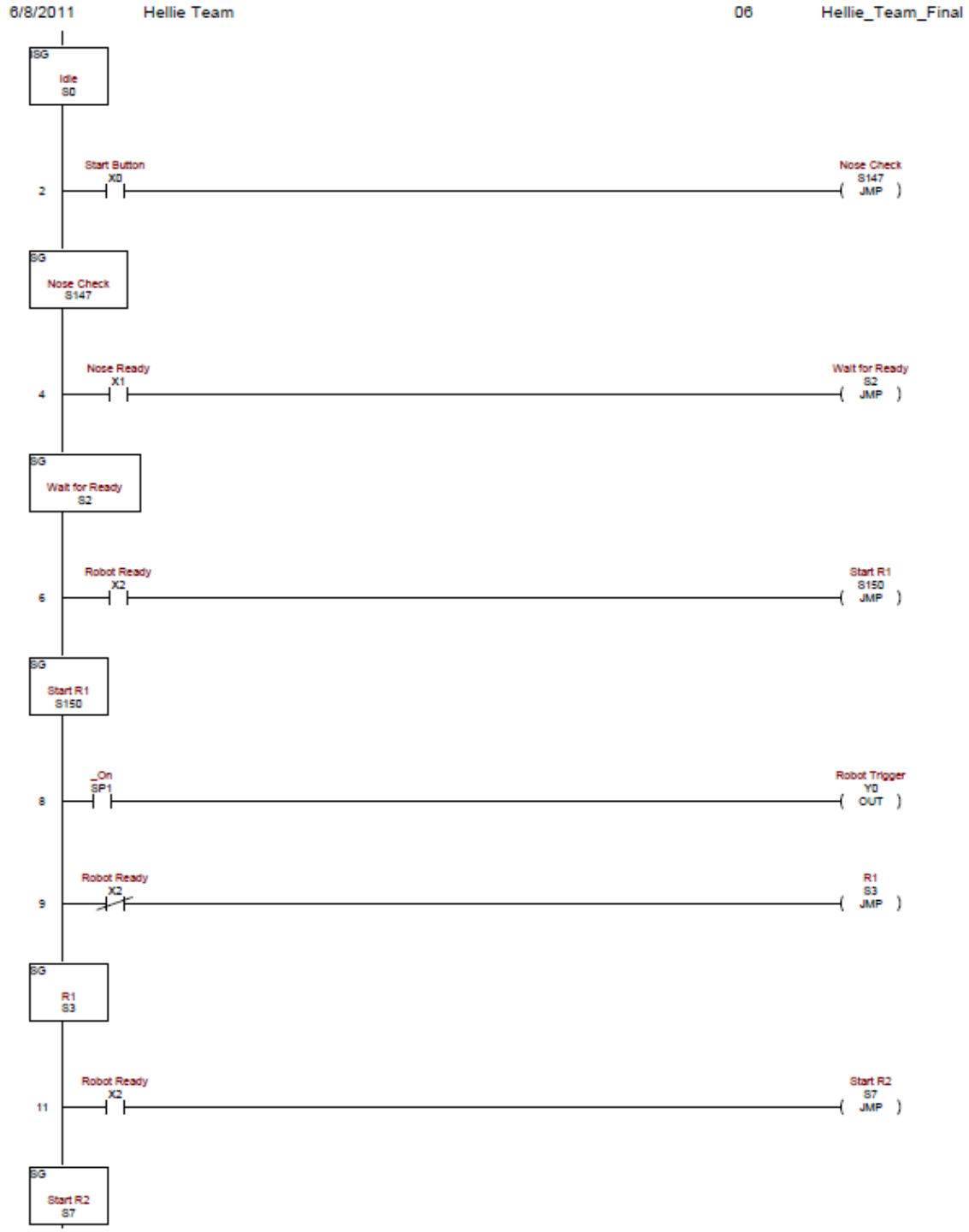
Figure 15: End Effecters

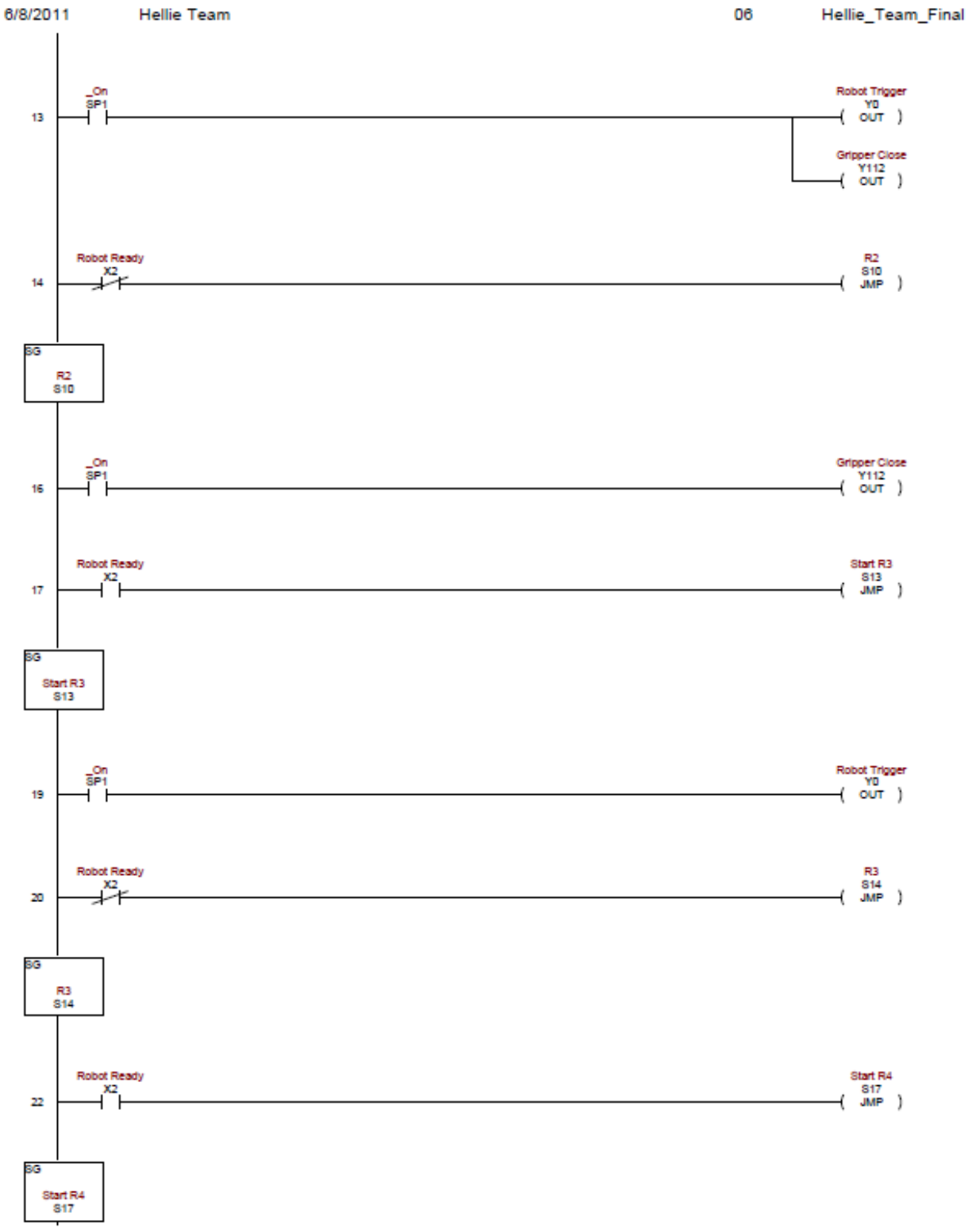
Suggestions for future improvements

- Improve dropping of the flashlight body and battery onto the final assembly threading station
- Machine a new snap ring station with tighter tolerances such that the ID of the station matches the OD of the snap rings
- Install a shaker on each tower to avoid o-ring jams
- Optimize robotic arm paths during assembly
- Install sensors at each part station to check if a part is available and update PLC logic
- Improve the rigidity of part stations

Appendices

Appendix A – Ladder Diagram

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Y112
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X2
R2
S10
JMP
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R2
S10
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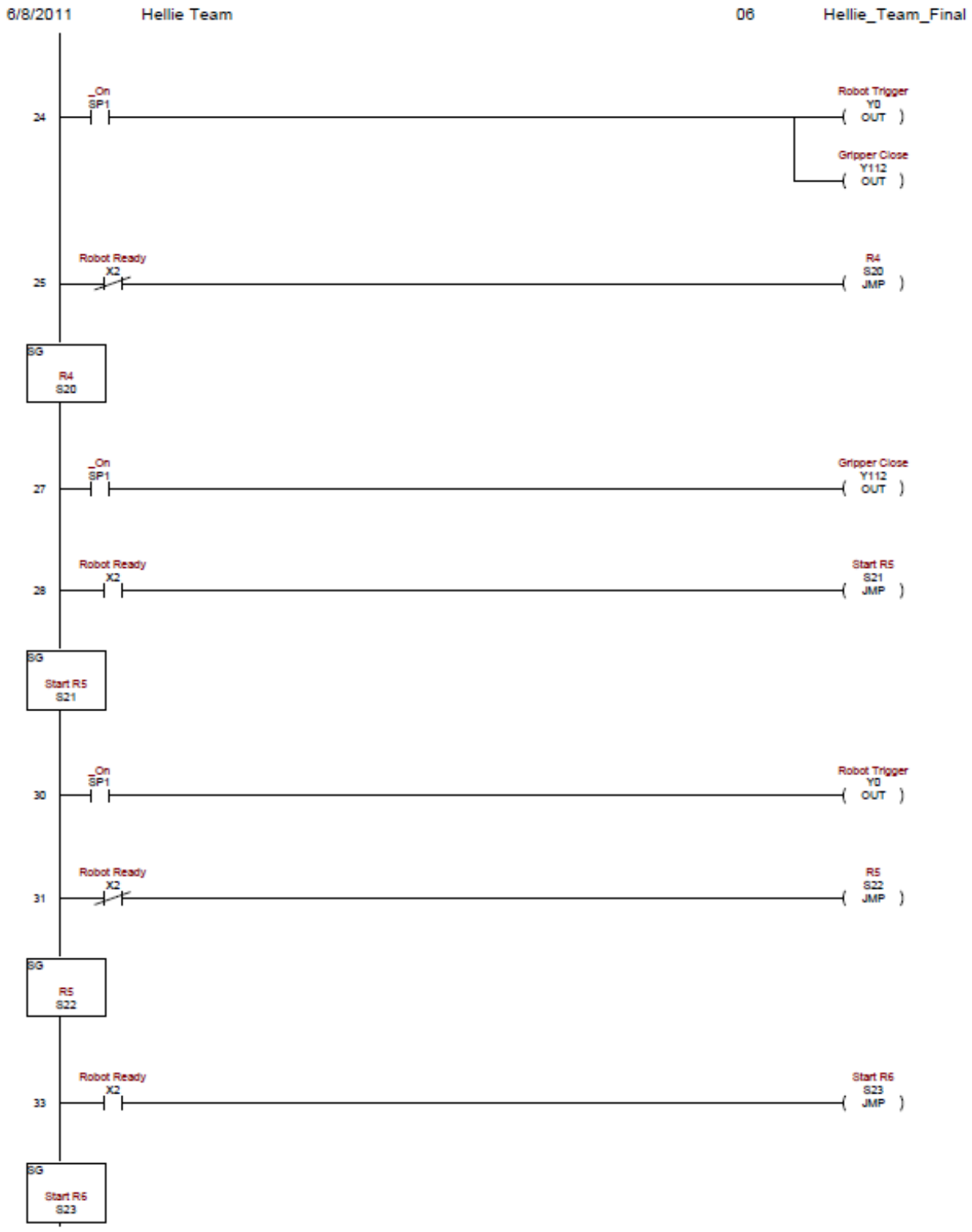
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OUT
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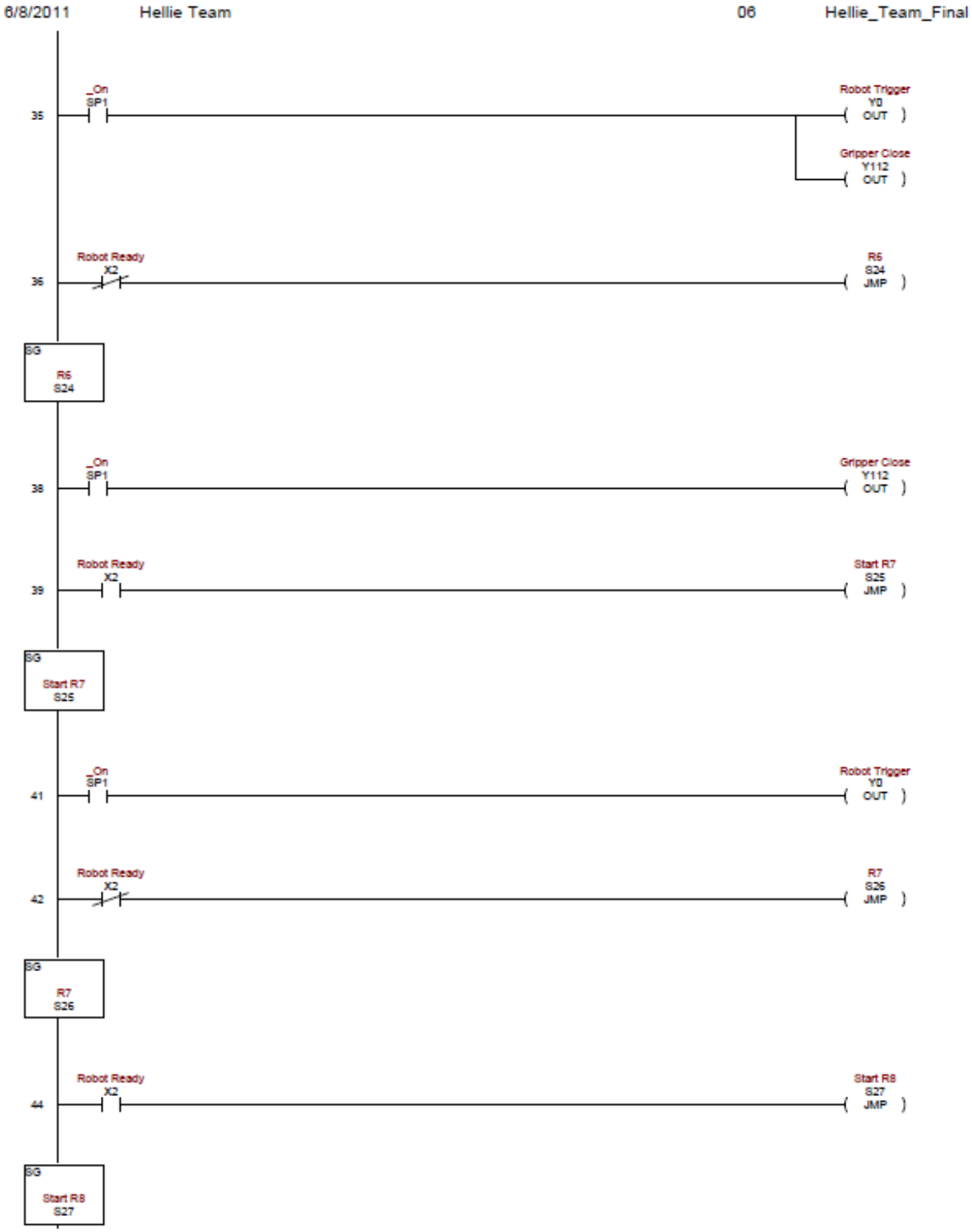
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Start R7
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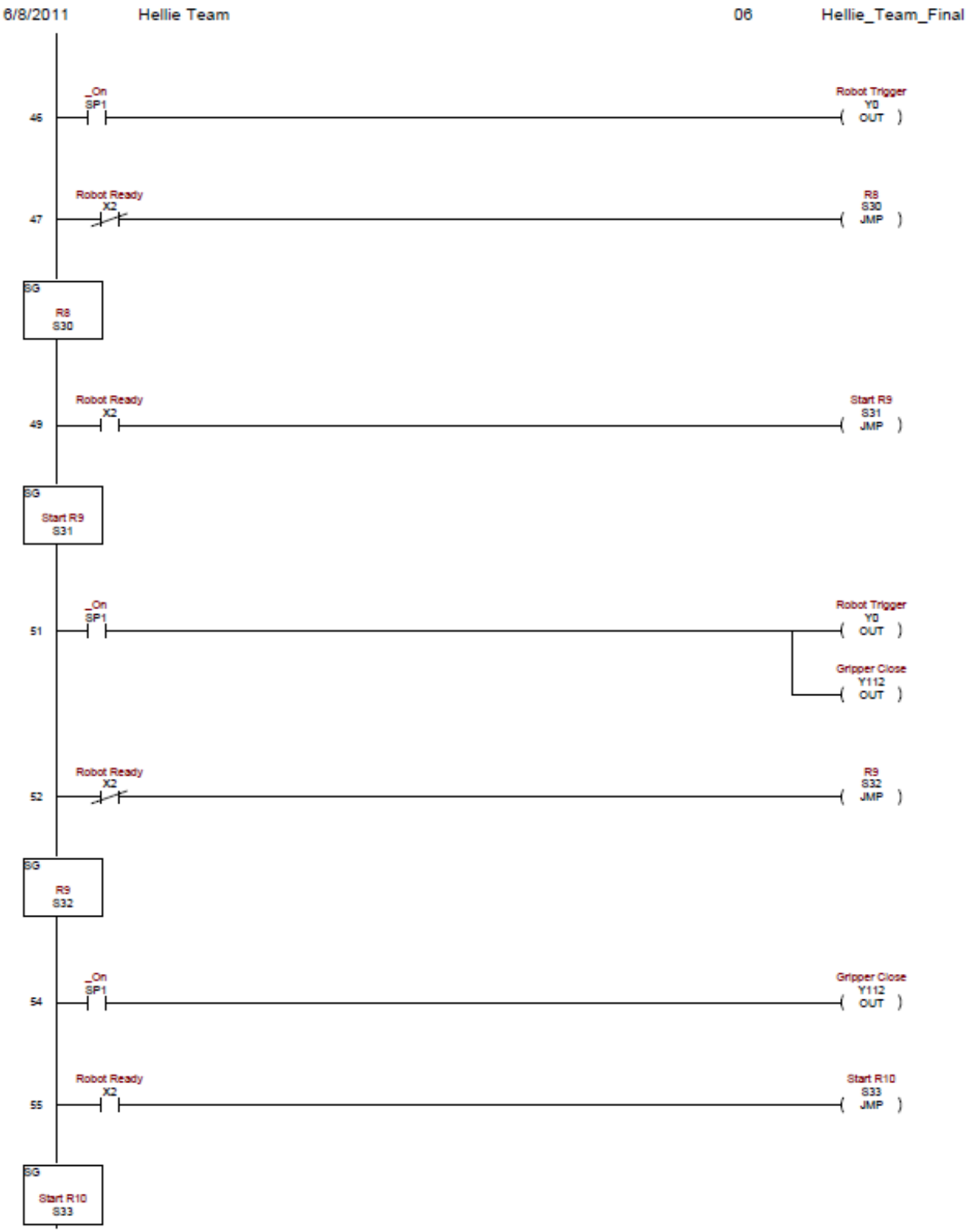
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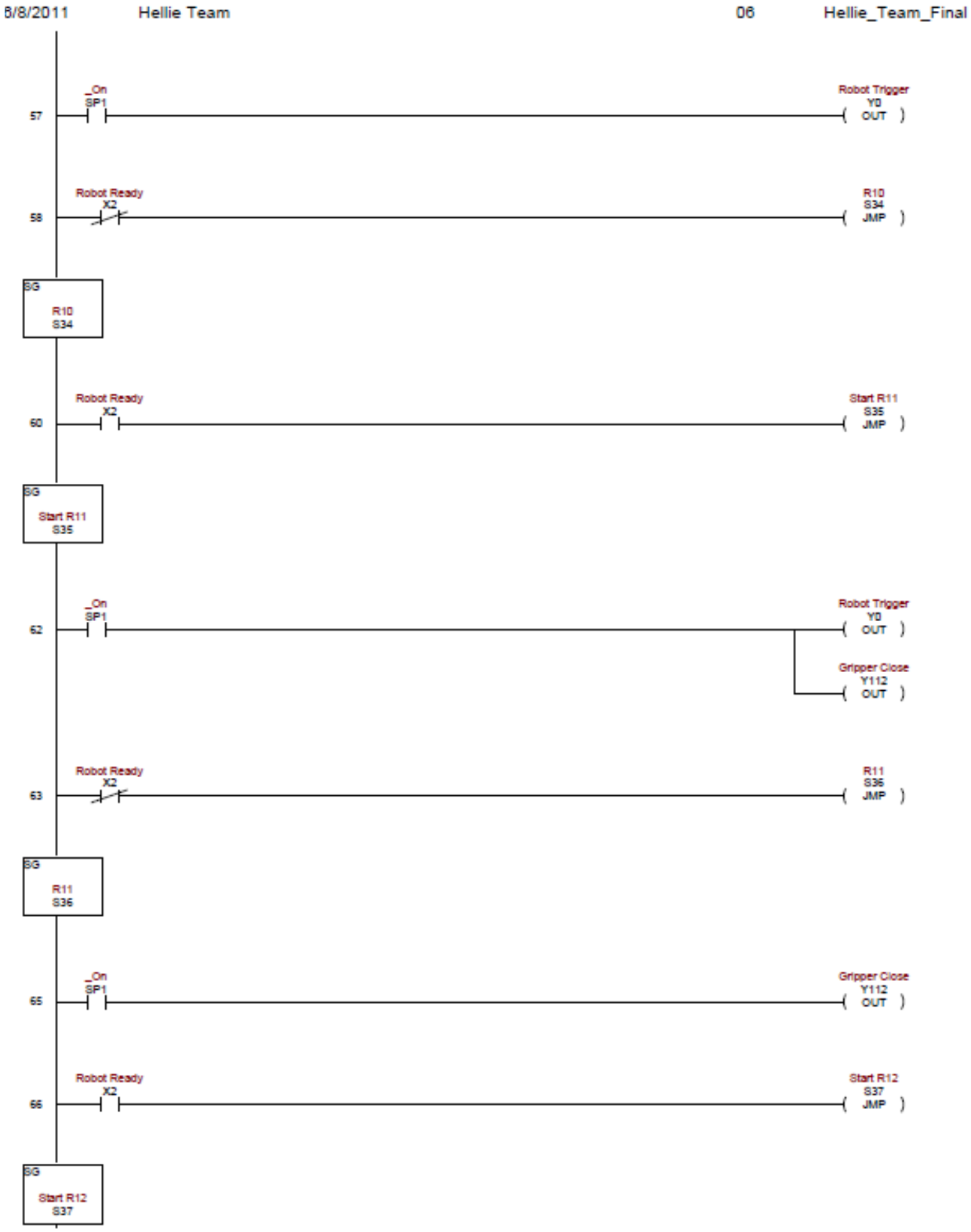
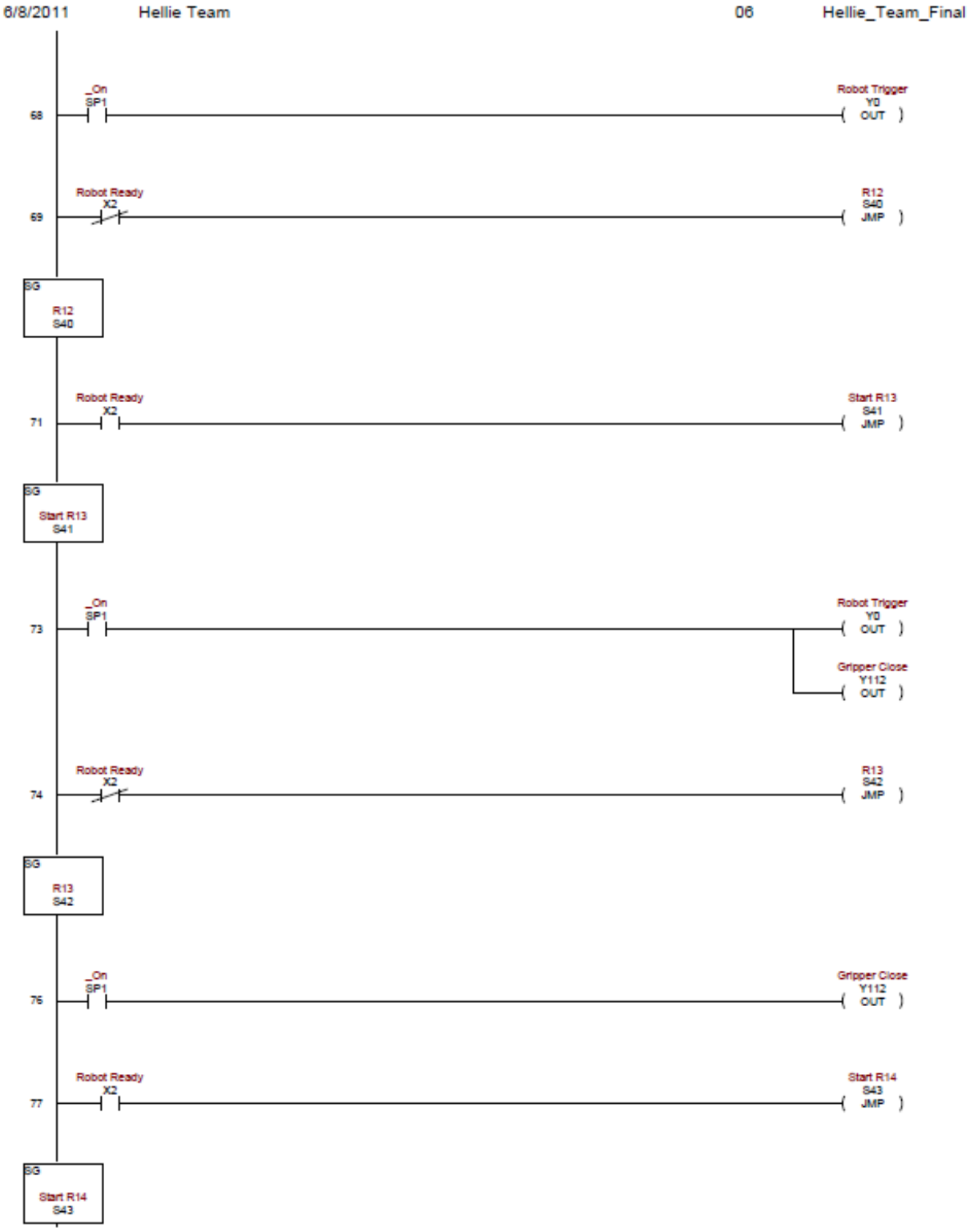
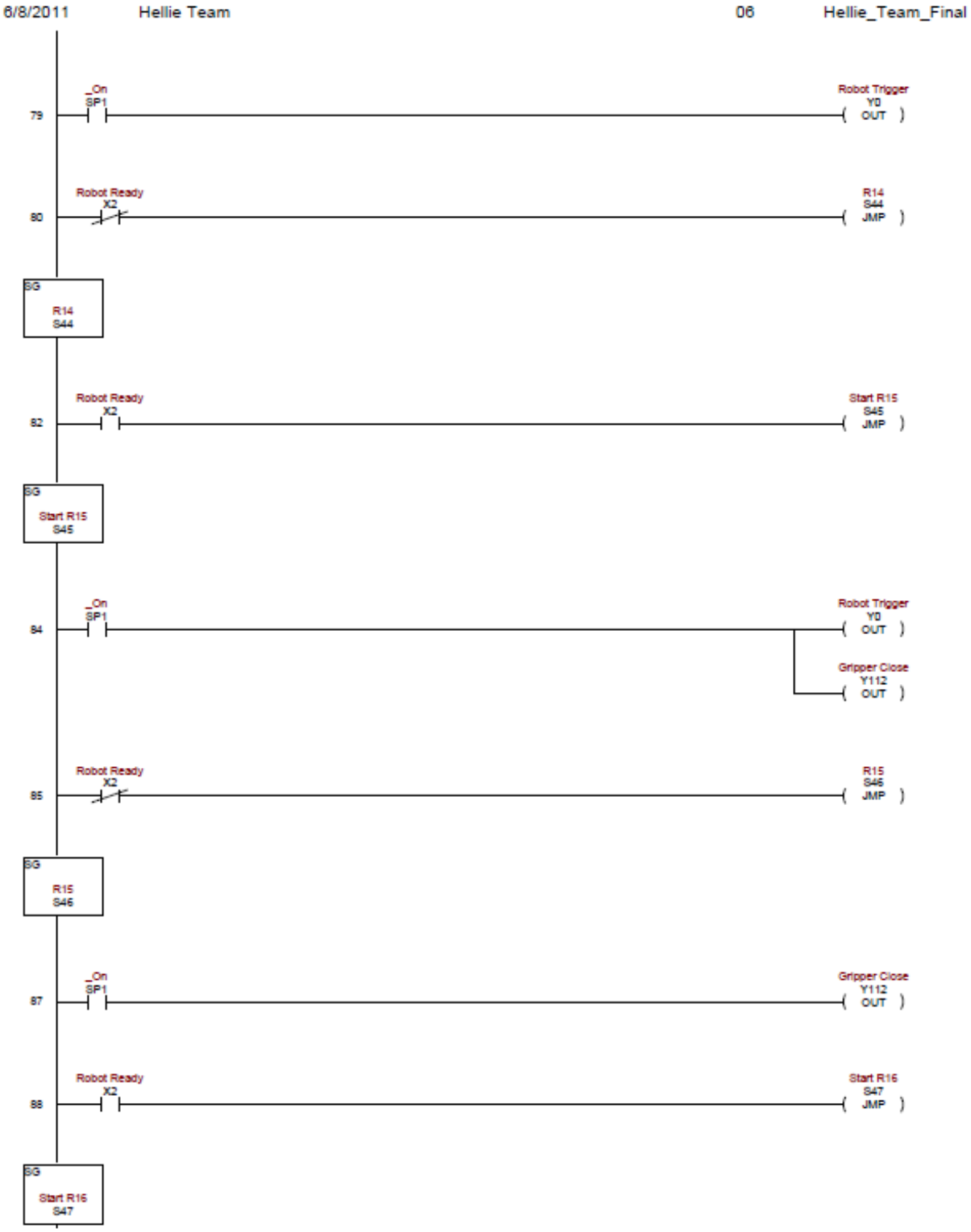
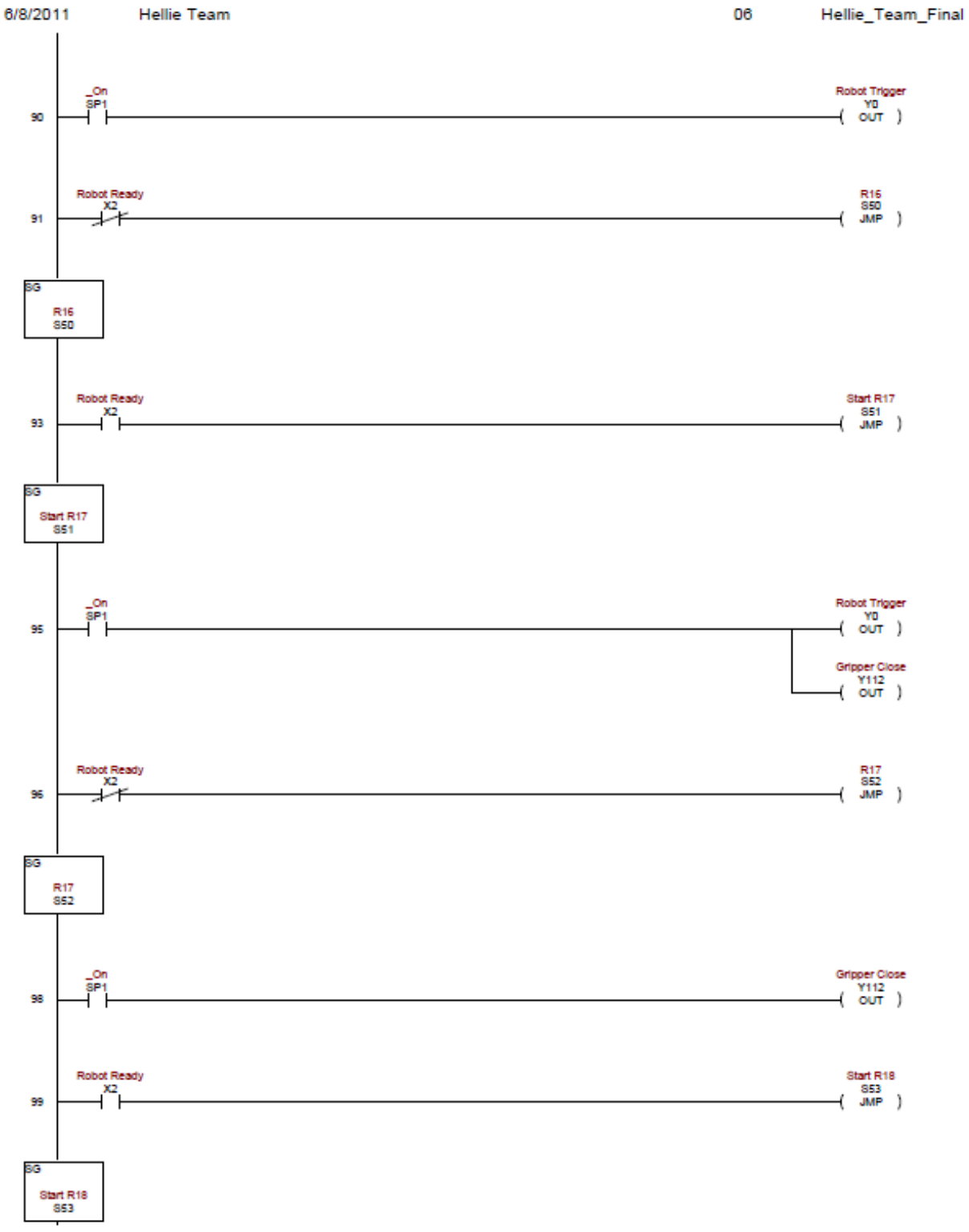
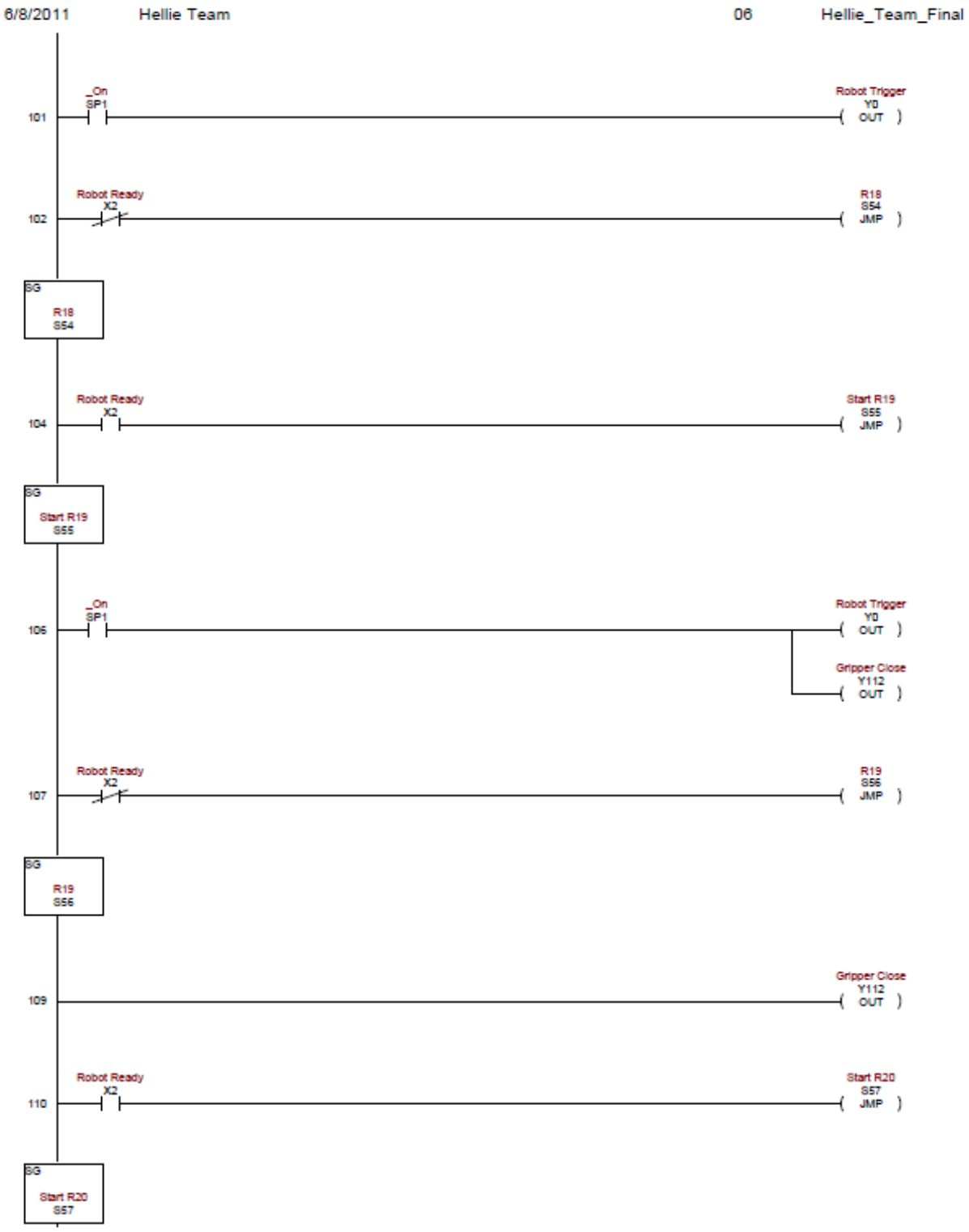
S33

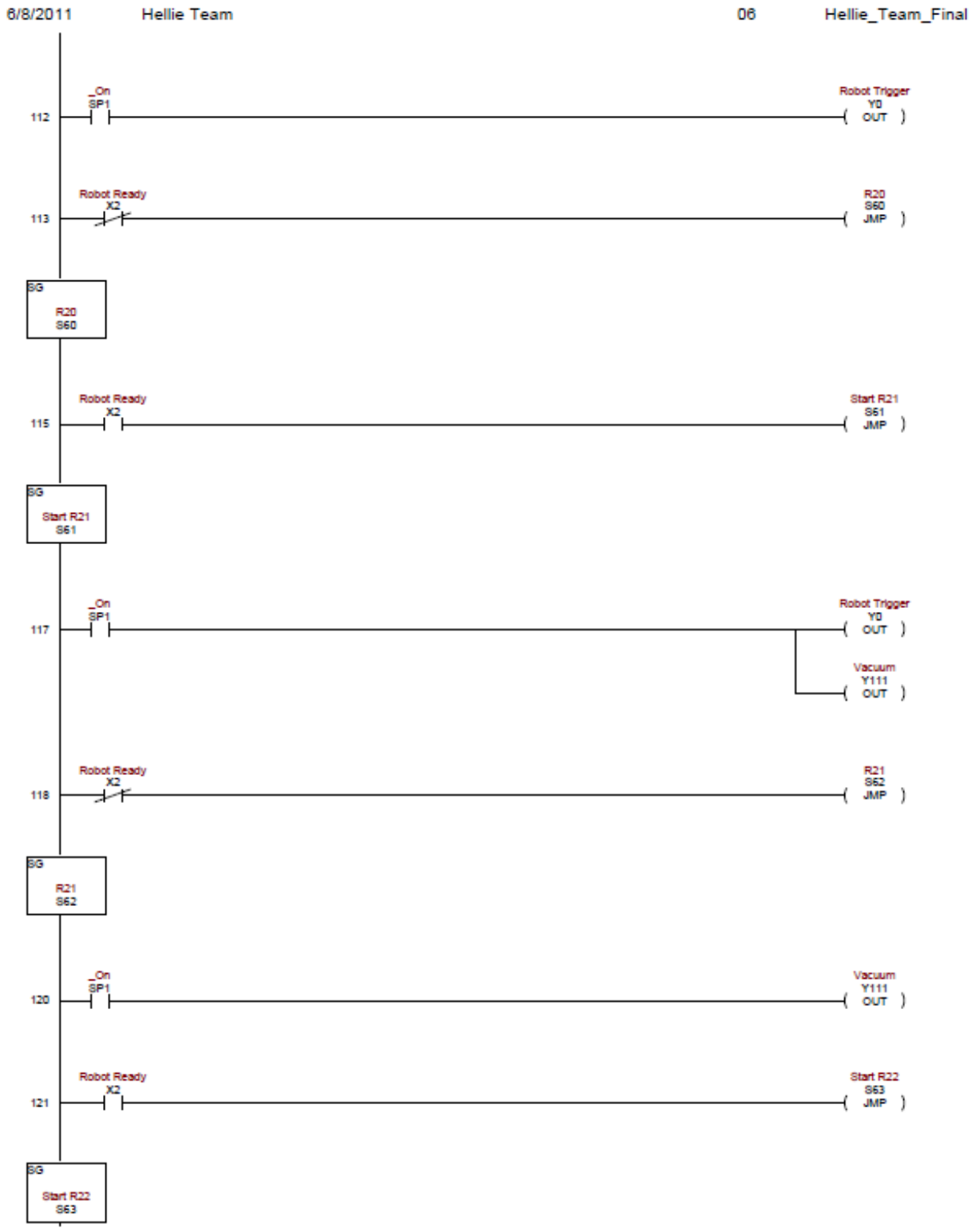

8/8/2011
Hellie Team
06
Hellie_Team_Final
57
_On
SP1
Robot Trigger
Y0
OUT
58
Robot Ready
X2
R10
S34
JMP
SG
R10
S34
60
Robot Ready
X2
Start R11
S35
JMP
SG
Start R11
S35
62
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
63
Robot Ready
X2
R11
S36
JMP
SG
R11
S36
65
_On
SP1
Gripper Close
Y112
OUT
66
Robot Ready
X2
Start R12
S37
JMP
SG
Start R12
S37

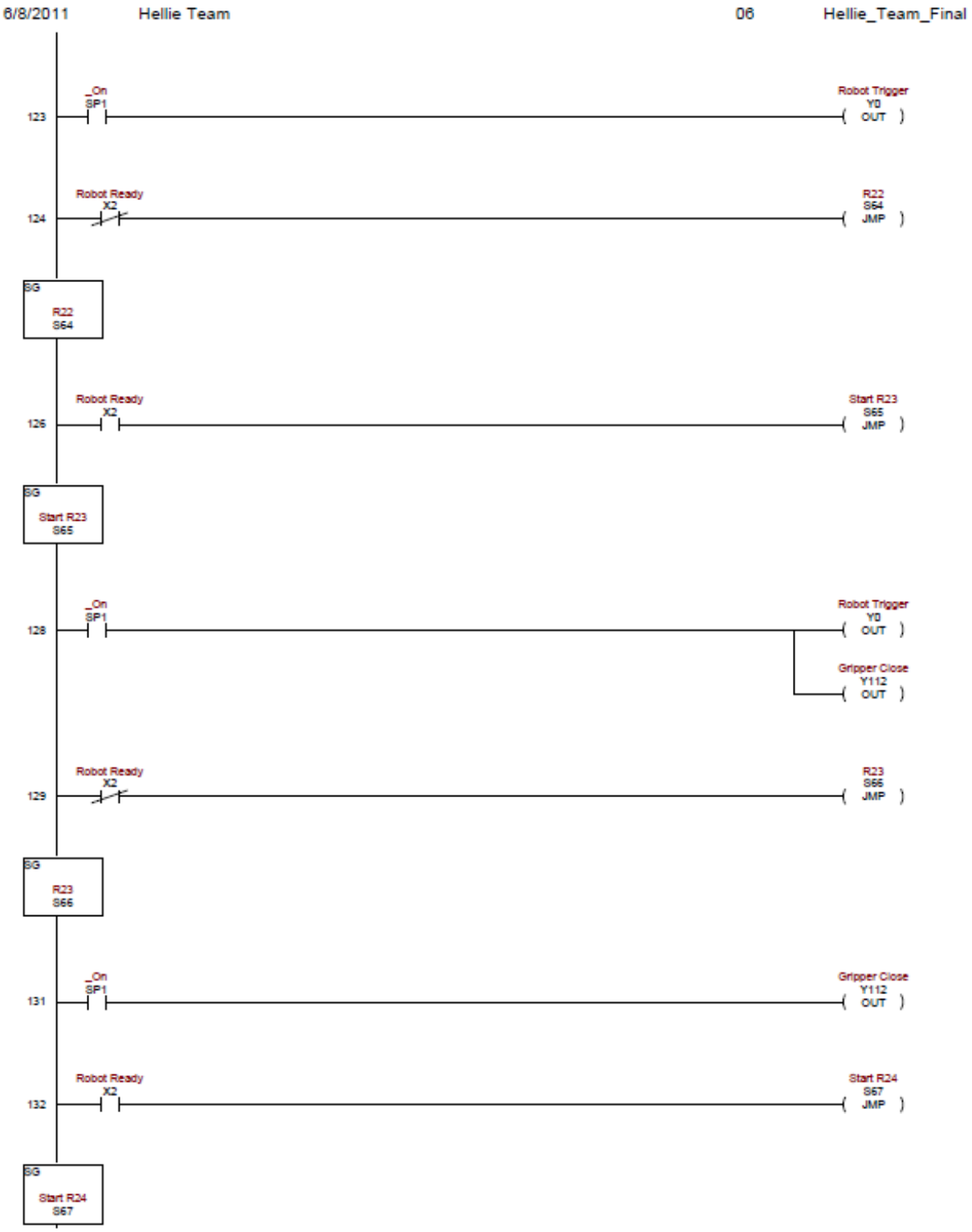

6/8/2011
Hellie Team
06
Hellie_Team_Final
68
_On
SP1
Robot Trigger
Y0
OUT
69
Robot Ready
X2
R12
S40
JMP
SG
R12
S40
71
Robot Ready
X2
Start R13
S41
JMP
SG
Start R13
S41
73
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
74
Robot Ready
X2
R13
S42
JMP
SG
R13
S42
76
_On
SP1
Gripper Close
Y112
OUT
77
Robot Ready
X2
Start R14
S43
JMP
SG
Start R14
S43

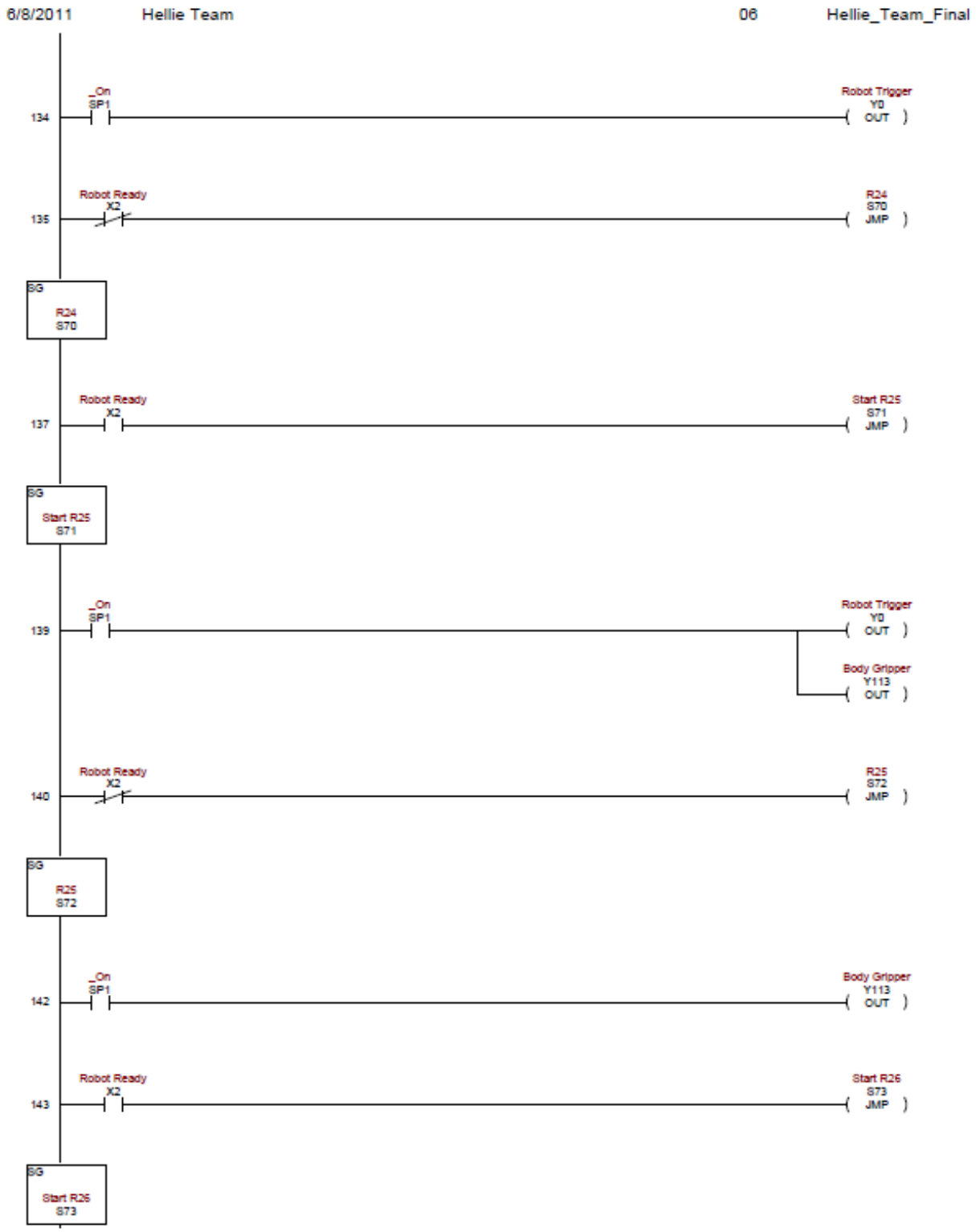

6/8/2011
Hellie Team
06
Hellie_Team_Final
79
_On
SP1
Robot Trigger
Y0
OUT
80
Robot Ready
X2
R14
S44
JMP
SG
R14
S44
82
Robot Ready
X2
Start R15
S45
JMP
SG
Start R15
S45
84
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
85
Robot Ready
X2
R15
S46
JMP
SG
R15
S46
87
_On
SP1
Gripper Close
Y112
OUT
88
Robot Ready
X2
Start R16
S47
JMP
SG
Start R16
S47

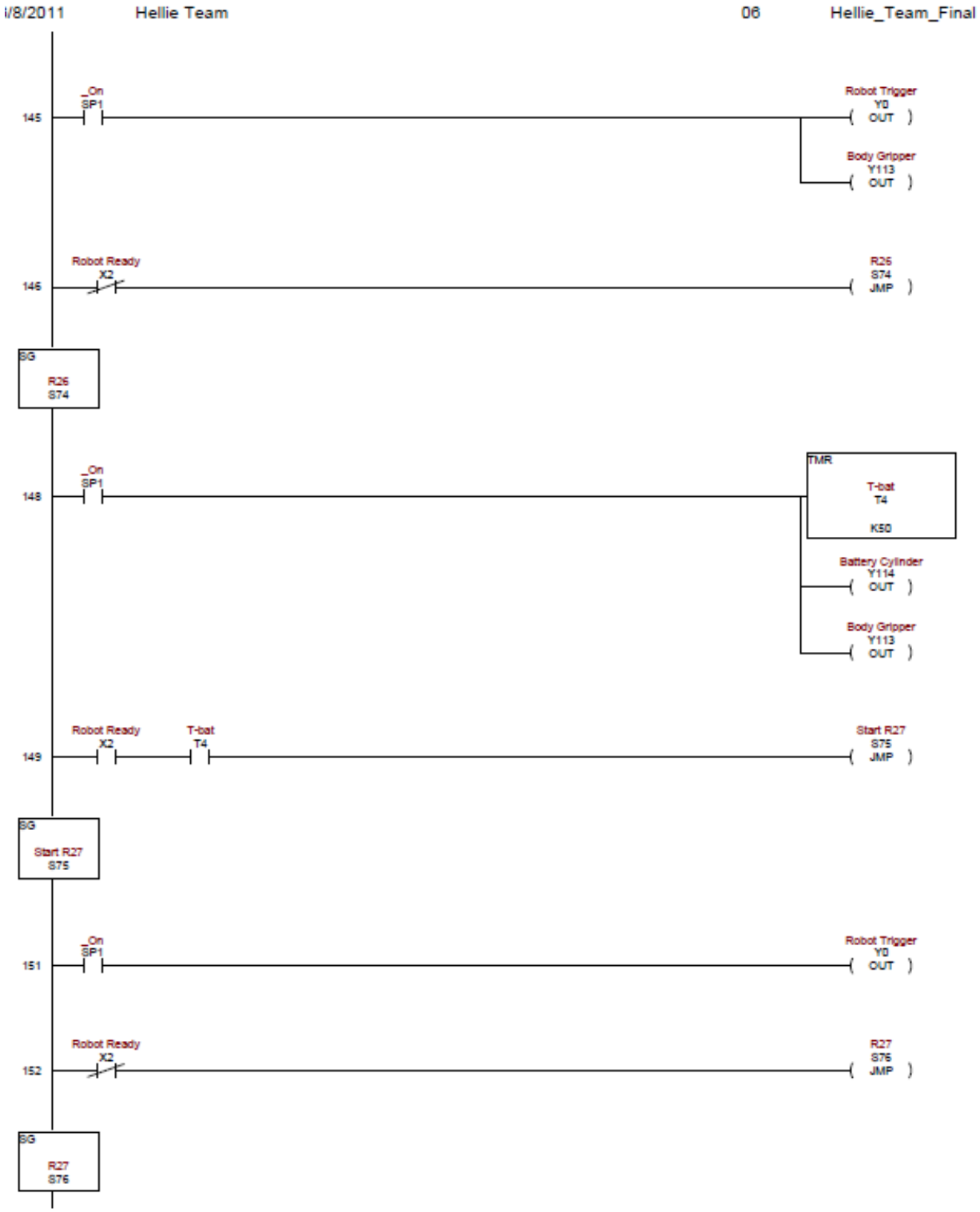

6/8/2011
Hellie Team
06
Hellie_Team_Final
90
_On
SP1
Robot Trigger
Y0
OUT
91
Robot Ready
X2
R16
S50
JMP
SG
R16
S50
93
Robot Ready
X2
Start R17
S51
JMP
SG
Start R17
S51
95
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
96
Robot Ready
X2
R17
S52
JMP
SG
R17
S52
98
_On
SP1
Gripper Close
Y112
OUT
99
Robot Ready
X2
Start R18
S53
JMP
SG
Start R18
S53

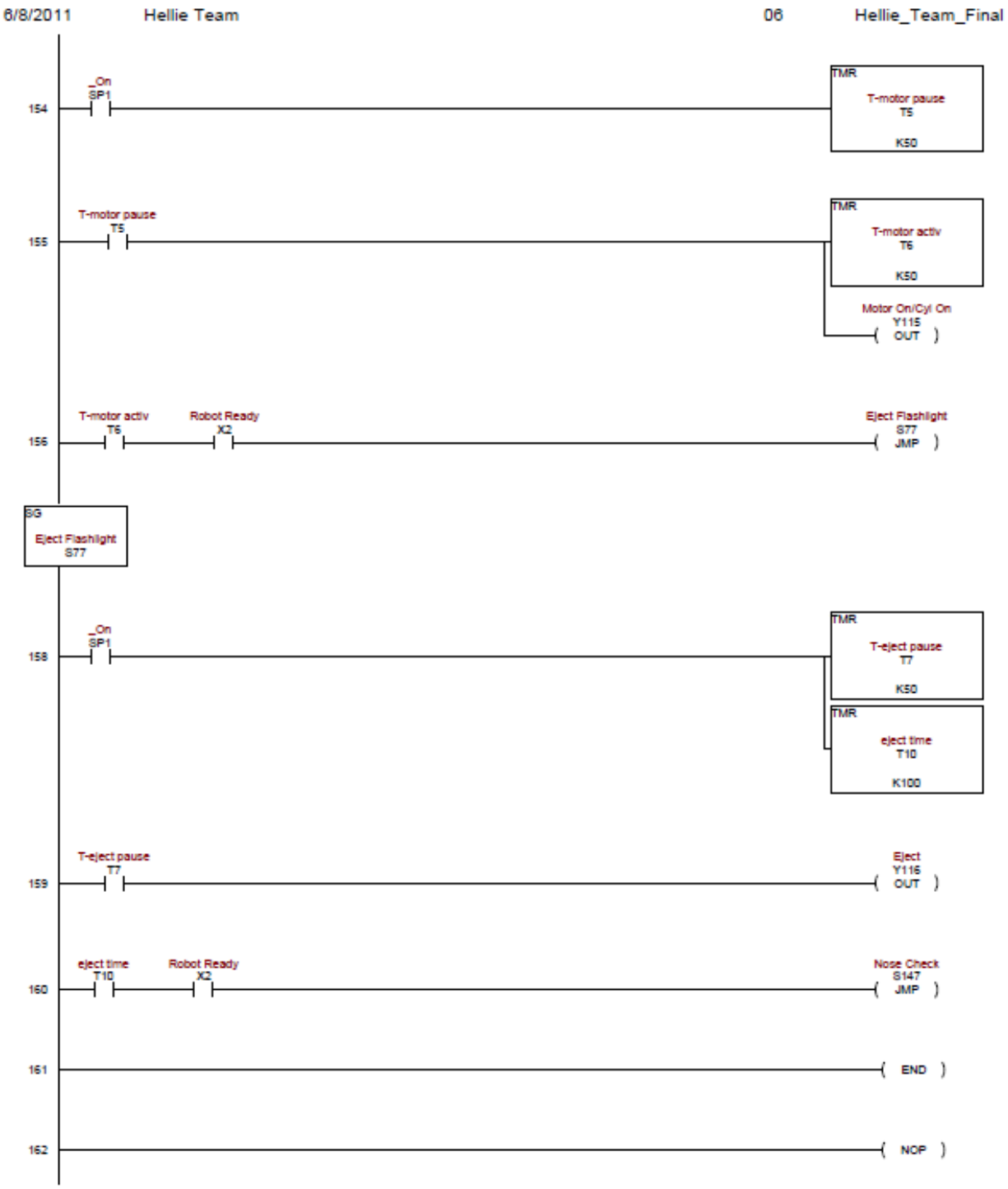

6/8/2011
Hellie Team
06
Hellie_Team_Final
101
_On
SP1
Robot Trigger
Y0
OUT
102
Robot Ready
X2
R18
S54
JMP
SG
R18
S54
104
Robot Ready
X2
Start R19
S55
JMP
SG
Start R19
S55
106
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
107
Robot Ready
X2
R19
S56
JMP
SG
R19
S56
109
Gripper Close
Y112
OUT
110
Robot Ready
X2
Start R20
S57
JMP
SG
Start R20
S57


6/8/2011
Hellie Team
06
Hellie_Team_Final
112
_On
SP1
Robot Trigger
Y0
OUT
113
Robot Ready
X2
R20
S60
JMP
SG
R20
S60
115
Robot Ready
X2
Start R21
S61
JMP
SG
Start R21
S61
117
_On
SP1
Robot Trigger
Y0
OUT
Vacuum
Y111
OUT
118
Robot Ready
X2
R21
S62
JMP
SG
R21
S62
120
_On
SP1
Vacuum
Y111
OUT
121
Robot Ready
X2
Start R22
S63
JMP
SG
Start R22
S63

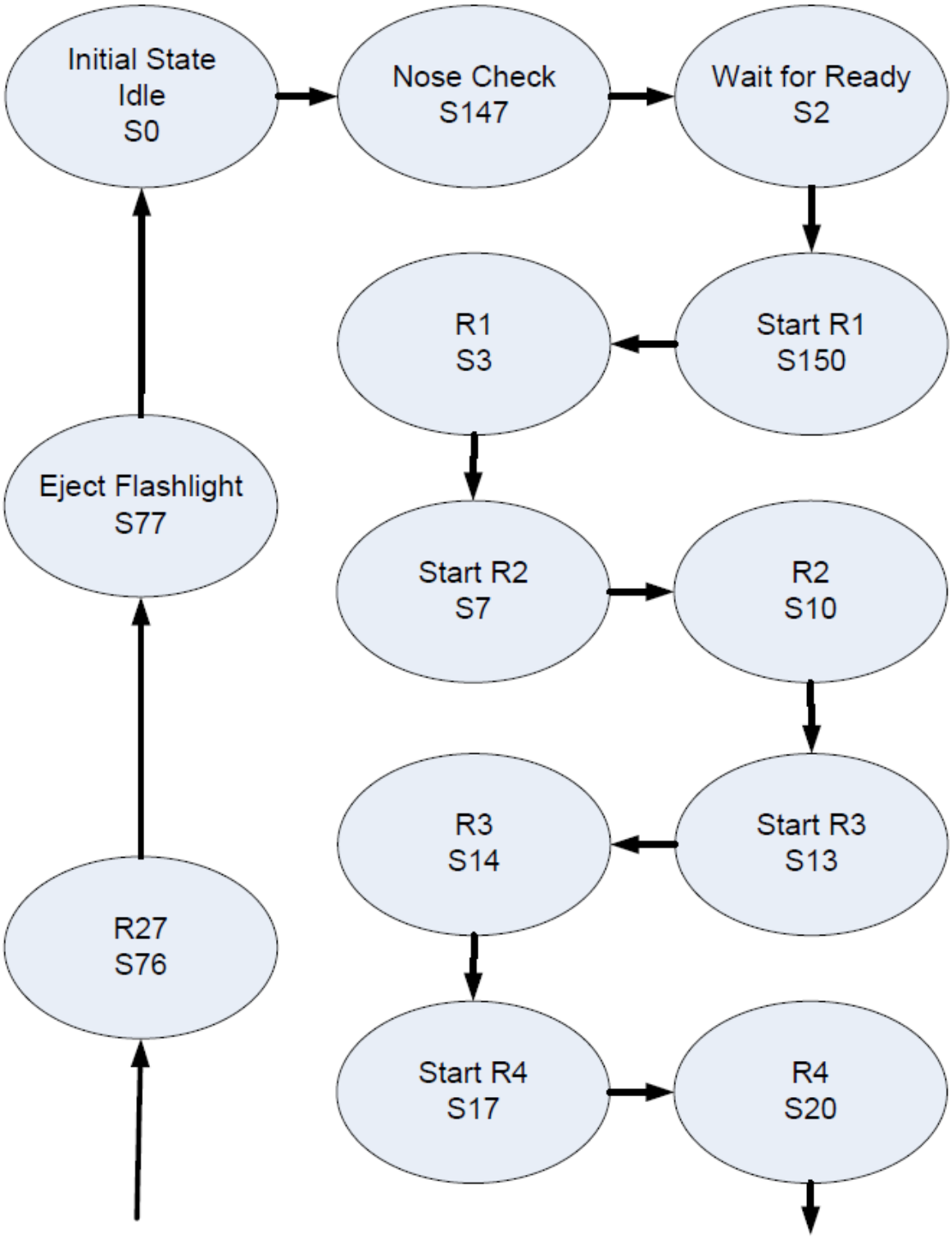

6/8/2011
Hellie Team
06
Hellie_Team_Final
123
_On
SP1
Robot Trigger
Y0
OUT
124
Robot Ready
X2
R22
S64
JMP
SG
R22
S64
126
Robot Ready
X2
Start R23
S65
JMP
SG
Start R23
S65
128
_On
SP1
Robot Trigger
Y0
OUT
Gripper Close
Y112
OUT
129
Robot Ready
X2
R23
S66
JMP
SG
R23
S66
131
_On
SP1
Gripper Close
Y112
OUT
132
Robot Ready
X2
Start R24
S67
JMP
SG
Start R24
S67

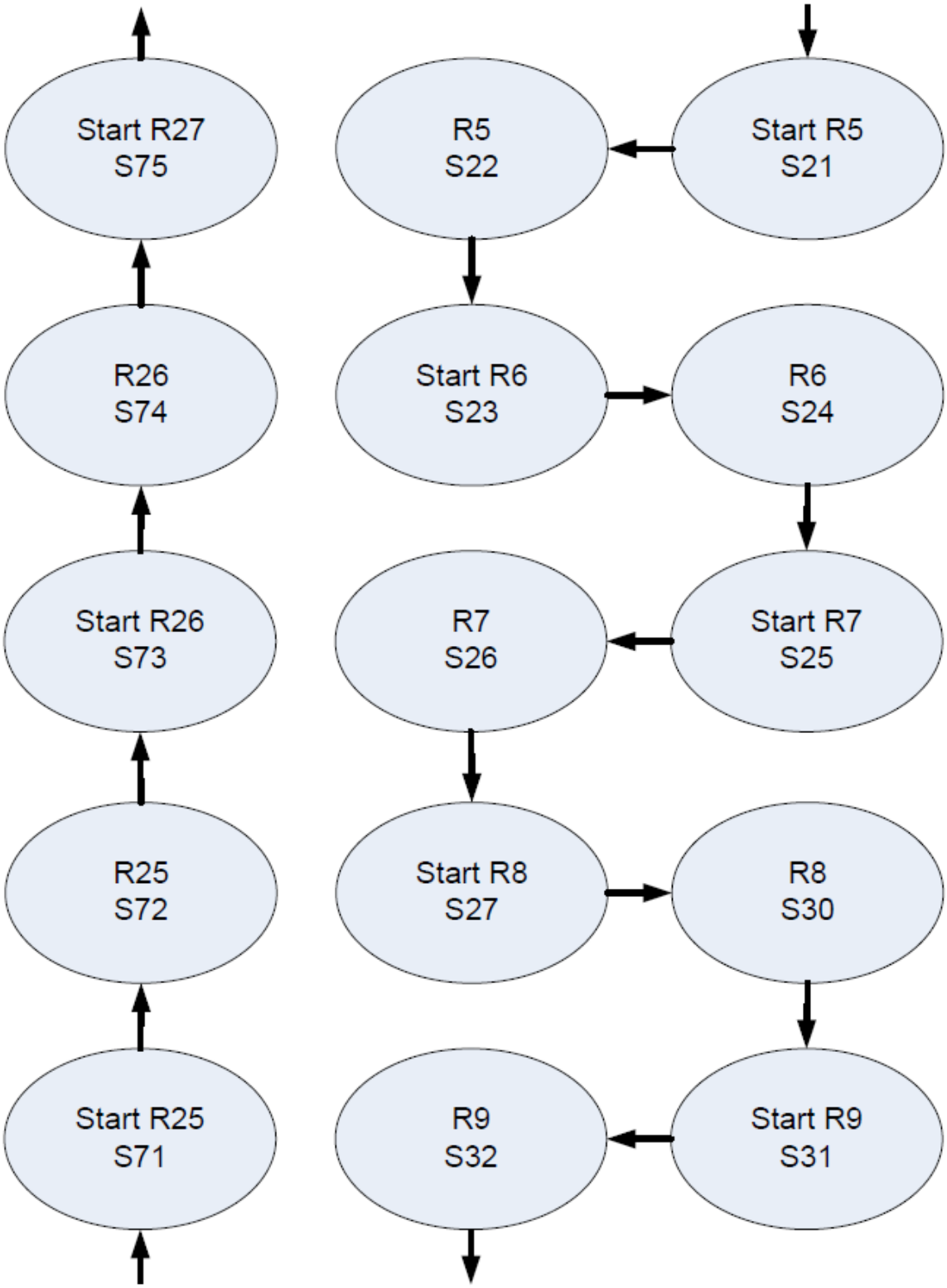

6/8/2011
Hellie Team
06
Hellie_Team_Final
134
_On
SP1
Robot Trigger
Y0
OUT
135
Robot Ready
X2
R24
S70
JMP
SG
R24
S70
137
Robot Ready
X2
Start R25
S71
JMP
SG
Start R25
S71
139
_On
SP1
Robot Trigger
Y0
OUT
Body Gripper
Y113
OUT
140
Robot Ready
X2
R25
S72
JMP
SG
R25
S72
142
_On
SP1
Body Gripper
Y113
OUT
143
Robot Ready
X2
Start R26
S73
JMP
SG
Start R26
S73

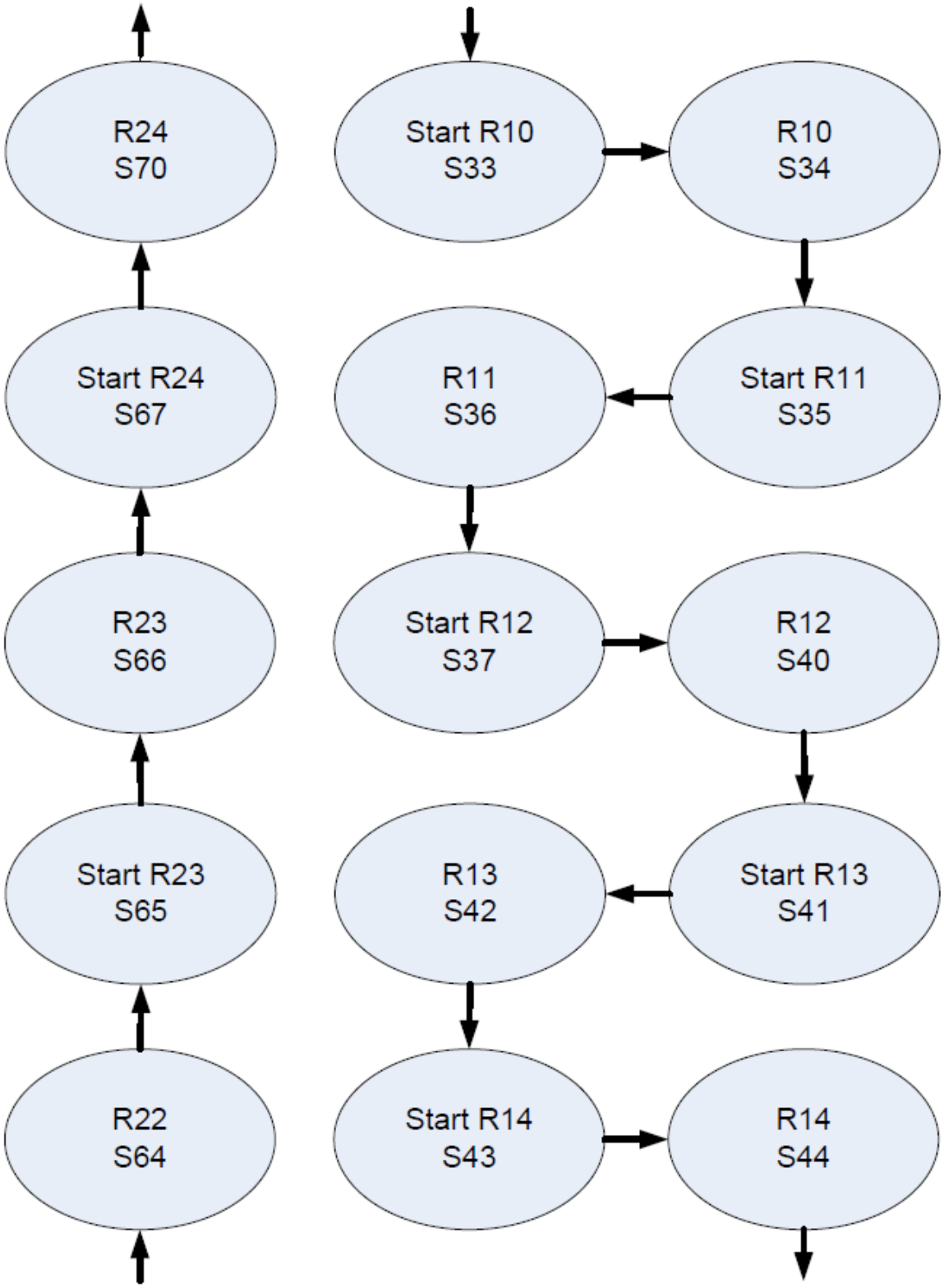

i/8/2011
Hellie Team
06
Hellie_Team_Final
145
_On
SP1
Robot Trigger
Y0
OUT
Body Gripper
Y113
OUT
146
Robot Ready
X2
R26
S74
JMP
SG
R26
S74
148
_On
SP1
TMR
T-bat
T4
K50
Battery Cylinder
Y114
OUT
Body Gripper
Y113
OUT
149
Robot Ready
X2
T-bat
T4
Start R27
S75
JMP
SG
Start R27
S75
151
_On
SP1
Robot Trigger
Y0
OUT
152
Robot Ready
X2
R27
S76
JMP
SG
R27
S76

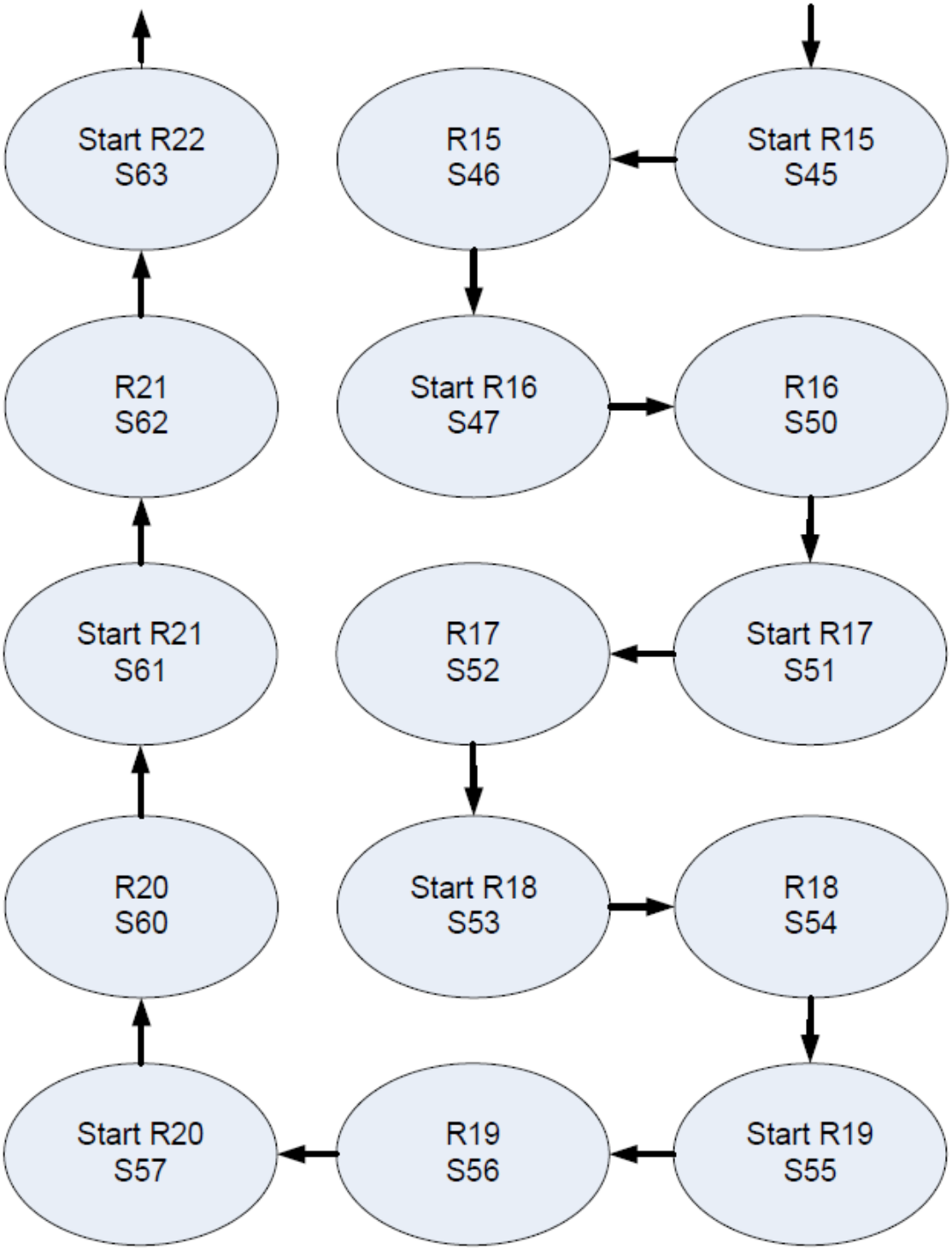

6/8/2011
Hellie Team
06
Hellie_Team_Final
154
_On
SP1
TMR
T-motor pause
T5
K50
155
T-motor pause
T5
TMR
T-motor activ
T6
K50
Motor On/Cyl On
Y115
OUT
156
T-motor activ
T6
Robot Ready
X2
Eject Flashlight
S77
JMP
SG
Eject Flashlight
S77
158
_On
SP1
TMR
T-eject pause
T7
K50
TMR
eject time
T10
K100
159
T-eject pause
T7
Eject
Y116
OUT
160
eject time
T10
Robot Ready
X2
Nose Check
S147
JMP
161
END
162
NOP

Appendix B – State Diagram




Start R27
S75
R5
S22
Start R5
S21
R26
S74
Start R6
S23
R6
S24
Start R26
S73
R7
S26
Start R7
S25
R25
S72
Start R8
S27
R8
S30
Start R25
S71
R9
S32
Start R9
S31


R24
S70
Start R10
S33
R10
S34
Start R24
S67
R11
S36
Start R11
S35
R23
S66
Start R12
S37
R12
S40
Start R23
S65
R13
S42
Start R13
S41
R22
S64
Start R14
S43
R14
S44


Start R22
S63
R15
S46
Start R15
S45
R21
S62
Start R16
S47
R16
S50
Start R21
S61
R17
S52
Start R17
S51
R20
S60
Start R18
S53
R18
S54
Start R20
S57
R19
S56
Start R19
S55

Appendix C – CNC Code

Flashlight Body

```
%
O1
;(FLASHLIGHT BODY--FOR BODY DRW_REV#10)
;(ANDREW HELLIE, WES BROWN, ANDY WOOLEY, GREG PETERSON)
;(STOCK: ALUM 38.1MM DIAMETER X #501 + 10MM)
;(14:00 APRIL 26, 2011)
;
; (TOOLS)
; (T0101 - 80DEG DIAMOND CNMG)
; (T0202)
; (T0303 - OD THREADING)
; (T0404)
; (T0505 - CENTER DRILL)
; (T0606)
; (T0707 - 19MM END MILL)
; (T0808 - INT THREADING TOOL)
; (T0909 - 14.4MM MIN DIAM BORING BAR)
; (T1010 - CUTOFF)
; (T1111)
; (T1212 - 0.5IN DRILL)
;
;(VARIABLES)
#1=1.0                                  (THREAD PITCH - MM)
#2=#1 * 0.5/TAN[30.0]   (THREAD HEIGHT)
#3=#2 * 5.0 / 8.0       (THREAD DEPTH - INT)
#4=3.0                          (NUMBER OF STARTS)
#5=0                                    (START NUMBER)
;
#500=38.1                       (STOCK DIAMETER)
#501=73.7                       (STOCK LENGTH)
#502=75.0                       (ROUGING SURFACE SPEED M/MIN)
#503=0.2                (ROUGHING FEED: MM/REV)
#504=0.05               (FINISHING FEED MM/REV)
#505=32.75                      (THREAD MAJOR DIAMETER)
#506=8.45               (THREAD LENGTH)
#507=1500                       (FINISHING SURFACE SPEED M/MIN)
;
;(INTIAL PARAMETERS)
G54                             (WORK OFFSET)
G21                             (METRIC UNITS)
G50 S2000 (LIMIT SPEED)
G96 S#502 (CONSTANT SURFACE SPEED)
G99                             (FEED PER REVOLUTION)
;
;(FACING)
N1
G28 U0 W0
G00 T0101                               (80 DEGREE DIAMOND TOOL)
M03                                                     (SPINDLE ON, NORMAL)
G00 X[#500+1.0] Z#501
M08                                                     (COOLANT ON)
G01 X-0.1 F#504                 (FACE FROM OUTSIDE DOWN TO -0.1)
G01 Z[#501+1.0] F1.0 (MOVE OFF FROM FACE)
M09                                                     (COOLANT OFF)
M05                                                     (SPINDLE OFF)
G28 U0 W0                                               (GO HOME)
M01                                                     (OPTIONAL STOP)
;
;
;(ROUGH OD TO +0.5MM)
;(USE 2.0 MM DOC-> xx PASSES)
N2
```

```
G00 T0101 (80DEG DIAMOND TOOL, TOOL 1)
G50 S2000 (CLAMP SPEED AT 2000)
G96 S#502 (CONST SURF SPEED)
G99 (FEED PER REV) (RETURN TO R LEVEL IN A FIXED CYCLE)
M03 (SPINDLE ON)
M08 (COOLANT ON)
G00 X[#500 + 0.5] Z#501 (INITIAL POINT FOR ROUGHING)
;
G00 X37.5 Z#501
;
G01 X37.5 Z-3.0 F#503 (FIRST PASS)
G01 X[#500 +0.5] F#503 (RETRACT X)
G00 Z#501 (RETRACT Z)
;
M09 (COOLANT OFF)
M05 (SPINDLE OFF)
G28 U0 W0 (GO HOME)
M01 (OPTIONAL STOP)
;
;
;(FINISH OD TO +0.0MM)
N3
;
G00 T0202 (30DEG DIAMOND TOOL, TOOL 2)
G50 S2000 (CLAMP SPEED AT 2000)
G96 S#507 (CONST SURF SPEED)
G99 (FEED PER REV)
M03 (SPINDLE ON)
M08 (COOLANT ON)
;
G00 X36.0 Z[#501+0.5]
G01 X36.0 Z#501 F#504
G01 X37.0 Z73.2 F#504
G01 X37.0 Z0.5 F#504
G01 X36.0 Z0.0 F#504
G01 X36.0 Z-1.0 F#504
;
G01 X[#500+1.0] F#504 (RETRACT X)
G00 Z#501 (RETRACT Z)
M09
M05
G28 U0 W0
M01                    (OPTIONAL STOP)
;
;
;(CENTER DRILL)
N4
G00 T0505              (CENTER DRILL)
G97 S1000      (CONSTANT SPINDLE SPEED 1000RPM)
G99                                          (FEED PER REVOLUTION)
M03                                          (SPINDLE ON, NORMAL)
M08                                          (COOLANT ON)
G00 X0.0 Z[#501 + 2.0]
G01 X0.0 Z[#501 - 2.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
M09                                          (COOLANT OFF)
M05                                          (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(DRILLING)
N5
G00 T1212                      (1/2" DRILL)
G97 S1000              (CONSTANT SPINDLE SPEED 1000RPM)
G99                                          (FEED PER REVOLUTION)
```

```
M03                                                    (SPINDLE ON, NORMAL)
M08                                                    (COOLANT ON)
G00 X0.0 Z[#501 + 5.0]
G83 Z2.0 Q10000 F0.2
G01 Z[#501+5.0] F2.0
M09                                                    (COOLANT OFF)
M05                                                    (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(BODY ROUGH BORE)
N6
IF [#505 + 2*#3 + 0.1 GE 19.0] GOTO 66
M01                                    (ERROR - BORE SMALLER THAN TOOL)
N66
G00 T0707                        (19MM END MILL)
G96 S#502                  (CONSTANT SURFACE SPEED)
G99                                                    (FEED PER REVOLUTION)
M03                                                    (SPINDLE ON, NORMAL)
M08                                                    (COOLANT ON)
G00 X19.0 Z[#501 + 2.0] (START POINT)
G71 U2.0 R0.5            (2MM DEPTH OF CUT, 0.5MM RETRACT)
G71 P20 Q25 U-0.7 W0.0 F#503
N20 G00 X[32.67] Z[#501 + 2.0]
   G01 X[32.67] Z[#501] F#504
              G01 X[31.67] Z[71.7] F#504
              G01 X[31.67] Z[63.75] F#504
              G01 X[28.0]  Z[63.75] F#504
              G01 X[27.0]  Z[63.25] F#504
              G01 X[27.0]  Z[2.0]  F#504
N25 G00 U-0.4
M09                                    (COOLANT OFF)
M05                                    (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(BODY FINISH BORE)
N7
G00 T0909         (14.4MM MIN DIAM BORING BAR)
G96 S#502
G99
M03                                    (SPINDLE ON, NORMAL)
M08                                    (COOLANT ON)
G00 X27.0 Z[#501 + 2.0]
G70 P20 Q25
G00 Z[#501 + 2.0]
M09                                    (COOLANT OFF)
M05                                    (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(INTERNAL THREAD)
N8
;
G00 T0808         (INT THREADING TOOL)
G00 X31.67 Z[#501 + 3 * #1 * #4]  (START 3x LEAD AWAY)
G97 S800          (FIXED 800RPM SPEED)
G99             (FEED PER REV)
M03
M08
WHILE [#5 LT #4] DO 1
  G00 X[#505 - #2 * 2] Z[#501 + #1 * #5 + 3 * #1 * #4]
  G76 P040060 Q005 R0.1
```

```
  G76 X[#505 + #3/2.0] Z[#501-#506] P[FIX[#3*1000]] Q0200 F[#1 * #4]
  #5 = #5 + 1
END 1
G00 Z[#501+2.0]
M09
M05
G28 U0 W0
M01
;
;(CUTOFF)
N9
G00 T1010
M03
M08
G50 S1000
G96 S#502
G00 X[#500+2.0]
G00 Z-2.4
G01 X0.0 Z-2.4 F#504
M09
M05
G28 U0 W0
M30
%
%
```

Flashlight Nose Cone

```
01
G28 U0W0
;(FLASHLIGHT NOSE 2011)
; (VARIABLES)
#500=38.1 (STOCK DIA)
#501=44.6 (STOCK LENGTH)
#502=75.0 (SURFACE M/MIN)
#503=0.4   (ROUGHING FEED)
#504=150.0              (Surface m/min finishing)
#505=0.05 (Finishing feed: mm/rev)
#1=1.0      (PITCH - MM)
#2=#1 * 0.5/TAN[30.0]   (H)
#3=#2 * 17.0 / 24.0     (THREAD DEPTH - EXT)
#4=3.0      (NUMBER OF STARTS)
#5=0        (START NUMBER)

N1
;(FACE PART)
G00 T0101
G50 S1000
G96 S#502
G99
M03
M08
G00 Z#501
G00 X[#500+1.0]
G01 X-0.1 F#503
G01 Z[#501+1.0]
M09
M05
G28 U0W0
M01
; (ROUGHING PASS)
N2
G00 T0101
G50 S2000
G96 S#502
G99
```

```
G00 X[#500+0.4] Z#501
M03
M08
G01 X37.2 Z#501 F#503 (BODY DIAMETER)
G01 X37.2 Z0.0 F#503
G01 X[#500+0.5] F#503
G00 Z#501
G01 X33.0 Z#501 F#503 (THREADED PORTION)
G01 X33.0 Z22.85 F#503
G01 X[#500+.4]
G00 Z#501
M09
M05
G28 U0W0(GO HOME)
M01                         (PAUSE)
;
N3
G00 T0202 (FINISH THEM!)
G50 S2000
G96 S#504
G99
M03
M08
G00 Z#501
G00 X[#500+0.4]
G01 X30.25 Z#501 F#505
G01 X32.75 Z41.35 F#505 (MAKES FIRST CHAMFER)
G01 X32.75 Z22.85 F#505 (MAKES LOWER ROUND)
G01 X36.0 Z22.85 F#505  (LOWER EDGE OF SMALL CHAMFER)
G01 X37.0 Z22.35 F#505  (UPPER EDGE OF SMALL CHAMFER)
G01 X37.0 Z3.0 F#505
G01 X34.0 Z0.0 F0.05
G01 X[#500+0.4] F#505
G00 Z#501
M09
M05
G28 U0W0
M01
;
N4
;(THIS IS WHERE I WILL THREAD)
G00 T0303         (EXT THREADING TOOL)
G00 X32.0 Z[#501 + 3 * #1 * #4]  (START 3x LEAD AWAY)
G97 S800          (FIXED 800RPM SPEED)
G99               (FEED PER REV)
M03
M08
WHILE [#5 LT #4] DO 1
  G00 X32.75 Z[#501 + #1 * #5 + 3 * #1 * #4]   (GO TO START POINT)
  G76 P040060 Q005 R0.2
  G76 X[32.75 - #3 * 2] Z[#501-15.0] P[FIX[#3*1000]] Q0544 F[#1 * #4]
  #5 = #5 + 1
END 1
G00 X[#500+2.0]
M09
M05
G28 U0 W0
M01
N5
;(THIS IS WHERE THE BORING WILL BE DONE)
G00 T0505               (CENTER DRILL)
G97 S1000       (CONSTANT SPINDLE SPEED 1000RPM)
G99                                                 (FEED PER REVOLUTION)
M03                                                 (SPINDLE ON, NORMAL)
M08                                                 (COOLANT ON)
G00 X0.0 Z[#501 + 2.0]
```

```
G01 X0.0 Z[#501 - 2.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
M09                                          (COOLANT OFF)
M05                                          (SPINDLE OFF)
G28 U0 W0
;
;
G00 T1212                    (1/2" DRILL)
G97 S1000          (CONSTANT SPINDLE SPEED 1000RPM)
G99                                          (FEED PER REVOLUTION)
M03                                          (SPINDLE ON, NORMAL)
M08                                          (COOLANT ON)
G00 X0.0 Z[#501 + 5.0]
G83 Z-2.0 R0.0 Q10000 F0.250
G01 Z[#501+5.0] F2.0
M09                                          (COOLANT OFF)
M05                                          (SPINDLE OFF)
G28 U0 W0
;
G00 T0707 (ENDMILL)
G97 S1000
G99
M03
M08
G00 X19.0 Z[#501 + 5.0]
G01 Z-2.0 F0.125
G00 Z[#501 + 5.0]
G00 X23.50
G01 Z-2.0 F0.125
G00 Z[#501 + 5.0]
G00 X26.0
G01 Z1.0 F0.125
G00 Z[#501 + 5.0]
G00 X28.25
G01 Z2.0 F0.125
G00 Z[#501 + 5.0]
M09
M05
G28 U0 W0
M01

G00 T0909 (BORING FINISH)
G97 S1000
G99
M03
M08
G00 Z[#501 + 5.0]
G00 X28.75
G01 Z2.0 F0.065
G01 X26.7
G01 X25.6 Z1.5 F0.065
G01 Z1.0 F0.065
G01 X23.0 F0.065
G01 Z-0.50 F0.065
G01 X22.0 F0.05
G00 Z[#501 + 5.0]
M09
M05
G28 U0 W0
M01

;(CUTOFF)
G00 T1010
G00 Z-0.0
M03
M08
```

```
G00 X[#500+0.4] Z-2.4
G01 X-1.0 F0.05
G00 X[#500+0.4]
M09         (COOLANT OFF)
M05                     (SPINDLE OFF)
G28 U0W0 (GO HOME)

M30
```

Flashlight On/Off Ring

```
%
O1
;(FLASHLIGHT RING)
;(NATHAN REEVES, DAN BIESENTHAL, JONATHAN SCHREVEN, BRIELLE STARR)
;(STOCK: ALUM 38.1MM DIAMETER X #501 + 10MM)
;(18:00 APRIL 10, 2011)
;
; (TOOLS USED)
; (T0101 - 80DEG DIAMOND CNMG)
; (T0202 - 30DEG DIAMOND)
; (T0303)
; (T0404)
; (T0505 - CENTER DRILL)
; (T0606)
; (T0707 - 19MM END MILL)
; (T0808)
; (T0909 - 14.4MM MIN DIAM BORING BAR)
; (T1010 - CUTOFF)
; (T1111)
; (T1212 - 0.5IN DRILL)
;
;(VARIABLES)
;
#500=38.1                       (STOCK DIAMETER)
#501=11.3                       (STOCK LENGTH)
#502=75.0                       (ROUGHING SURFACE SPEED M/MIN)
#503=0.2                (ROUGHING FEED: MM/REV)
#504=0.05               (FINISHING FEED MM/REV)
#505=150.0                      (FINISHING SURFACE SPEED M/MIN)
;
;(INTIAL PARAMETERS)
G54                             (WORK OFFSET)
G21                             (METRIC UNITS)
G50 S2000 (LIMIT SPEED)
G96 S#502 (CONSTANT SURFACE SPEED)
G99                             (FEED PER REVOLUTION)
;
;(FACING)
N1
G28 U0 W0
G00 T0101                               (80 DEGREE DIAMOND TOOL)
M03                                                     (SPINDLE ON, NORMAL)
G00 X[#500+1.0] Z#501
M08                                                     (COOLANT ON)
G01 X-0.2 Z#501 F#503           (FACE FROM OUTSIDE DOWN TO -0.5)
G01 Z[#501+1.0] F1.0 (MOVE OFF FROM FACE)
M09                                                     (COOLANT OFF)
M05                                                     (SPINDLE OFF)
G28 U0 W0                                               (GO HOME)
M01                                                     (OPTIONAL STOP)
;
;
;(CENTER DRILL)
N2
```

```
G00 T0505              (CENTER DRILL)
G97 S1000      (CONSTANT SPINDLE SPEED 1000RPM)
G99                                          (FEED PER REVOLUTION)
M03                                          (SPINDLE ON, NORMAL)
M08                                          (COOLANT ON)
G00 X0.0 Z[#501 + 2.0]
G01 X0.0 Z[#501 - 2.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
M09                                          (COOLANT OFF)
M05                                          (SPINDLE OFF)
G28 U0 W0
M01
;
;
;
;(DRILLING)
N3
G00 T1212                    (1/2" DRILL)
G97 S1000              (CONSTANT SPINDLE SPEED 1000RPM)
G99                                          (FEED PER REVOLUTION)
M03                                          (SPINDLE ON, NORMAL)
M08                                          (COOLANT ON)
G00 X0.0 Z[#501 + 5.0]
G83 Z1.0 Q10000 F0.5
G01 Z[#501+5.0] F2.0
M09                                          (COOLANT OFF)
M05                                          (SPINDLE OFF)
G28 U0 W0
M01
;
;(ROUGH BORE)
N4
G00 T0707                (19MM END MILL)
G96 S#502              (CONSTANT SURFACE SPEED)
G99                          (FEED PER REVOLUTION)
M03                          (SPINDLE ON, NORMAL)
M08                          (COOLANT ON)
G00 X19.0 Z[#501 + 2.0] (START POINT)
G71 U2.0 R0.5          (2MM DEPTH OF CUT, 0.5MM RETRACT)
G71 P20 Q25 U-0.7 W0.0 F#503
N20 G00 X32.0 Z[#501 + 2.0]
  G01 X32.0 Z[#501]
  G01 X32.0 Z-2.0 F#504
N25 G00 U-0.4
M09                          (COOLANT OFF)
M05                          (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(FINISH BORE)
N5
G00 T0909       (14.4MM MIN DIAM BORING BAR)
G96 S#502
G99
M03                          (SPINDLE ON, NORMAL)
M08                          (COOLANT ON)
G00 X33.0 Z[#501 + 2.0]
G70 P30 Q33
N30 G00 X33.0 Z[#501 + 2.0]
  G01 X33.0 Z[#501]
  G01 X33.0 Z-1.0 F#504
N33 G00 U-0.4
G00 Z[#501 + 2.0]
M09                          (COOLANT OFF)
M05                          (SPINDLE OFF)
```

```
G28 U0 W0
M01
;
;
;
;(FINISH BORE FOR NOTCH)
N6
G00 T0808 (3.175MM GROOVING TOOL)
G96 S#502
G99
M03
M08
G00 X32.0 Z[#501+2.0]
G01 X32.0 Z1.3 F#504
G01 X35.2 Z1.3 F#504
G01 X33.0 Z1.3 F#504
G01 X33.0 Z6.3 F#504
G01 X35.2 Z6.3 F#504
G01 X35.2 Z1.3 F#504
G01 X32.0 Z1.3 F#504
G01 X32.0 Z[#501+1.0] F#503
M09                    (COOLANT OFF)
M05                    (SPINDLE OFF)
G28 U0 W0
M01
;
;
;(ROUGH OD TO +0.5MM)
;(USE 2.0 MM DOC-> xx PASSES)
N7
G00 T0101 (80DEG DIAMOND TOOL, TOOL 1)
G50 S2000 (CLAMP SPEED AT 2000)
G96 S#502 (CONST SURF SPEED)
G99 (FEED PER REV) (RETURN TO R LEVEL IN A FIXED CYCLE)
M03 (SPINDLE ON)
M08 (COOLANT ON)
G00 X37.5 Z[#501+1.0] (INITIAL POINT FOR ROUGHING)
;
G01 X37.5 Z-2.0 F#503 (FIRST PASS)
G01 X[#500+0.5] F#503 (RETRACT X)
G00 Z[#501+2.0] (RETRACT Z)
;
M09 (COOLANT OFF)
M05 (SPINDLE OFF)
G28 U0 W0 (GO HOME)
M01 (OPTIONAL STOP)
;
;
;(FINISH OD TO +0.0MM)
N8
;
G00 T0202 (30DEG DIAMOND TOOL, TOOL 2)
G50 S2000 (CLAMP SPEED AT 2000)
G96 S#505 (CONST SURF SPEED)
G99 (FEED PER REV)
M03 (SPINDLE ON)
M08 (COOLANT ON)
;
G00 X36.0 Z[#501+0.5]
G01 X36.0 Z#501 F#504
G01 X37.0 Z[#501-0.5] F#504
G01 X37.0 Z0.5 F#504
G01 X36.0 Z0.0 F#504
G01 X36.0 Z-2.0 F#504
;
G01 X[#500+2.0] F#504 (RETRACT X)
```

```
G00 Z#501 (RETRACT Z)
M09
M05
G28 U0 W0
M01  (OPTIONAL STOP)
;
;
;(CUTOFF)
N9
G00 T1010
M03
M08
G50 S1000
G96 S#502
G00 X[#500+2.0]
G00 Z-2.5
G01 X-0.5 Z-2.4 F0.3
M09
M05
G28 U0 W0
M30
%
```

Nose O-ring Guide

```
%
O1
;       (GREG PETERSON)
;       (MANUFACTURING LAB#1)
;       (EXAMPLE PART-ALUMINUM)
;
;       (VARIABLES)
#500=38.1 (STOCK DIAMETER)
#501=59.3 (STOCK LENGTH)
#502=75.0 (SURFACE M/MIN)
#503=0.4   (ROUGHTING FEED: MM/REV)
#504=150.0          (SURFACE M/MIN FINISHING)
#505=0.1   (FINISHING FEED: MM/REV)
;
G54                         (WORK OFFSET)
G21                         (METRIC)
G28 U0 W0           (GO HOME)
G50 S2000 (MAX SPINDLE SPEED)
;
;       (FACE WITH 80 DEG DIAMOND TOOL AND SPEED LIMITING)
N1
G00 T0101           (80DEG DIAMOND TOOL, TOOL 1)
G50 S1000           (CLAMP SPEED AT 1000RPM)
G96 S#502           (CONSTANT SURFACE SPEED)
G99                                 (FEED PER REV)
;
M03                                 (SPINDLE ON, NORMAL DIR)
G00 Z#501           (INITIAL Z POSITION)
G00 X[#500+1.0]     (INITIAL X POSITION)
M08                                 (TURN ON COOLANT)
G01 X-0.1 F#503     (FACE FROM OUTSIDE DOWN TO -0.1)
G01 Z[#501+1.0] F1.0 (MOVE OFF FROM FACE)
M09                                 (TURN OFF COOLANT)
M05                                 (TURN OFF SPINDLE)
G28 U0 W0                   (RETURN TO HOME)
M01                                 (OPTIONAL STOP)
;       (ROUGH OD 38.0 TO 30.0MM)
;       (THEN DO EACH STEPDOWN AT 10.0MM AND 20.0MM)
;       (USE 2.0MM DOC -> 4 PASSES)
N2
```

```
G00 T0101              (80DEG DIAMOND TOOL, TOOL 1)
G50 S1000              (CLAMP SPEED AT 1000RPM)
G96 S#502              (CONSTANT SURFACE SPEED)
G99                                    (FEED PER REV)
G00 X[#500 + 0.5] Z#501          (INITIAL POINT FOR ROUGHING)
M03                                    (SPINDLE ON)
M08                                    (TURN ON COOLANT)
G00 X36.0 Z#501
G01 X36.0 Z-3.0 F#503 (FIRST PASS)
G01 X[#500+0.5] F#503 (RETRACT X)
G00 Z#501                        (RETRACT Z)
G00 X34.0
G01 X34.0 Z-3.0 F#503 (SECOND PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X32.0
G01 X32.0 Z-3.0 F#503 (THIRD PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X31.0
G01 X31.0 Z-3.0 F#503 (FOURTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X28.0
G01 X31.0 Z18.6 F#503 (FIFTH PASS-START OF FIRST STEP DOWN)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X26.0
G01 X31.0 Z18.6 F#503 (SIXTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X24.0
G01 X31.0 Z18.6 F#503 (SEVENTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X22.0
G01 X31.0 Z18.6 F#503 (EIGHTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X20.0
G01 X31.0 Z18.6 F#503 (NINTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X18.0
G01 X31.0 Z18.6 F#503 (TENTH PASS-START OF SECOND STEP DOWN)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X16.0
G01 X31.0 Z18.6 F#503 (ELEVENTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X14.0
G01 X31.0 Z18.6 F#503 (TWELTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X12.0
G01 X31.0 Z18.6 F#503 (13TH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X10.0
G01 X31.0 Z18.6 F#503 (14TH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X8.0
G01 X31.0 Z18.6 F#503 (ELEVENTH PASS)
G01 X[#500+0.5] F#503
```

```
G00 Z#501
G00 X6.0
G01 X31.0 Z18.6 F#503 (TWELTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X4.0
G01 X31.0 Z18.6 F#503 (13TH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
G00 X2.0
G01 X31.0 Z18.6 F#503 (TWELTH PASS)
G01 X[#500+0.5] F#503
G00 Z#501
;
M09                                     (TURN OFF COOLANT)
M05                                     (TURN OFF SPINDLE)
G28 U0 W0                               (RETURN TO HOME)
M01                                     (OPTIONAL STOP)
;           (FINISH OD 28.8,18.8,8.8)
N3
G00 T0202           (30DEG DIAMOND TOOL, TOOL 2)
G50 S2000           (CLAMP SPEED AT 2000)
G96 S#504           (CONST SURF SPEED)
G99                                     (FEED PER REV)
G00 X[#500+0.5]
G00 Z#501
M03                                     (SPINDLE ON)
M08                                     (TURN ON COOLANT)
G00 X0.5
G01 X30.88 Z18.6 F#505
G01 X30.88 Z10.0 F#505
G01 X29.5 Z9.0 F#505
G01 X29.5 Z-3.0 F#505
G01 X[#500+0.5] F#503
G00 Z#501
G00 Z10.0
G01 X28.00 Z9.0 F#505
G01 X28.00 Z-3.0
G01 X[#500+0.5] F#505
G00 Z#501
M09
M05
G28 U0 W0
M01
M30                                     (END PROGRAM)
%
```

Central Assembly Platform

```
%
O4321
(NOSE AND CONE HOLDER)
(K:\Common\ENGR480\Hellie Team\nose_cone_holder.ncl.1)
(05/31/11-17:28:38)
G54
N0010T4M06
S2500M03
G00X-.9051Y-.4015
G43Z1.H04M08
Z.125
G01Z-.05F3.
X-1.0949F9.
G03X-1.3574Y-.5107I.0949J-.5985
G01X-.6426
G02X-.5281Y-.6198I-.3574J-.4893
G01X-1.4719
```

G03X-1.542Y-.729I.4719J-.3802
G01X-.458
G02X-.416Y-.8381I-.542J-.271
G01X-1.584
G03X-1.6037Y-.9473I.584J-.1619
G01X-.3963
X-.394Y-1.
X-.3967Y-1.0565
X-1.6033
G03X-1.5829Y-1.1656I.6033J.0565
G01X-.4171
G02X-.4599Y-1.2748I-.5829J.1656
G01X-1.5401
G03X-1.4689Y-1.3839I.5401J.2748
G01X-.5311
G02X-.6477Y-1.4931I-.4689J.3839
G01X-1.3522
G03X-1.067Y-1.6023I.3522J.4931
G01X-.933
G03X-.933Y-1.6023I-.067J.6023
G02X-1.067Y-1.6023I-.067J.6023
G01Z-.1F3.
X-.933F9.
G03X-.6478Y-1.4931I-.067J.6023
G01X-1.3522
G02X-1.4688Y-1.3839I.3522J.4931
G01X-.5311
G03X-.4599Y-1.2748I-.4689J.3839
G01X-1.5401
G02X-1.5829Y-1.1656I.5401J.2748
G01X-.4171
G03X-.3967Y-1.0565I-.5829J.1656
G01X-1.6033
X-1.606Y-1.
X-1.6037Y-.9473
X-.3963
G03X-.416Y-.8381I-.6037J-.0527
G01X-1.584
G02X-1.542Y-.729I.584J-.1619
G01X-.458
G03X-.5281Y-.6198I-.542J-.271
G01X-1.4719
G02X-1.3575Y-.5106I.4719J-.3802
G01X-.6426
G03X-.9051Y-.4015I-.3574J-.4894
G01X-1.0949
G03X-1.0949Y-.4015I.0949J-.5985
G01Z-.15F3.
X-.9051F9.
G02X-.6426Y-.5107I-.0949J-.5985
G01X-1.3574
G03X-1.4719Y-.6198I.3574J-.4893
G01X-.5281
G02X-.458Y-.729I-.4719J-.3802
G01X-1.542
G03X-1.584Y-.8381I.542J-.271
G01X-.416
G02X-.3963Y-.9473I-.584J-.1619
G01X-1.6037
X-1.606Y-1.
X-1.6033Y-1.0565
X-.3967
G02X-.4171Y-1.1656I-.6033J.0565
G01X-1.5829
G03X-1.5401Y-1.2748I.5829J.1656
G01X-.4599

G02X-.5311Y-1.3839I-.5401J.2748
G01X-1.4689
G03X-1.3522Y-1.4931I.4689J.3839
G01X-.6478
G02X-.933Y-1.6023I-.3522J.4931
G01X-1.067
G03X-1.067Y-1.6023I.067J.6023
G01Z-.2F3.
X-.933F9.
G03X-.6478Y-1.4931I-.067J.6023
G01X-1.3522
G02X-1.4688Y-1.3839I.3522J.4931
G01X-.5311
G03X-.4599Y-1.2748I-.4689J.3839
G01X-1.5401
G02X-1.5829Y-1.1656I.5401J.2748
G01X-.4171
G03X-.3967Y-1.0565I-.5829J.1656
G01X-1.6033
X-1.606Y-1.
X-1.6037Y-.9473
X-.3963
G03X-.416Y-.8381I-.6037J-.0527
G01X-1.584
G02X-1.542Y-.729I.584J-.1619
G01X-.458
G03X-.5281Y-.6198I-.542J-.271
G01X-1.4719
G02X-1.3575Y-.5106I.4719J-.3802
G01X-.6426
G03X-.9051Y-.4015I-.3574J-.4894
G01X-1.0949
G03X-1.0949Y-.4015I.0949J-.5985
G01Z-.25F3.
X-.9051F9.
G02X-.6426Y-.5107I-.0949J-.5985
G01X-1.3574
G03X-1.4719Y-.6198I.3574J-.4893
G01X-.5281
G02X-.458Y-.729I-.4719J-.3802
G01X-1.542
G03X-1.584Y-.8381I.542J-.271
G01X-.416
G02X-.3963Y-.9473I-.584J-.1619
G01X-1.6037
X-1.606Y-1.
X-1.6033Y-1.0565
X-.3967
G02X-.4171Y-1.1656I-.6033J.0565
G01X-1.5829
G03X-1.5401Y-1.2748I.5829J.1656
G01X-.4599
G02X-.5311Y-1.3839I-.5401J.2748
G01X-1.4689
G03X-1.3522Y-1.4931I.4689J.3839
G01X-.6478
G02X-.933Y-1.6023I-.3522J.4931
G01X-1.067
G03X-1.067Y-1.6023I.067J.6023
G01Z-.3F3.
X-.933F9.
G03X-.6478Y-1.4931I-.067J.6023
G01X-1.3522
G02X-1.4688Y-1.3839I.3522J.4931
G01X-.5311
G03X-.4599Y-1.2748I-.4689J.3839

G01X-1.5401
G02X-1.5829Y-1.1656I.5401J.2748
G01X-.4171
G03X-.3967Y-1.0565I-.5829J.1656
G01X-1.6033
X-1.606Y-1.
X-1.6037Y-.9473
X-.3963
G03X-.416Y-.8381I-.6037J-.0527
G01X-1.584
G02X-1.542Y-.729I.584J-.1619
G01X-.458
G03X-.5281Y-.6198I-.542J-.271
G01X-1.4719
G02X-1.3575Y-.5106I.4719J-.3802
G01X-.6426
G03X-.9051Y-.4015I-.3574J-.4894
G01X-1.0949
G03X-1.0949Y-.4015I.0949J-.5985
G01Z-.35F3.
X-.9051F9.
G02X-.6426Y-.5107I-.0949J-.5985
G01X-1.3574
G03X-1.4719Y-.6198I.3574J-.4893
G01X-.5281
G02X-.458Y-.729I-.4719J-.3802
G01X-1.542
G03X-1.584Y-.8381I.542J-.271
G01X-.416
G02X-.3963Y-.9473I-.584J-.1619
G01X-1.6037
X-1.606Y-1.
X-1.6033Y-1.0565
X-.3967
G02X-.4171Y-1.1656I-.6033J.0565
G01X-1.5829
G03X-1.5401Y-1.2748I.5829J.1656
G01X-.4599
G02X-.5311Y-1.3839I-.5401J.2748
G01X-1.4689
G03X-1.3522Y-1.4931I.4689J.3839
G01X-.6478
G02X-.933Y-1.6023I-.3522J.4931
G01X-1.067
G03X-1.067Y-1.6023I.067J.6023
G01Z-.375F3.
X-.933F9.
G03X-.6478Y-1.4931I-.067J.6023
G01X-1.3522
G02X-1.4688Y-1.3839I.3522J.4931
G01X-.5311
G03X-.4599Y-1.2748I-.4689J.3839
G01X-1.5401
G02X-1.5829Y-1.1656I.5401J.2748
G01X-.4171
G03X-.3967Y-1.0565I-.5829J.1656
G01X-1.6033
X-1.606Y-1.
X-1.6037Y-.9473
X-.3963
G03X-.416Y-.8381I-.6037J-.0527
G01X-1.584
G02X-1.542Y-.729I.584J-.1619
G01X-.458
G03X-.5281Y-.6198I-.542J-.271
G01X-1.4719

G02X-1.3575Y-.5106I.4719J-.3802
G01X-.6426
G03X-.9051Y-.4015I-.3574J-.4894
G01X-1.0949
G03X-1.0949Y-.4015I.0949J-.5985
G01Z1.
G00X-3.2475Y-.567
Z.125
G01Z-.05F3.
X-3.2525F9.
G03X-3.5353Y-.6743I.0025J-.433
G01X-2.9647
G02X-2.8761Y-.7816I-.2853J-.3257
G01X-3.6239
G03X-3.6685Y-.8889I.3739J-.2184
G01X-2.8315
G02X-2.817Y-.9963I-.4185J-.1111
G01X-3.683
Y-1.
G03X-3.6704Y-1.1036I.433J0.
G01X-2.8296
G02X-2.8718Y-1.2109I-.4204J.1036
G01X-3.6282
G03X-3.5437Y-1.3182I.3782J.2109
G01X-2.9563
G02X-3.1699Y-1.4255I-.2937J.3182
G01X-3.3301
G03X-3.3301Y-1.4255I.0801J.4255
G01Z-.1F3.
X-3.1699F9.
G03X-2.9563Y-1.3182I-.0801J.4255
G01X-3.5437
G02X-3.6282Y-1.2109I.2937J.3182
G01X-2.8718
G03X-2.8296Y-1.1036I-.3782J.2109
G01X-3.6704
G02X-3.683Y-1.I.4204J.1036
G01Y-.9963
X-2.817
G03X-2.8315Y-.8889I-.433J-.0037
G01X-3.6685
G02X-3.6239Y-.7816I.4185J-.1111
G01X-2.8761
G03X-2.9647Y-.6743I-.3739J-.2184
G01X-3.5353
G02X-3.2525Y-.567I.2853J-.3257
G01X-3.2475
G03X-3.2475Y-.567I-.0025J-.433
G01Z-.15F3.
X-3.2525F9.
G03X-3.5353Y-.6743I.0025J-.433
G01X-2.9647
G02X-2.8761Y-.7816I-.2853J-.3257
G01X-3.6239
G03X-3.6685Y-.8889I.3739J-.2184
G01X-2.8315
G02X-2.817Y-.9963I-.4185J-.1111
G01X-3.683
Y-1.
G03X-3.6704Y-1.1036I.433J0.
G01X-2.8296
G02X-2.8718Y-1.2109I-.4204J.1036
G01X-3.6282
G03X-3.5437Y-1.3182I.3782J.2109
G01X-2.9563
G02X-3.1699Y-1.4255I-.2937J.3182

G01X-3.3301
G03X-3.3301Y-1.4255I.0801J.4255
G01Z-.2F3.
X-3.1699F9.
G03X-2.9563Y-1.3182I-.0801J.4255
G01X-3.5437
G02X-3.6282Y-1.2109I.2937J.3182
G01X-2.8718
G03X-2.8296Y-1.1036I-.3782J.2109
G01X-3.6704
G02X-3.683Y-1.I.4204J.1036
G01Y-.9963
X-2.817
G03X-2.8315Y-.8889I-.433J-.0037
G01X-3.6685
G02X-3.6239Y-.7816I.4185J-.1111
G01X-2.8761
G03X-2.9647Y-.6743I-.3739J-.2184
G01X-3.5353
G02X-3.2525Y-.567I.2853J-.3257
G01X-3.2475
G03X-3.2475Y-.567I-.0025J-.433
G01Z-.25F3.
X-3.2525F9.
G03X-3.5353Y-.6743I.0025J-.433
G01X-2.9647
G02X-2.8761Y-.7816I-.2853J-.3257
G01X-3.6239
G03X-3.6685Y-.8889I.3739J-.2184
G01X-2.8315
G02X-2.817Y-.9963I-.4185J-.1111
G01X-3.683
Y-1.
G03X-3.6704Y-1.1036I.433J0.
G01X-2.8296
G02X-2.8718Y-1.2109I-.4204J.1036
G01X-3.6282
G03X-3.5437Y-1.3182I.3782J.2109
G01X-2.9563
G02X-3.1699Y-1.4255I-.2937J.3182
G01X-3.3301
G03X-3.3301Y-1.4255I.0801J.4255
G01Z-.3F3.
X-3.1699F9.
G03X-2.9563Y-1.3182I-.0801J.4255
G01X-3.5437
G02X-3.6282Y-1.2109I.2937J.3182
G01X-2.8718
G03X-2.8296Y-1.1036I-.3782J.2109
G01X-3.6704
G02X-3.683Y-1.I.4204J.1036
G01Y-.9963
X-2.817
G03X-2.8315Y-.8889I-.433J-.0037
G01X-3.6685
G02X-3.6239Y-.7816I.4185J-.1111
G01X-2.8761
G03X-2.9647Y-.6743I-.3739J-.2184
G01X-3.5353
G02X-3.2525Y-.567I.2853J-.3257
G01X-3.2475
G03X-3.2475Y-.567I-.0025J-.433
G01Z-.35F3.
X-3.2525F9.
G03X-3.5353Y-.6743I.0025J-.433
G01X-2.9647

```
G02X-2.8761Y-.7816I-.2853J-.3257
G01X-3.6239
G03X-3.6685Y-.8889I.3739J-.2184
G01X-2.8315
G02X-2.817Y-.9963I-.4185J-.1111
G01X-3.683
Y-1.
G03X-3.6704Y-1.1036I.433J0.
G01X-2.8296
G02X-2.8718Y-1.2109I-.4204J.1036
G01X-3.6282
G03X-3.5437Y-1.3182I.3782J.2109
G01X-2.9563
G02X-3.1699Y-1.4255I-.2937J.3182
G01X-3.3301
G03X-3.3301Y-1.4255I.0801J.4255
G01Z-.375F3.
X-3.1699F9.
G03X-2.9563Y-1.3182I-.0801J.4255
G01X-3.5437
G02X-3.6282Y-1.2109I.2937J.3182
G01X-2.8718
G03X-2.8296Y-1.1036I-.3782J.2109
G01X-3.6704
G02X-3.683Y-1.I.4204J.1036
G01Y-.9963
X-2.817
G03X-2.8315Y-.8889I-.433J-.0037
G01X-3.6685
G02X-3.6239Y-.7816I.4185J-.1111
G01X-2.8761
G03X-2.9647Y-.6743I-.3739J-.2184
G01X-3.5353
G02X-3.2525Y-.567I.2853J-.3257
G01X-3.2475
G03X-3.2475Y-.567I-.0025J-.433
G01Z1.
M30
%
```

Appendix D – Motoman Tool Paths/Points

Sequence of Robot Positions

Job Number	Position Number	Position Description
	p001	Home Position
	p002	Position part way between home and nose station
	p003	Position above nose at nose station
HELLIETEAM	p004	Position to grip nose at nose station
	p003	Position above nose at nose station
	p002	Position part way between home and nose station
	p038	Position along path to place nose at central assembly station
	p005	Position above nose at central assembly station
R2	p006	Position at central assembly station for grabbing/releasing nose
	p005	Position above nose at central assembly station
	p007	Position above guide at central assembly station
R3	p008	Position at central assembly station for grabbing/releasing guide

	p007	Position above guide at central assembly station
	p039	Position above nose at central assembly station for inserting guide
R4	p009	Position at central assembly station for grabbing/releasing guide
	p005	Position above nose at central assembly station
	p010	Position above big o-ring at big o-ring station
R5	p011	Position to grip big o-ring at big o-ring station
	p010	Position above big o-ring at big o-ring station
	p012	Position at central assembly station to begin big o-ring placement
R6	p013	Position at central assembly station to end big o-ring placement
	p040	Position along path to begin big o-ring brush down
	p041	Position along path to begin big o-ring brush down
	p014	Position to begin big o-ring brush down
	p015	Position at end of big o-ring brush down
	p016	Position to move away after big o-ring brush down
R7	p051	Position to move up after big o-ring brush down
	p017	Position above on/off ring at on/off ring station
R8	p018	Position to grip on/off ring at on/off ring station
	p017	Position above on/off ring at on/off ring station
	p042	Position along path to place on/off ring
	p043	Position above central assembly station to place on-off ring
R9	p019	Position at central assembly station to end on/off ring placement
	p043	Position above central assembly station to place on-off ring
	p047	Position along path to grab second big o-ring
	p052	Position along path to grab second big o-ring
	p005	Position above central assembly station
	p010	Position above big o-ring at big o-ring station
R10	p011	Position to grip big o-ring at big o-ring station
	p010	Position above big o-ring at big o-ring station
	p012	Position at central assembly station to begin big o-ring placement
R11	p013	Position at central assembly station to end big o-ring placement
	p040	Position along path to begin big o-ring brush down
	p041	Position along path to begin big o-ring brush down
	p014	Position to begin big o-ring brush down
	p053	Position at end of second big o-ring brush down
	p054	Position to move away after second big o-ring brush down
	p051	Position along path after second big o-ring brush down
	p005	Position above central assembly station
R12	p009	Position at central assembly station for grabbing/releasing guide in nose
	p005	Position above central assembly station
	p007	Position above guide at central assembly station
R13	p059	Position at central assembly station for grabbing/releasing guide
	p007	Position above guide at central assembly station
R14	p055	Position along path to grab small o-ring

	p056	Position along path to grab small o-ring
	p020	Position above small o-ring at small o-ring station
	p021	Position to grip small o-ring at small o-ring station
	p020	Position above small o-ring at small o-ring station
	p060	Position along path to place small o-ring
	p061	Position along path to place small o-ring
	p022	Position at central assembly station above position to place small o-ring
R15	p071	Position at central seembly station to place small o-ring into nose cone
	p022	Position at central assembly station above position to place small o-ring
	p005	Position above nose at central assembly station
R16	p058	Position at central assembly station for grabbing/releasing nose
	p062	Position above nose at central assembly station
	p063	Position above guide at central assembly station
	p064	Position at guide at central assembly station for aligning small o-ring
	p063	Position above guide at central assembly station
	p062	Position above nose at central assembly station
R17	p058	Position at central assembly station for grabbing/releasing nose
	p005	Position above nose at central assembly station
	p024	Position above heat sink at heat sink station
R18	p025	Position to grip heat sink at heat sink station
	p024	Position above heat sink at heat sink station
	p005	Position above nose at central assembly station
R19	p026	Position at central assembly station to place heat sink
	p005	Position above nose at central assembly station
	p027	Position above snap ring at snap ring station
R20	p028	Position to grip snap ring at snap ring station
	p027	Position above snap ring at snap ring station
	p029	Position with snap ring vacuum above nose at central assembly station
R21	p030	Position at central assembly station to place snap ring
	p029	Position with snap ring vacuum above nose at central assembly station
	p005	Position above nose at central assembly station
R22	p058	Position at central assembly station for grabbing/releasing nose
	p005	Position above nose at central assembly station
	p031	Position above final assembly threading station
R23	p032	Position above final assembly threading station to drop nose
	p031	Position above final assembly threading station
	p033	Position above body at body station
	p034	Position slightly above body at body station
R24	P070	Position to grip body at body station
	p035	Position above battery at battery station
R25	p036	Position to insert battery at battery station
	p035	Position above battery at battery station
R26	p031	Position above final assembly threading station

	p037	Position above final assembly threading station to drop body
R27	p031	Position above final assembly threading station

Appendix E – Motoman Robot Jobs

Hellie Team – (R1)

```
/JOB
//NAME HELLIETEAM
//POS
///NPOS 0,0,0,4,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00001=84786,4004,-28328,57,-60085,-7711
P00002=-37659,4004,-28333,57,-60083,65978
P00003=-50205,49031,-14869,-34876,-66192,84009
P00004=-42974,54873,-21922,-39618,-57744,86336
//INST
///DATE 2011/06/07 20:32
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) ON
WAIT IN#(2)=ON
DOUT OT#(1) OFF
MOVL P001 V=100.0 PL=0
MOVL P002 V=100.0 PL=0
MOVL P003 V=100.0 PL=0
MOVL P004 V=75.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R2
END
```

R2

```
/JOB
//NAME R2
//POS
///NPOS 0,0,0,5,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00002=-37659,4004,-28333,57,-60083,65978
P00003=-50205,49031,-14869,-34876,-66192,84009
P00005=34980,2999,-30800,-3852,-56677,-12003
P00006=34981,22550,-44229,-5470,-35212,-10445
P00038=2927,-7760,-26465,-249,-68223,363
//INST
///DATE 2011/06/06 14:41
///ATTR SC,RW
///GROUP1 RB1
```

```
NOP
DOUT OT#(1) OFF
MOVL P003 V=100.0 PL=0
MOVL P002 V=100.0 PL=0
MOVL P038 V=100.0 PL=0
MOVL P005 V=100.0 PL=0
MOVL P006 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R3
END
```

R3

```
/JOB
//NAME R3
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00007=46309,13414,-29252,45,-52944,-17477
P00008=46263,30798,-38523,55,-35723,-17473
//INST
///DATE 2011/06/06 14:42
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=100.0 PL=0
MOVL P007 V=100.0 PL=0
MOVL P008 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R4
END
```

R4

```
/JOB
//NAME R4
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00007=46309,13414,-29252,45,-52944,-17477
P00009=37513,20343,-42019,17,-39501,-14091
P00039=37513,5868,-32040,14,-55480,-14088
//INST
```

```
///DATE 2011/06/06 15:05
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P007 V=100.0 PL=0
MOVL P039 V=100.0 PL=0
MOVL P009 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R5
END
```

R5

```
/JOB
//NAME R5
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00010=-26318,-5494,2129,302,-86752,111982
P00011=-22884,7976,8051,324,-82925,110649
//INST
///DATE 2011/06/06 20:22
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=50.0 PL=0
MOVL P010 V=50.0 PL=0
MOVL P011 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(1)=ON T=0.50
WAIT IN#(2)=ON
JUMP JOB:R6
END
```

R6

```
/JOB
//NAME R6
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00010=-26318,-5494,2129,302,-86752,111982
P00012=51357,-15092,-71835,947,-39416,81702
P00013=58454,-7089,-69317,1021,-36460,78918
```

```
//INST
///DATE 2011/06/06 13:56
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVS P010 V=100.0 PL=0
MOVL P012 V=100.0 PL=0
MOVL P013 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R7
END
```

R7

```
/JOB
//NAME R7
//POS
///NPOS 0,0,0,6,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00014=17287,-5023,-59833,504,-41054,-7964
P00015=17287,40644,-66259,2125,-8814,-9056
P00016=-1100,39957,-67745,756,-8095,-1148
P00040=71398,-13896,-55593,878,-50454,24351
P00041=45820,1629,-43691,804,-49497,-17551
P00051=17036,-5340,-54956,465,-44784,-57499
//INST
///DATE 2011/06/06 14:27
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P040 V=100.0 PL=0
MOVL P041 V=100.0 PL=0
MOVS P014 V=100.0 PL=0
MOVL P015 V=20.0 PL=1
WAIT IN#(1)=ON T=1.00
MOVL P016 V=50.0 PL=0
MOVL P051 V=100.0 PL=5
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R8
END
```

R8

```
/JOB
//NAME R8
//POS
```

```
///NPOS 0,0,0,2,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00017=24550,-26802,-46049,22934,-25959,-123501
P00018=20415,-3507,-43769,35663,-14146,-131343
//INST
///DATE 2011/06/05 23:51
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P017 V=50.0 PL=0
MOVL P018 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R9
END
```

R9

```
/JOB
//NAME R9
//POS
///NPOS 0,0,0,4,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00017=24550,-26802,-46049,22934,-25959,-123501
P00019=49103,3725,-64032,-928,-34395,-122404
P00042=19325,-25919,-56664,6682,-31711,-60528
P00043=49103,-18117,-51024,-639,-57018,-122680
//INST
///DATE 2011/06/06 14:32
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P017 V=50.0 PL=0
MOVL P042 V=100.0 PL=0
MOVL P043 V=100.0 PL=0
MOVL P019 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R10
END
```

R10

```
/JOB
//NAME R10
```

```
//POS
///NPOS 0,0,0,6,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00010=-26318,-5494,2129,302,-86752,111982
P00011=-22884,7976,8051,324,-82925,110649
P00043=49103,-18117,-51024,-639,-57018,-122680
P00047=27468,-23086,-50764,-3480,-58537,-60278
P00052=27468,-23086,-50766,-3480,-58537,-7149
//INST
///DATE 2011/06/06 20:24
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P043 V=100.0 PL=0
MOVL P047 V=100.0 PL=0
MOVL P052 V=100.0 PL=0
MOVL P005 V=100.0 PL=0
MOVL P010 V=100.0 PL=0
MOVL P011 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(1)=ON T=0.50
WAIT IN#(2)=ON
JUMP JOB:R11
END
```

R11

```
/JOB
//NAME R11
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00010=-26318,-5494,2129,302,-86752,111982
P00012=51357,-15092,-71835,947,-39416,81702
P00013=58454,-7089,-69317,1021,-36460,78918
//INST
///DATE 2011/06/06 14:33
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P010 V=100.0 PL=0
MOVL P012 V=100.0 PL=0
MOVL P013 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
```

```
JUMP JOB:R12
END
```

R12

```
/JOB
//NAME R12
//POS
///NPOS 0,0,0,8,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00009=37513,20343,-42019,17,-39501,-14091
P00014=17287,-5023,-59833,504,-41054,-7964
P00040=71398,-13896,-55593,878,-50454,24351
P00041=45820,1629,-43691,804,-49497,-17551
P00051=17036,-5340,-54956,465,-44784,-57499
P00053=17287,42160,-66148,2346,-7979,-9198
P00054=-517,41511,-67635,902,-7235,-1464
//INST
///DATE 2011/06/06 19:57
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P040 V=100.0 PL=0
MOVL P041 V=100.0 PL=0
MOVL P014 V=100.0 PL=0
MOVL P053 V=50.0 PL=0
MOVL P054 V=50.0 PL=0
MOVL P051 V=100.0 PL=0
MOVL P005 V=100.0 PL=0
MOVL P009 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R13
END
```

R13

```
/JOB
//NAME R13
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00007=46309,13414,-29252,45,-52944,-17477
```

```
P00059=46074,29750,-38082,-69,-36626,-17337
//INST
///DATE 2011/06/06 19:58
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=100.0 PL=0
MOVL P007 V=100.0 PL=0
MOVL P059 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R14
END
```

R14

```
/JOB
//NAME R14
//POS
///NPOS 0,0,0,5,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00007=46309,13414,-29252,45,-52944,-17477
P00020=1175,16461,-52759,2571,-14952,100237
P00021=932,38734,-42823,4061,-8694,99354
P00055=42918,-3319,-47066,1486,-51740,84942
P00056=5761,-2598,-63155,2504,-39013,114971
//INST
///DATE 2011/06/06 19:59
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P007 V=100.0 PL=0
MOVL P055 V=100.0 PL=0
MOVL P056 V=100.0 PL=0
MOVL P020 V=100.0 PL=0
MOVL P021 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R15
END
```

R15

```
/JOB
//NAME R15
//POS
///NPOS 0,0,0,5,0,0
///TOOL 0
```

```
///POSTYPE PULSE
///PULSE
P00020=1175,16461,-52759,2571,-14952,100237
P00022=33566,8945,-56664,15903,-44120,-73691
P00060=25376,11118,-40509,-4320,-44475,926
P00061=26626,7437,-50464,8086,-44346,-42016
P00071=33027,10943,-57627,16518,-42246,-74021
//INST
///DATE 2011/06/06 21:41
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P020 V=100.0 PL=0
MOVL P060 V=100.0 PL=0
MOVL P061 V=100.0 PL=0
MOVL P022 V=100.0 PL=0
MOVL P071 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R16
END
```

R16

```
/JOB
//NAME R16
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00022=33566,8945,-56664,15903,-44120,-73691
P00058=37092,22133,-42966,520,-37901,-15986
//INST
///DATE 2011/06/06 21:50
///ATTR SC,RW
///GROUP1 RB1
NOP
WAIT IN#(1)=ON T=0.50
DOUT OT#(1) OFF
MOVL P022 V=50.0 PL=0
MOVL P005 V=100.0 PL=0
MOVL P058 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R17
END
```

R17

```
/JOB
//NAME R17
//POS
///NPOS 0,0,0,4,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00058=37092,22133,-42966,520,-37901,-15986
P00062=37092,8974,-35703,415,-51117,-15888
P00063=45945,14328,-30894,418,-51408,-19284
P00064=45944,21899,-35846,470,-43264,-19337
//INST
///DATE 2011/06/06 20:02
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P062 V=100.0 PL=0
MOVL P063 V=100.0 PL=0
MOVL P064 V=50.0 PL=0
MOVL P063 V=100.0 PL=0
MOVL P062 V=100.0 PL=0
MOVL P058 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R18
END
```

R18

```
/JOB
//NAME R18
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00024=32472,61118,-11567,-105778,-80595,-22031
P00025=37233,64197,-7503,-108120,-78597,-22074
//INST
///DATE 2011/06/06 20:03
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=100.0 PL=0
MOVL P024 V=50.0 PL=0
MOVL P025 V=50.0 PL=0
DOUT OT#(1) ON
```

```
WAIT IN#(2)=ON
JUMP JOB:R19
END
```

R19

```
/JOB
//NAME R19
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00024=32472,61118,-11567,-105778,-80595,-22031
P00026=34940,19455,-43835,-292,-38649,-21305
//INST
///DATE 2011/06/06 00:22
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P024 V=50.0 PL=0
MOVL P005 V=50.0 PL=0
MOVL P026 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R20
END
```

R20

```
/JOB
//NAME R20
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00027=37456,57944,13039,-466,-57624,-14554
P00028=37473,70642,7743,-550,-46112,-14732
//INST
///DATE 2011/06/06 00:24
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=50.0 PL=0
MOVL P027 V=50.0 PL=0
MOVL P028 V=50.0 PL=0
```

```
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R21
END
```

R21

```
/JOB
//NAME R21
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00027=37456,57944,13039,-466,-57624,-14554
P00029=30520,5700,-58313,1107,-37144,38953
P00030=30520,28284,-62225,1875,-20669,38392
//INST
///DATE 2011/06/06 20:32
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P027 V=50.0 PL=0
MOVL P029 V=100.0 PL=0
MOVL P030 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R22
END
```

R22

```
/JOB
//NAME R22
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00029=30520,5700,-58313,1107,-37144,38953
P00058=37092,22133,-42966,520,-37901,-15986
//INST
///DATE 2011/06/06 20:19
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P029 V=50.0 PL=0
MOVL P005 V=100.0 PL=0
```

```
MOVL P058 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R23
END
```

R23

```
/JOB
//NAME R23
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00005=34980,2999,-30800,-3852,-56677,-12003
P00031=167576,41065,13959,44356,-89793,-66412
P00032=167576,50749,112,43880,-79501,-76043
//INST
///DATE 2011/06/06 20:06
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P005 V=100.0 PL=0
MOVL P031 V=100.0 PL=0
MOVL P032 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R24
END
```

R24

```
/JOB
//NAME R24
//POS
///NPOS 0,0,0,4,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00031=167576,41065,13959,44356,-89793,-66412
P00033=145737,27962,-7645,56272,-78567,-50677
P00034=93979,78472,-22797,103646,-62774,-50557
P00070=82356,89997,-8933,109769,-61943,-43578
//INST
///DATE 2011/06/06 20:07
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P031 V=100.0 PL=0
```

```
MOVL P033 V=100.0 PL=0
MOVL P034 V=100.0 PL=0
MOVL P070 V=100.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R25
END
```

R25

```
/JOB
//NAME R25
//POS
///NPOS 0,0,0,2,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00035=94360,45365,-26358,92780,-57899,-33784
P00036=89174,48240,-23635,96138,-54793,-34195
//INST
///DATE 2011/06/06 18:49
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P035 V=50.0 PL=0
MOVL P036 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R26
END
```

R26

```
/JOB
//NAME R26
//POS
///NPOS 0,0,0,3,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00031=167576,41065,13959,44356,-89793,-66412
P00035=94360,45365,-26358,92780,-57899,-33784
P00037=158773,48408,3153,23360,-63679,-67540
//INST
///DATE 2011/06/06 23:07
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
WAIT IN#(1)=ON T=3.00
```

```
MOVL P035 V=50.0 PL=0
MOVL P031 V=50.0 PL=0
MOVL P037 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:R27
END
```

R27

```
/JOB
//NAME R27
//POS
///NPOS 0,0,0,1,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00031=167576,41065,13959,44356,-89793,-66412
//INST
///DATE 2011/06/07 00:24
///ATTR SC,RW
///GROUP1 RB1
NOP
DOUT OT#(1) OFF
MOVL P031 V=50.0 PL=0
DOUT OT#(1) ON
WAIT IN#(2)=ON
JUMP JOB:HELLIETEAM
END
```