STRATEGIC ENGINEERING PTY LTD

final report

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Prototype automated shackle loading system

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1 Scope

This report details the conclusion of all milestone two and milestone three outcomes for the Automated Shackle Loading System project, including the details of the prototype constructed, results of the trial and the way forward for this area of research and development.

Note: From this point acronyms may be used

BST – Beef Shackling Tool
ASLS – Automated Shackle Loading System

2 Design Objective

To develop an Automated Shackle Loading System for the Beef Shackling Tool.

The Automated Shackle Loading System has been designed to automatically grab the top and bottom shackle links from the bleed roller then pick and place the shackles into the appropriate grips located in the Beef Shackling Tool, the ASLS is designed to integrate with existing shackle return systems used in the industry.

The benefits of the Automated Shackle Loading System are:

- Reduced labour required for shackling.
- Prevention of operator injury and OH&S costs.
- Increased consistency and reliability of the shackle application
- The Automated Shackle Loading System is a part required by the Greater Robotic Beef Shackling System.

Figure 1: ASLS loading shackles into BST

Design Overview

A simple top level design overview for the Automated Shackle Loading System is shown in **Figure 2**. Further detail is given following the figure. These design blocks will also be discussed in further depth in the following sections of this report.

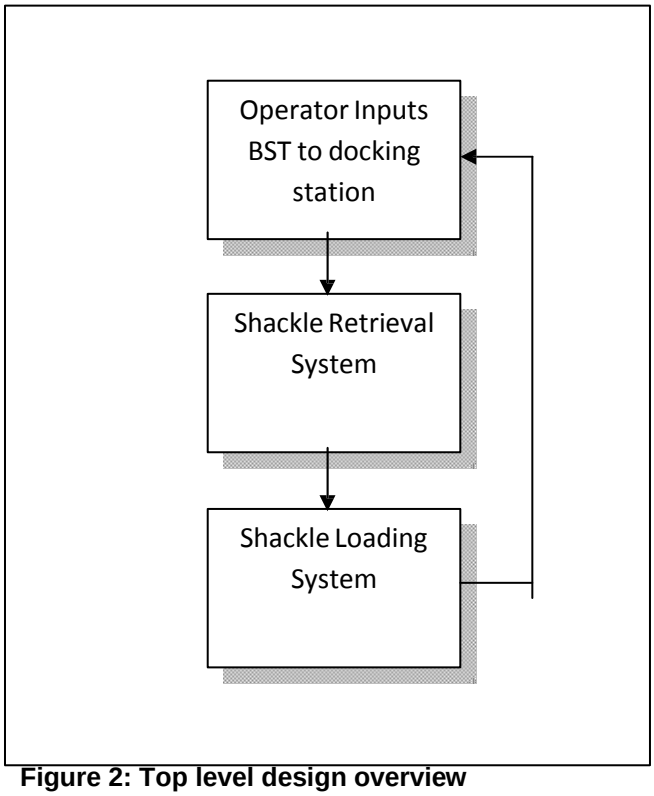


Figure 2: Top level design overview

The operator loads the Beef Shackling Tool into the docking station of the Automated Shackle loading System. The ASLS grips the top and bottom shackle links. The shackles are then loaded into the BST.

Additional top level design expanded to show sensors, PLC and pneumatics for the ASLS shown in figure 3.

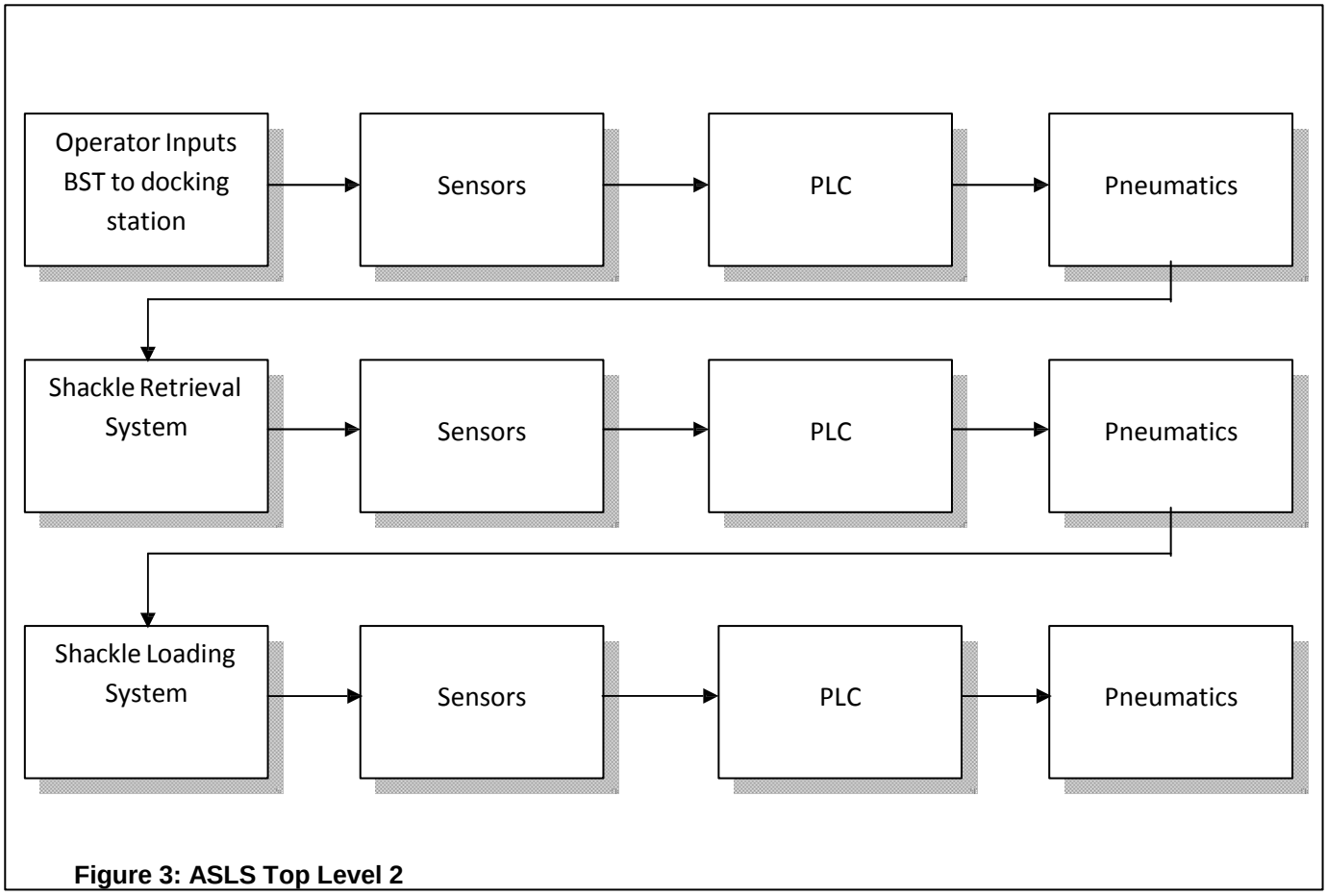


Figure 3: ASLS Top Level 2

2. **Mechanism**

Docking of the Beef Shackling Tool

- Docking is accomplished by placing the BST onto the ASLS docking station. The BST sits into negative groves and is pressed down by a pneumatic cylinder 0, this holds the BST in place while the loading operation takes place. There are also two pneumatic rods that extend from the docking plate to locate the BST into a precise location.

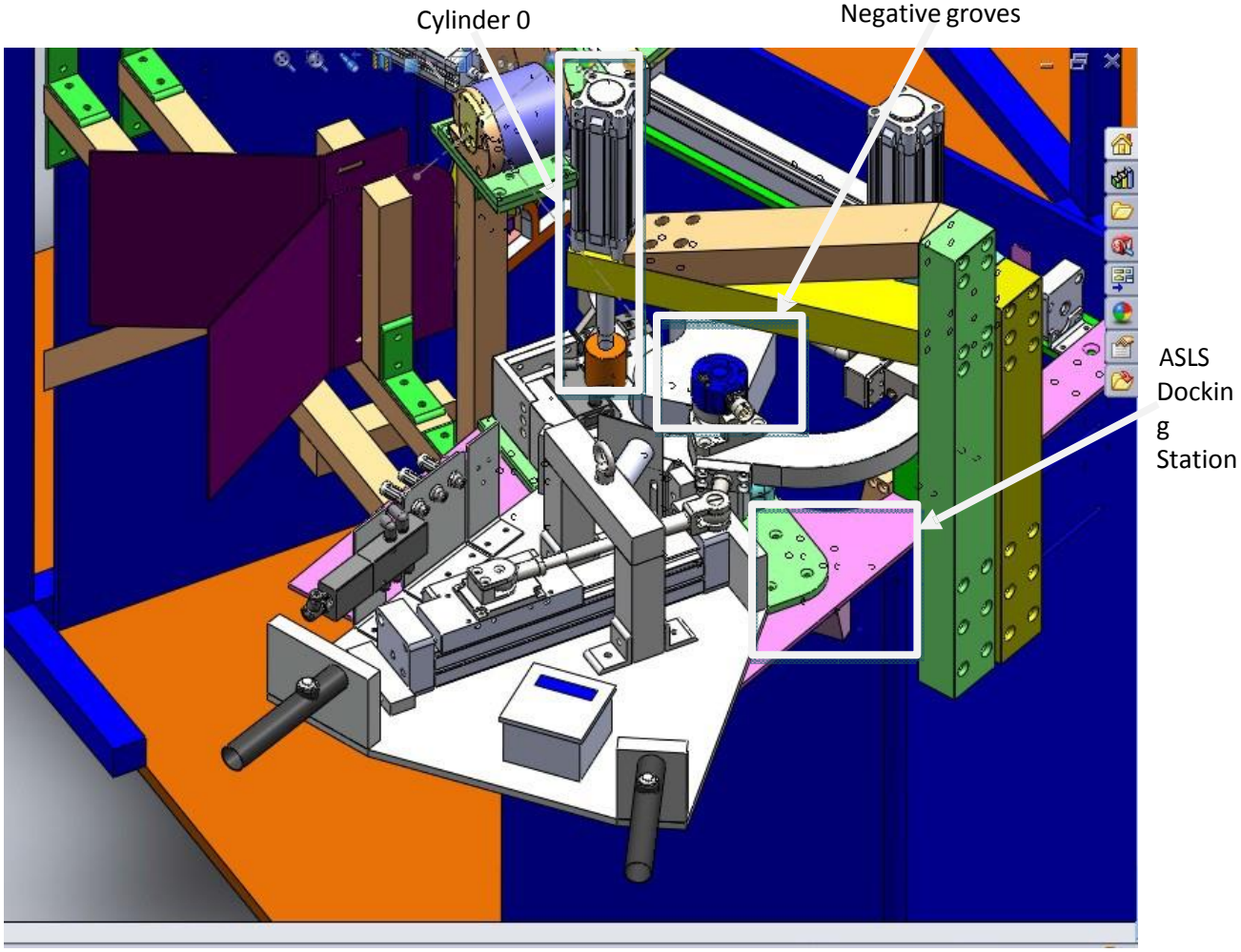


Figure 4: BST Docked

Loading of the Top Shackle Link into the Beef Shackling Tool

- The bleed roller assembly runs down the rail with the shackle attached, it is then stopped and guided into position by the Rodless Cylinder/stopper assembly.

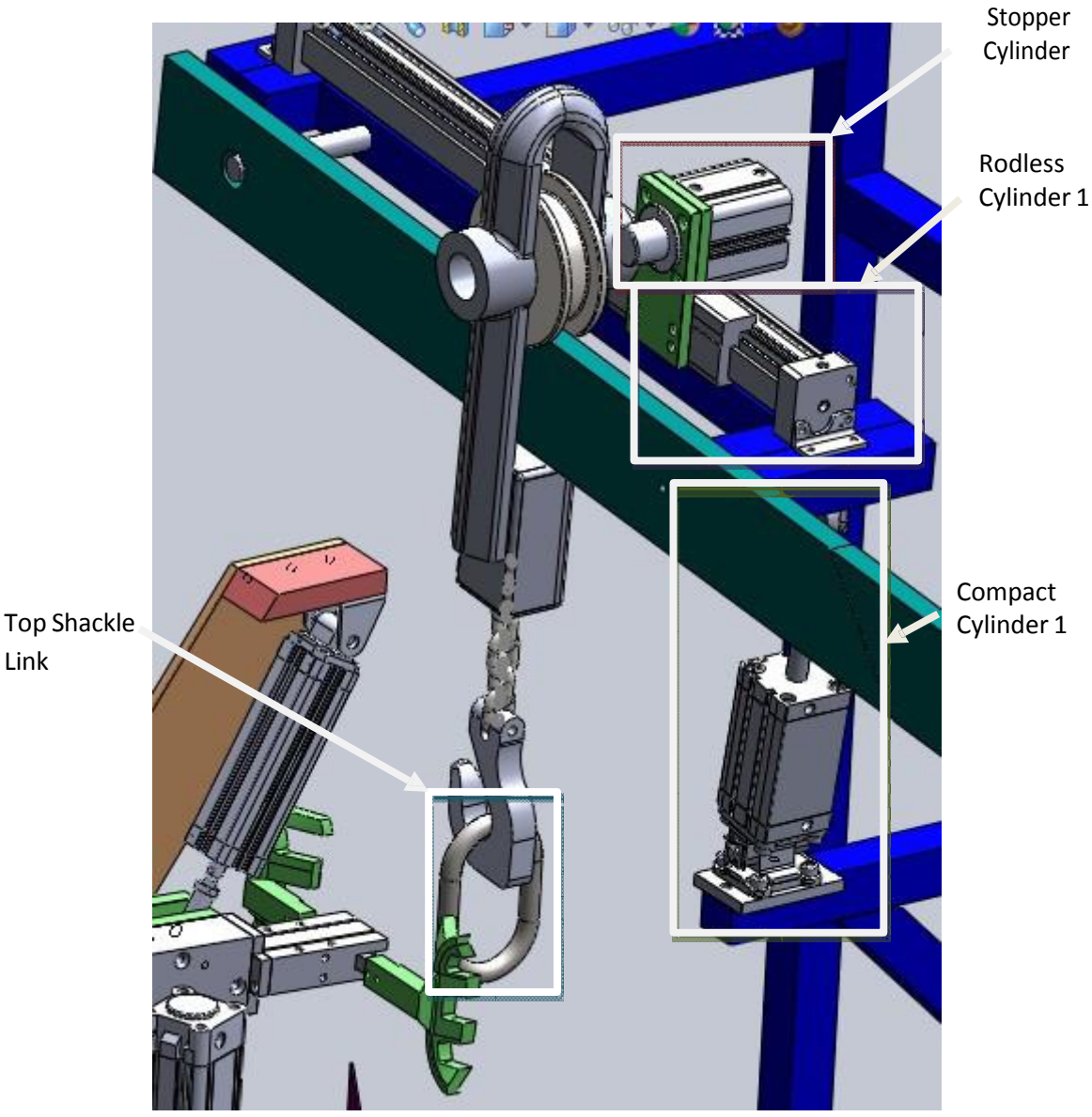


Figure 5: loading Top Shackle

- The top link is then gripped by a pneumatically operated 180 degree finger gripper.

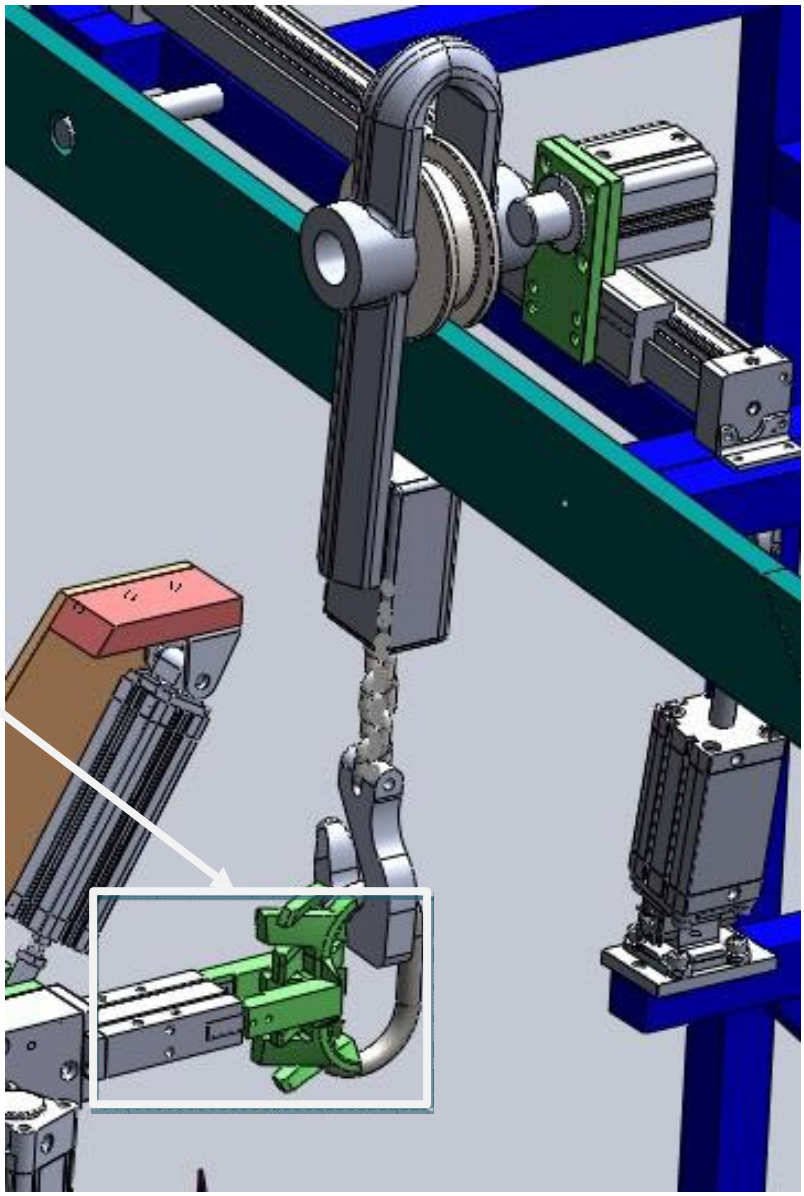


Figure 6: Top link gripped

- The bleed roller is guided off the top shackle link. This is achieved by simultaneously lowering the bleed rail by retracting Compact Cylinder 1 and guiding it back with the aid of Rodless Cylinder 1 and the pneumatic stopper cylinder

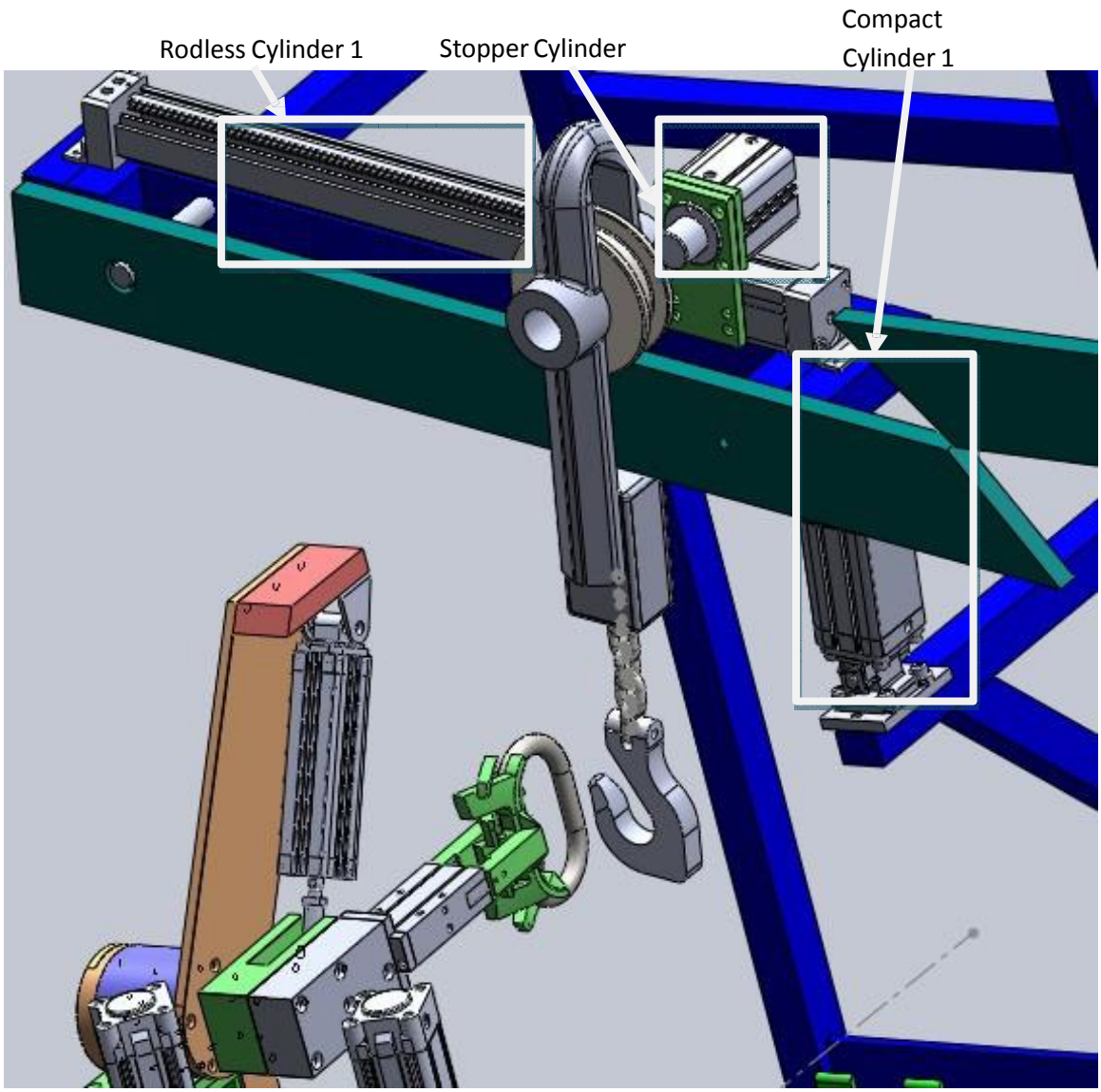


Figure 7: Bleed Rail lowered

- Once the bleed roller has been disconnected from the shackle, the bleed rail is raised by Compact Cylinder 1.
- The stopper cylinder retracts allowing the bleed roller to continue travelling.
- The next step will involve compact cylinder 2 rotating the finger type gripper 90 degrees into the Beef Shackling Tool.

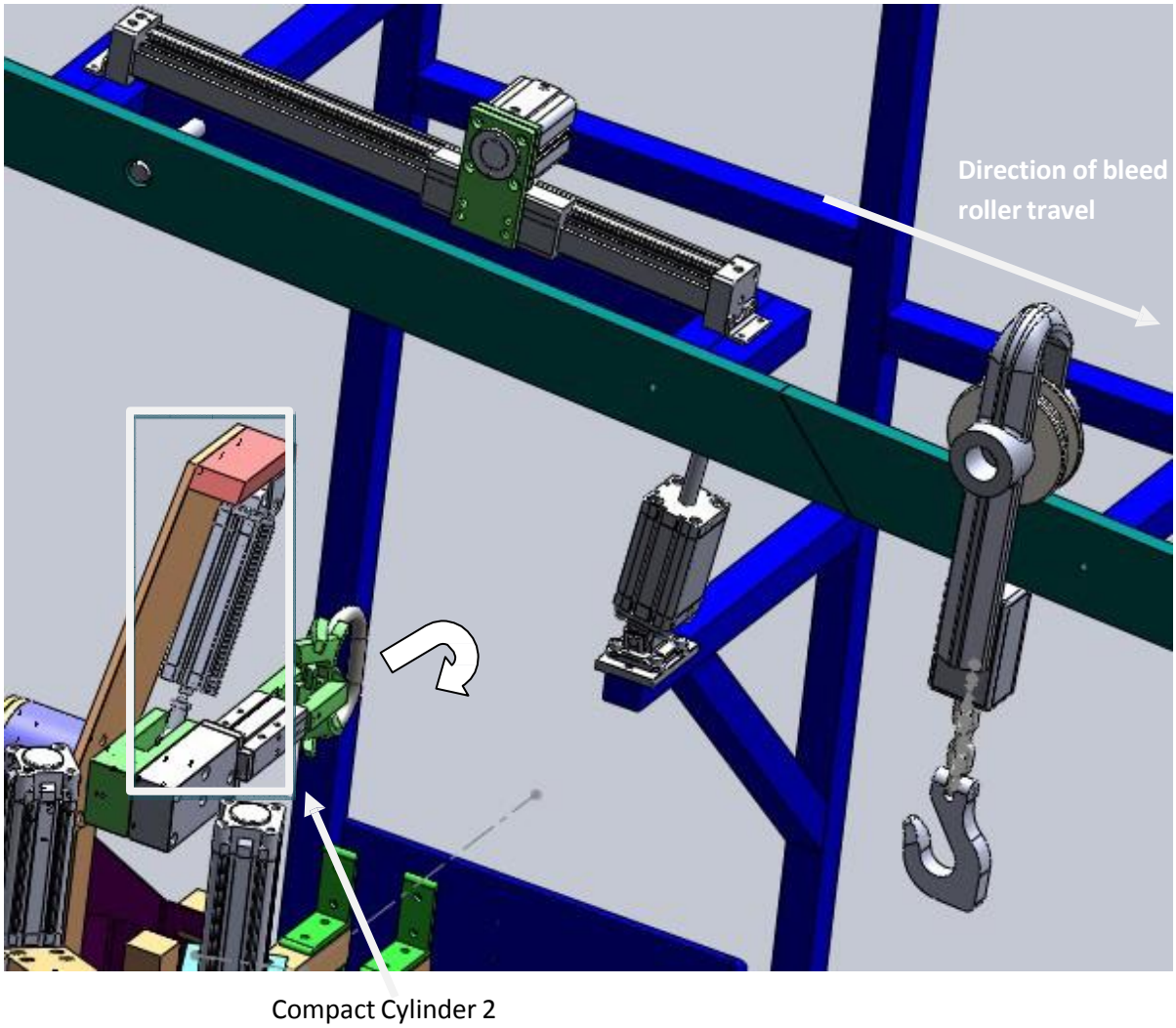


Figure 8: Bleed Roller Extracted

- The top shackle is rotated 90 degrees by Compact Cylinder 2 and placed into the Beef Shackling Tool. The parallel grippers on the BST grip the shackle.
- Compact Cylinder 2 retracts to reset the finger grippers to the original position; the loading of the top shackle link is now complete.

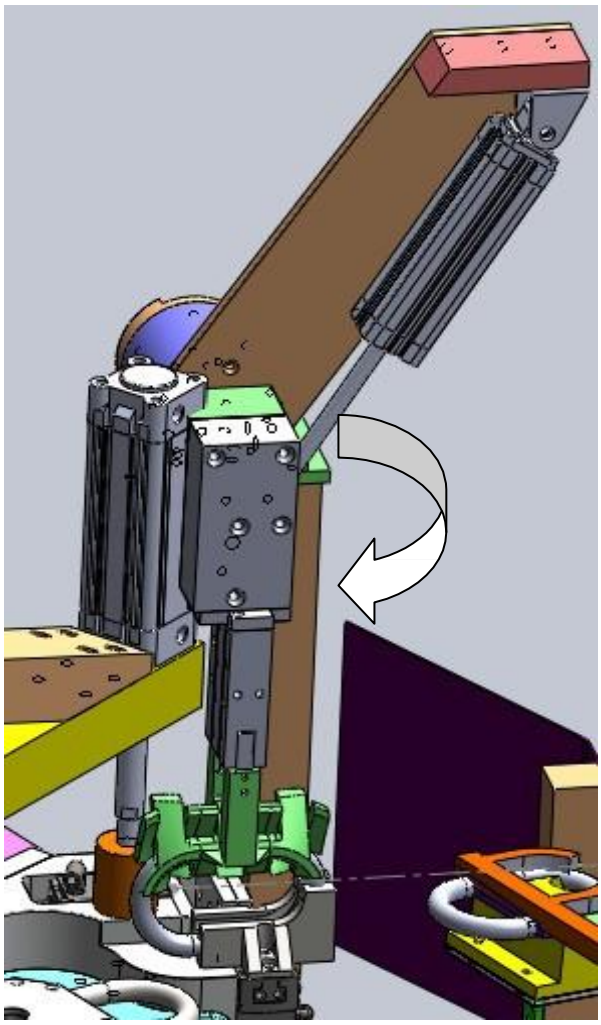


Figure 9: Top Link 90 Deg Rotation

Bottom Link Insertion into the Beef Shackling Tool

The Bottom Shackle Link is being handled simultaneously with the Top Link; the operations have been separated for ease of understanding

- While the bleed roller and shackle assembly are travelling on the bleed rail, the bottom shackle link must first go through two Guide Plates which bring the link into a restricted region ready for capture.
- (Note) Shackle chain not present.

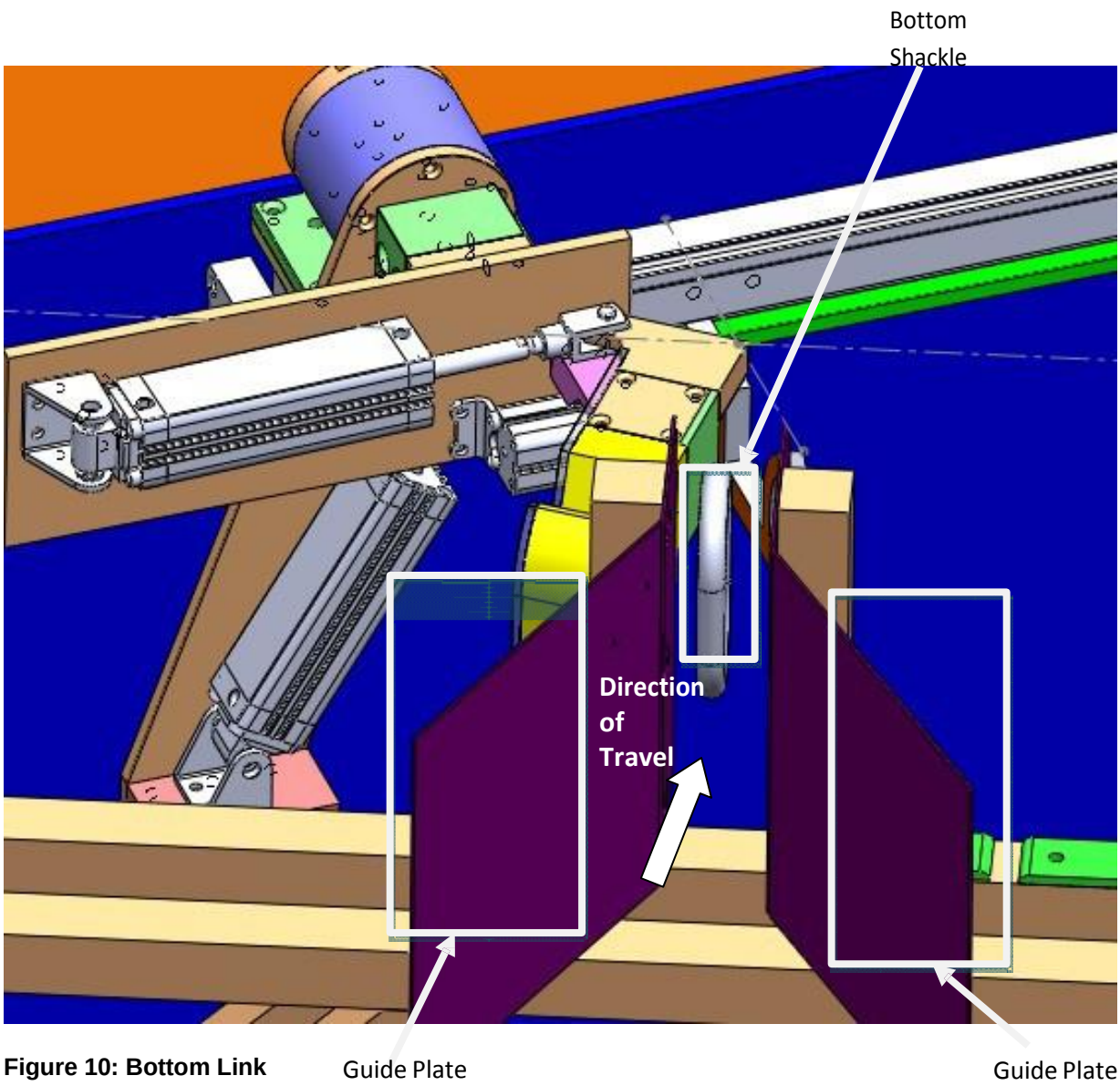


Figure 10: Bottom Link

- View of bottom shackle Link before capture.

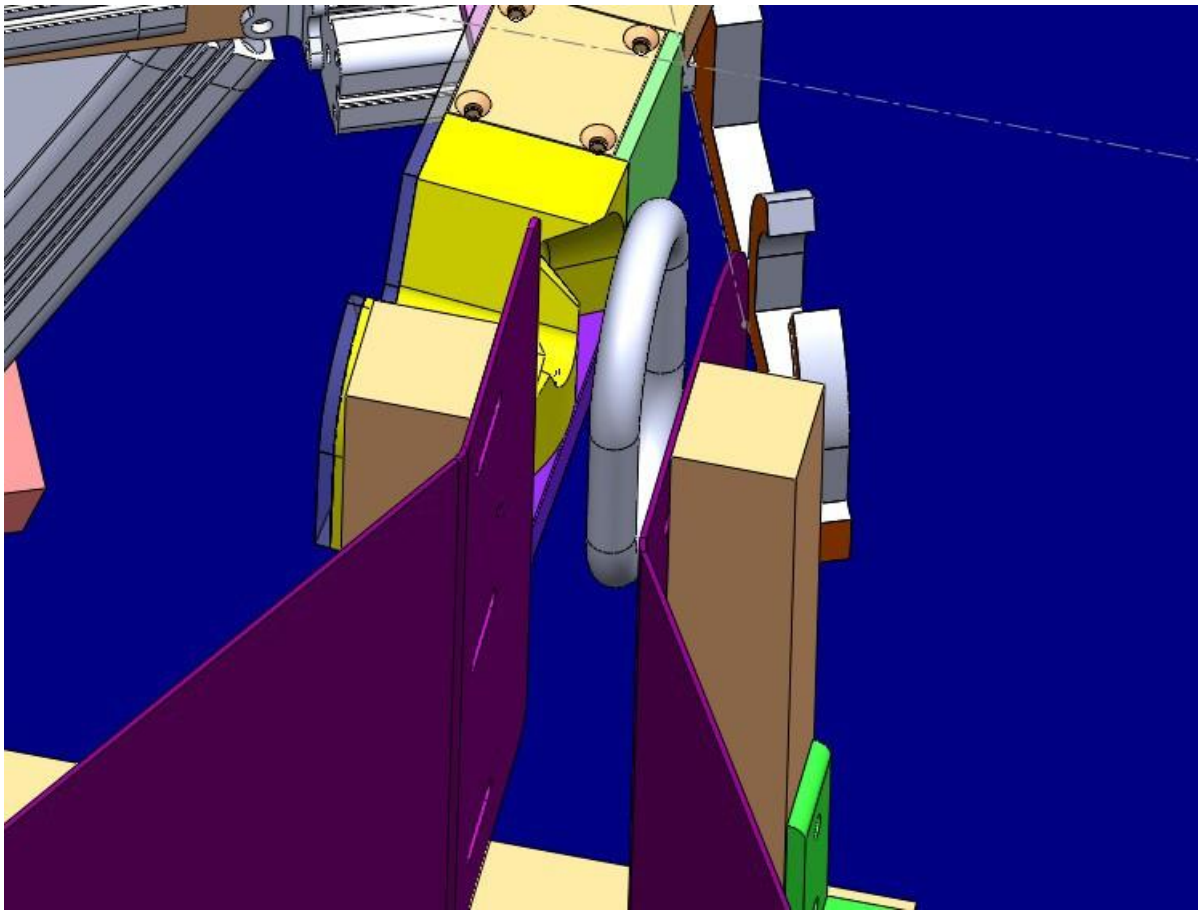


Figure 11: Bottom Link nest

- The bottom shackle is seated into a nylon nest (Yellow) by retracting compact cylinder 3. The Nest has a concavity the shape of the bottom shackle link as well as some lead in which allows it to capture the link from a variable position.
- The right arm grip (Orange) is then pulled back by a Compact Cylinder (out of view) to clamp the Bottom Link into the Nest.
- The next step is to rotate the shackle 90 degrees.

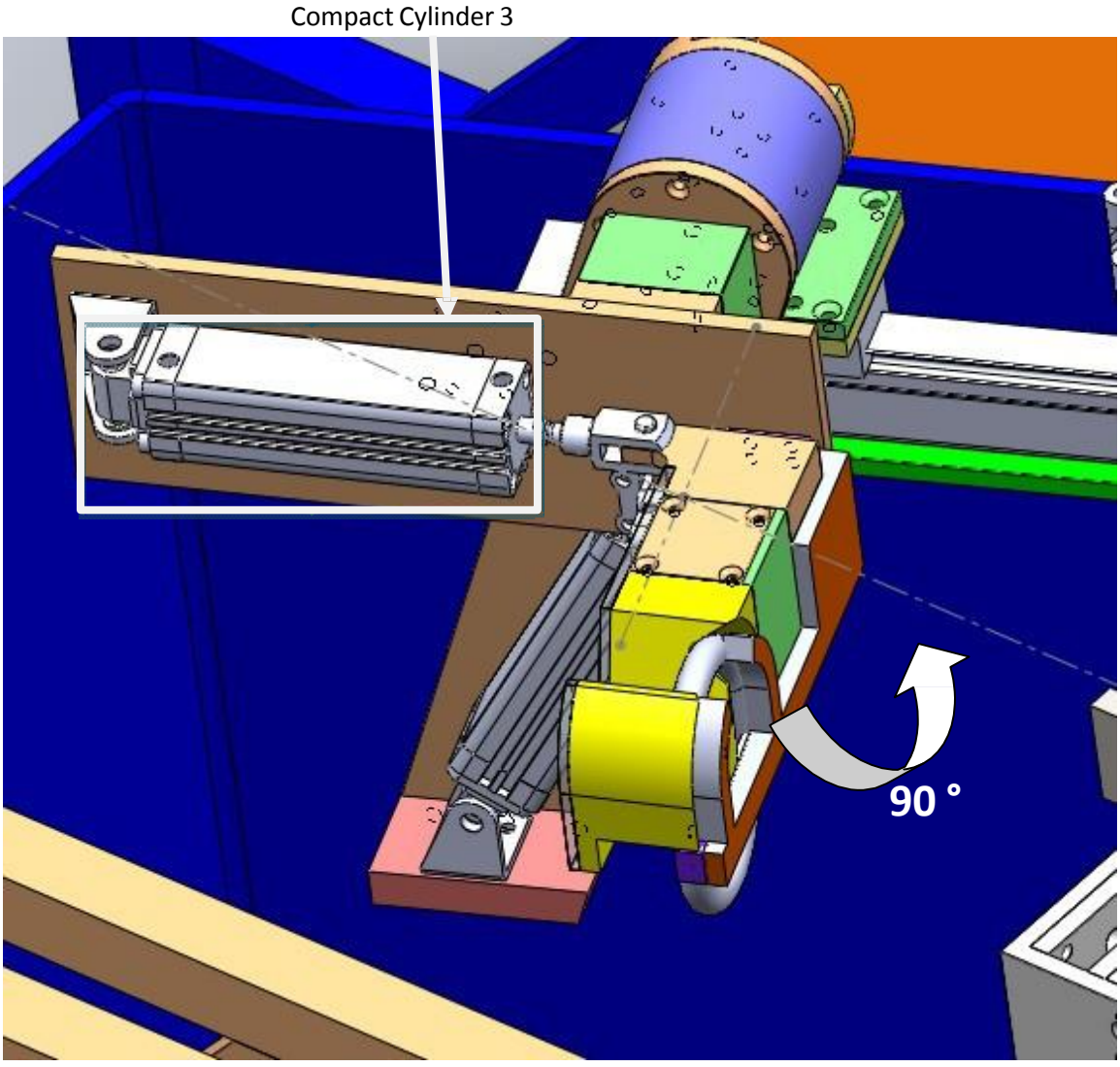


Figure 12: Bleed Roller Extracted

- The Bottom shackle is rotated 90 degrees by Compact Cylinder 4 extending and the whole assembly is moved linearly towards the BST using Rodless Cylinder 2

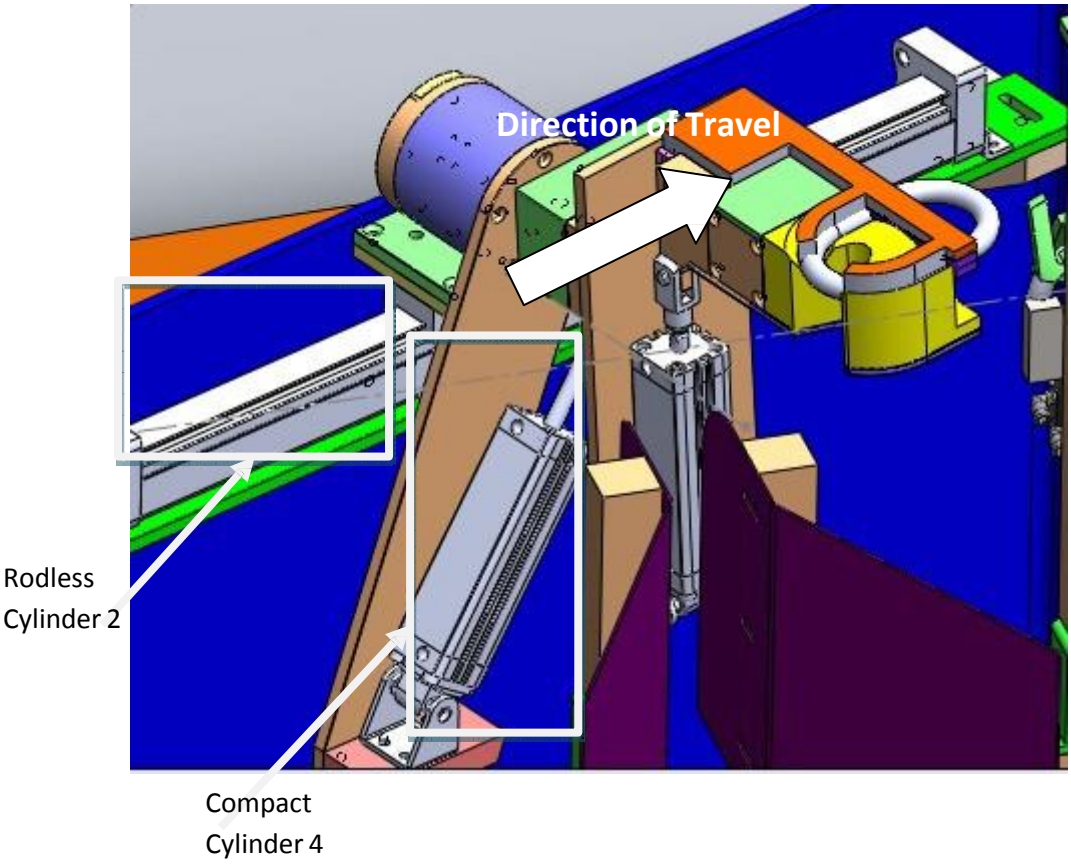


Figure 13: Bottom Shackle 90 Deg Rotation

- Prior to bottom link insertion Compact Cylinder 5 presses open the spring loaded grip on the BST.

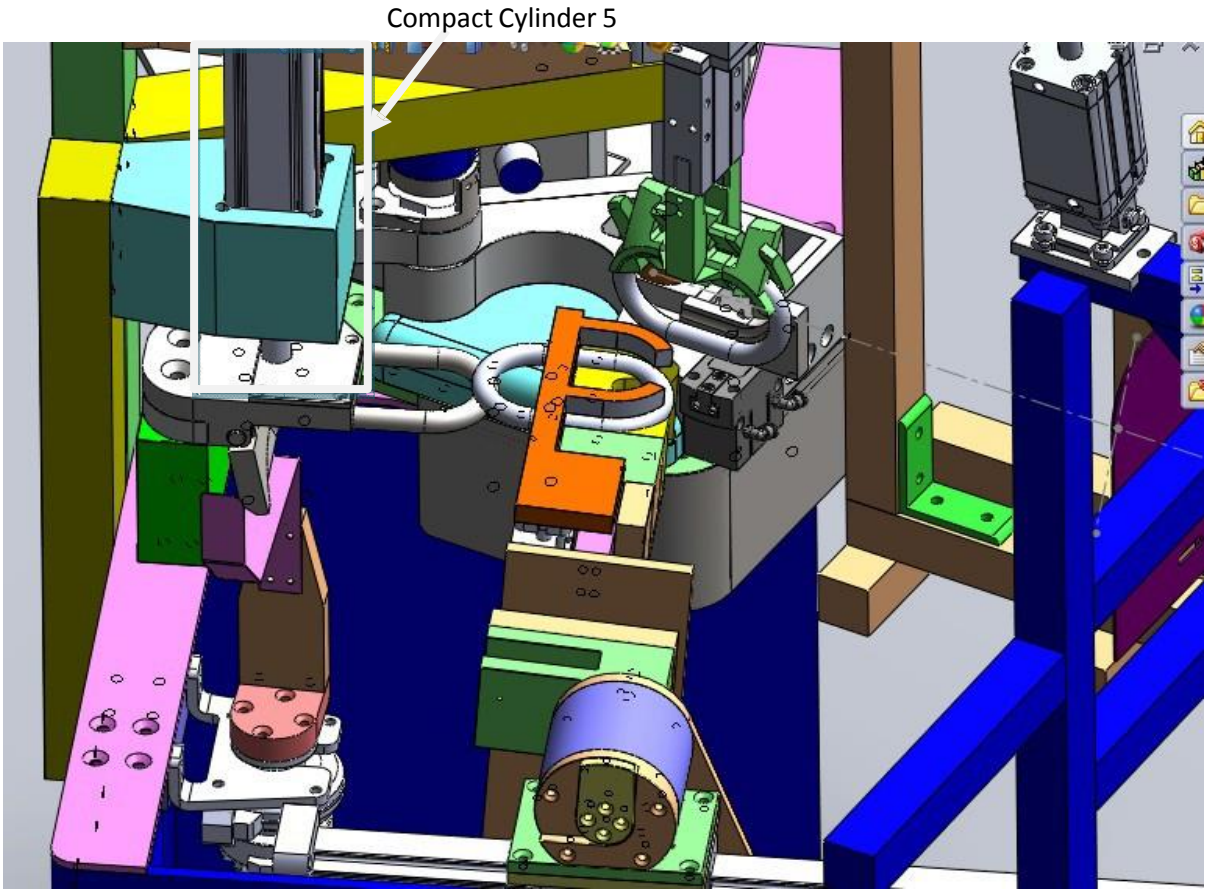


Figure 14: Spring Loaded Grip

- The bottom shackle link is located into position, Compact Cylinder 5 retracts to lock the shackle into place

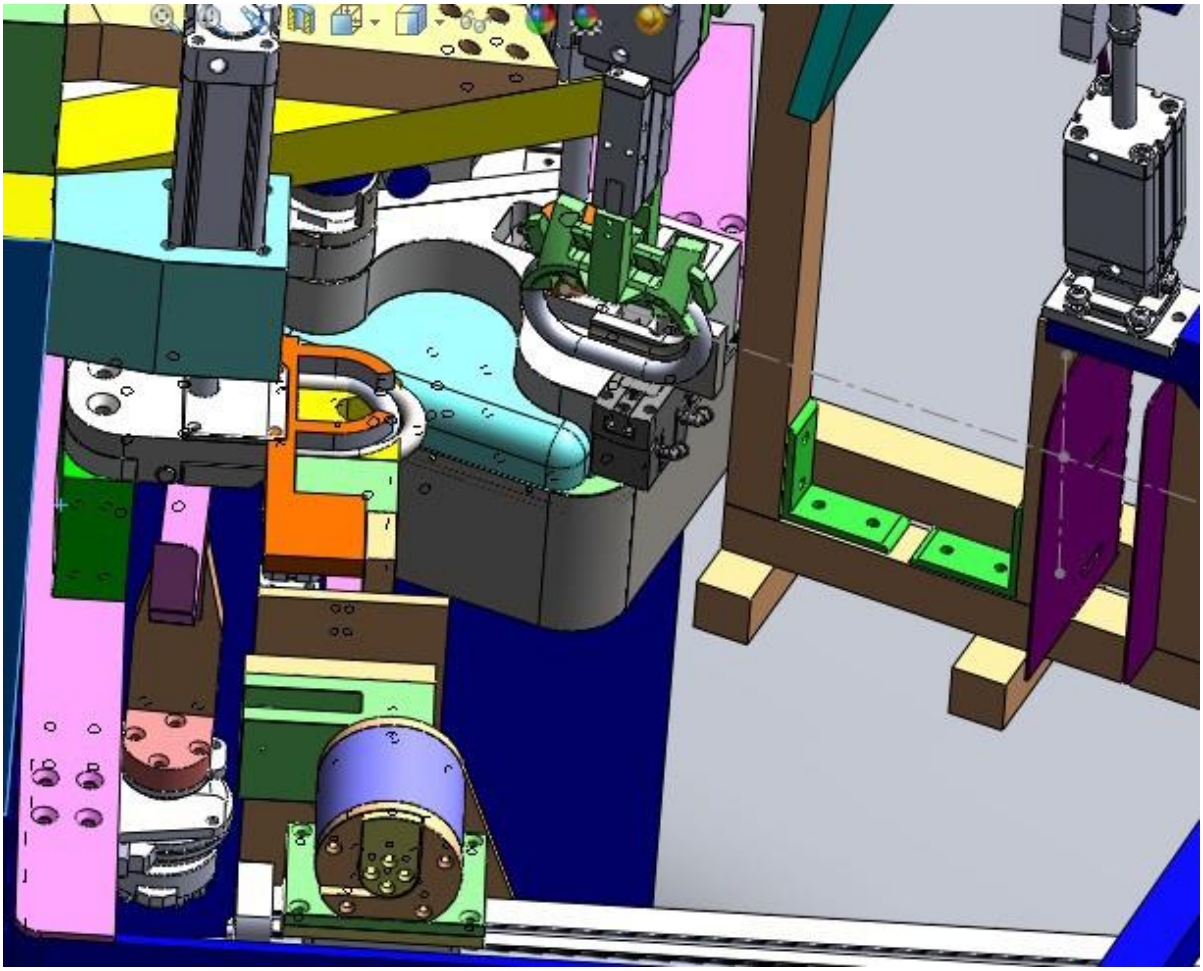


Figure 15: Bottom Shackle Located

- The Bottom shackle is now loaded and being held in place by a spring inside the BST
- The bottom shackle gripping assembly is then reset to the original position
- The shackle's chain is pushed into the inner jaws and onto the magnetic restraint of the BST by a Rotary Cylinder and Pusher Arm.

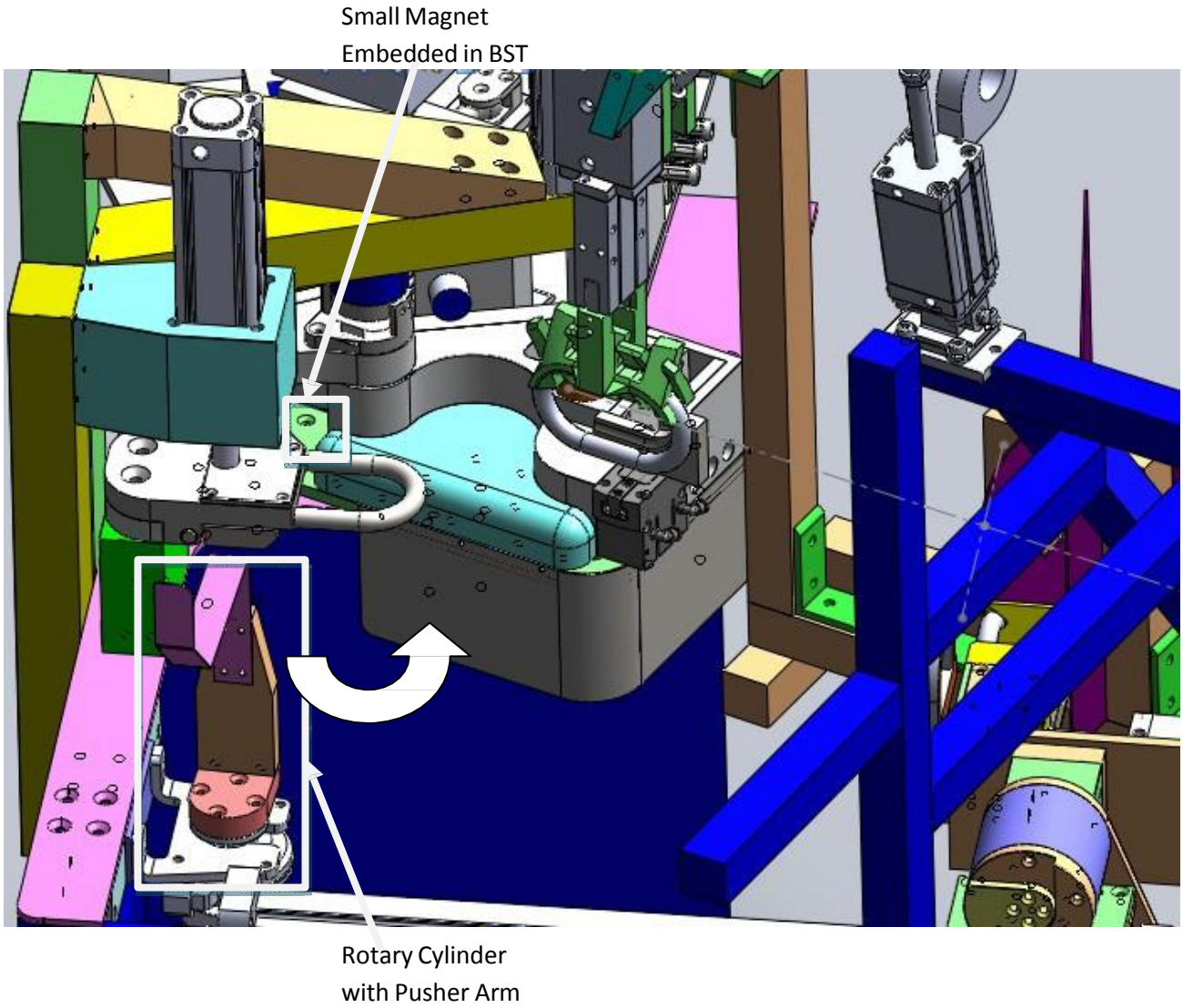


Figure 16: Completed Operation

3 Pneumatics

The pneumatic system provides the actuation for the mechanical parts of the system. It includes regulation of the air pressure, flow control, compact cylinders, associated tubing and connectors that link the system together. Shown below is a pneumatic flowchart for the ASLS. It should be noted that a source of compressed air is required for the Automated Shackle Loading System.

Figure 17, together with the detailed descriptions that follow, outlines the functionality of the pneumatic system.

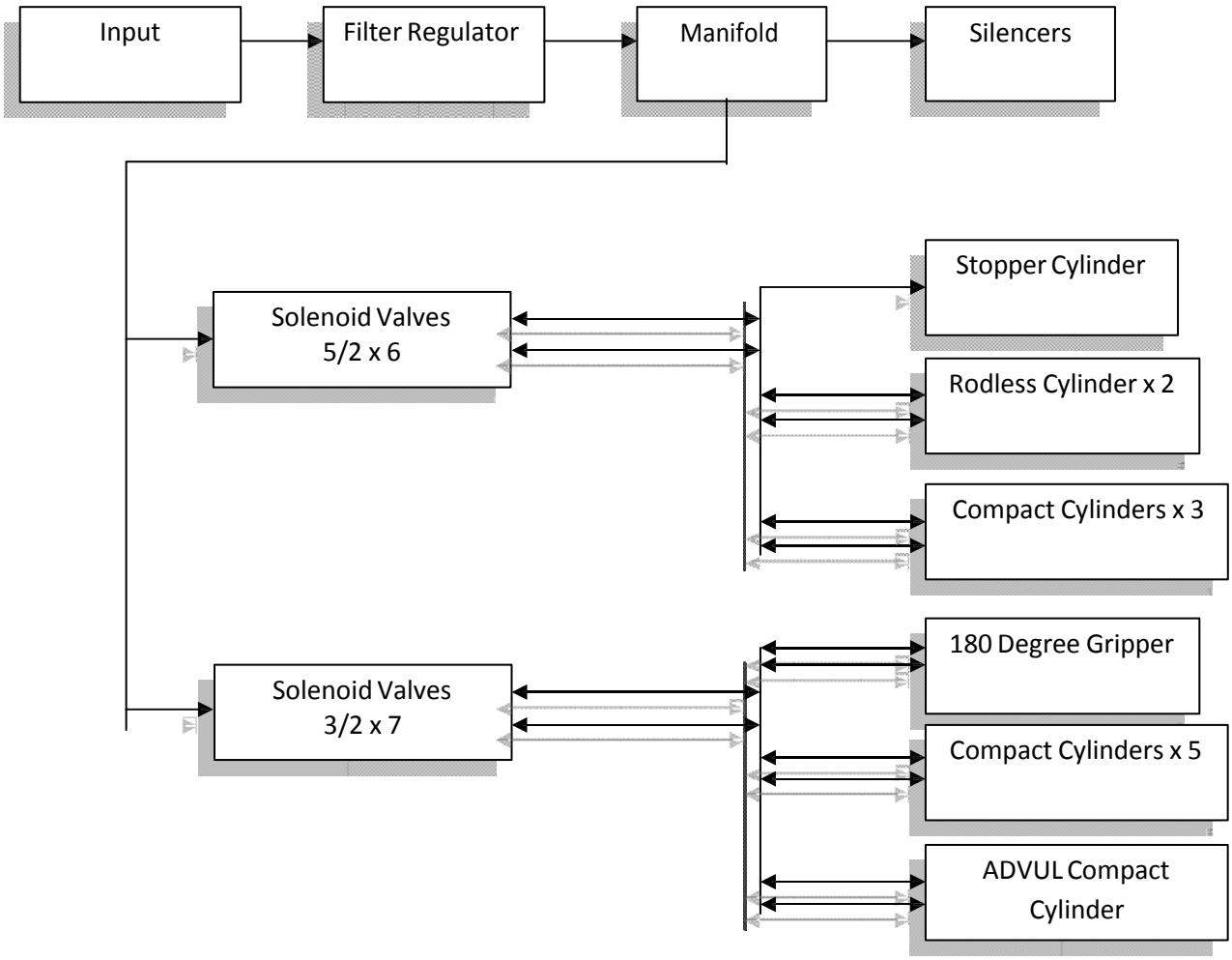


Figure 17: Pneumatic Flowchart

3.1 Input

Any air supply compressed to at least 6 Bar and supplied to the Isolation Valve (**Figure 18**) via an 8mm hose. It is preferable that the supplied air is clean and dry. The Isolation Valve allows the air supply to be shut off independently of the Filter Regulator so the working pressure does not need to be reset every time the unit is turned off or disconnected from the air supply.

3.2 Regulation

The Filter Regulator (**Figure 19**) reduces the pressure of the air supply to the desired working pressure. It also has the job of removing any contaminants such as water, dust or oil from the air supply so as not to damage or increase wear or corrosion on components.

Figure 18: Isolation Valve

Figure 19: Filter Regulator

3.3 Rodless Cylinder

The Rodless Cylinder (**Figure 20**) moves a carousel up and down a slide. The direction of travel depends on which of its two input/output ports are intake or exhaust. The operating speed is dependent on the amount of flow across the two ports.

Figure 20: Rodless Cylinder

3.4 Solenoid Valve

The Solenoid Valves (**Figure 21**) takes an input of compressed air and directs it to two ports based on digital electrical signals from the Control System. The returned air is exhausted via the exhaust port.

Figure 21: Solenoid Valve

Of the two Solenoid Valves used one is of the type 5/2 and the other 3/2. These two different types behave very similarly with the only difference being the 5/2 variety in addition to directing flow to its two ports, can also seal off both ports so as to not allow flow in either direction through either port.

The signals from the PLC are digital values with zero volts representing a digital low (0) and twenty four volts representing a digital high (1). The following truth tables (**Figure 22**) detail all possible digital inputs and the corresponding action of the valve.

5/2 Solenoid Valve		
Input 1	**Input 2**	**Action**
0	0	No Flow
0	1	Flow Through Port 1
1	0	Flow Through Port 2
1	1	Undefined (No Change)

3/2 Solenoid Valve		
Input 1	**Input 2**	**Action**
0	0	Undefined (No Change)
0	1	Flow Through Port 1
1	0	Flow Through Port 2
1	1	Undefined (No Change)

Figure 22: Solenoid Valve truth tables

3.5 Flow Control Valves

The Flow Control Valves (**Figure 23**) are used to control the flow of air manually. The amount of flow to the actuator needs to be set only once to calibrate the speed of the actuator.

Figure 23: Flow Control Valve

3.6 Compact Cylinder

The Compact Cylinder (**Figure 24**) is an actuator that takes air input from a solenoid valve, extending or retracting a shaft depending on the direction of flow to its input/output ports.

Figure 24: Compact Cylinder

3.7 180 Degree Gripper

The 180 Degree Gripper (Figure 25) is an actuator that takes an air input from a solenoid valve. Depending on the flow across its input/output ports the 180 Degree Gripper will close or open its two fingers 180 degrees.

Figure 25: 180 Degree Gripper

3.8 Silencers

Silencers (**Figure 26**) are placed wherever air is exhausted to atmosphere to help reduce the operating noise of the device.

Figure 26: Silencer

4 Electrical

All electrical components used in the Automated Shackle Loading System require 24Volt DC power. As the supplied power is 240 Volt AC, a 24Volt DC transformer has been used to supply power (**Figure 27**)

Figure 27: 24Volt DC Power Supply

The electrical component the transformer supplies 24VDC to are as follows:

- PLC
- Solenoid valves
- Sensors

5 Control System

The Control System is facilitated by a Programmable Logic Controller (PLC) (**Figure 28**) which interfaces between the electrical parts of the ASLS.

The PLC chosen has the following required functions:

- analogue output
- analogue input
- digital input
- digital output
- LCD Display

Figure 28: Unitronics PLC

The diagram below (**Figure 29**) shows all the input/output interactions of the PLC.

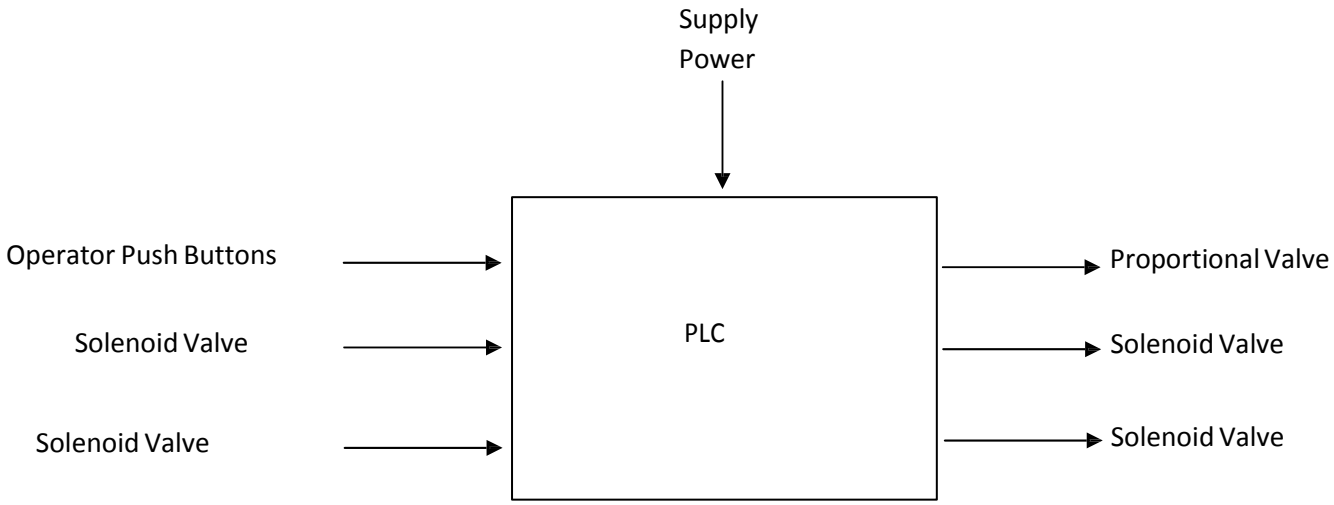
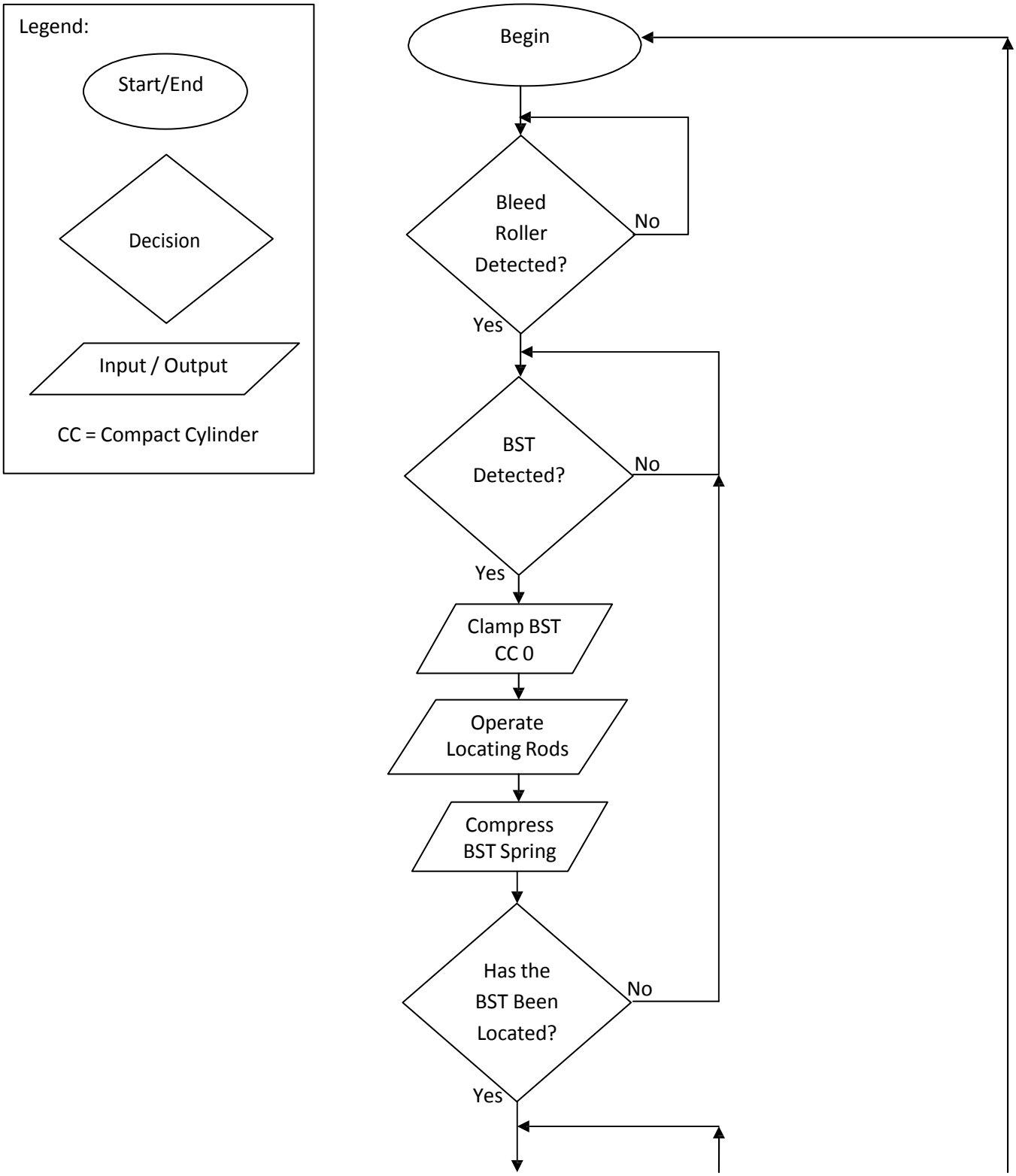
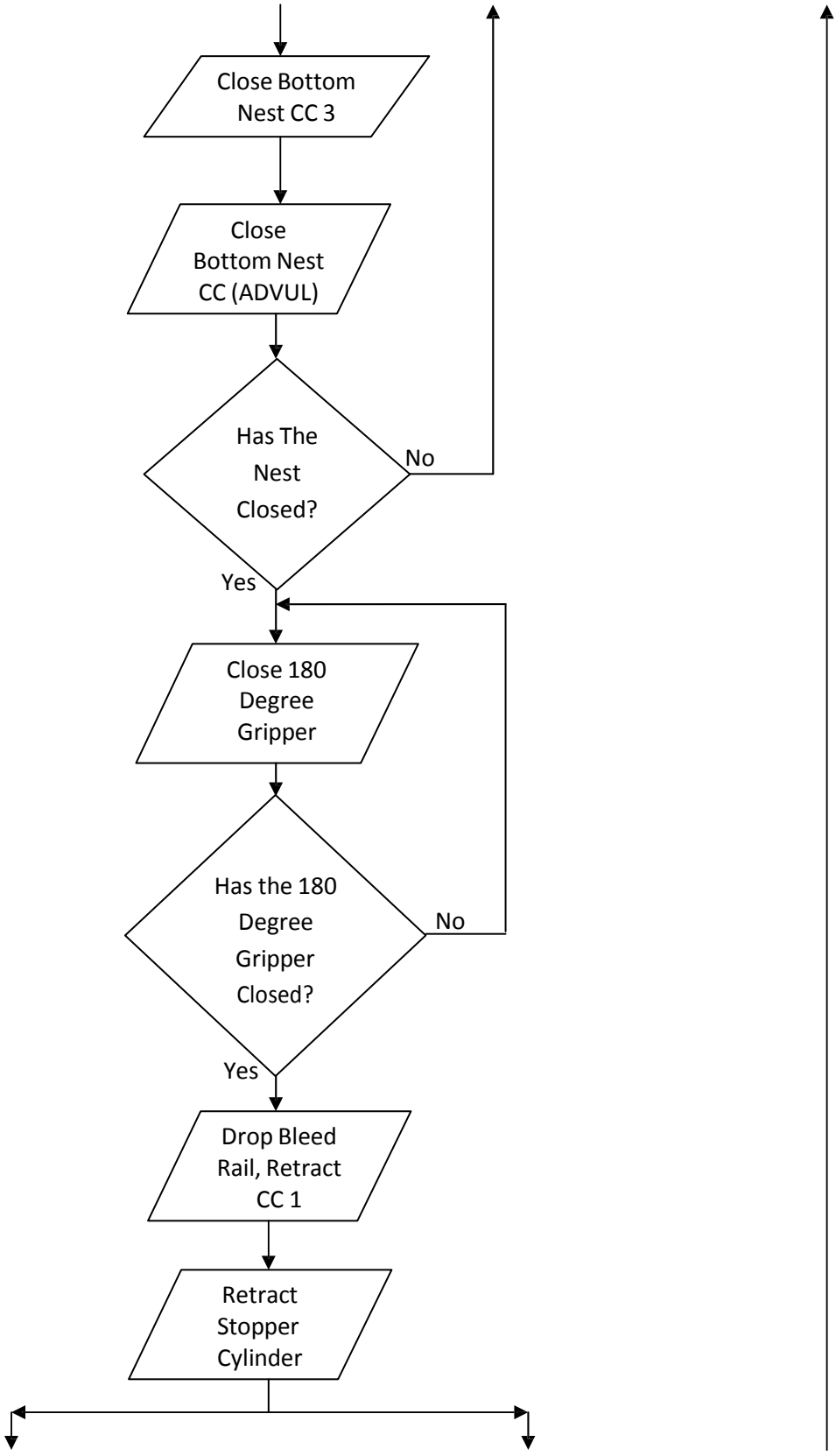
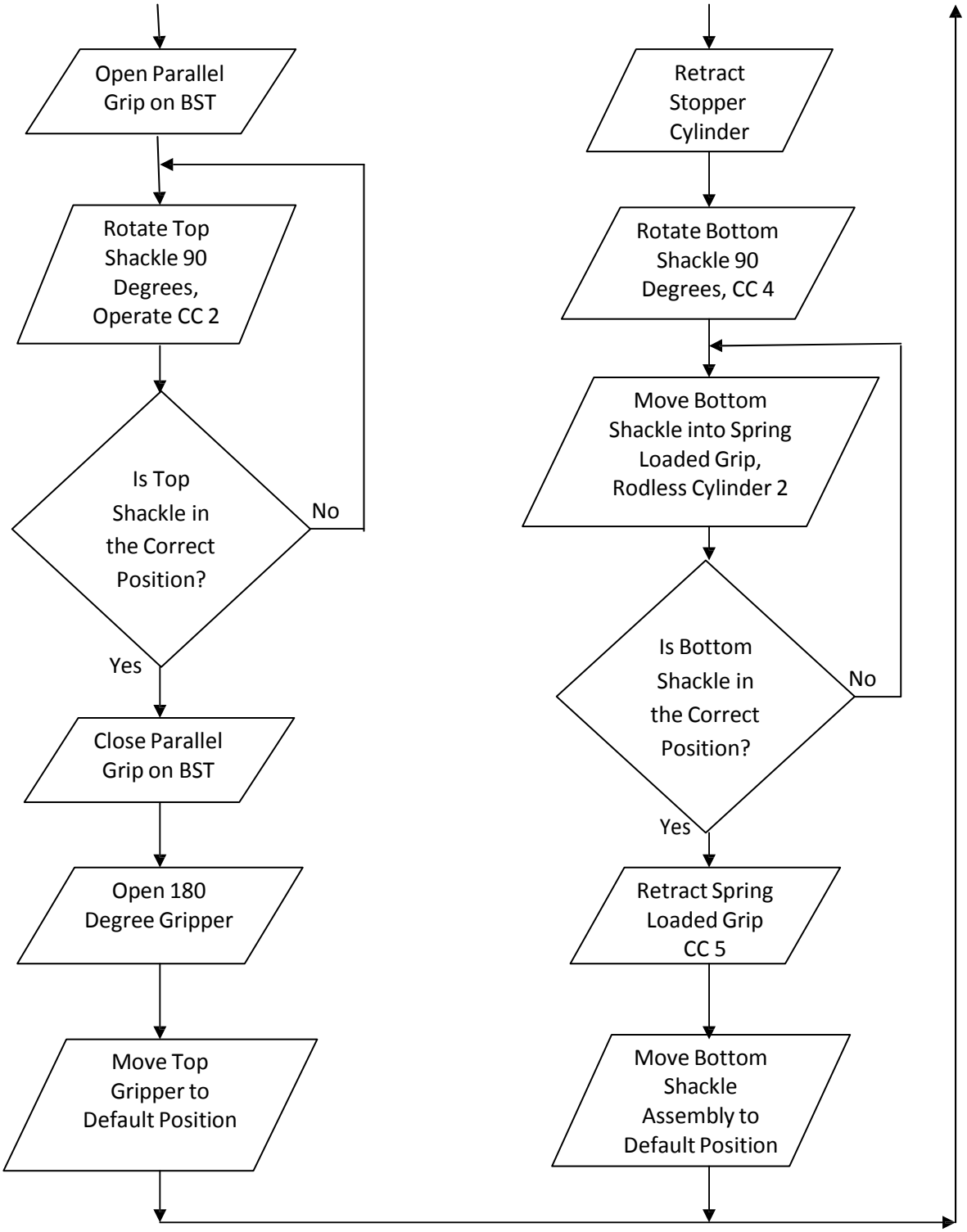


Figure 29: Input/Output Unitronics PLC

6 Program Flowchart




Close Bottom Nest CC 3
Close Bottom Nest CC (ADVUL)
Has The Nest Closed?
No
Yes
Close 180 Degree Gripper
Has the 180 Degree Gripper Closed?
No
Yes
Drop Bleed Rail, Retract CC 1
Retract Stopper Cylinder


Open Parallel Grip on BST
Rotate Top Shackle 90 Degrees, Operate CC 2
Is Top Shackle in the Correct Position?
No
Yes
Close Parallel Grip on BST
Open 180 Degree Gripper
Move Top Gripper to Default Position
Retract Stopper Cylinder
Rotate Bottom Shackle 90 Degrees, CC 4
Move Bottom Shackle into Spring Loaded Grip, Rodless Cylinder 2
Is Bottom Shackle in the Correct Position?
No
Yes
Retract Spring Loaded Grip CC 5
Move Bottom Shackle Assembly to Default Position

6.1 Movement Relationship

The Movement of the shackles is governed by the following steps

- The bleed roller is guided into position by the Rodless cylinder and the pneumatic stopper into a default position
- From this known position the bottom shackle is gripped by moving two compact cylinders
- Once the bottom shackle is gripped the top shackle can be gripped
- The bleed rail is dropped so the bleed roller can be separated from the shackles
- Both shackles move simultaneously into their locations
- The top shackle moves 90 degrees by a compact cylinder and mechanical arrangement
- The bottom shackle moves into position also by moving 90 degrees, then by Rodless cylinder
- The system now moves back to its default state ready for the next bleed roller to arrive

7 Operation

The steps that follow the procedure for operation of the Automated Shackle Loading System

- Turn on the air by turning the Isolation Valve counter-clockwise (**Figure 30**).

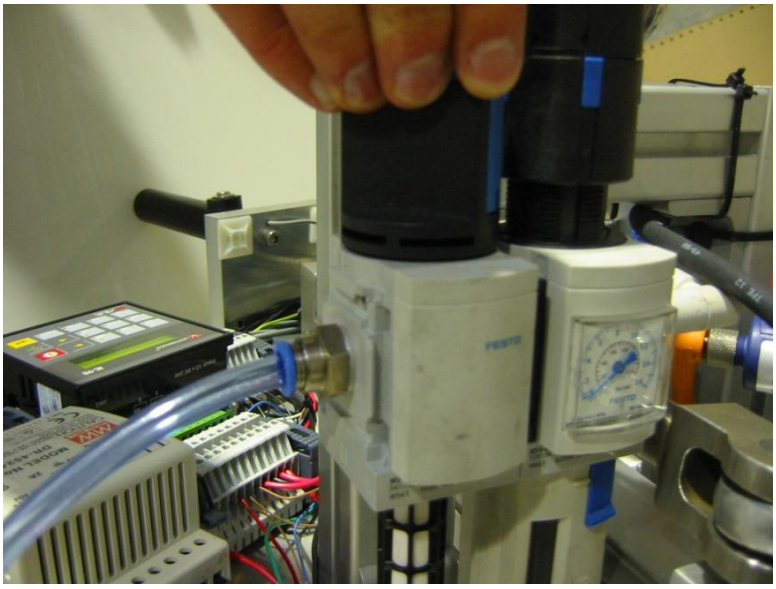


Figure 30: Turning the air on

- Inspect the Filter Regulator and ensure that the working pressure is at between 6 and 8 bar. If the pressure needs to be adjusted do so by turning the knob on the Filter Regulator (**Figure 31**).

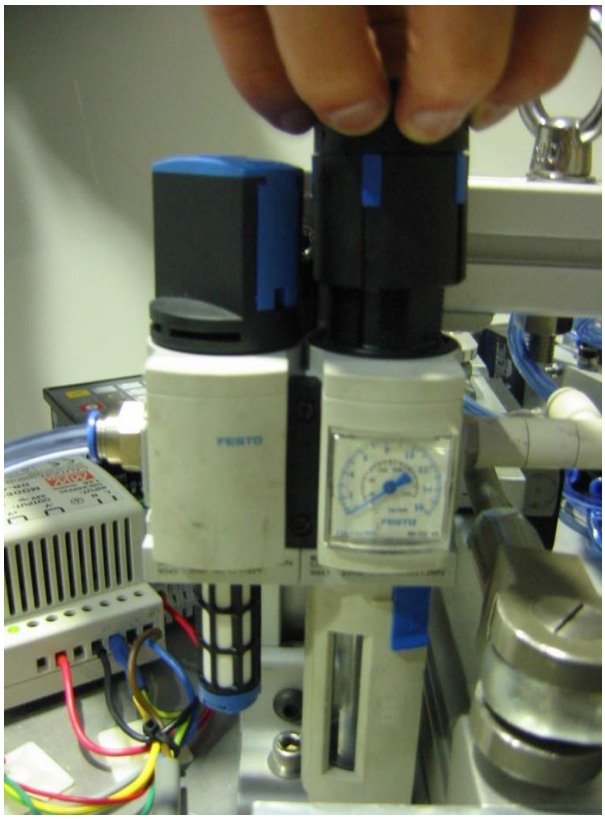


Figure 31: Adjusting air pressure

- Loading the BST to the ASLS, the operator simply places the BST on the docking station of the ASLS then slides the tool towards negative groves located on the ASLS. The negative groves locate the BST into default position.

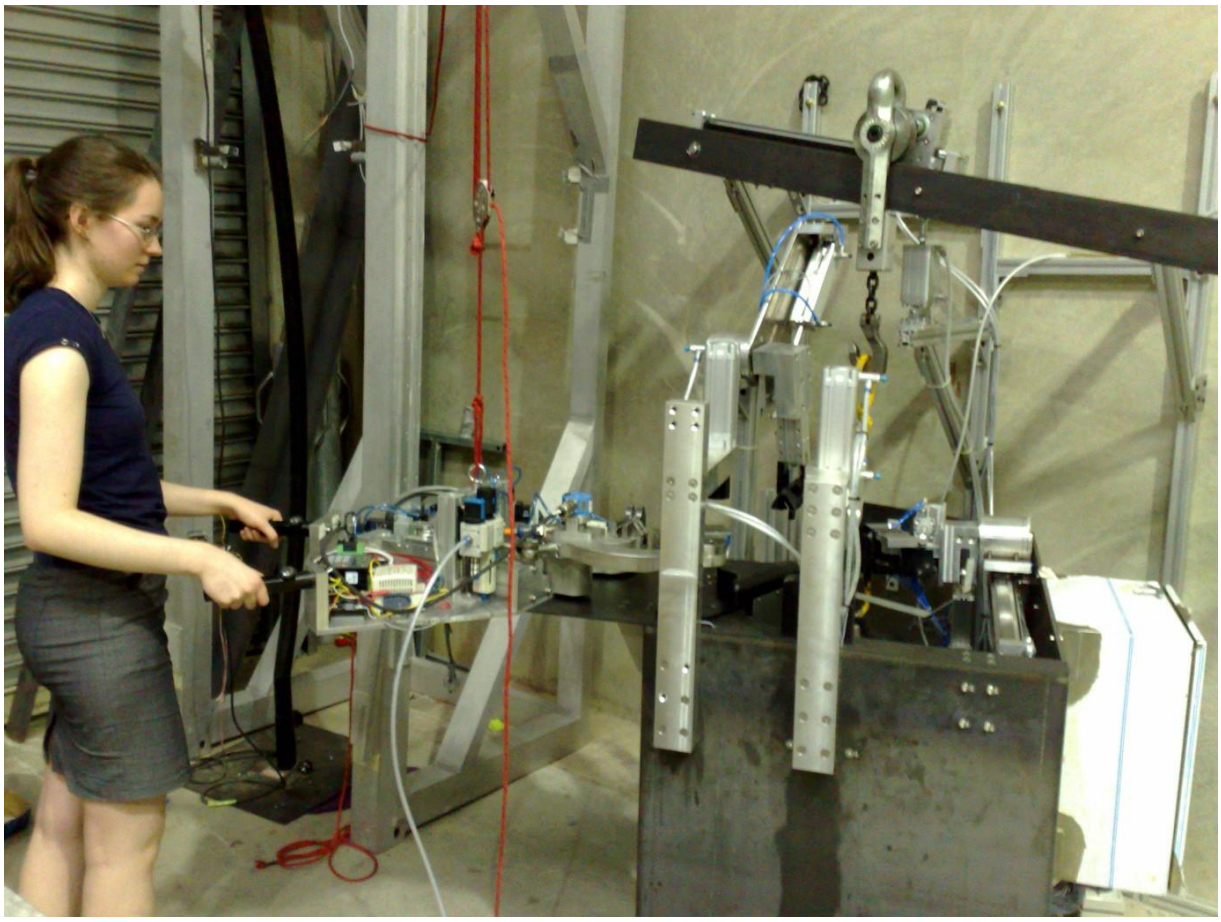


Figure 32: Loading the BST to the ASLS

- Image showing the BST loaded onto the ASLS

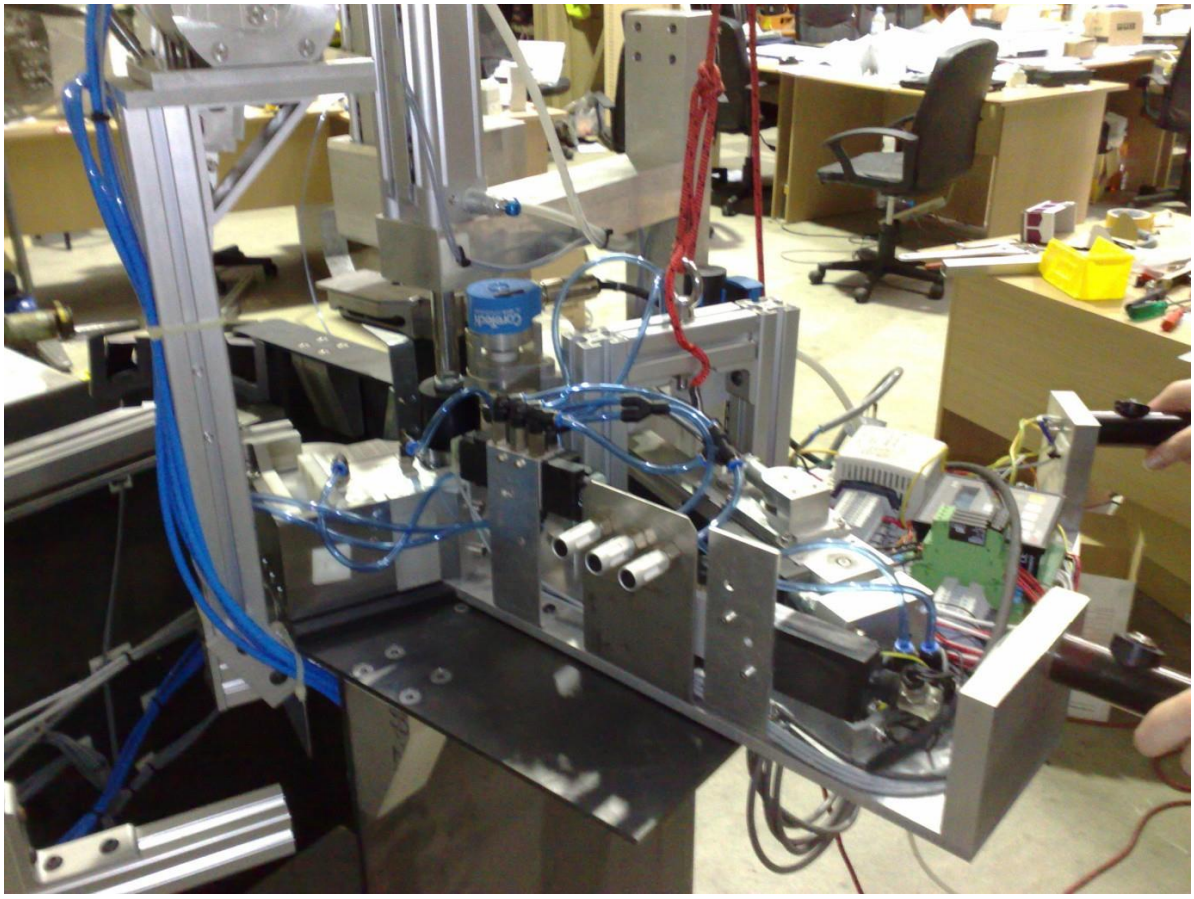


Figure 33: BST Loaded onto the ASLS

8 Results

Testing of the Automated Shackle Loading System performed exactly as intended, the ASLS grips the bottom shackle and pushes the link into a nylon nest, following this the ASLS then grips the top shackle, releases the bleed roller and places the shackle links in the appropriate Beef Shackling Tool grip.

The total time taken to load the shackles was 12 seconds

Figure 34: Shackle Links Successfully Loaded into the Beef Shackling Tool

9 Construction

When choosing construction materials the intended work environment had to be considered, and for this reason the Automated Shackle Loading System is constructed primarily out of Aluminium and Nylon.

The exceptions to this are mostly bushings and pneumatic fittings/tubing which are made out of inert plastics.

Aluminium was used on parts due to weight considerations of moving components or where high strength was not required, Aluminium once anodised exhibits excellent corrosion resistance.

Nylon was selected for the materials good wear characteristics as well as weight considerations and where high strength was not required.

10 Development Path

As can be seen in the research and development path in **Figure 33**, this area of research can be broken down into three specific directions; Beef Hock Location Vision System, the Prototype Operator Controlled Beef Shackling System and now the Prototype Robot Beef Shackling System.

10.1 Operator Controlled Beef Shackling System

This branch of research would involve further developing the Automated Beef Shackling Tool into a working model for use in meat processing plants including design of any peripheral equipment. This would also involve a full trial in a real plant to test the system and assess any unforseen issues that may arise. Development of this in-plant working model would also be of great importance to the development of a greater Robotic Beef Shackling System.

10.2 Beef Hock Location Vision System

A Beef Hock Location Vision System would aid further research into a greater Robotic Beef Shackling System by allowing any robotic system to easily track and locate the beast's leg for shackling.

10.3 Prototype Robotic Beef Shackling System

Research into the Prototype Robotic Beef Shackling System would remove the human operator of the Beef Shackling Tool and replace it with an autonomous robot. This will drastically reduce labour content, OH&S issues and cost associated with shackling.

Note that research into the Beef Hock location Vision System must first be completed prior to beginning this project.

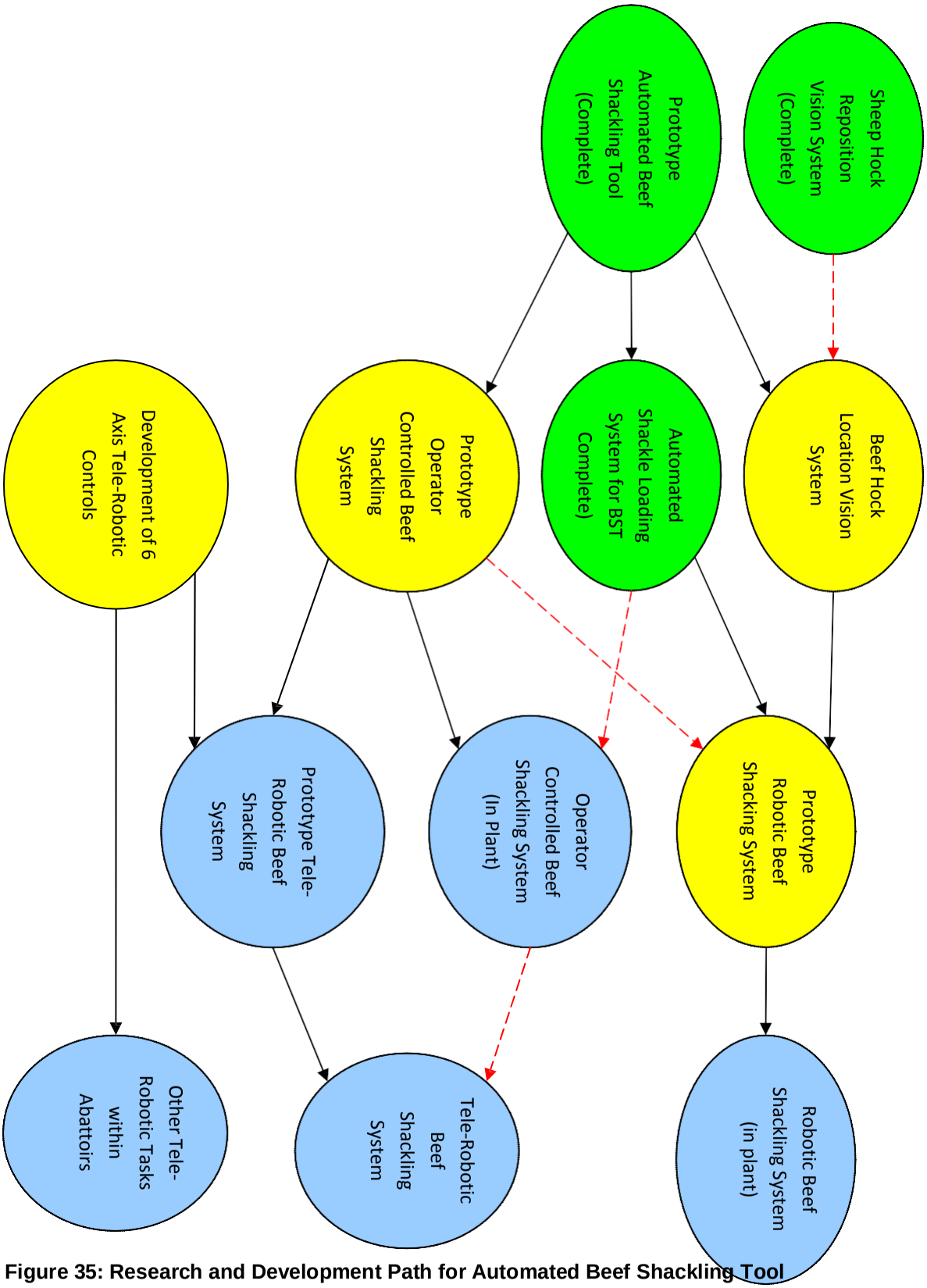


Figure 35: Research and Development Path for Automated Beef Shackling Tool

10. **Refinement**

Areas of the ASLS that can be refined:

Bottom shackle grips. After testing the prototype a previous design of gripping the bottom shackle was found to work more efficiently. The system would use a 180 degree gripper similar to the one used to grip the top shackle. This will reduce the number of components used. The redesign will also make the system simpler which in turn reduces costs

To suit the Beef Shackling Tool and the Automated Shackle Loading System to abattoirs, autonomous winch control will be used to grab the bleed roller automatically or manually controlled by an operator as in figure 36

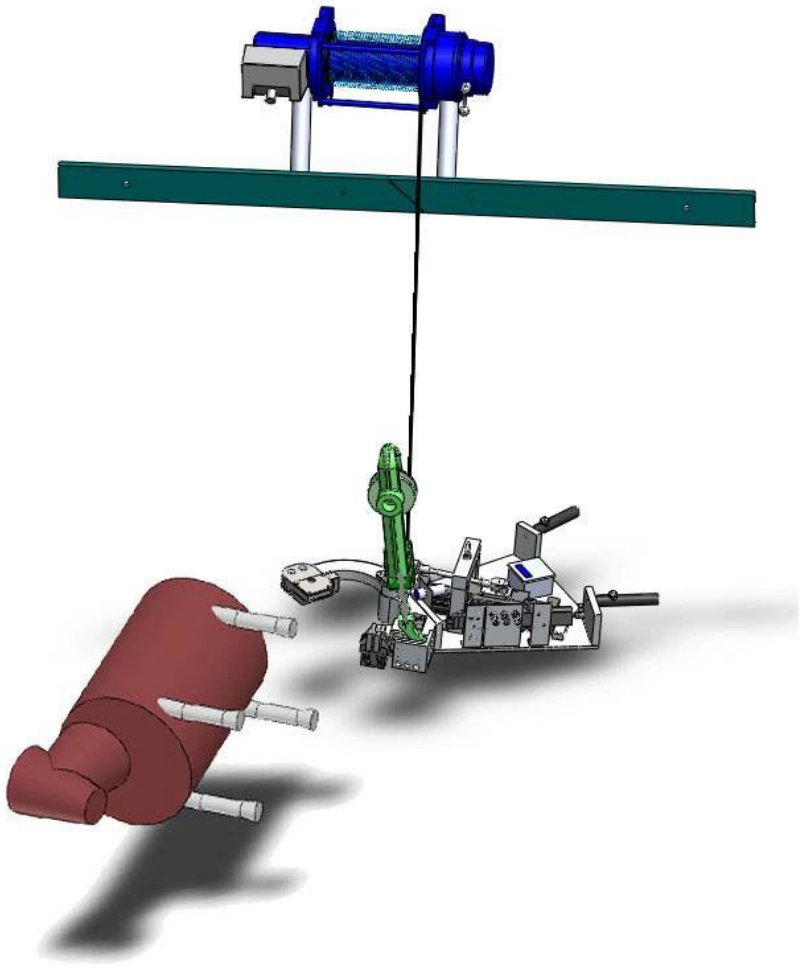


Figure 36: Winch control to grab the bleed roller automatically or manually controlled by an operator

To aid the operator and or robot the Beef Shackling Tool will be constructed from smaller components. The smaller components reduce the weight of the tool providing increased manoeuvrability. The reduction in weight also reduces the load on the robot which means less strain on components.

11. Summary

This report sees the completion of milestone 3 and hence the completion of project no. A.TEC.0069, the Automated Shackle Loading System. The prototype was designed and constructed, and a trial of the system was carried out successfully. The completion of the system clearly points the way forward for further research into this area with the ultimate goal of a greater system combining this and other research into a completely automated system which not only reduces labour contact but also reduced OH&S hazards involved in the shackling process.