ILSCO Robotic Laser Marking Cell

A Baccalaureate Thesis Senior Design Report submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

This document is a partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering &
Mechanical Engineering Technology

by

Daniel Tokarczyk
Matthew Cecil
John Morris

April 2020

Faculty Advisor: Janet Dong

Project Sponsor: ILSCO Corporation

Abstract

ILSCO Corporation in Cincinnati, Ohio has coordinated with the University of Cincinnati to address an issue regarding their automated part marker cell. ILSCO is a manufacturer of electrical connectors and accessories with 120 years of experience and service to the electrical industry. The robotic cell in question was designed with the intent that 30 different part numbers are marked with a laser in their respective positions on the 30 different part types. Each part that is made is required to have part traceability including the part number, material type, conduction range, and connector type. The robotic cell was designed to handle a large throughput of parts during a shift and have the ability to easily changeover to a different batch of parts when necessary. However, the robotic cell was not able to meet ILSCO requirements, with an average cycle time of 40 seconds per part when working properly. The cell is not being used in production due to how often the cell needs to be reset due to design flaws, resulting in lower throughput of parts than at optimal.

The goal for this project was to work with ILSCO and provide a cost effective re-engineered design of the robotic cell which reduced the cycle time and improved production reliability. After many design concept reviews and making sure our design met the laser safety guidelines, a semi-autonomous design was chosen in which an operator could buffer parts onto an infeed conveyor, making sure the parts are already placed in the correct orientation to simplify the robot programming and increase production. Future work and a simulation of the design was provided to ensure that the project is able to be carried out at a later date due to the coronavirus outbreak placing constraints on the realization.

Special Acknowledgements

The University of Cincinnati Engineering Team would like to thank our sponsor, ILSCO, for helping us with the realization of our design and getting to work with their team.

- Steve Jackson
- Jacob Frysinger
- Drew Kramer
- Ted Kappers
- Rod Derek
- Michael Klebau

Table of Contents

List of Figures

List of Tables

Problem Statement

The problem presented involves the infeed design in which an entire batch of parts is dumped into a hopper and carried into the cell for marking via an inclined conveyor. This process can cause the thin, translucent conveyor belt to be nicked as the parts fell onto it. Dirt and other particulate get trapped in the nicks on the conveyor belt causing the vision system to become unreliable when a picture is captured and failure of the robot to pick up the part. The current infeed method causes parts to occasionally overlap and be presented to the vision system in an unorganized fashion. These orientation issues also cause difficulty for the vision system and robotic arm to pick the parts from the conveyor as well as increase the complexity of the programs necessary for the operation. All of these problems result in inconsistent part orientation resulting in increased cycle time.

Project Objectives

The objective of the project is to redesign the cell in any way that would address the mentioned issues and allow the cell to run all required part numbers while improving cycle time and reliability. Each of the 30 parts need to have a good quality of marking so that the part can have traceability back to it, including the part number and specifications of the part. The most critical requirement of this is to redesign the infeed of parts to be in a controlled manner. Thus, the infeed process is the driving factor of the design. The rest of the cell will be altered, as necessary, to accommodate the infeed. The intent of the new infeed was that parts will be presented to the robotic arm in the most optimal position for marking. This would reduce cycle time by eliminating the robot repositioning steps required before the part can be presented to the laser for marking.

The scope and limits of the project pertain to the one laser marking cell. The cell includes the infeed, transportation of the part to the laser marker, and the outfeed. The 30 different part types were scoped to the largest and smallest part type with the opportunity to expand the parts as time allows. Limitations include financial and time constraints as well as the work required from in-house technical experts at ILSCO such as machinists and robot programmers. Some of these factors are dependent on each other such as extensive reprogramming requiring significant time investment from the robot programmer. There are also safety limitations that must be considered regarding the laser being used. All these factors must be considered from the project's inception to ensure it proceeds as planned and prevents major revisions later.

Initial Process Flow

Step 1: A batch of parts are dumped into a hopper and slide down the sheet metal surface toward the incline conveyor seen in Figure 1. Figure 2 shows one of the complications of this process where a part is stuck in the hopper during the loading process.

Figure 1: Hopper & Incline Conveyor

Figure 2: Stuck Part

Step 2: As seen in Figure 3, the incline conveyor has rungs large enough to pick up the parts. The inclined material infeed conveyor in Figure 4 picks up the parts sliding down the hopper and brings them to the top of the black rectangular sheet metal pictured below. Then, the parts slide down the opposite side on sheet metal.

Figure 4: Infeed Conveyor

Figure 3: Conveyor Rungs

Step 3: The parts turn 90 degrees and drop a short distance from the infeed chute to land on the backlit conveyor as seen in Figure 5. The backlit conveyor is the off-white object shown. A brush is located above the conveyor to separate parts that may overlap, but it is inconsistent in its ability to perform the task causing the vision system to miss the parts.

Figure 5: Drop Chute onto Backlit Conveyor

Step 4: Shown in Figure 6, the backlit conveyor transports the parts until they are above the backlit section of the conveyor when a sensor detects the part and stops the conveyor. The camera, located on the end of the robot arm, detects the orientation of the part. For each part, there are at least six different pictures in the vision software to tell the robot what orientation the part is in. Then, the robot will grasp a part with its two-finger gripper and place it on a backlit table to reposition the part to the correct orientation before presenting it to the laser marker. An important note is that these photos were only possible because we opened the cell. The cell is closed off to the operator during operation because of the high-powered laser.

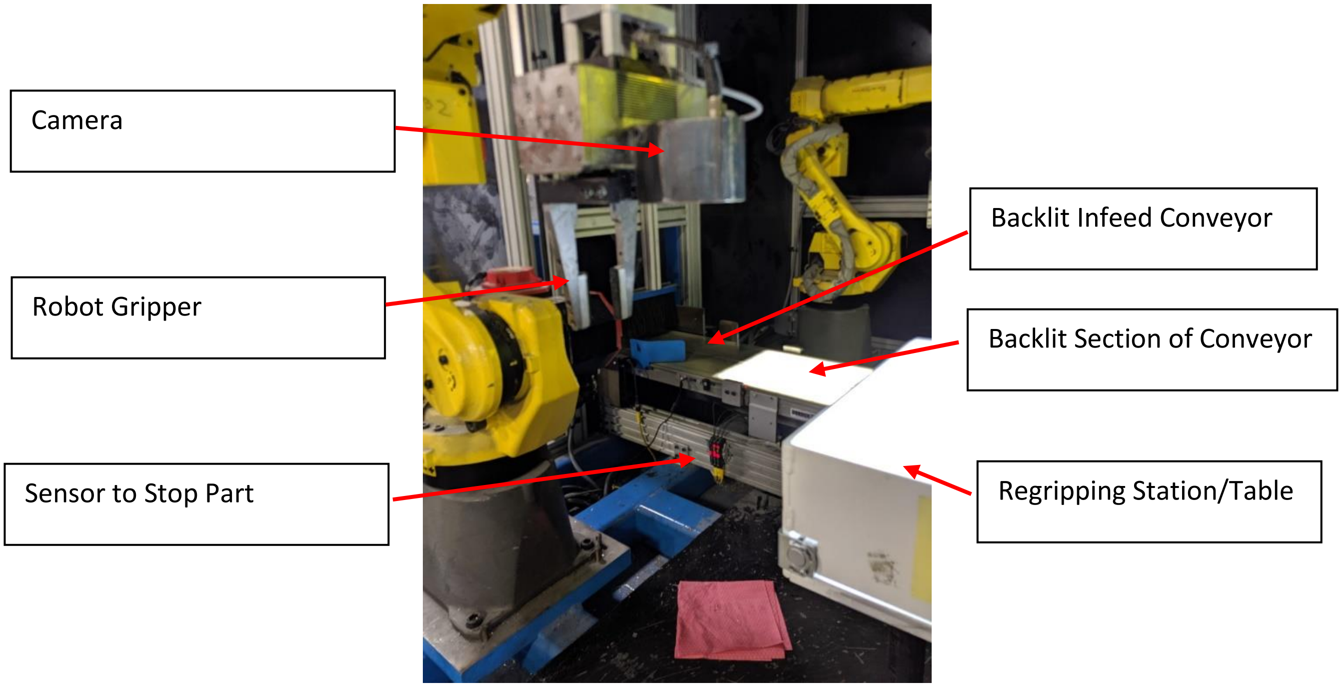


Figure 6: Robot Positioning

Step 5: After the part has been orientated correctly, the robot brings the part from the backlit table to the laser marker and holds the part while the laser marking process is occurring. The marking takes approximately 10 seconds for each part as the laser marker must make two passes. Once marked, the robot drops the part down the exit chute (**Error! Reference source not found.**) onto a conveyor outside the cell. The finished parts are placed in a bin by the operator. A picture of what the operator sees during operation through a viewing window can be seen in Figure 8.

Figure 7: Exit Chute

Figure 8: View During Operation

Engineering Standards and Codes

OSHA Technical Manual Section III: Chapter 6

This document provides standards from the federal government that must be met to ensure the safety of laborers working with or around lasers. These must be considered in the project, especially since design concepts proposed redesigning the cell so that it is not entirely closed off to the surrounding work area. The laser in the marking cell is of the following variety:

- Class: IV
- Laser Type: Q-switched Ytterbium fiber
- Wavelength: 1060 nm
- Power: 100 W

A laser of this variety with a 10 second exposure is unsafe for 792 meters of direct contact, but after one bounce of diffusion the laser is unsafe for only 0.8 meters (1). The cell design process takes this into consideration to ensure the laser bounces at least once before exiting the cell and that the distance between the first bounce and possible human contact is greater than 0.8 meters.

The sheet metal shielding surrounding the infeed in the final design was designed to be greater than 0.8 meters to coincide with this requirement and protect the at-risk personnel if the laser were to exit the cell.

ANSI Z 136.1

This ANSI standard specifies the requirements for various lasers. The laser in the cell is compliant with these standards as purchased from the manufacturer and as such does not need to be adjusted. This standard is referenced in the aforementioned OSHA standard and is available for additional laser safety information.

Constraints

Economic Constraints

A fixed budget was not provided by ILSCO. At the beginning of the project, no parts were being run on the cell with the primary marking being performed on an air marking station instead. However, all aspects of the design process are taking cost into consideration to ensure the project is as inexpensive as possible without compromising on necessary quality. ILSCO engineers were also consulted during design reviews to reduce costs where possible. For example, tolerancing was adjusted to reduce cost while still maintaining the original design intent. One design alternative was abandoned due to the material and manufacturing costs of the numerous metal trays needed amongst other factors.

Environmental Constraints

Environmental constraints are a negligible consideration for the project. Since the project is a modification to an already existing, indoor cell, the environmental impact is minimal. The cell will run on the same power source used prior to redesign and thus excluded from the scope of the project so no alternative power methods were explored.

Sustainability Constraints

At the start of the project, the cell was not running any parts for production. Any alterations must allow the cell to run in a more sustainable manner. The improved design must have the ability to have a lower cycle time to increase throughput. The initial infeed design also caused the backlit conveyor to be damaged over time as parts entered so having the parts enter in a more orderly fashion in the redesign allows the conveyor belt to not need replaced as often. The overall cell layout of the infeed and outfeed were positioned so that there would not have to be further revisions to adjust the concern over wasted motion of the operator to remove marked parts from the back of the cell. The length of the new infeed conveyor was considered to allow for a buffer of parts to be built up by the operator so they could perform other tasks as the parts were marked. This will allow the operator to increase their overall productivity. An additional consideration was to relocate the air part marker to the area of the laser marking cell to allow the operator to mark parts on the air marker after the other parts were staged on the conveyor belt.

Manufacturability Constraints

Manufacturability was a primary constraint of the project. This, along with time constraints, was one of the deciding factors in choosing the final design concept. One proposal featured a system of trays with customizable inserts for each of the thirty-part types. Since this required a large amount of manufacturing, cost, and time, the decision was made to focus on redesigning the infeed. When creating drawing packages, tolerancing and dimensions were considered so that the original design intent could be met when manufactured.

Ethical Constraints

Ethical constraints were a small consideration. An ethical concern would be to overlook the safety requirements to claim the completion of the redesign. By performing research on the safety hazards of the laser used, it would be the design team's duty to ensure these are met. This was considered unacceptable to all team members involved and was addressed to ensure the safety of the workers and reduced risk to the ILSCO corporation.

Health and Safety Constraints

Safety was another primary constraint in the project, regarding the cell's use of a laser. The laser is classified as a Class IV which comes with certain safety standard requirements. One large consideration in finalizing the design was ensuring the infeed allows for the laser beam to bounce before it would exit the cell. The power of the laser is then reduced to the point that it is safe enough to strike a human. The bounce requirement was defined by the ILSCO engineering team and confirmed through research. It is considered a remote probability that the laser would ever strike anywhere besides the part it is marking, but the safety precautions to protect ILSCO personnel deemed it necessary that these countermeasures must be applied.

Specification Constraints

The design must comply with the OSHA and ANSI standards mentioned previously. It must also meet the requirements for marking the part, but this is already accounted for in the existing design between the vision system, robot arm, and laser. To reduce the cycle time, the ILSCO engineering team investigated changes to the number of passes the laser made to mark the part while adhering to the depth specification from their quality department. This was able to be achieved. Another possibility would be to reduce the information that is marked on the parts to increase cycle time but then the part would not meet the quality specifications of ILSCO.

Design Alternatives and Basis for Selection

Initial Designs

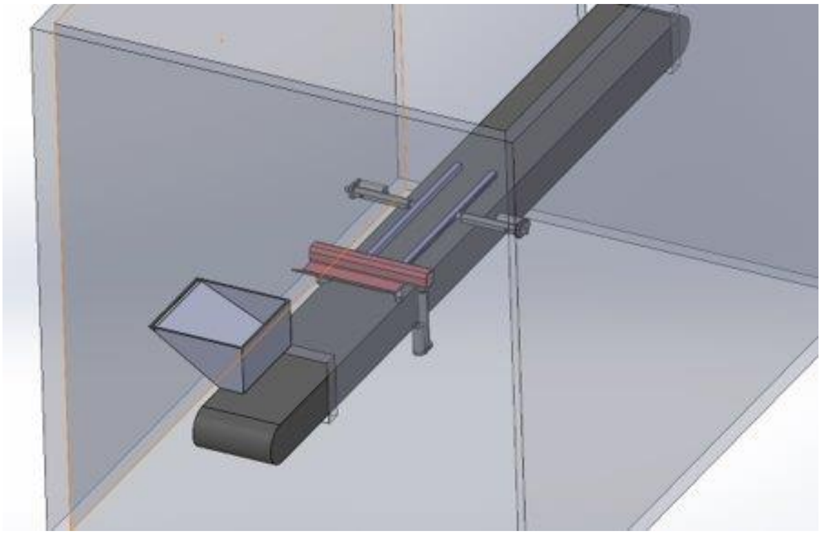


Figure 9: Actuator Concept

The concept illustrated above was aimed at changing very little to the current system to reduce the costs that would be incurred by ILSCO. Parts would still be dumped into a hopper, but the inclined conveyor would be removed. A series of actuators would adjust to the part type to orient the part. This was deemed not effective enough to ensure reliability of consistently oriented parts. The camera program would remain as complicated as previously and the conveyor belt would still be damaged from the parts falling on it.

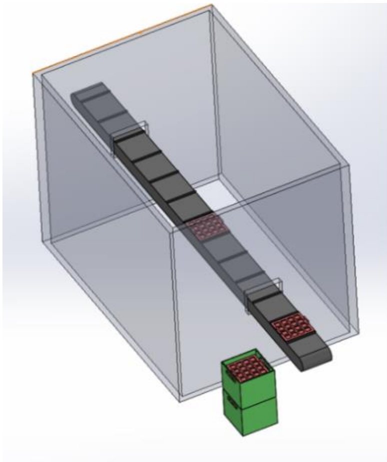


Figure 10: Early Tray Concept

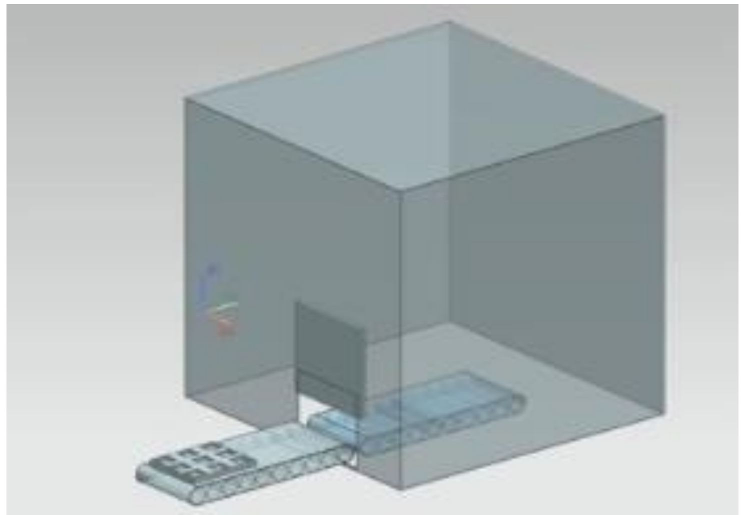


Figure 11: Early Tray Concept with Shielding

In the above tray-utilized designs of Figure 10 and Figure 11, trays of parts would be placed directly onto the conveyor and actuators would position the tray to a true zero for the robot. The robot program would follow a grid pattern to pick the parts. The tray, pictured below in Figure 12, would position the part consistently in such a way that the vision system is no longer needed and eliminate the nicking of parts. The shielding, pictured above in Figure 11, utilized a door that would raise and lower to block the laser from escaping the cell.

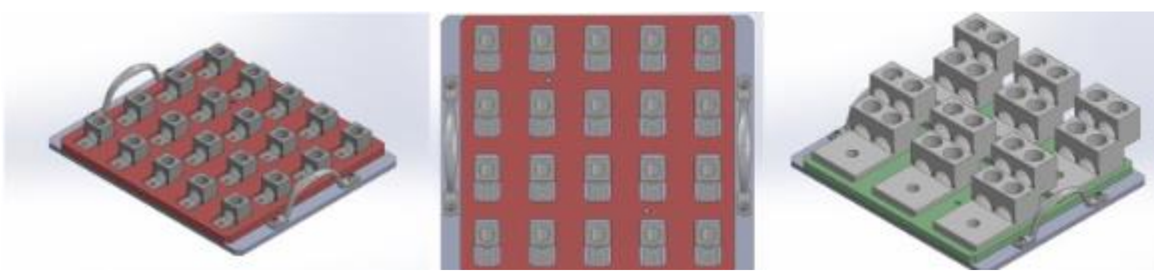


Figure 12: Tray Design 1

The initial tray design utilized a metal base that would be common to all parts and the inserts, shown in red and green above in Figure 12, would be changed over for each specific part type. Shown above are the completed concepts for the largest and smallest part. Below in Figure 13 and Figure 14 is the working, fabricated tray from Tray Design 1.

Figure 13: Fabrication of Tray Design 1 – Part D3225

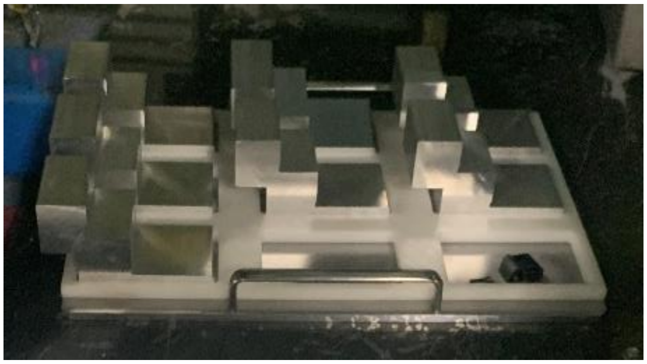


Figure 14: Fabrication of Tray Design 1 – Part D3281

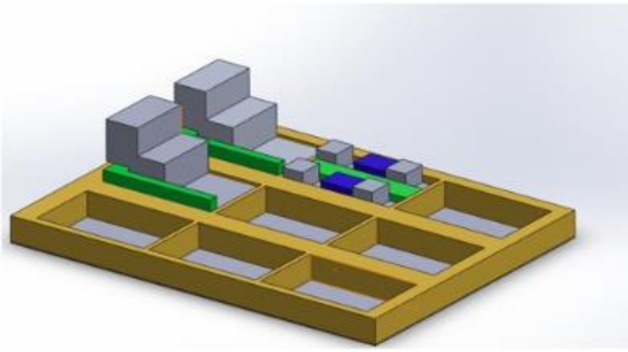
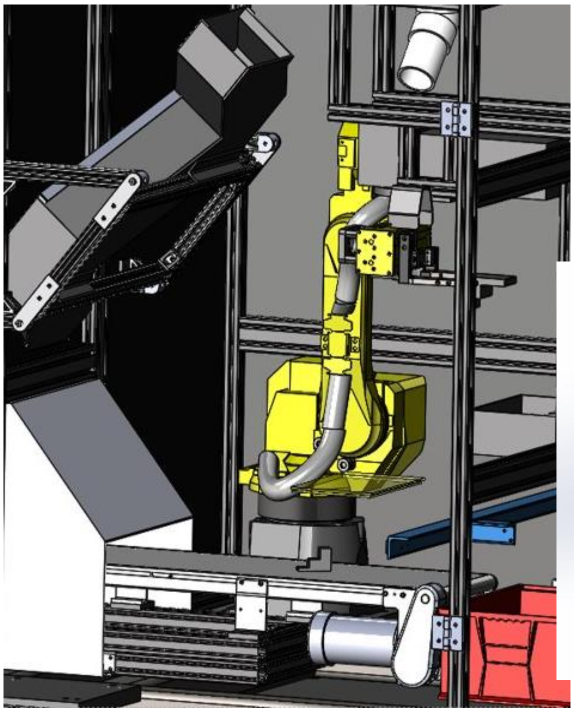


Figure 15: Tray Design 2

A concept, shown in Figure 15, was explored where inserts would be placed in a common tray to accommodate housing all part types. This would require time for part changeover and still face manufacturability concerns. Inserts could also be misplaced by operators increasing running costs. Another concern this specific tray concept faced was not offering a consistent location for the robot arm to pick parts without a vision system as no grid would be able to be followed.

Final Concept Proposals



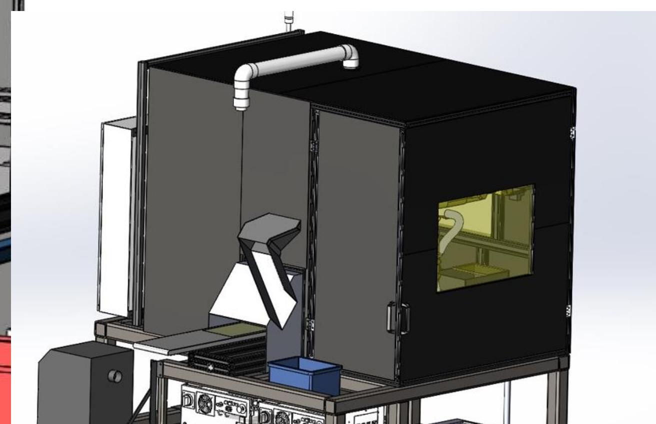


Figure 16: Final Concept 1 – Inside View **Figure 17: Final Concept 1 – Outside View**

A design without trays is pictured above in Figure 16 and Figure 17. This would feature a longer conveyor than the current one extending out of the cell, onto which parts would be placed directly by an operator in the optimal position for the robot to pick the parts to reduce the intermediate steps at the regrip station. The commitment of an operator to be stationed at the cell was consistent between both final designs. There would be sheet metal shielding that extends into the cell and outside of the cell to prevent the laser from bouncing out while it was still too powerful. The part exit chute would be moved to the same area as the infeed so that the operator would not have to move to the opposite side of the cell to keep emptying full marked parts bins. This was selected as the design that would be expanded on and adapted for the final design.

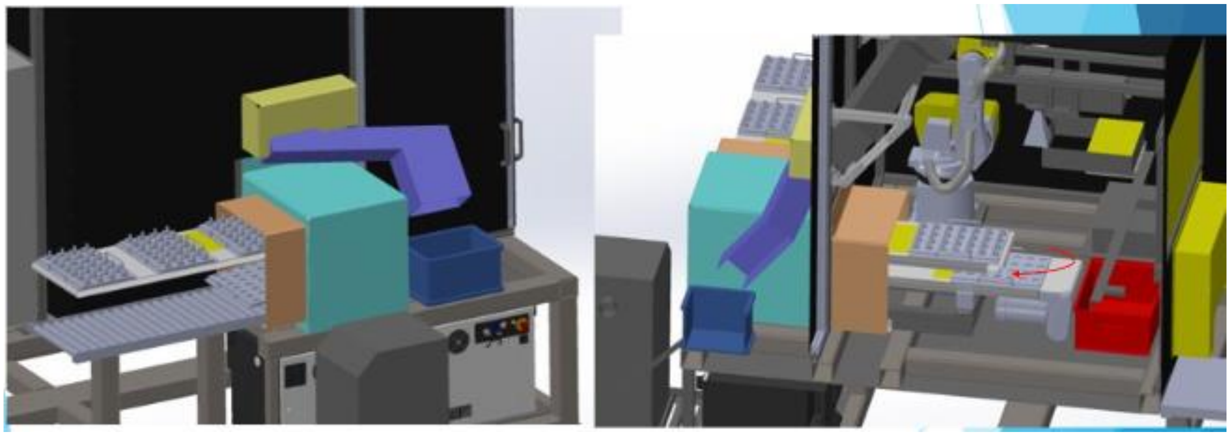


Figure 18: Final Concept 2

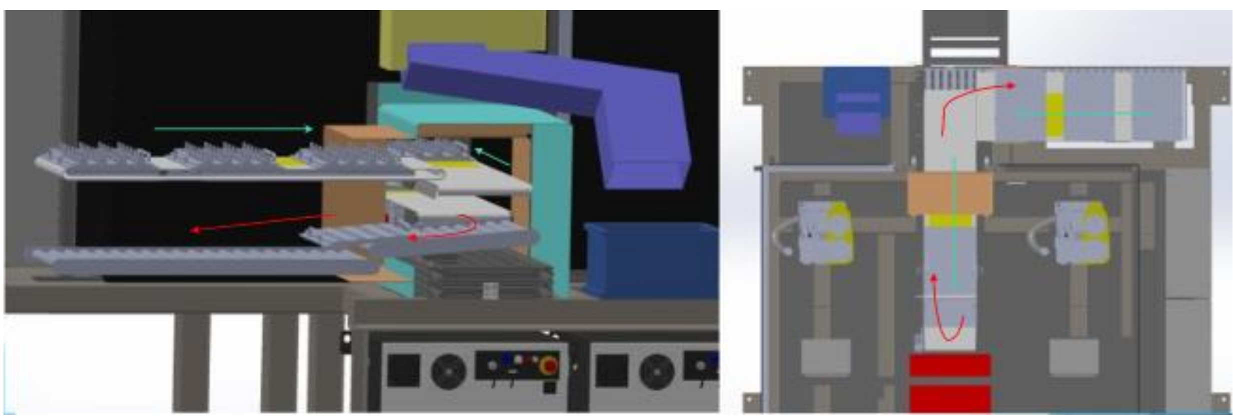


Figure 19: Final Concept 2 – Process Flow

A more developed design for the tray concept, shown above in Figure 18 and Figure 19, included a way for the trays to be returned out of the cell. The trays would be staged on a conveyor and be transferred to another conveyor to enter the cell as shown by the green arrows in Figure 19. Once the parts were picked from the tray, the red arrows show how the tray would be transferred to the bottom conveyor and onto gravity rollers. This prevented the need for an operator to move to retrieve trays. The part chute, shown in purple in Figure 19, was moved to the front of the cell to reduce unnecessary movement by the operator to retrieve the finished, marked parts. The tray concept was ultimately deemed too costly, time consuming with part changeover, and logistically demanding to manufacture the high number of trays that would be required. Besides trays, there would need to be an additional two conveyors purchased along with the gravity rollers. The existing programming would work with the non-tray process and revised to be more efficient rather than complete reprogramming of the trays that would take potentially months to complete.

Final Design

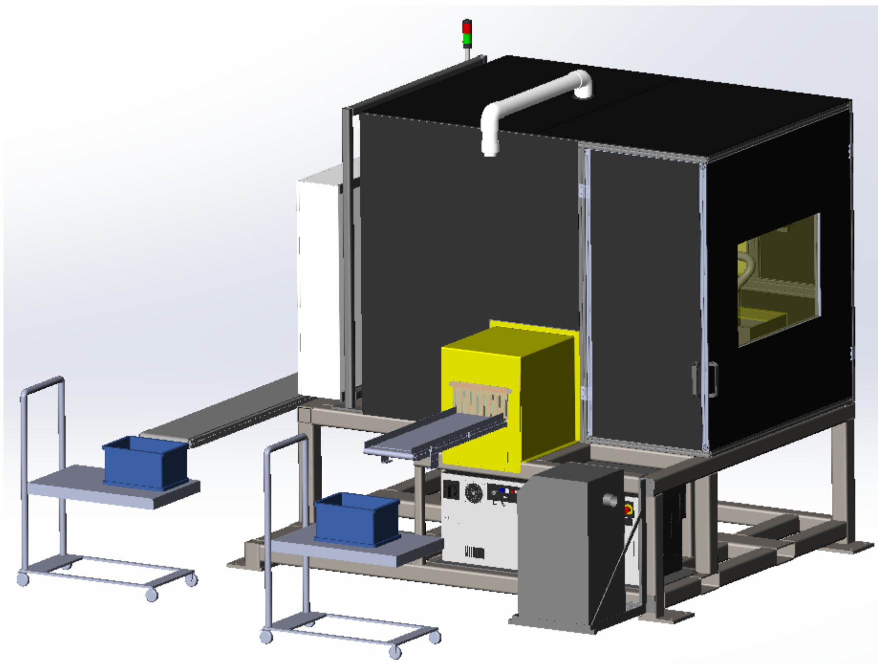


Figure 20: Final Design – Front

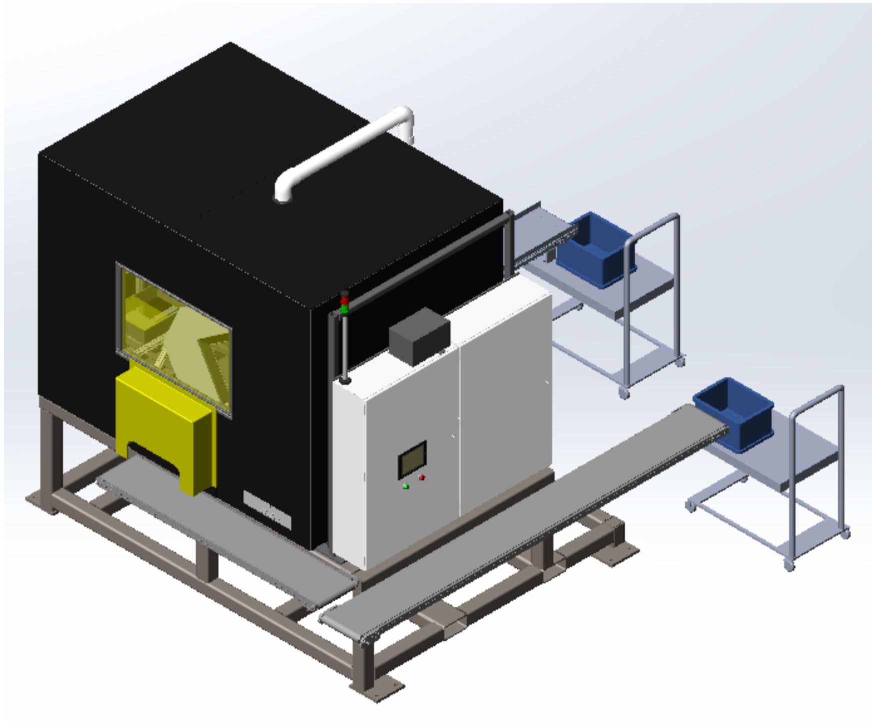


Figure 21: Final Design – Back

The final design for the project features modifications of two main areas of the original design. The first area addressed is the infeed. As seen in Figure 20, the original sloped material infeed was removed in favor of extending the infeed conveyor to protrude outside the cell. The infeed conveyor selected was a Dorner 2200 Backlit Conveyor, with a load capacity of 80 lbs, which can easily hold and transfer any part number during operation. It allows the operator to place parts directly onto the conveyor and be brought into the cell. Directly placing the parts on the conveyor allows the part orientation to be controlled while optimizing their positioning to reduce cycle time. The optimization of their position involves positioning the part face to be marked face up. Whereas the tray system would have eliminated the need for the vision system, the final design takes advantage of the fact that the vision system is already an operable component of the cell and will not need changed before operation can begin. Over time, unused sections of the program can be eliminated to streamline the program. This system is at least as efficient as the tray system in terms of cycle time benefits and would easier to quickly implement.

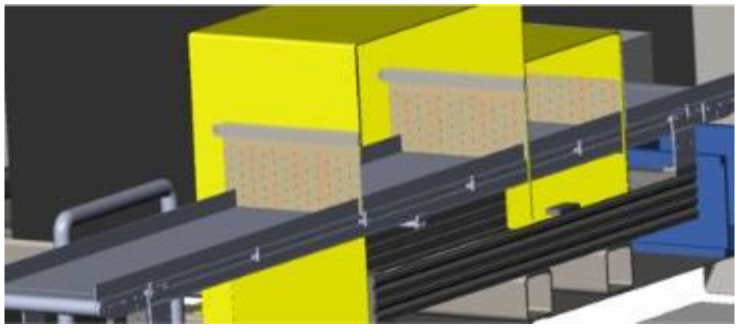


Figure 22: Cutaway View of Laser Curtains

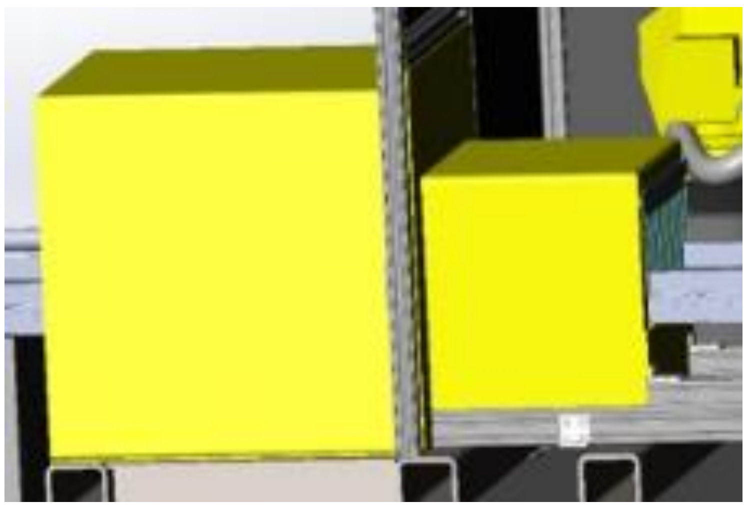


Figure 23: Sheet Metal Shield Box

The infeed required implementations of new countermeasures to ensure laser safety. The new design offers the potential for laser to shoot straight out of the cell, so shielding was designed to prevent the laser from escaping in the unlikely event of a misfire. This type of design is noted as a limited open beam path by OSHA standards. With this design, it allows for parts to move through the cell while the laser remains stationary. According to the OSHA standard, a Class IV-Nd:YAG laser of a 100 Watt and 1.064 μm wavelength is safe for human exposure after traveling 0.8 meters after one diffusion for a 10 second exposure (1). In the unlikely case that the laser was to miss the part and not diffuse, shield curtains were designed to ensure that the beam radiation was stopped before reaching the operator and the operator's vision would be protected during operation. These shield curtains are mounted to the shielding boxes. The shielding boxes, shown in yellow in Figure 22, are made of sheet metal and can be fabricated at ILSCO or purchased from a vendor. The shielding extends both inside and outside of the cell and has only a small opening through which the parts enter on the conveyor. Three shielding curtain assemblies are placed along the length of the shielding box, shown in Figure 22, with one located at each box opening and one in between. The curtains are made of a laser resistant fabric which can be cut to allow the incoming parts to pass through it. Each curtain assembly is composed of two differently cut layers of fabric, so the cuts are staggered. If a part is passing through the fabric, the amount of fabric opening will be reduced and decreases the probability of an escaping laser beam. All these precautions and design considerations were combined to ensure the safety of the cell to personnel.

The outfeed of the cell was also redesigned. The new design features two conveyors positioned in a "L" shape after the parts exit the cell through the outfeed chute. The first conveyor brings the part to the side of the cell with the control panel in Figure 21 and drops it onto the second conveyor, which then brings the parts back to the front of the cell. This always allows the operator to stay at the front of the cell without needing to leave to collect finished parts. This is an ergonomic improvement that also follows lean manufacturing principles to ensure that the infeed conveyor is always fully loaded and wasted travel is reduced.

Cycle Time

Process	Cycle Time (s)	Production per hour	Production per shift (8 hours)	Production per week(2 shifts per day and 7 days per week)
Old Method	40* from Jacob	90	720	10,080
New Method (with new laser marking technique)	11	327	2,616	36,624
Net Increase	-29	+237	+1896	+26544 263% increase

Table 1: Cycle Time

The cycle times listed above in Table 1 show the comparison of the material infeed that was previously used to the optimized final design. The cycle time from the old method was provided by a member of the ILSCO engineering team for part number D6473. The data for these calculations is referenced in Appendix D – Cycle Time vs. Quality Matrix in which the laser's cycle time was increased and the parts were inspected to see if they passed the quality check with the increased speed. From the data, Part D6473 had an average cycle time of around 5.4 seconds during its first run using laser speed 2 which is the second fastest speed the laser could mark parts. Run 2 resulted in similar cycle times. The parts did not pass the quality inspection on laser speed 3 which is the fastest laser speed. Therefore, the parts cycle time includes the robot picking up the part, using the re-gripping station, and bringing the part to laser equals 6.6 seconds with the actual laser marking time of 5.4 seconds. This equals an 11 second cycle time or 8 parts in 1 minute and 25 seconds.

Project Management

During the concept phase, each team member created a separate idea and depiction using SolidWorks to be presented to the ILSCO team at the next joint meeting. These meetings typically occurred biweekly. After receiving feedback from the ILSCO engineering team, the same process would be repeated for the next meeting as the ideas began to be narrowed and the team chose what to focus on. This demonstrates an iterative design process. Deliverables would be decided on for the next meeting by the ILSCO team. Once the final concept was chosen, the work was divided between team members to research applicable safety regulations and to design a final model which would comply with those standards. A drawing package was prepared, and quotes were obtained by respective team members to be presented for fabrication and purchasing.

Schedule

The following is a summary of the project's timeline.

- Friday, 10/25/19 - Initial meeting with Dr. Dong to learn about project
- Friday, 11/1/19 - Initial project meeting between UC team and ILSCO
- Monday, 11/18/19 - Initial concept proposal by UC team to ILSCO
- Friday, 11/22/19 - Review of previous ILSCO meeting information with Dr. Dong
- Monday, 12/2/19 - Safety training and refined proposal presentation at ILSCO
- Monday, 12/16/19 - Tray drawing package sent to ILSCO for fabrication
- Friday, 1/17/20 - Review meeting with Dr. Dong before ILSCO presentation
- Monday, 1/20/20 - Final concept proposals and selection by UC team to ILSCO
- Thursday, 2/6/20 - Review meeting with Dr. Dong before ILSCO presentation
- Friday, 2/7/20 - Final design and timeline meeting at ILSCO

- Friday, 2/14/20 - Desired conveyor ordering date to ensure delivery
- Wednesday, 2/19/20 - Midterm report due
- Between 2/14/20 and 4/23/20 - Create work instructions, laser shielding, design simulation, and instructions for future work
- Wednesday, 2/26/20 - Progress report with Dr. Dong
- Tuesday, 3/24/20 - Meeting with Dr. Huston to give a progress report of operations at ILSCO and requirements going forward.
- Thursday, 4/2/20 - Meeting with Dr. Dong to discuss simulation progress.
- Thursday, 4/16/20 - Meeting with Dr. Dong to discuss the presentation and need to include planned fabrication, testing, report, and assembly instructions.
- Monday, 4/20/20 - Meeting with Dr. Huston to discuss submission of the report and presentation.
- Thursday, 4/23/20 - Final project presentation submission
- Tuesday, 4/28/20 - Final project report due

Proposed and Actual Schedules

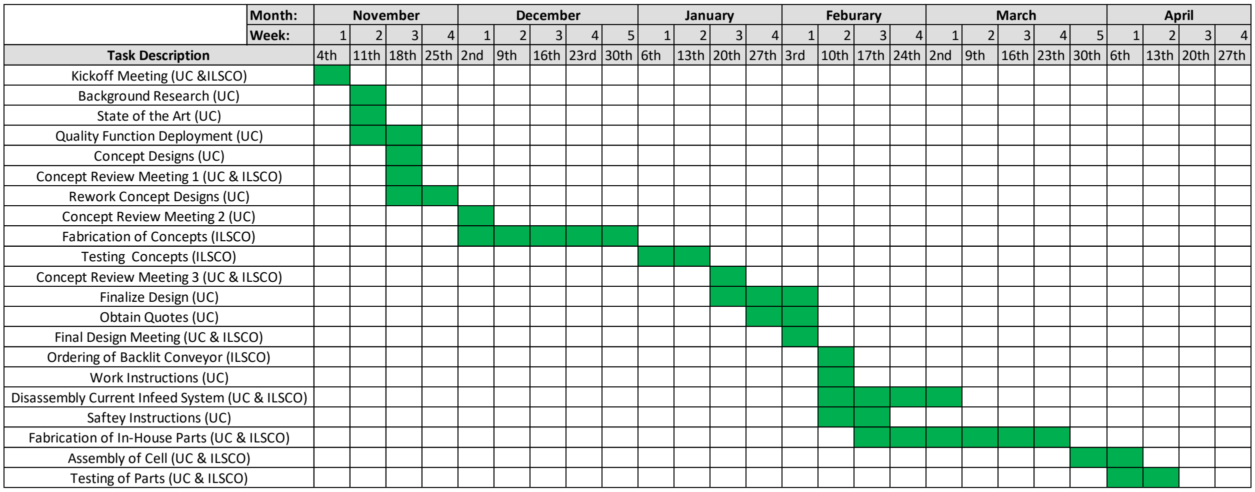


Table 2: Proposed Schedule

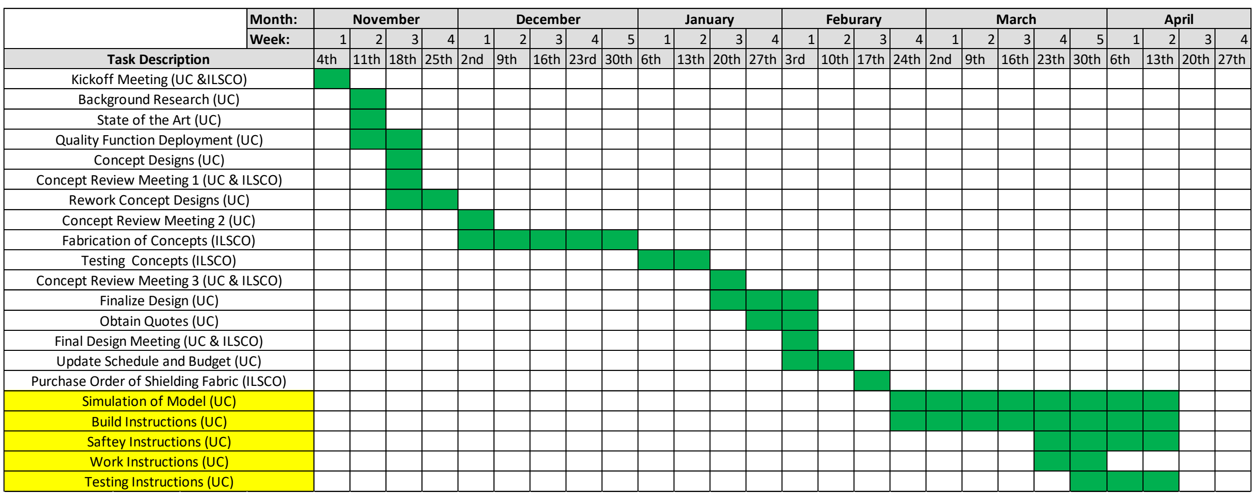


Table 3: Actual Schedule

*The timeline of the events highlighted in yellow were changed from the proposed due to COVID-19.

Budget

Sub-System	Item	Value	QTY
Infeed System	2200 Dorner Backlit Conveyor	$7,412.38	1
	Inner Shield*	$588	1
	Outer Shield*	$1,662.71	1
	Strip Curtain Plates*	$16.62	2
	Conveyor Under Shield*	$69.15	1
	Inside Flat Plate*	$318.16	1
	Lower Plate*	$84.49	1
	THORLABS Safety Fabric	$339	1
	Hardware	$100	1
Outfeed System	Outfeed Conveyor	$1,827.00	1
Total		$12,417.20	

Table 4: Budget

The budget in Table 4 indicates values obtained from quotes for the completion of the project. An asterisk indicates the values based on Midwest's Steel and Aluminum Supply price calculator for AISI 304 stainless steel sheet metal, although it is noted ILSCO may already have this sheet metal in their tool room (2).

Summary/Suggestions

Our team was able to complete a finalized design of reorienting the parts to be marked with the design consideration of the laser cell to ILSCO. The completed design package will be provided to ILSCO including quotes for parts to be purchased, drawings of shielding parts to be fabricated, an updated SolidWorks model of the cell, and a simulation model of how the process would work. The senior design team worked with ILSCO to ensure this design satisfied their needs of an improved cycle time for all the parts and theoretical reliability improvements. Due to a purchasing constraint, ILSCO decided that they would not purchase the longer Dorner backlit conveyor at this time. Before the coronavirus, ILSCO agreed to purchase the other parts and materials needed for fabrication so they were prepared for when they could place an order for the conveyor. The deliverables were modified to test parts traveling through assembled shield curtains at ILSCO to determine if they altered the orientation of the part and to provide a 3D printed scale of our design with a simulation. This deliverables were altered again due to increased restrictions imposed by the coronavirus. This led our team to provide future work for the ILSCO team to complete the implementation of the design at a more fitting time which includes a design simulation, instructions on how to test and build our design, work instructions for operators, and safety instructions.

References

1. Laser Hazards. *OSHA.* [Online] United States Department of Labor.

2. Midwest Steel and Aluminum. *midweststeelsupply.com/store.* [Online] 2020.

3. Guide to Laser Safety Training. *CertifyMe.net.* [Online]

4. Berkeley Environment, Health & Safety. *ehs.berkeley.edu.* [Online] 2018.

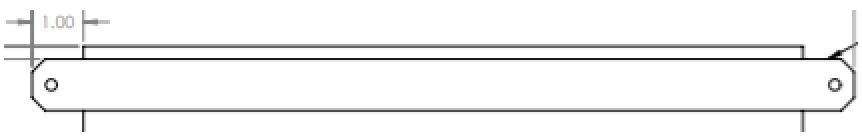
Appendices

Appendix A – Future Work

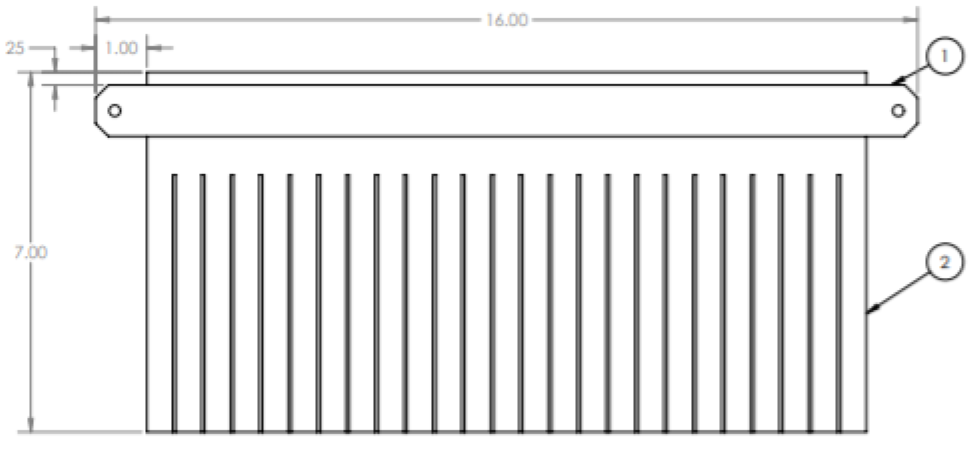
Testing Instructions

These instructions explain how to test a part traveling through a shield curtain with troubleshooting steps. The goal would be to make sure every part can travel through the shield curtain while maintaining the same orientation before the rest of the new cell layout is assembled.

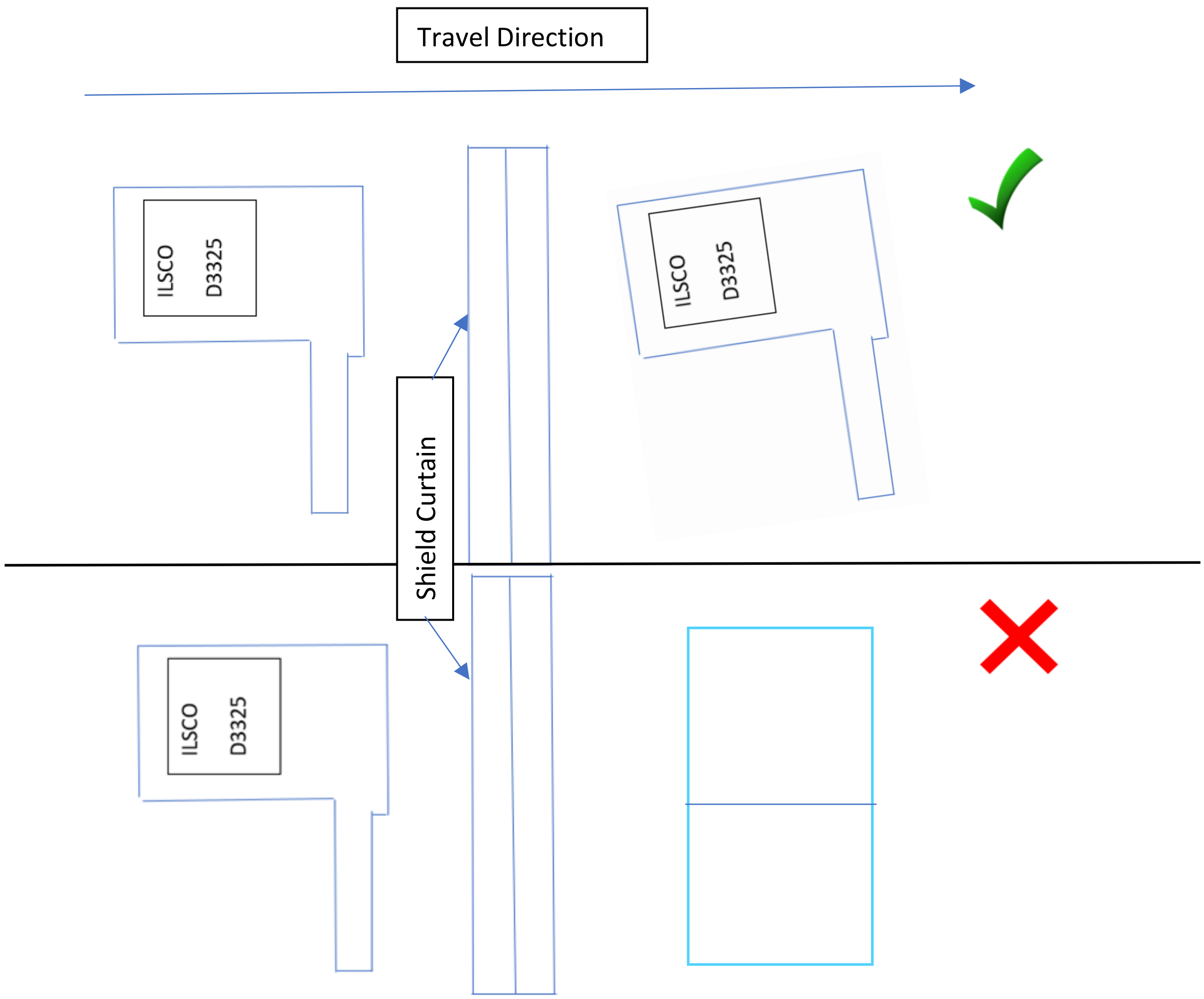
1. Lay the strip curtain plate (part D-101) flat on a working table.
2. Measure an inch out from each side of D-101 that will provide the margins of the shielding fabric.



3. Place strip curtain A (Part D-102) within the margins on top of the strip curtain plate.
4. Place strip curtain B (Part D-103) directly over strip curtain A.
5. Lay another strip curtain plate over the strip curtain and line up the holes with the other strip curtain plate.
6. Pinch everything together in the center and place two #10 hex screws through the holes and secure with hex nuts.
7. This finished assembly should look like the drawing # A-100.



8. With the laser cell in manual mode, open the cell to where the you can access the current infeed conveyor. Please take the necessary precautions to make sure the laser and robotic arms are turned off during this testing.
9. Place part D-3325 on the conveyor in the correct orientation with the side that is going to marked facing up. For reference on how to place the parts correctly, reference the Master Part List that shows where the marking is on the part.
10. While holding the shield curtain assembly with the flaps touching the conveyor, observe how easily the part goes through the shield curtain. It is ok if the part gets rotated slightly during this process, if the marked side doesn't get flipped over. A top view of the part going through the shield curtain can be seen below.

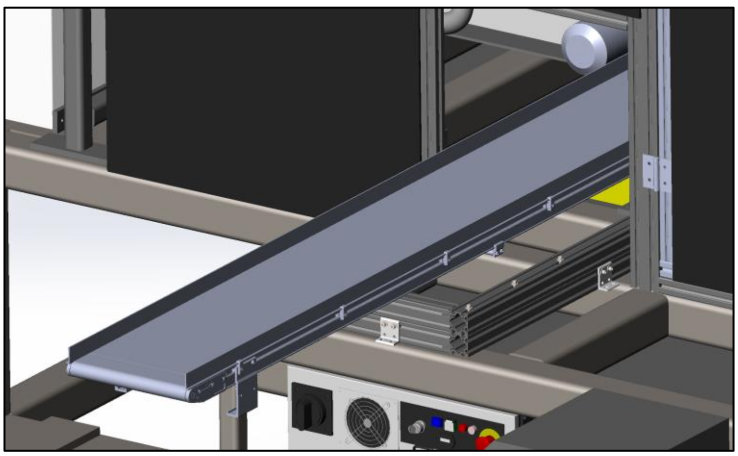


11. If the part does not pass through the shield curtain, there are a couple of options to troubleshoot it to work.
    a. Since the infeed conveyor is a variable speed, try to speed up the conveyor rpm.
    b. The shield curtain assembly has two shield fabric pieces. Remove one of the shield fabric pieces and test to see if the part can now go through it.
    c. Reduce the size of the current flaps by half of their size to reduce the contact resistance of the flaps.
    d. Using a combination of all these techniques, hopefully the smallest part (D3325) can pass through the shield curtain. If the material proves to be to heavy, more research on an alternative material would need to be done.

12. If the smallest part makes it through the shield curtain, all the other parts should be to pass through the curtain as well. However, it wouldn’t hurt to test a few other parts, especially the obscure shaped parts.
13. Construct multiple A-100 assemblies and test parts going through 2 shield curtains and then 3 shield curtains at a time since this will be how many shield curtains the parts will be going through in the final design.

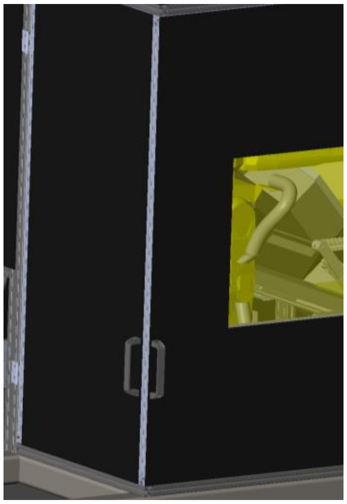
<u>Build Instructions</u>

Infeed Conveyor Installation

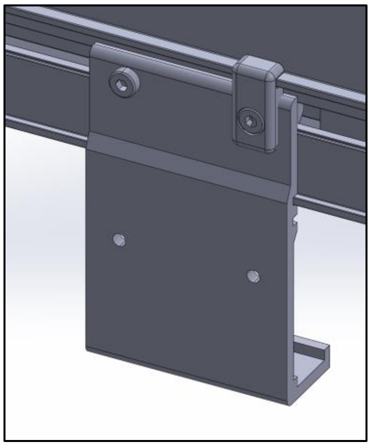


The infeed conveyor was selected to be a comparable model to the previous Dorner 2200 series infeed conveyor to ensure compatibility. With no conveyor in the cell, proceed with the following steps:

1. Ensure the power to the cell is off before starting installation.

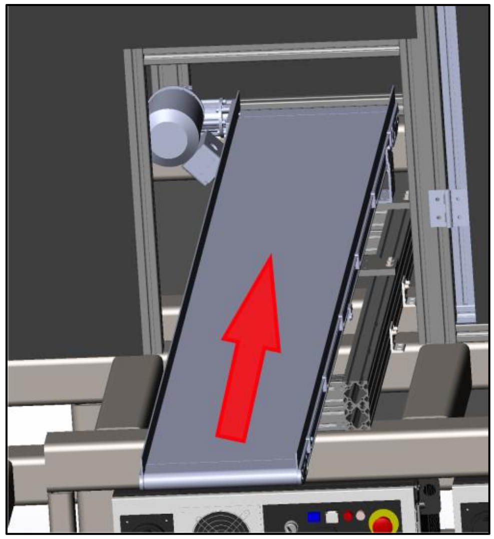


2. Open the cell with the handles located on the side adjacent to the polycarbonate window.

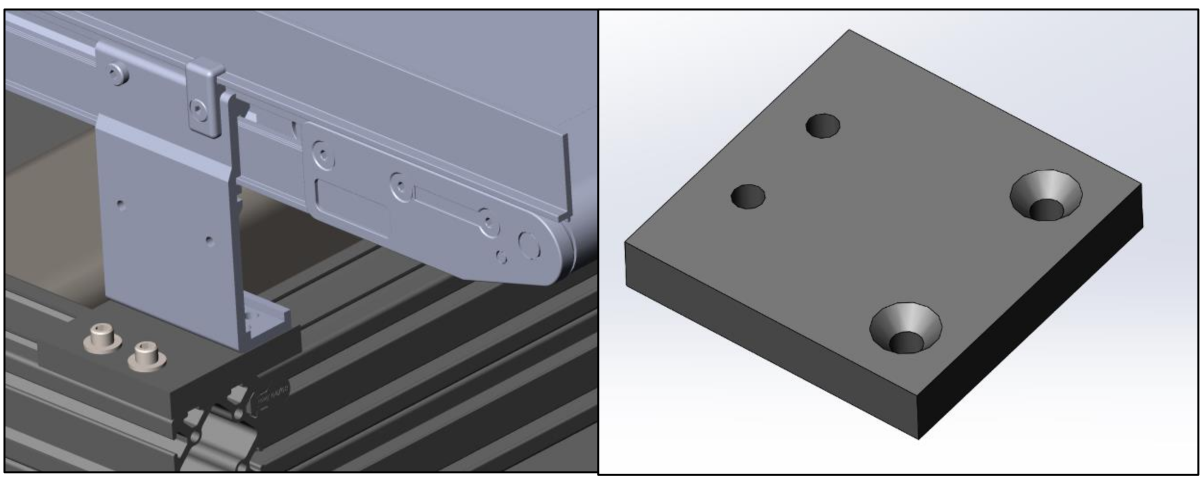


3. Prepare at least 4 Dorner conveyor mounting brackets with the appropriate fasteners as pictured above.

4. Attach the Dorner conveyor mounting brackets to the side of the conveyor as shown above circled in red. The brackets should not be completely tightened to allow them to slide along the conveyor during installation.



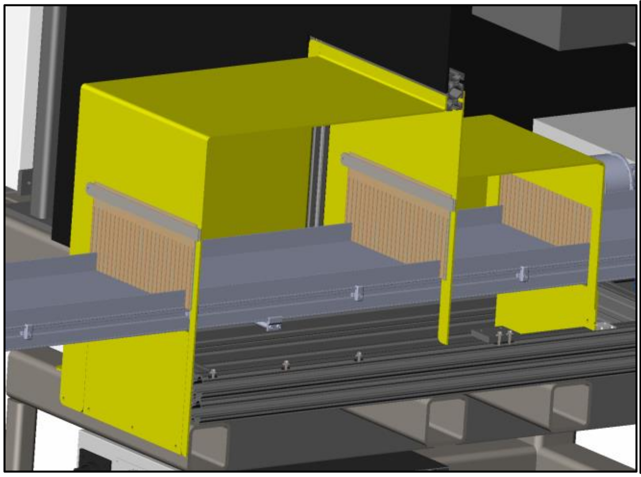
5. With multiple people or mechanical assistance, the conveyor can be lifted into the 20” by 23” opening in the side of the cell.

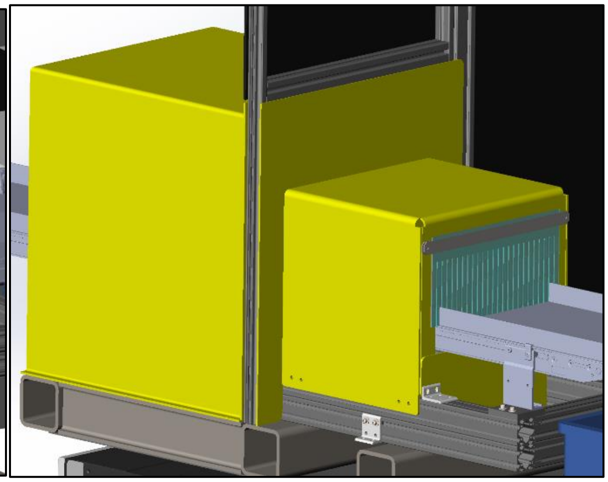


6. Adjust the brackets to line up with the countersunk holes on the plate pictured right. It may be necessary to remove the plate from the 80/20 rail to attach the bracket to the plate before then attaching the plate to the 80/20 rail. Repeat this for each of the 4 brackets while making sure the conveyor is level. If the conveyor is unable to be leveled, new plates or brackets may be needed.
7. Verify that the conveyor motor unit delivered matches the same connections as the previous unit in the motor unit manual.

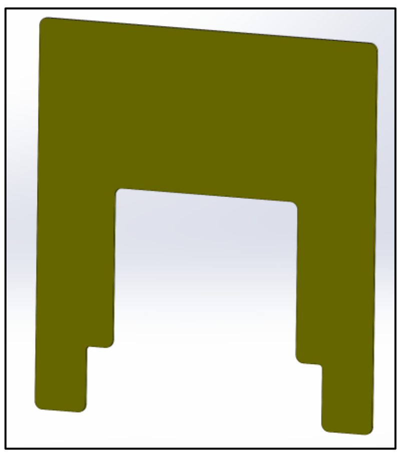
8. Attach the power and necessary inputs to the conveyor motor unit.

Shielding Installation





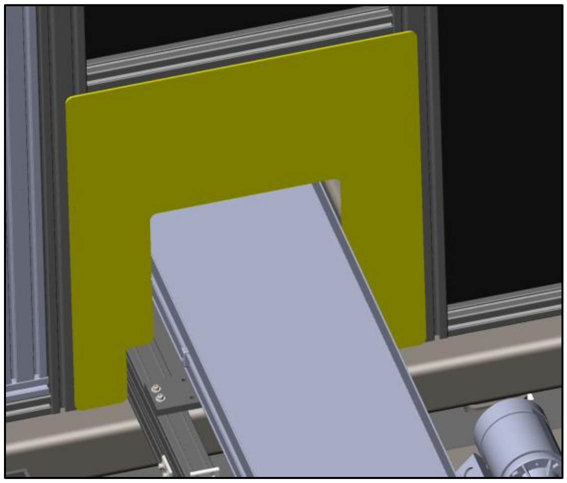
Inside Flat Plate



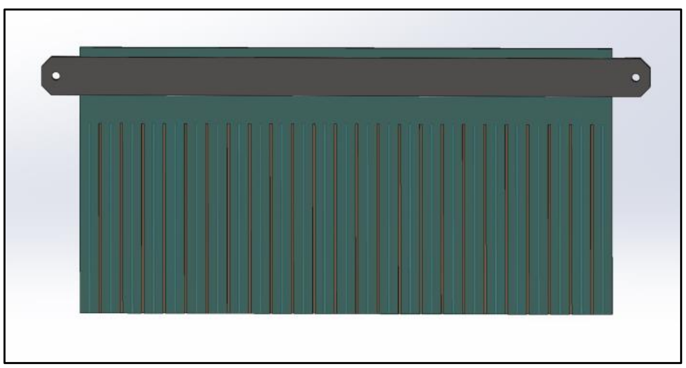
Note: The inner shield should not be installed before the inside flat plate.

1. From the inside of the cell, hold the flat plate flush with the 80/20 rails around the conveyor.
2. When centered around the conveyor, drill pilot holes for a minimum of 4 fasteners located at each corner of the plate.
3. Widen the holes on the plate and through the 80/20 railing to the desired fastener size.

4. Use a through bolt and a nut at each hole location to attach the plate to the cell wall. Once installed, the plate should look like the image below.

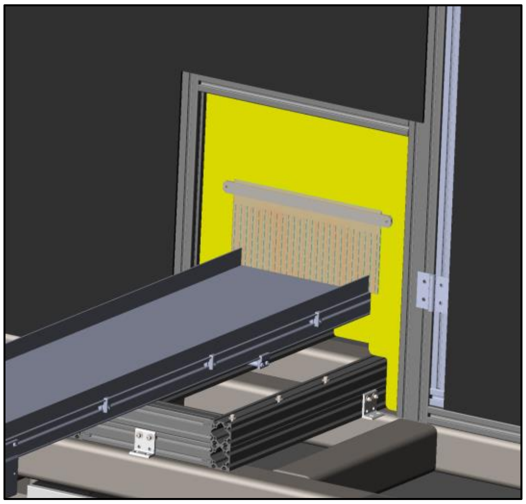


Flat Plate Strip Curtain

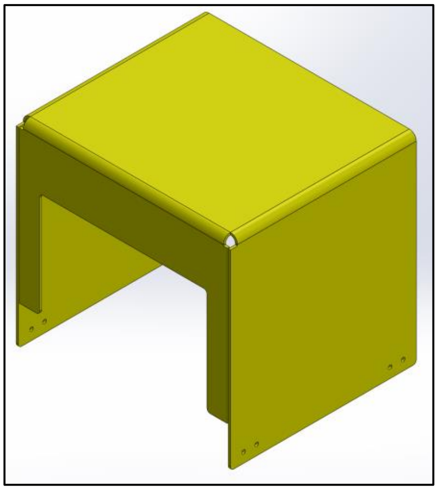


1. After the inside flat plate is secure, hold the strip curtain to the plate until a height is reached where the bottom of the strips begins to contact the surface of the conveyor.
2. Use a level to ensure the sheet metal part of the strip curtain is level before continuing.
3. Drill 2 through holes into the inside flat plate that are concentric with the holes on the strip curtain.
4. Attach the strip curtain with a #10 through bolt and nut for each hole.

5. If necessary, the strip curtain material may need adjusted higher or lower depending on the part testing to reduce the possibility of escaping laser reflections. The completed assembly is shown below.

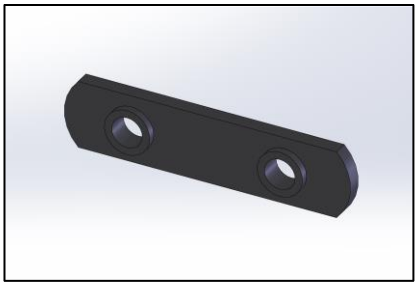


Inner Shield

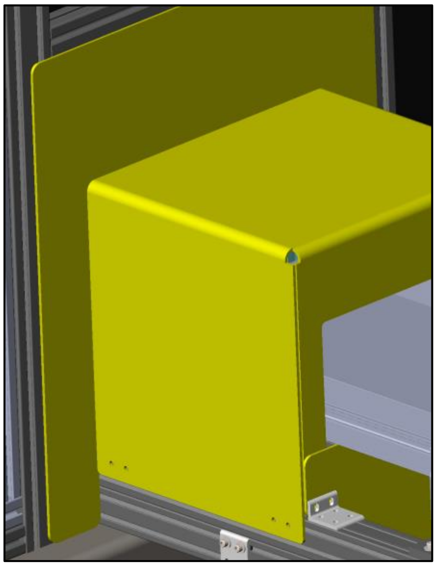


Note: The inner shield should not be installed before the inside flat plate.

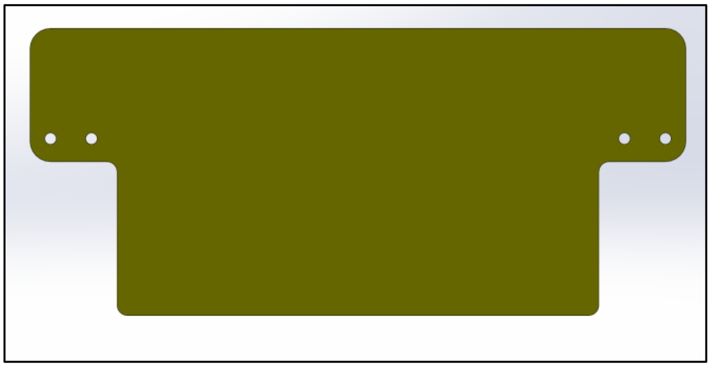
1. Two double nut T-slotted framing fasteners, pictured below, should be placed in top slot of the 80/20 rails on each side of the conveyor. Four of these fasteners are needed in total for this operation.



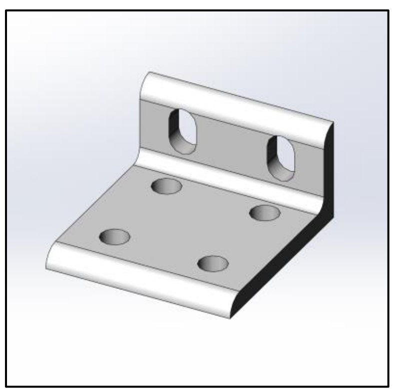
2. The inner shield is placed over the conveyor before sliding it down to meet the 80/20 framing. Ensure that the shield will not pinch any wires that may be present and that the smaller opening faces the center of the cell.
3. Use 8 fasteners to attach the inner shield to the 80/20 railing but do not tighten.
4. Make sure the inner shield is in contact with the inner flat plate before tightening the fasteners the rest of the way. This is shown below.



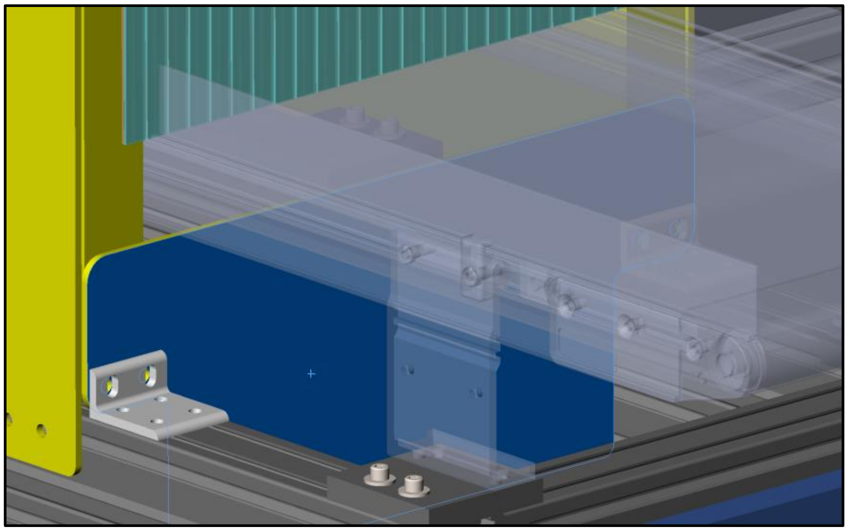
Inner Under Conveyor Shield



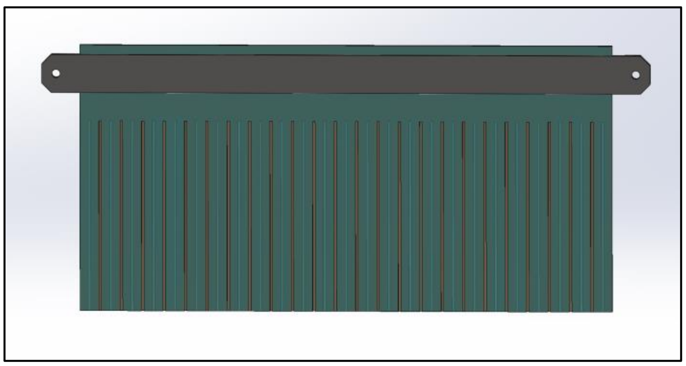
1. Once the inner shield is installed, hold the inner under conveyor shield so the largest face is parallel to the ground to fit it under the conveyor.
2. Slowly rotate the shield to be perpendicular to the ground and hold it away from the inner shield. This operation is needed to be able to fit the shield into the tight space under the conveyor.
3. Attach the inner under conveyor shield to the two 6 hole corner brackets, pictured below, that are connected to the top of the 80/20 rails.



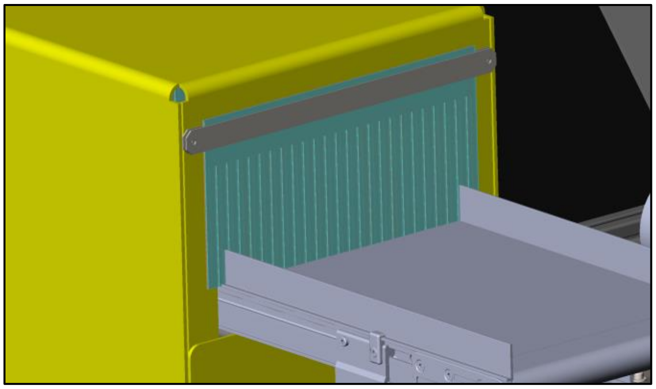
4. Slide the shield flush against inner shield to complete the installation as highlighted in blue below.



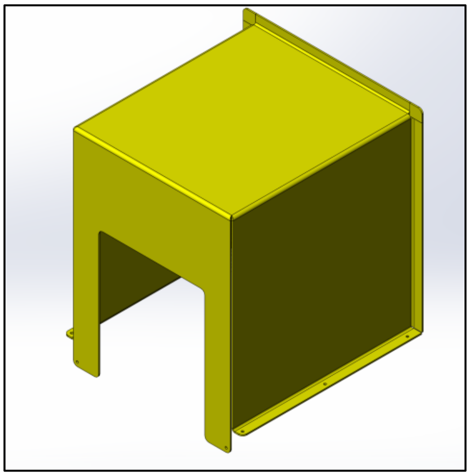
Inner Shield Strip Curtain



1. After the inner shield is secure, hold the strip curtain to the shield until a height is reached where the bottom of the strips begins to contact the surface of the conveyor.
2. Use a level to ensure the sheet metal part of the strip curtain is level before continuing.
3. Drill 2 through holes into the inner shield that are concentric with the holes on the strip curtain.
4. Attach the strip curtain with a #10 through bolt and nut for each hole.
5. If necessary, the strip curtain material may need adjusted higher or lower depending on the part testing to reduce the possibility of escaping laser reflections.

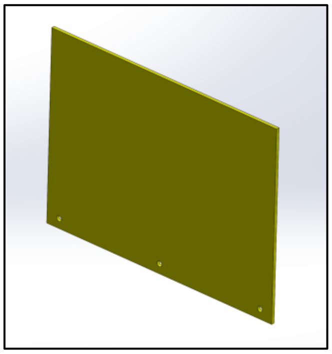


Outer Shield Assembly

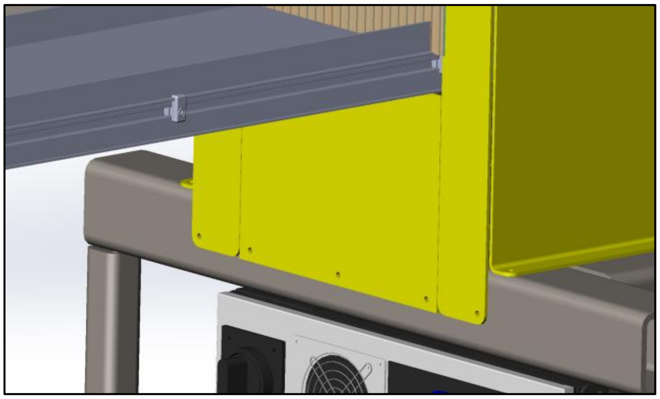


1. With the conveyor in place, the outer shield is placed over the conveyor before sliding it down to meet the cell frame. Ensure that the shield will not pinch any wires that may be present.
2. The outer shield will require 8 fasteners for 9/32" holes and fit over the holes already drilled and tapped in the cell frame from the previous shielding. If the shield does not meet these tapped holes, it may require the holes in the frame or shielding to be redrilled.

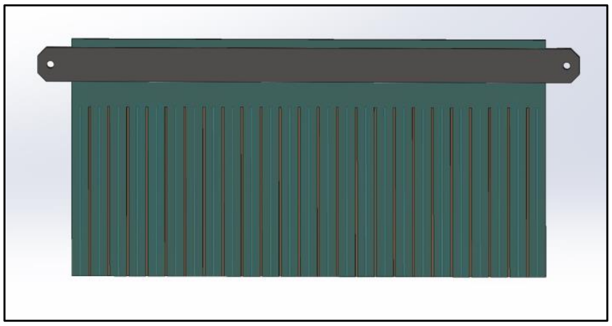
Outer Shield Lower Plate



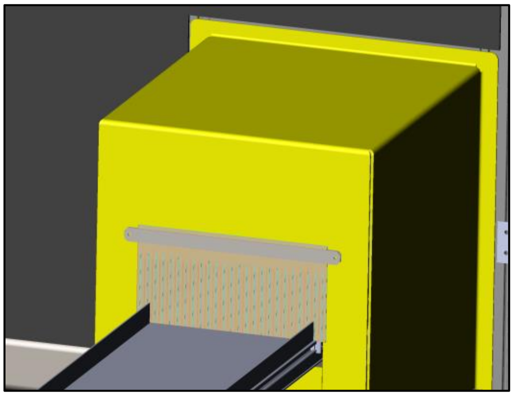
1. After the outer shield is installed, the outer shield lower plate will fit underneath the conveyor.
2. Drill and tap 3 new holes in the cell frame to match with the fastener that fits the 9/32” holes located on the bottom edge of the plate.
3. Hold the plate up to the cell frame and tighten the fasteners as shown below.



Outer Shield Strip Curtain



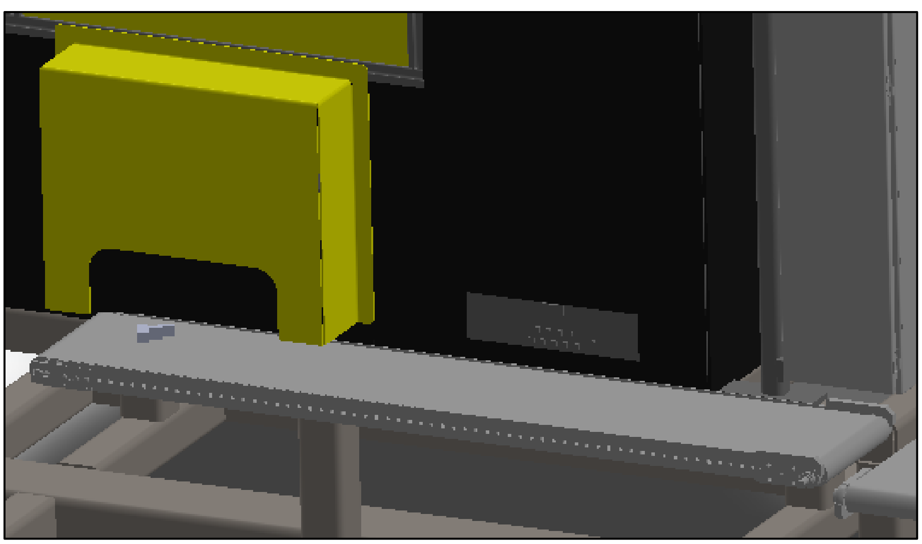
1. After the outer shield is secure, hold the strip curtain to the shield until a height is reached where the bottom of the strips begins to contact the surface of the conveyor.
2. Use a level to ensure the sheet metal part of the strip curtain is level before continuing.
3. Drill 2 through holes into the outer shield that are concentric with the holes on the strip curtain.
4. Attach the strip curtain with a #10 through bolt and nut for each hole.
5. If necessary, the strip curtain material may need adjusted higher or lower depending on the part testing to reduce the possibility of escaping laser reflections. The shield once installed will look similar to the image below.



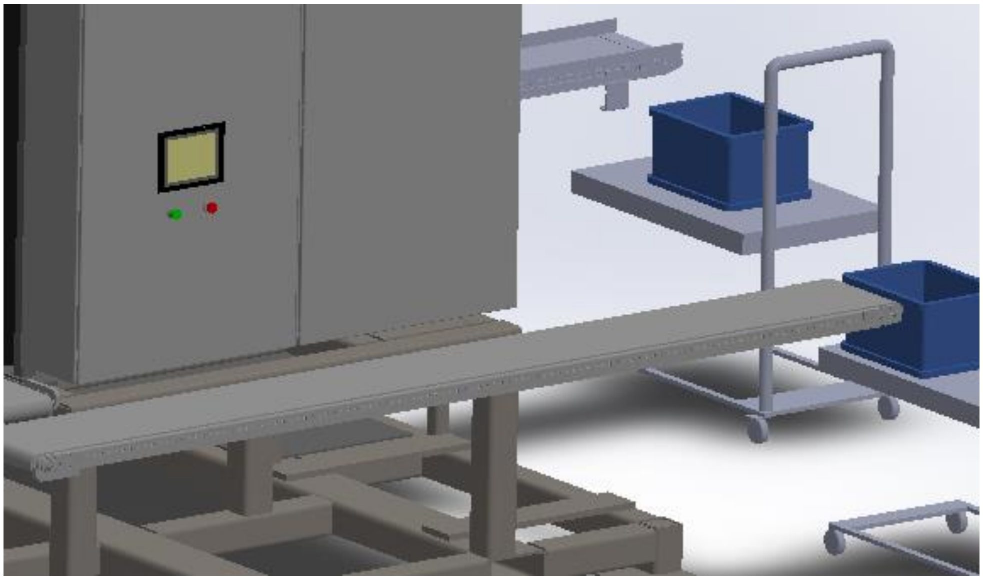
Outfeed Conveyor Installation

Two motorized conveyors, like the one shown above, will be used for the outfeed conveyor configuration. An equivalent self-contained conveyor on wheels can replace the Dorner outfeed conveyor, if available.

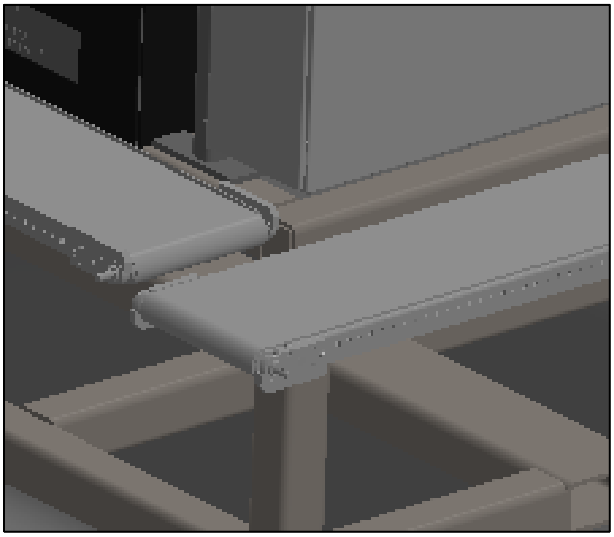
1. Position the first conveyor so that parts drop onto it from the outfeed chute as shown below. It should also extend a few inches past the edge of the cell.



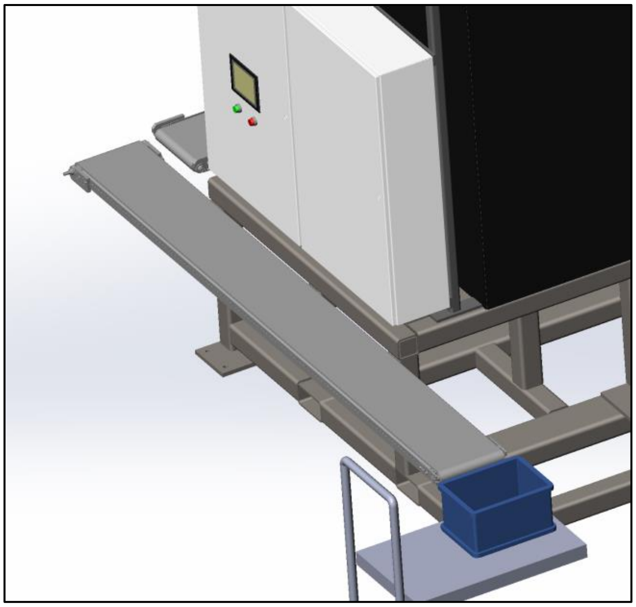
2. Position the second conveyor so that one end aligns with the edge of the first conveyor so that parts will fall from the first conveyor onto the second. The second conveyor should be long enough to at least reach to the edge of the cell or longer if desired for part drop-off into a bin.



3. Ensure the first conveyor is positioned higher off the floor to allow the parts to fall onto the second conveyor as shown below. This may require adjustments depending on the behavior of the parts when getting transferred conveyor to conveyor.



4. A bin can be placed at the end of the second conveyor so finished parts are returned to the operator for collection.



Safety Instructions

Required Action Items for Proper Operation of Laser Cell

The laser being used inside the Laser Marking Cell is a Telesis FQ50 Class IV Laser. Class IV lasers are the highest categorized lasers by ANSI and require significant control measures, as well as safety programs to ensure proper use of the laser. The purpose of this document is meant to provide ILSCO with steps to ensure the company takes all the necessary actions required. This document should **not** be used as a certified training document involving laser use. Failing to provide proper laser safety training can result in fines through an OSHA inspection or result in an injured employee. A more thorough list can be found from https://www.certifyme.net/laser-safety-training/ (3).

Required Action Items

1. Select or hire an employee that can become the designated Laser Safety Officer (LSO). They are responsible for overseeing the laser's operation, maintenance, and training. LSOs are mandatory for class 3b and /or class 4 lasers.

2. Maintain records of all laser safety policies, rules, and procedures that can be easily accessed by operators and supervisors. This can be done through a Standard Operating Procedure or SOP. More information on this below.

3. Create a master document that can provide a category of all lasers on the manufacturing floor.

4. List required PPE needed for the laser operation on site.

5. File training records for every employee who is qualified to use and work on the laser cell.

6. Create a laser accident response plan to keep the situation from escalating and helping those involved in the incident.

7. Ensure proper labeling of the laser and that it matches OSHA standards.

8. Require employees to obtain a laser safety certificate.

The link above will ensure all employees who work with the laser cell are certified and will have the knowledge they need to prevent eye or skin injury. Our team has put together a couple of common-sense rules to follow, as well as guidance from the OSHA Technical Manual on Laser Hazards that should be checked over by the LSO and supervisor team.

Information from OSHA Technical Manual on Laser Hazards

- Make sure that all engineering controls used on the cell are in proper working condition. A list of all engineering controls can be found in Section VI. – Control measures and Safety Programs, subsection J. A full detailed list of all control measures for a class four laser can also be found in this section.
- The laser marking cell operates under the conditions of a Limited Open Beam Path. A full description of this can be found in Section VI-D. In summary, it is a design that allows for parts to move through the system with the laser remaining stationary. The manual states that with a Limited Open Beam Path, the "NHZ will be extremely limited and procedural controls, rather than elaborate engineering controls, will ensure sufficient use" (1). It is important to keep all the engineering controls that are currently used with the laser. Using a similar laser outlined in the manual, the Nominal Hazard Zone for the laser beam after one diffusion is 0.8 meters. The operator lining parts on the conveyor will be at a greater distance than 0.8 meters and will be at a safe distance away from the laser radiation. This NHZ is only an estimate and software should be used to calculate the exact MPE and NHZ of the laser.
- From Section VI-E, "*Class IIIB and Class IV lasers*: Require the ANSI DANGER sign format: white background, red laser symbol with black outline and black lettering (see Appendix III:6-4). Note that under ANSI Z 136.1 criteria, area posting is required only for Class IIIB and Class IV lasers" (1).
- Since the laser-controlled area is defined to inside the cell, entryway control measures are only needed while servicing inside the cell itself. More information on this can be found on Section VI-E,G.
- General requirements for a class four laser can be found in Section VI-F.

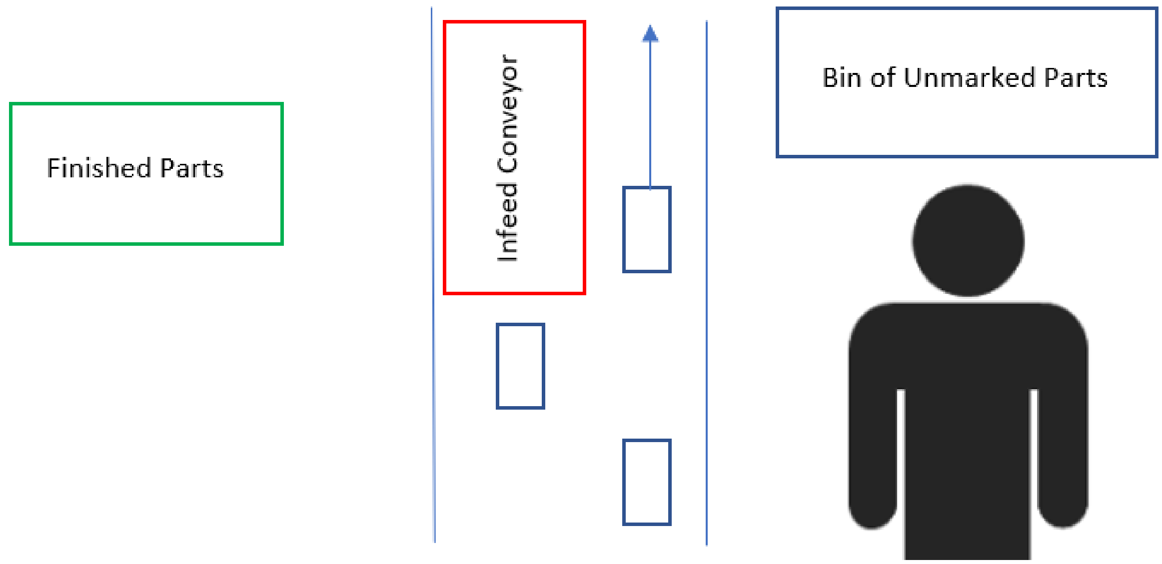
- Administrative and Procedural Controls can be accomplished by doing the following: Creating a Standard Operating Procedure (SOP), Creating Alignment Procedures, Limiting the Access of Employees, and Using Protective Equipment. More detailed information can be found in section VI, paragraph I.
- A template for a SOP can be found here https://ehs.berkeley.edu/laser-safety/standard-operating-procedures-sops-lasers (4).
- Alignment guidelines can be found in the appendix of the template from above.
- People that are not currently operating the cell should not be near the cell or look through the opening to the cell. There are 3 laser curtains to prevent employees from seeing the laser and to prevent laser radiation or eye damage.
- Since the laser radiation will not exceed dangerous levels outside of the cell, it will be ok for the operator to not wear laser protective eyewear. However, if the NHZ is calculated to be greater than 0.8 meters, eyewear and proper clothing may be needed. Proper eyewear needs be used when beam alignment is needed. The cell should always be closed when the laser is in use.

Work Instructions

Operator Work Instructions

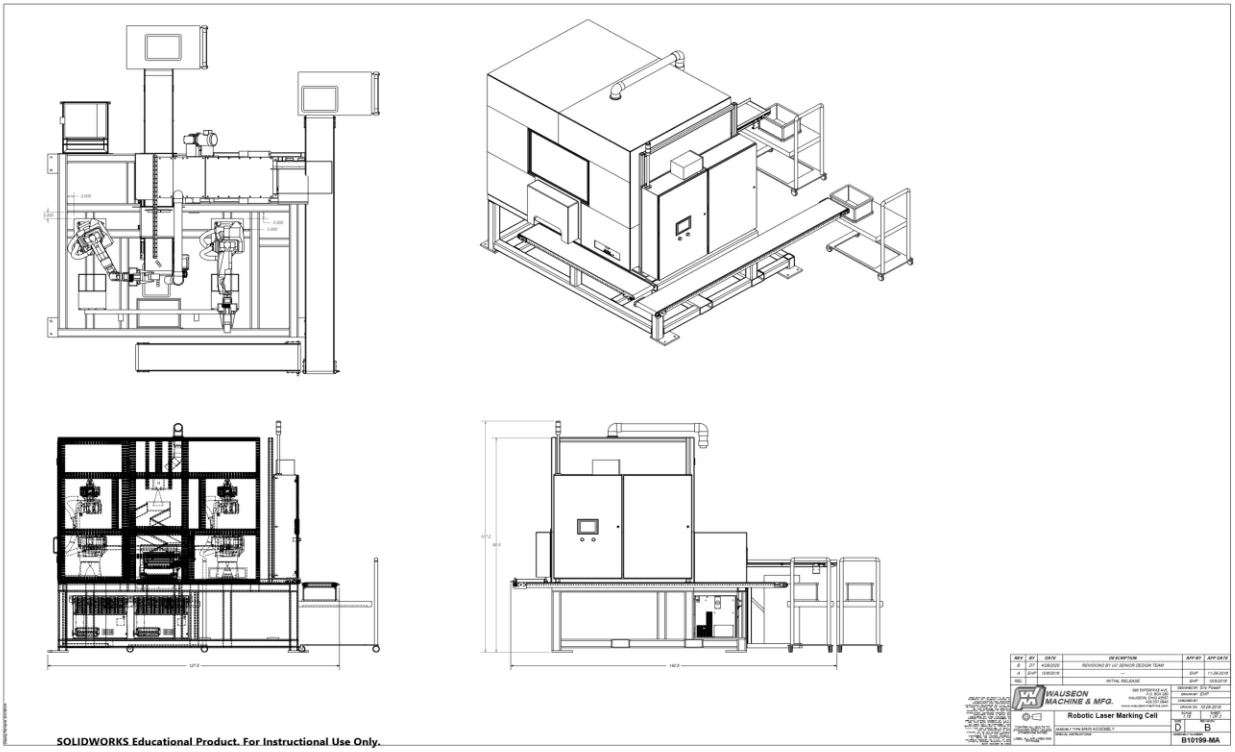
1. Using the Control Panel, the operator should select which part is being used and select the robot programming for the part.
2. The parts should be in a bin raised on working table next to the infeed conveyor. Pick up the part and place the part on the conveyor with the side that is going to be marked facing up. Note: Almost every part should be able to sit flush with the belt conveyor. Reference the Master Part List for which side the part should be marked. Those that cannot sit flush should be placed on its largest flat face.

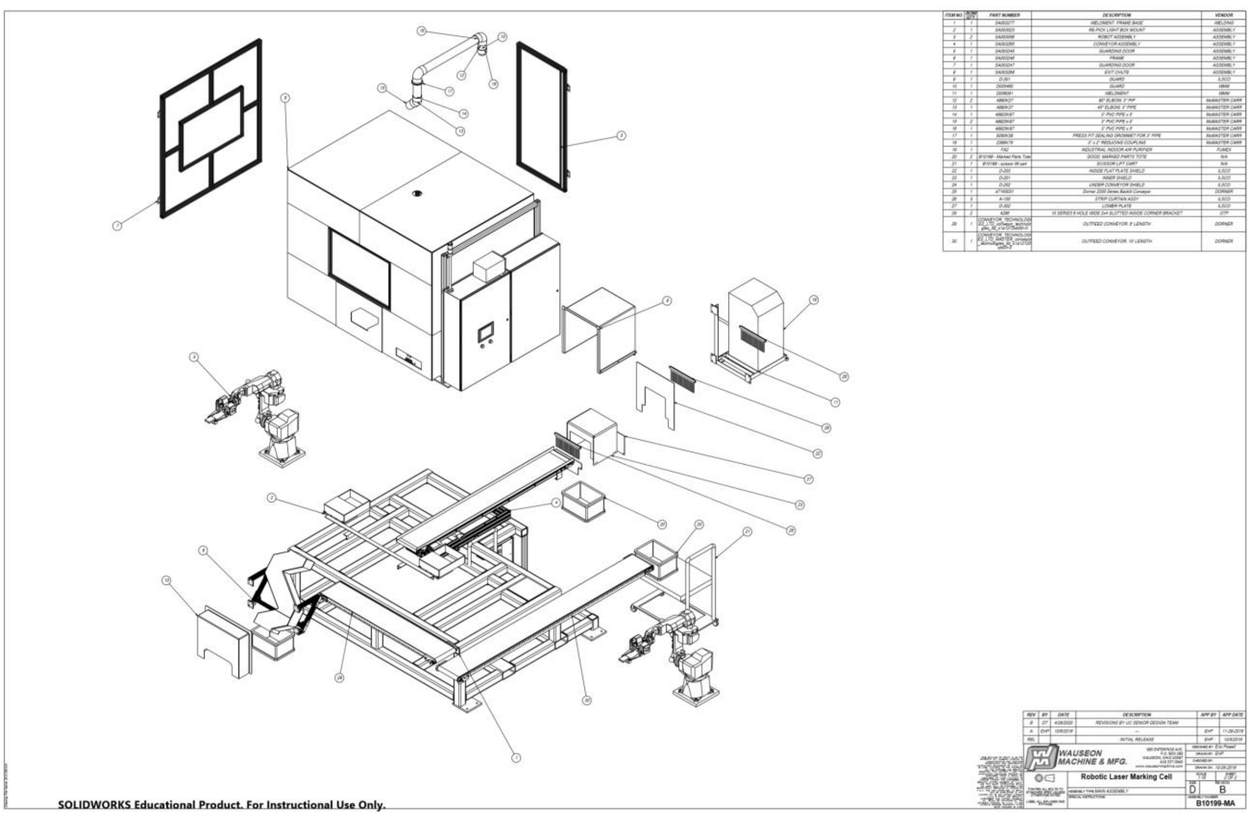
3. After the conveyor has moved the part forward, another part can be placed on the conveyor with the same orientation as the part before. The part should be staggered from the part before it and not overlap as shown below.

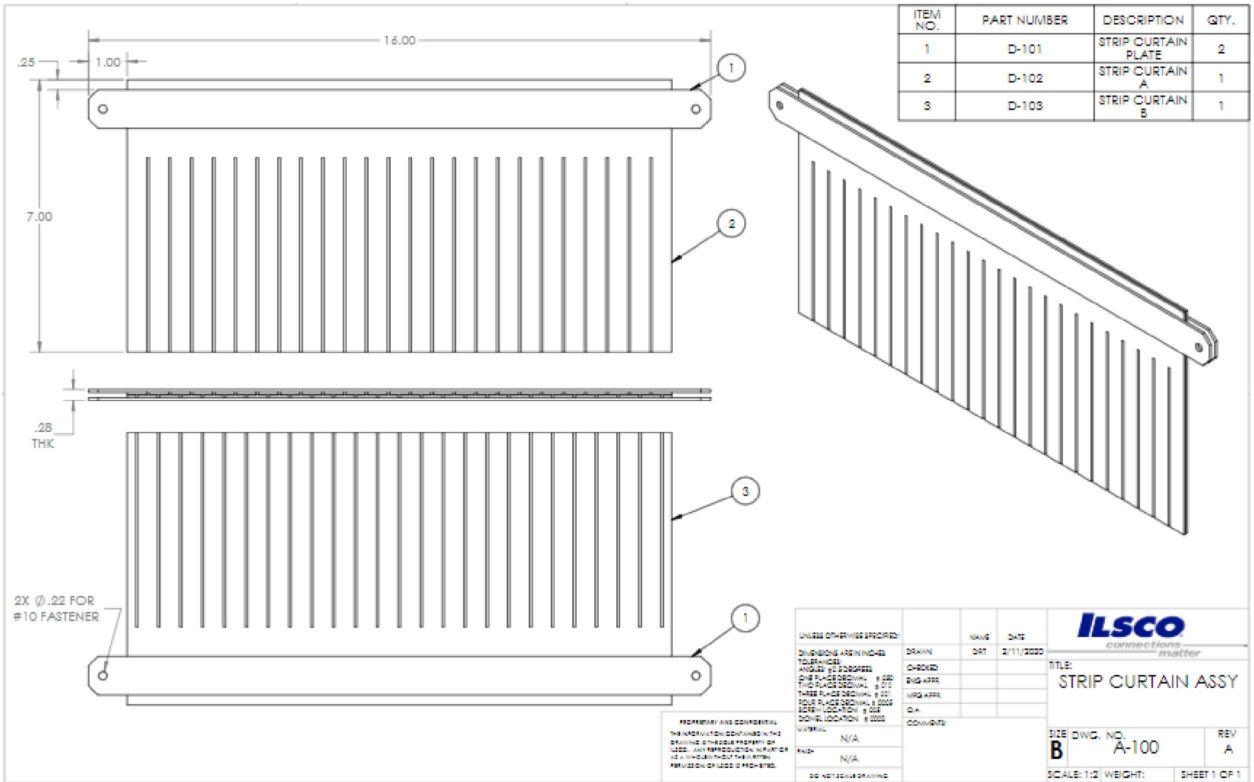


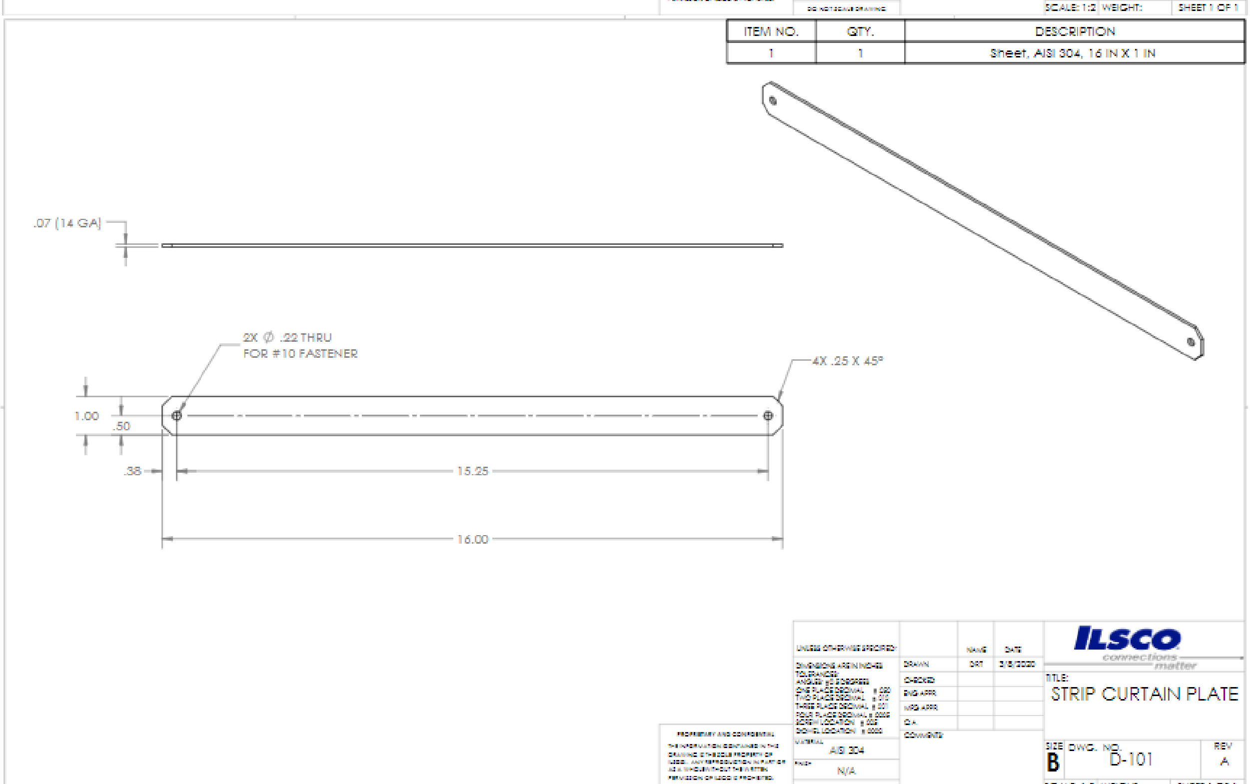
4. With both robots running, the conveyor will be indexing every 11 seconds, so it is important to maintain concentration on orienting the parts.
5. The parts will be exiting the cell and transported to a finished part bin close by. Once the weight of the bin is almost to 30 pounds, the bin should be swapped out with a new bin.

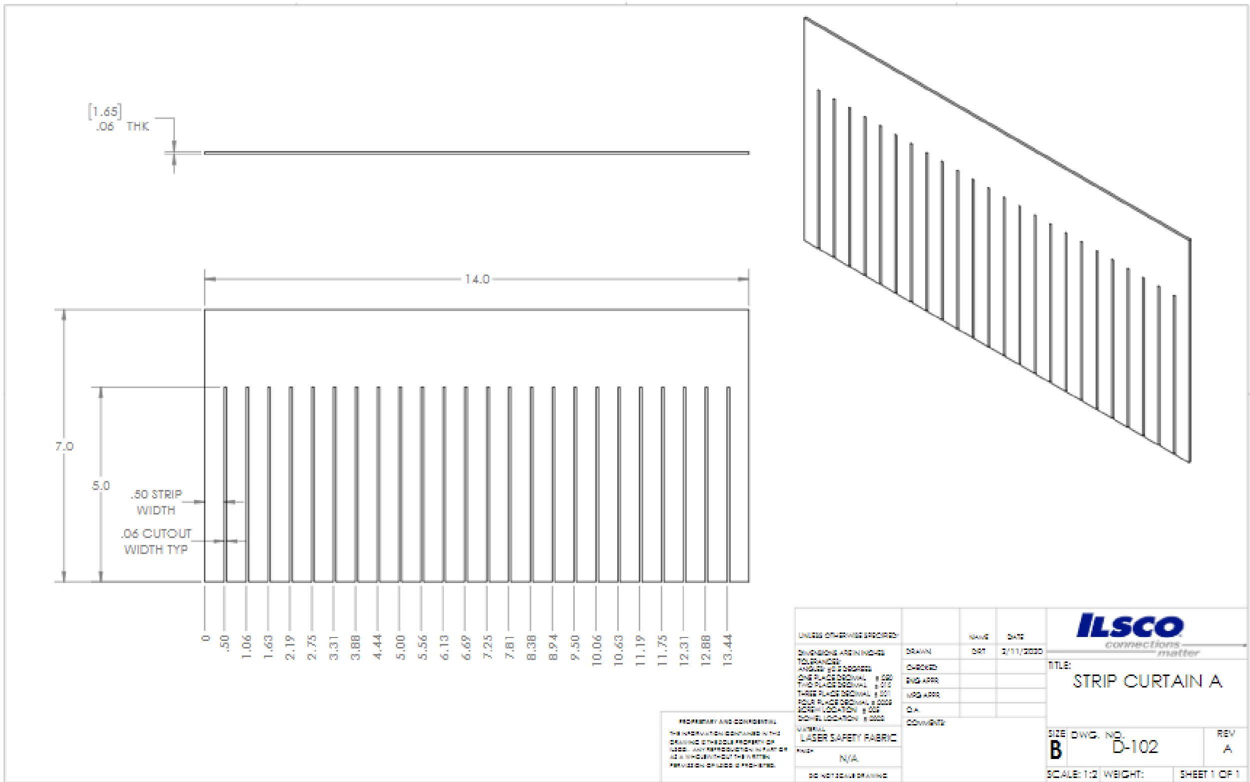
Appendix B – Design Drawings

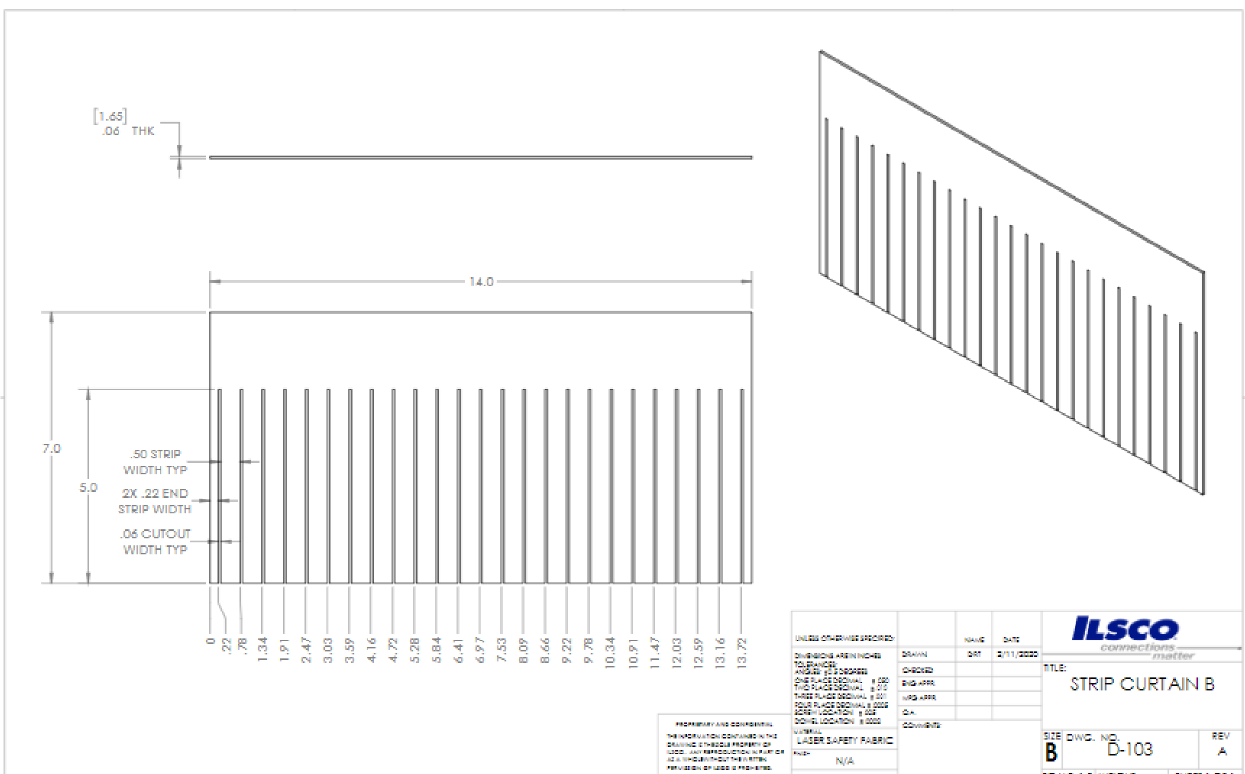


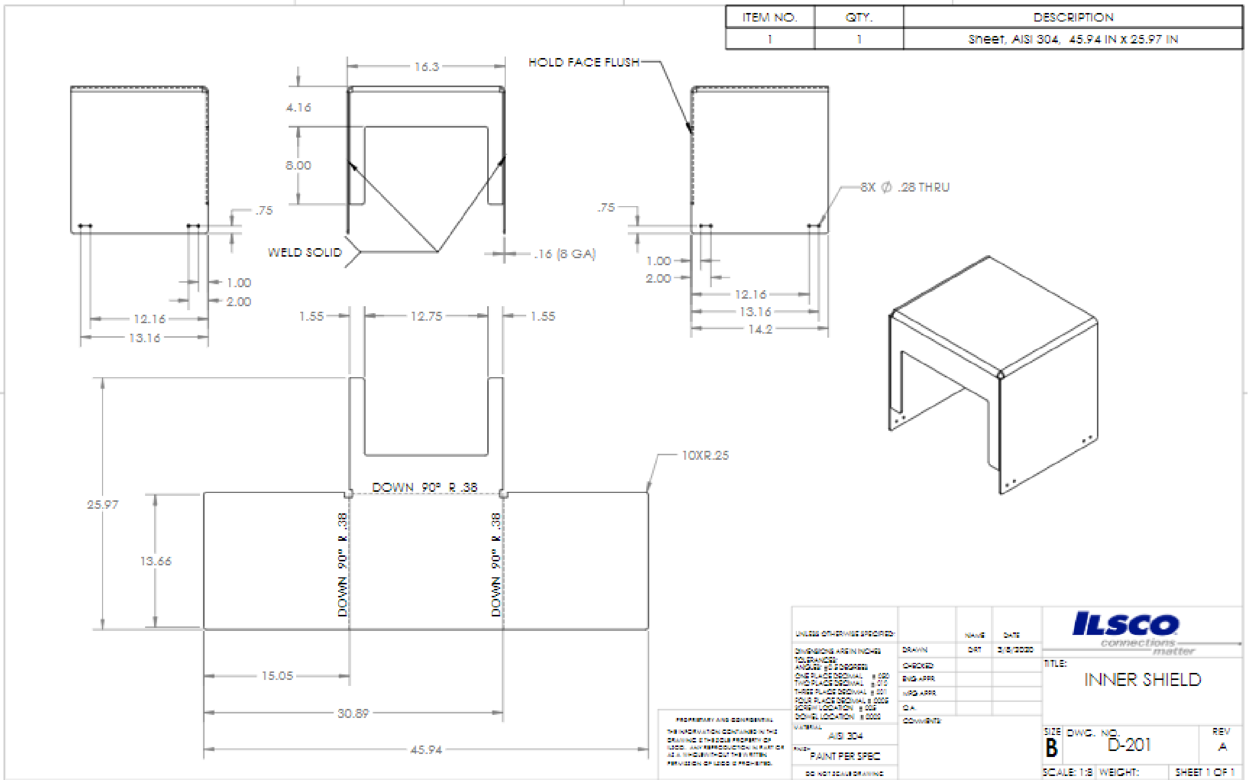


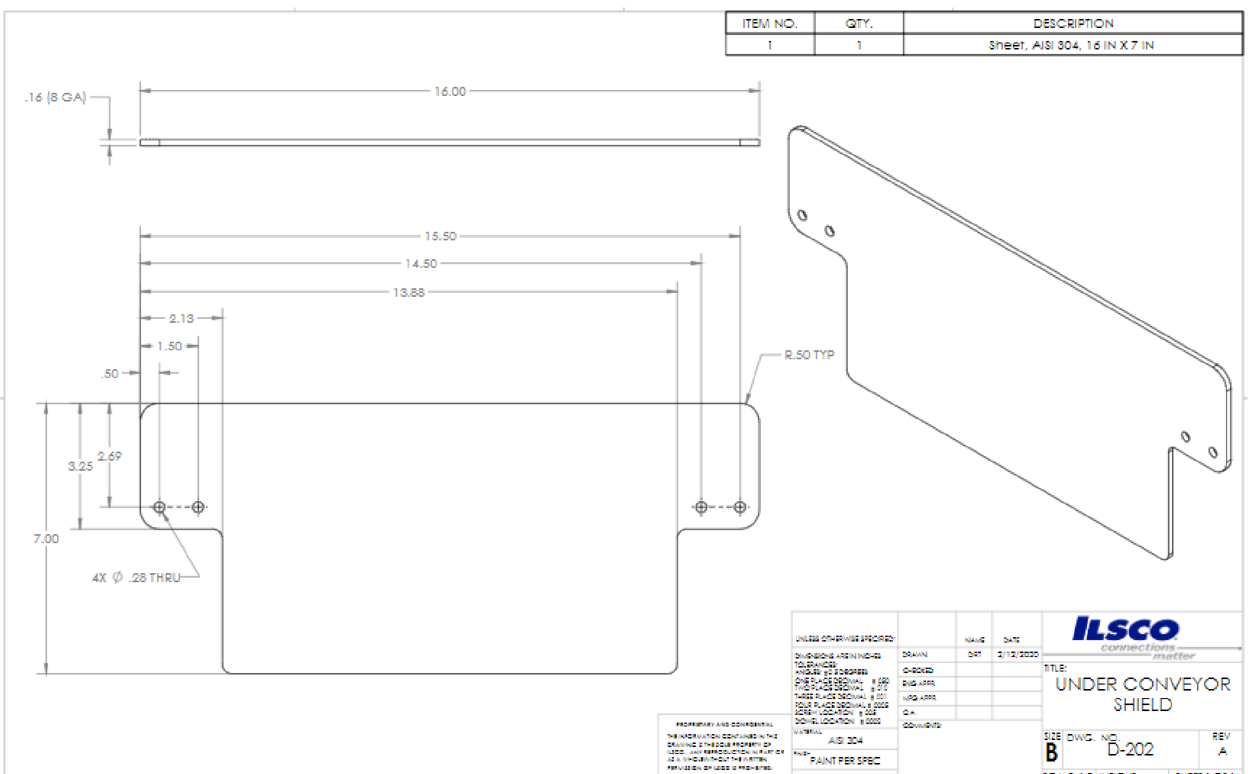

ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
1 D-101 STRIP CURTAIN PLATE 2
2 D-102 STRIP CURTAIN A 1
3 D-103 STRIP CURTAIN B 1
16.00
.25
1.00
7.00
.28 THK
2X ∅ .22 FOR #10 FASTENER
ILSCO connections matter
TITLE:
STRIP CURTAIN ASSY
SIZE B
DWG. NO. A-100
REV A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
N/A
N/A

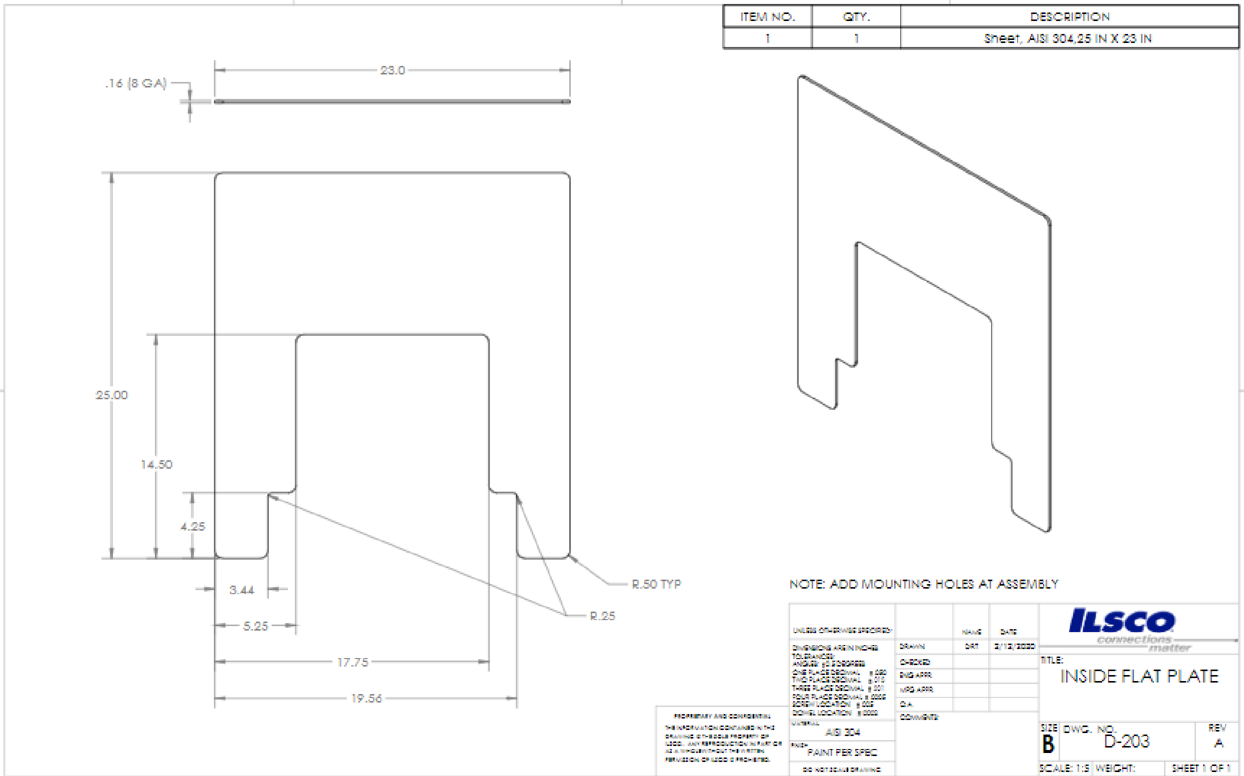

ITEM NO.
QTY.
DESCRIPTION
1 1 Sheet, AISI 304, 16 IN X 1 IN
.07 (14 GA)
2X ∅ .22 THRU FOR #10 FASTENER
4X .25 X 45°
1.00
.50
.38
15.25
16.00
ILSCO connections matter
TITLE:
STRIP CURTAIN PLATE
SIZE B
DWG. NO. D-101
REV A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
AISI 304
N/A

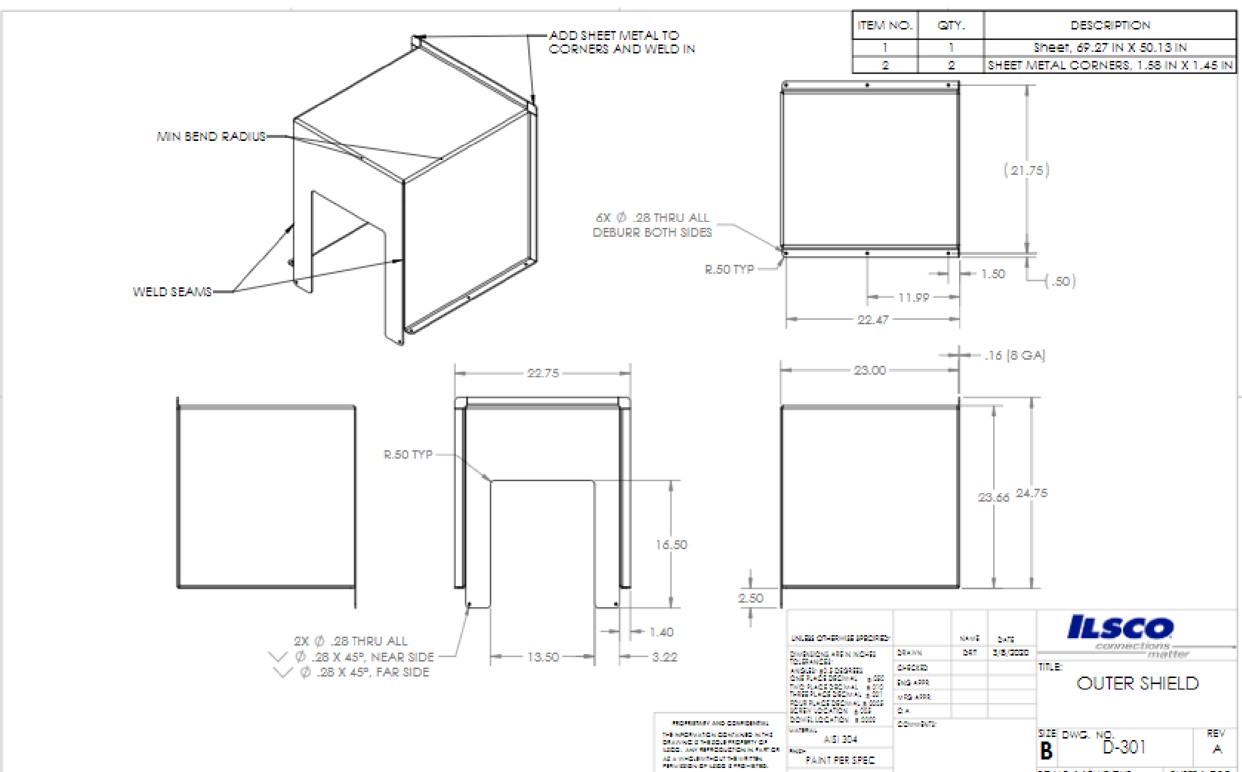

[1.65]
.06 THK
14.0
7.0
5.0
.50 STRIP WIDTH
.06 CUTOUT WIDTH TYP
0
.50
1.06
1.63
2.19
2.75
3.31
3.88
4.44
5.00
5.56
6.13
6.69
7.25
7.81
8.38
8.94
9.50
10.06
10.63
11.19
11.75
12.31
12.88
13.44
ILSCO
connections matter
TITLE:
STRIP CURTAIN A
LASER SAFETY FABRIC
N/A
SIZE B
DWG. NO. D-102
REV A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

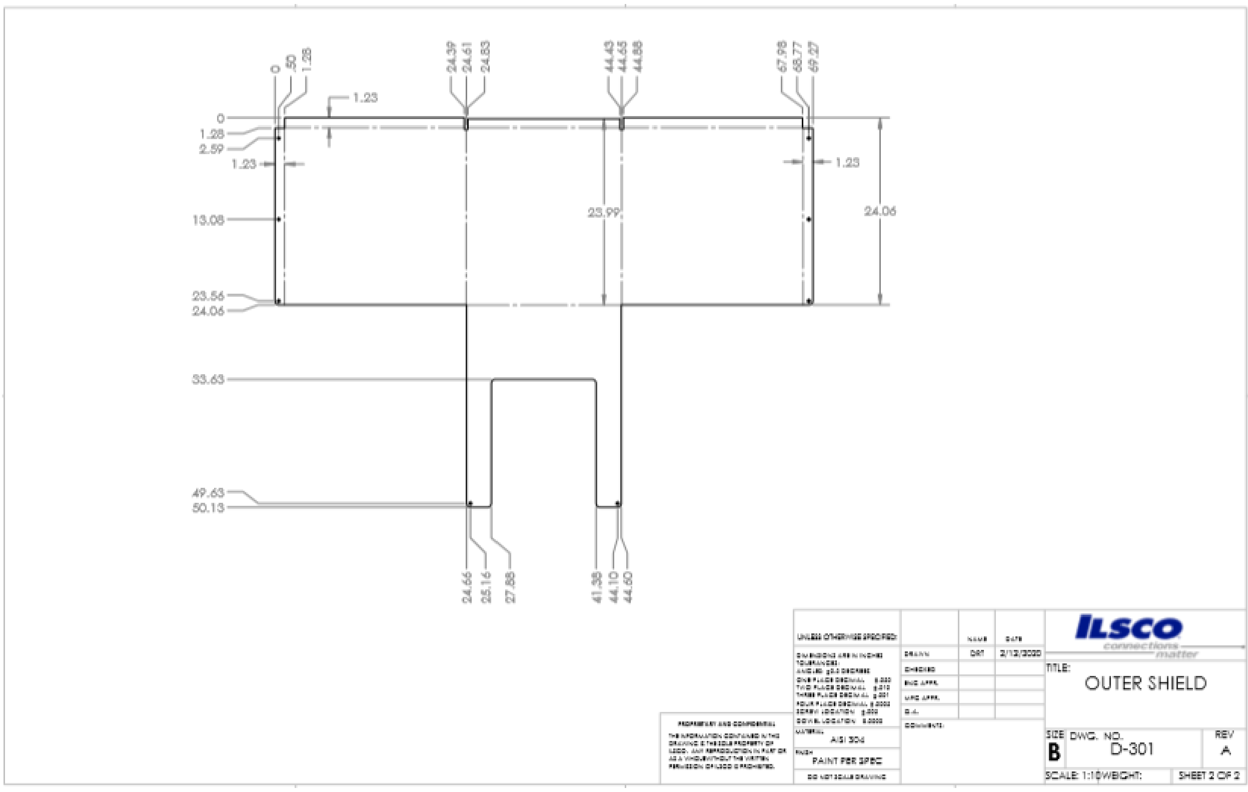

[1.65]
.06 THK
14.0
7.0
5.0
.50 STRIP WIDTH TYP
2X .22 END STRIP WIDTH
.06 CUTOUT WIDTH TYP
0
.22
.78
1.34
1.91
2.47
3.03
3.59
4.16
4.72
5.28
5.84
6.41
6.97
7.53
8.09
8.66
9.22
9.78
10.34
10.91
11.47
12.03
12.59
13.16
13.72
ILSCO
connections matter
TITLE:
STRIP CURTAIN B
LASER SAFETY FABRIC
N/A
SIZE B
DWG. NO. D-103
REV A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1


ITEM NO.
QTY.
DESCRIPTION
1
1
Sheet, AISI 304, 45.94 IN x 25.97 IN
16.3
HOLD FACE FLUSH
4.16
8.00
.75
WELD SOLID
.16 (8 GA)
8X ∅ .28 THRU
1.00
2.00
12.16
13.16
14.2
1.55
12.75
10XR.25
DOWN 90° R .38
25.97
13.66
15.05
30.89
45.94
ILSCO
connections matter
TITLE:
INNER SHIELD
AISI 304
PAINT PER SPEC
SIZE B
DWG. NO.
D-201
REV A
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1

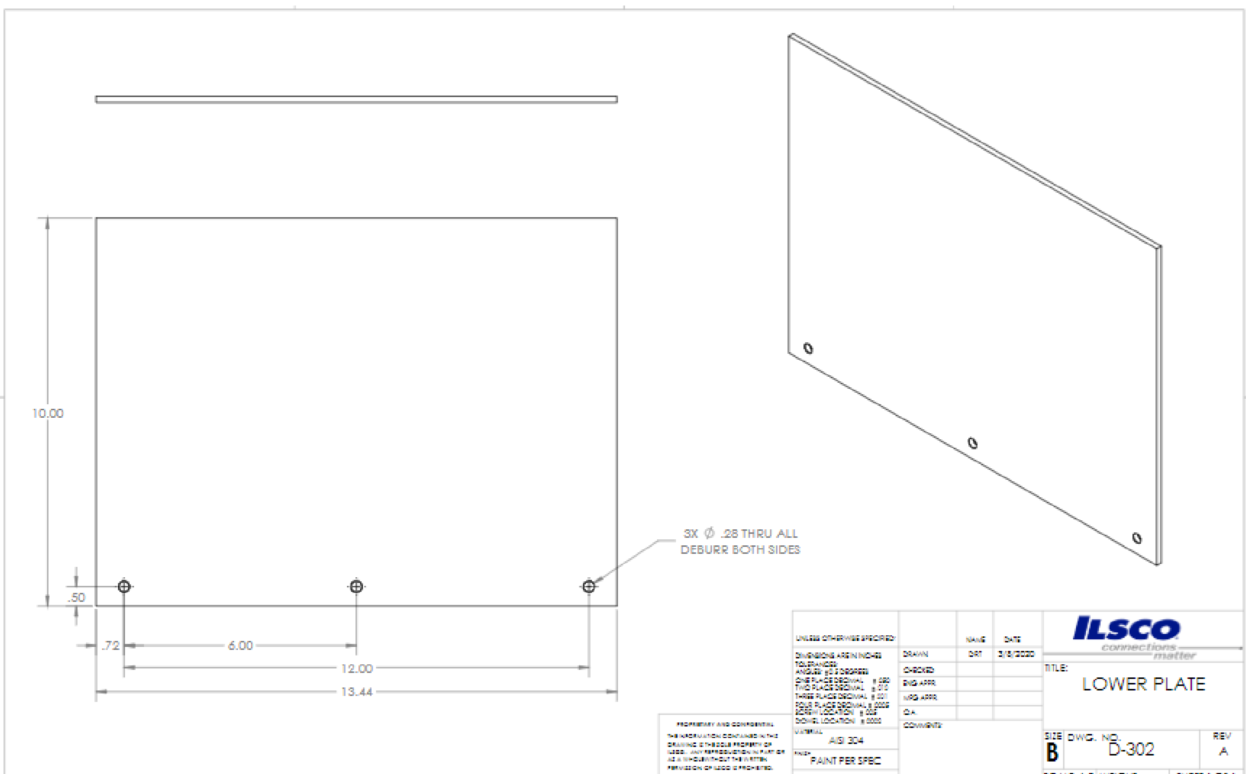

ITEM NO.
QTY.
DESCRIPTION
1
1
Sheet, AISI 304, 16 IN X 7 IN
.16 (8 GA)
16.00
15.50
14.50
13.88
2.13
1.50
.50
R.50 TYP
3.25
2.69
7.00
4X ∅ .28 THRU
ILSCO
connections matter
TITLE:
UNDER CONVEYOR SHIELD
AISI 304
PAINT PER SPEC
SIZE B
DWG. NO.
D-202
REV A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1


ITEM NO.
QTY.
DESCRIPTION
1
1
Sheet, AISI 304,25 IN X 23 IN
.16 (8 GA)
23.0
25.00
14.50
4.25
3.44
5.25
17.75
19.56
R.50 TYP
R.25
NOTE: ADD MOUNTING HOLES AT ASSEMBLY
ILSCO
connections matter
TITLE:
INSIDE FLAT PLATE
SIZE
B
DWG. NO.
D-203
REV
A
AISI 304
PAINT PER SPEC
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1


ITEM NO.
QTY.
DESCRIPTION
1
1
Sheet, 69.27 IN X 50.13 IN
2
2
SHEET METAL CORNERS, 1.58 IN X 1.45 IN
ADD SHEET METAL TO CORNERS AND WELD IN
MIN BEND RADIUS
WELD SEAMS
6X ∅ .28 THRU ALL
DEBURR BOTH SIDES
R.50 TYP
(21.75)
1.50
(.50)
11.99
22.47
.16 (8 GA)
23.00
22.75
R.50 TYP
16.50
23.66
24.75
2.50
2X ∅ .28 THRU ALL
∅ .28 X 45°, NEAR SIDE
∅ .28 X 45°, FAR SIDE
13.50
1.40
3.22
ILSCO
connections matter
TITLE:
OUTER SHIELD
SIZE
B
DWG. NO.
D-301
REV
A
AISI 304
PAINT PER SPEC
SCALE: 1:10
WEIGHT:
SHEET 1 OF 2



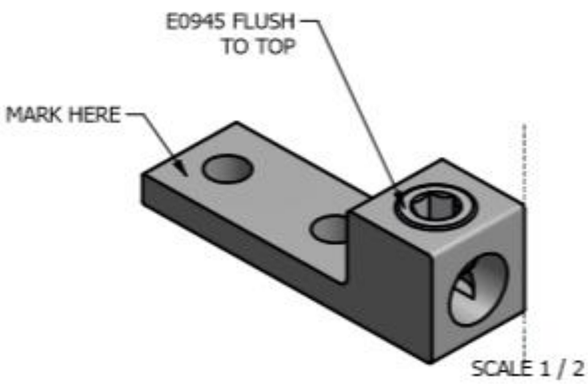
0
.50
1.28
24.39
24.61
24.83
44.43
44.65
44.88
67.98
68.77
69.27
1.23
0
1.28
2.59
1.23
1.23
13.08
23.99
24.06
23.56
24.06
33.63
49.63
50.13
24.66
25.16
27.88
41.38
44.10
44.60
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
DRT
2/12/2020
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
MATERIAL
AISI 304
FINISH
PAINT PER SPEC
DO NOT SCALE DRAWING
ILSCO
connections matter
TITLE:
OUTER SHIELD
SIZE
DWG. NO.
REV
B
D-301
A
SCALE: 1:10
WEIGHT:
SHEET 2 OF 2



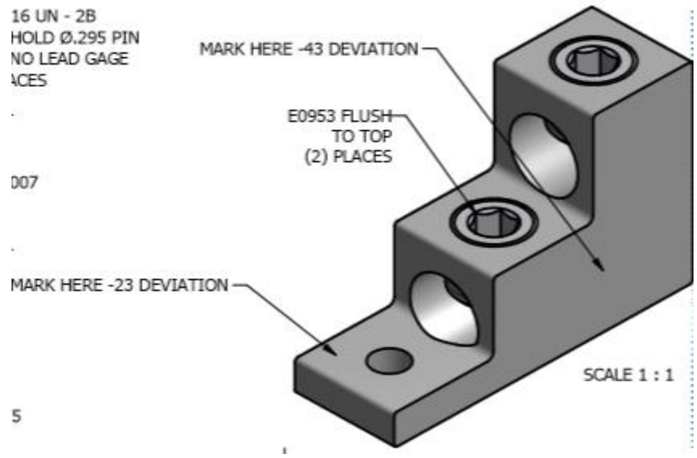
10.00
.50
.72
6.00
12.00
13.44
3X Ø .28 THRU ALL
DEBURR BOTH SIDES
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
DRT
2/5/2020
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
MATERIAL
AISI 304
FINISH
PAINT PER SPEC
DO NOT SCALE DRAWING
ILSCO
connections matter
TITLE:
LOWER PLATE
SIZE
DWG. NO.
REV
B
D-302
A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

Appendix C – ILSCO Parts

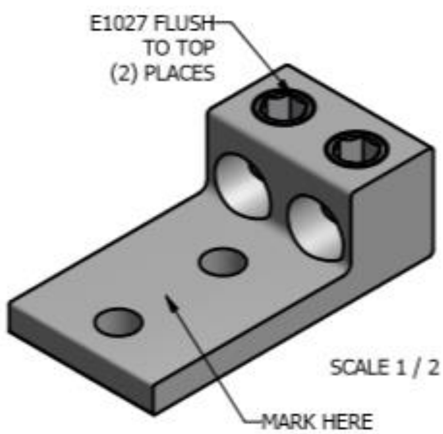
D2054-22



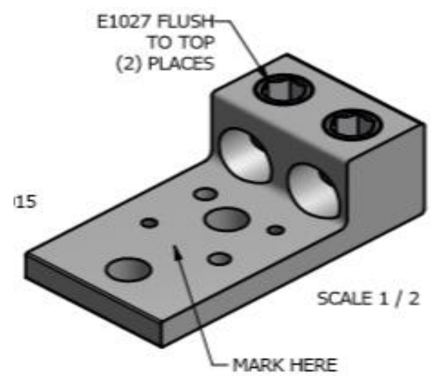
D1601



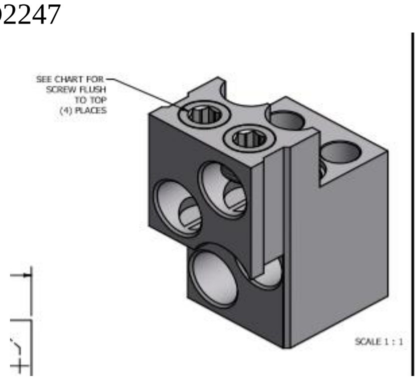
D2058-22



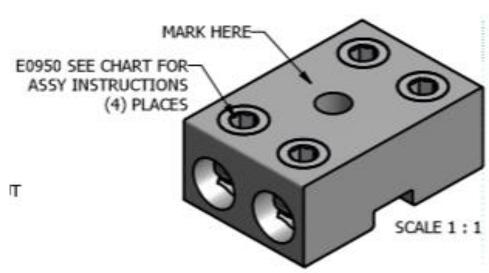
D2058-23



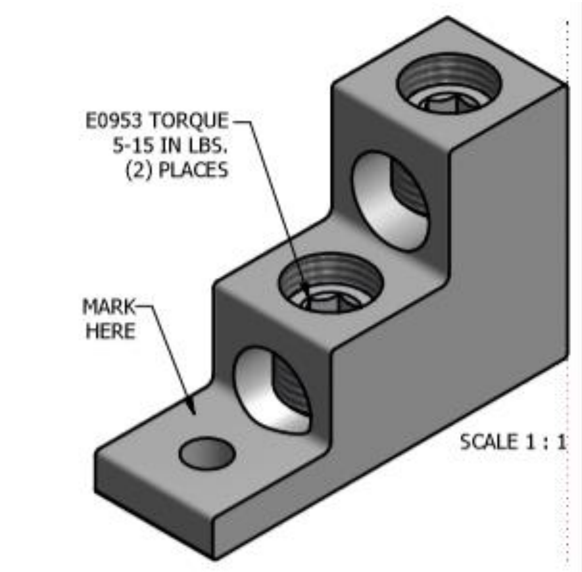
D2247



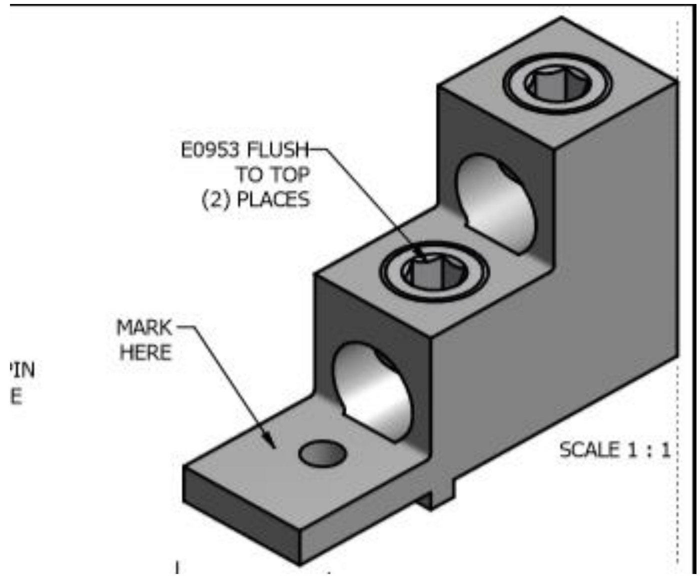
D2713



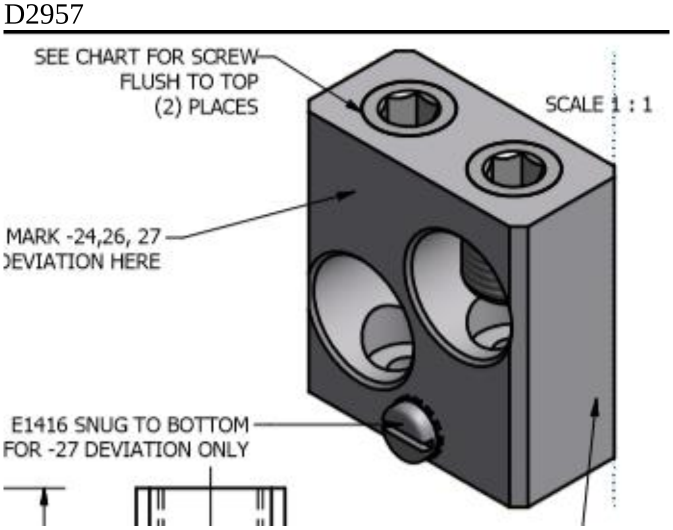
D2822-22

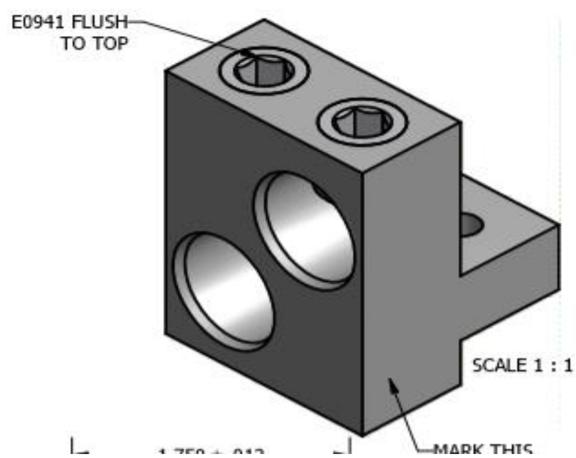


D2874

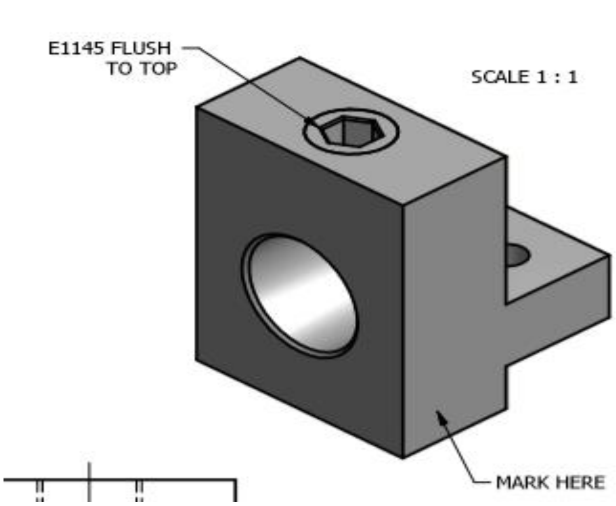


D2957

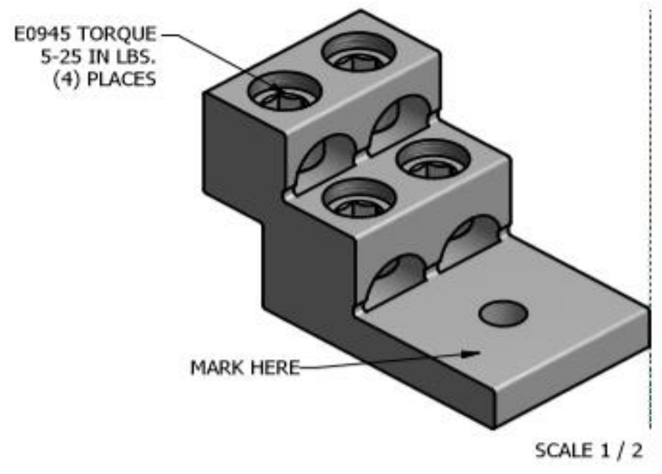




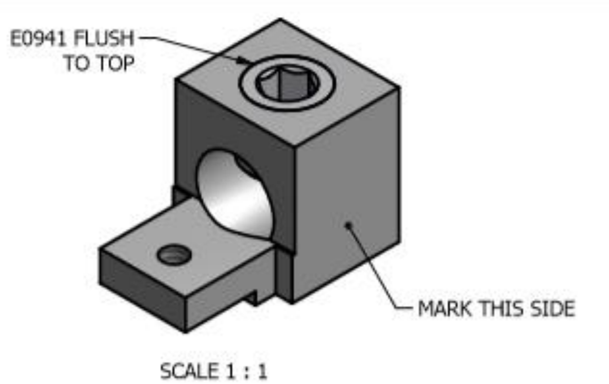
D3226



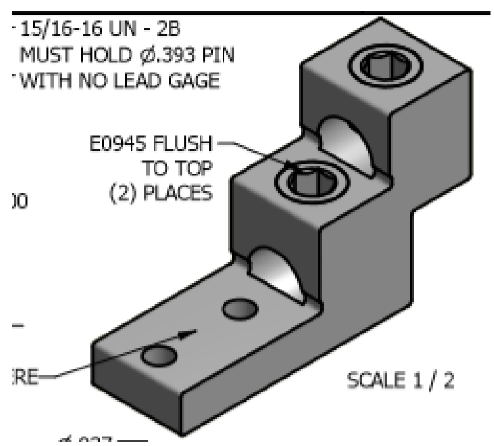
D3281



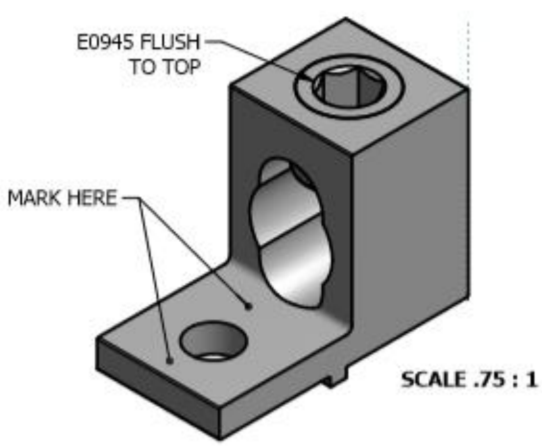
D3325



D3342

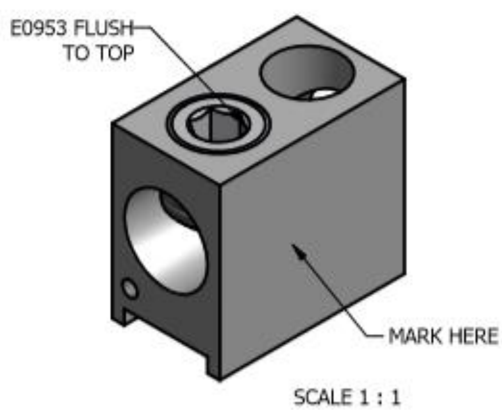


D3481

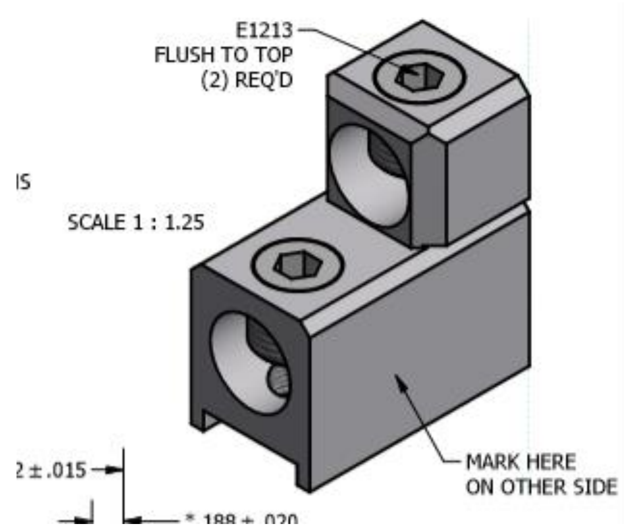


D3564-22

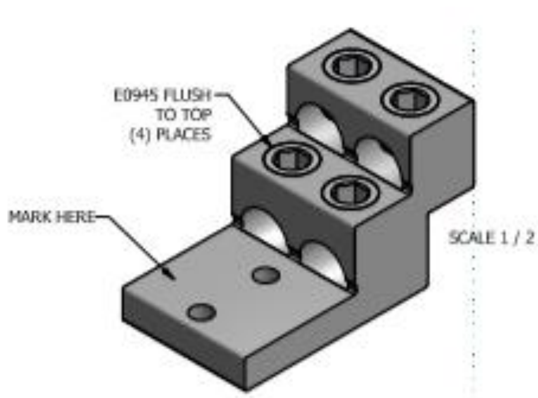
D3608-22



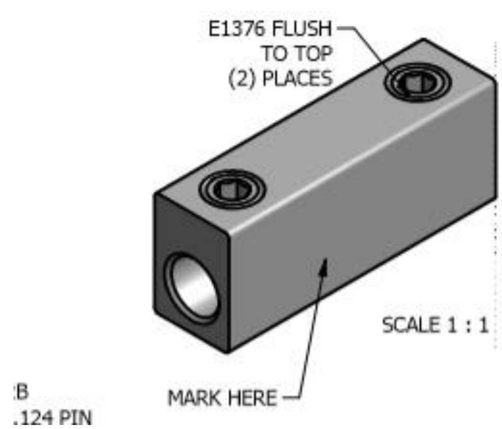
D3687-23



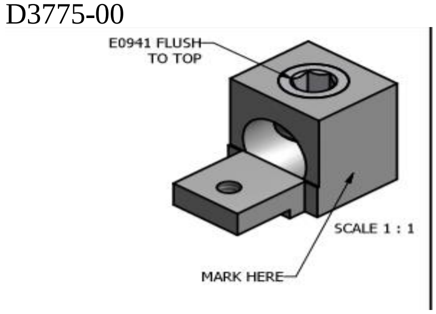
D3715-22



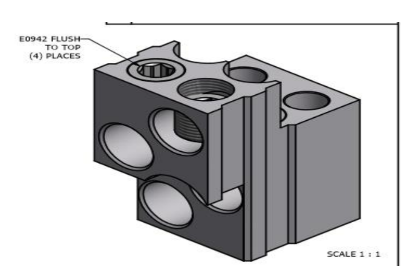
D3728



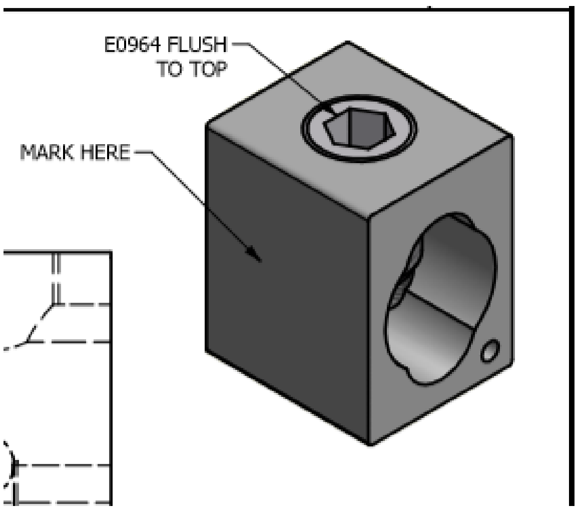
D3775-00



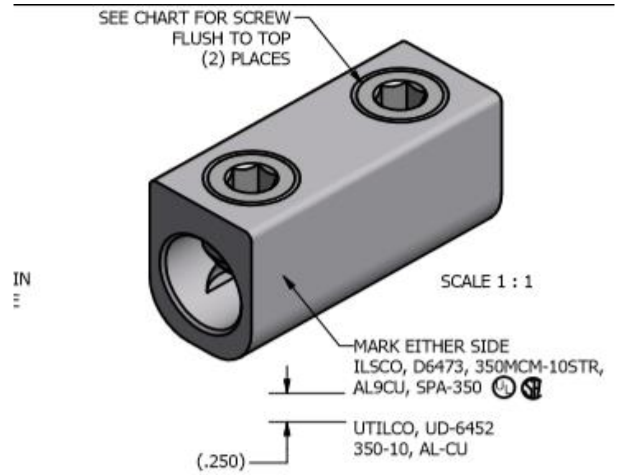
D3827



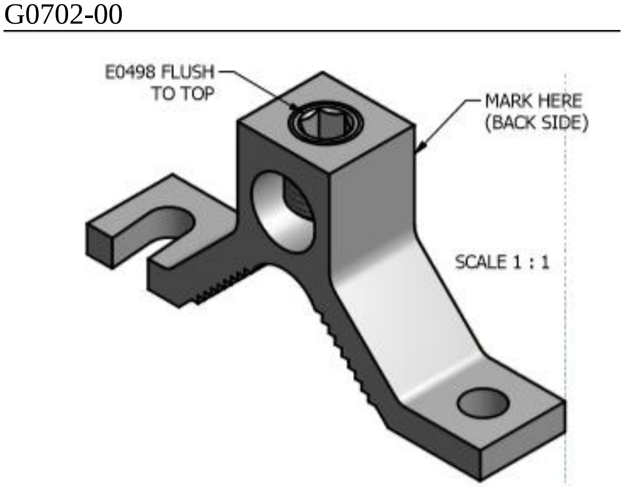
D3858



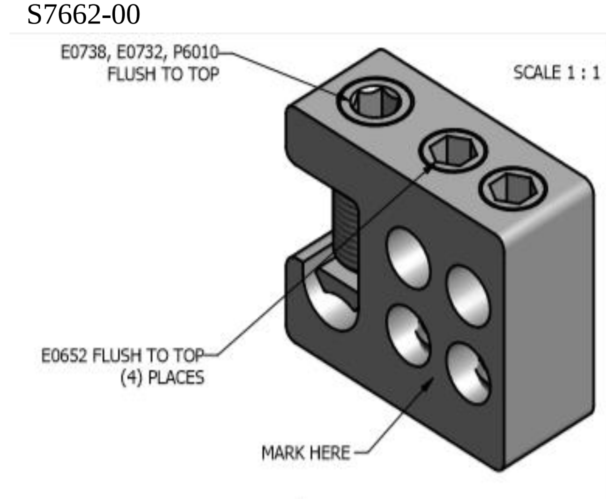
D6473



G0702-00

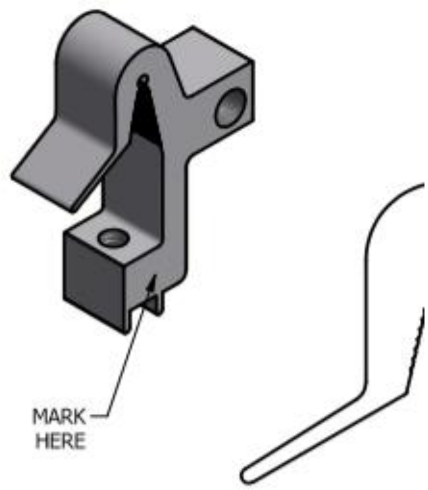


S7662-00

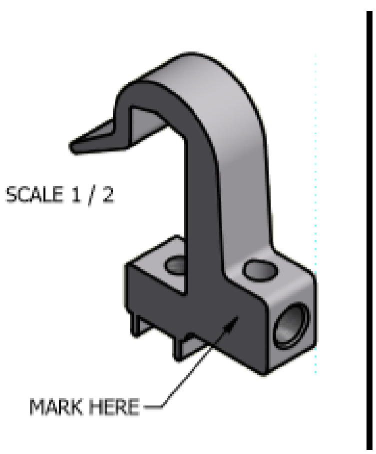


S7686-00

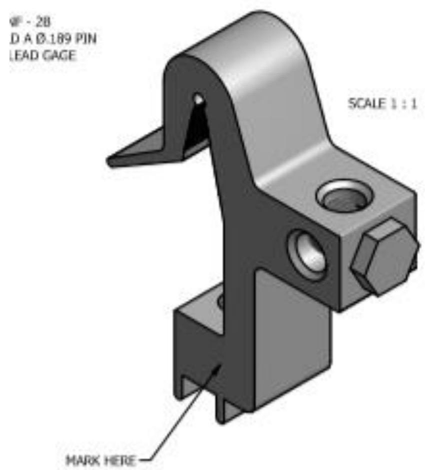
S7698



S7706



D7714



Appendix D – Cycle Time vs. Quality Matrix

D3325

Mark Speed 1	Robot Speed 100	Total Time 2:19
R1 Mark Time	R2 Mark Time	
9.7	10.6	
10.23	10.1	
9.88	9.67	
9.99	10.2	

Mark Speed 2	Robot Speed 100	Total Time 1:38
R1 Mark Time	R2 Mark Time	
5.3	5.4	
5.6	5.3	
5.1	5.6	
5.5	5	

Mark Speed 3	Robot Speed 100	Total Time 1:33
R1 Mark Time	R2 Mark Time	
3.7	3.8	
4	3.8	
3.8	3.7	
3.9	3.9	

D6473

Mark Speed 1	passes 4	Total Time 2:00
R1 Mark Time	R2 Mark Time	
6.9	7	
6.9	7.2	
6.9	7.3	
7	8.1	

Mark Speed 2	passes 1	Total Time 1:25
R1 Mark Time	R2 Mark Time	
5.3	5.4	
5.6	5.3	
5.1	5.6	
5.5	5	

Mark Speed 3	passes 1	Total Time

Poor Quality

D3281

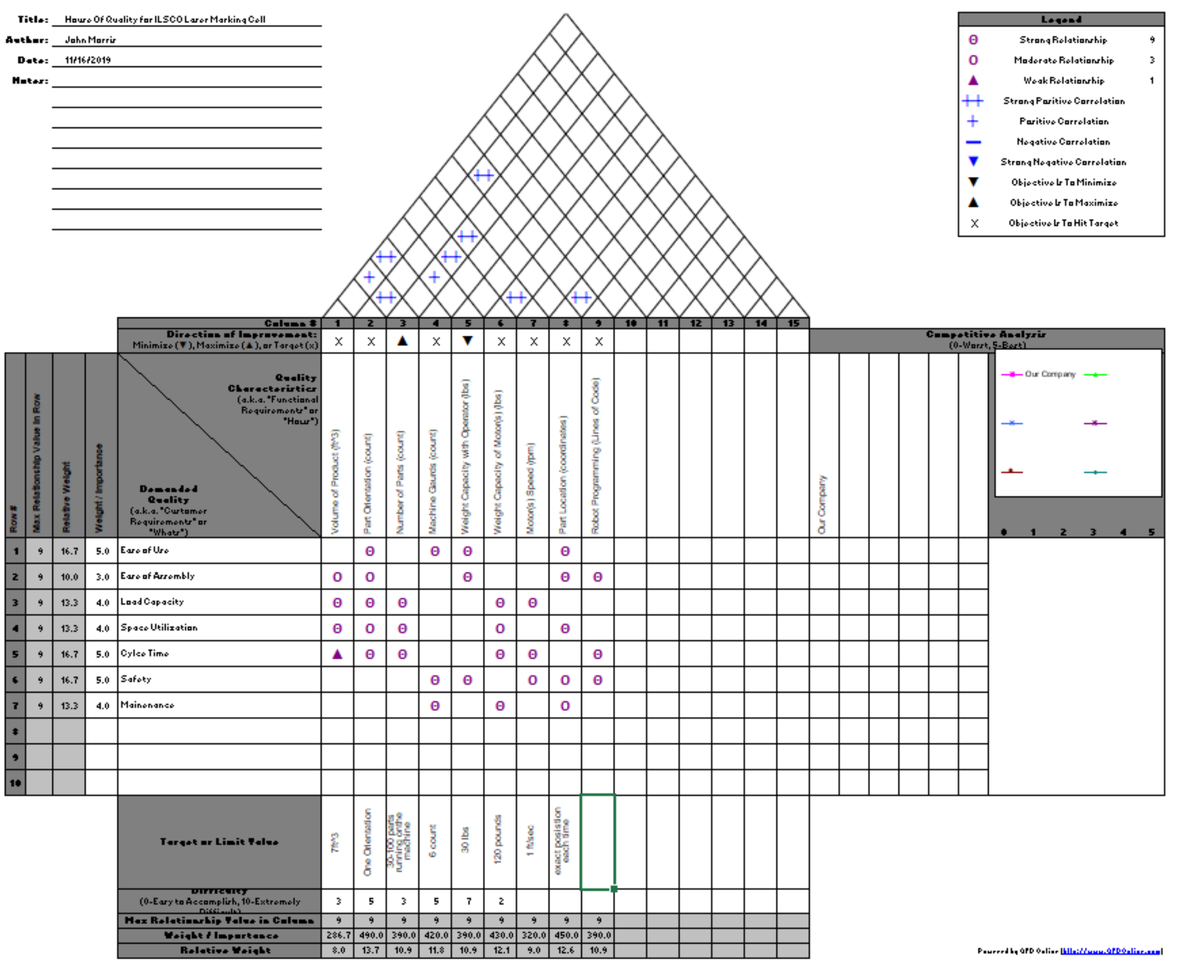
Mark Speed	passes	Total Time 2:10
R1 Mark Time	R2 Mark Time	
6.9	7	
6.9	7.2	
6.9	7.3	
7	8.1	

Mark Speed	passes	Total Time 1:20
R1 Mark Time	R2 Mark Time	
6.9	7	
6.9	7.2	
6.9	7.3	
7	8.1	

Note: No benefit of increasing speed

*Note- This experiment was conducted by an ILSCO employee.

Appendix E – House of Quality



Column #					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)					X	X	▲	X	▼	X	X	X	X						
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Volume of Product (ft^3)	Part Orientation (count)	Number of Parts (count)	Machine Gaurds (count)	Weight Capacity with Operator (lbs)	Weight Capacity of Motor(s) (lbs)	Motor(s) Speed (rpm)	Part Location (coordinates)	Robot Programming (Lines of Code)						
1	9	16.7	5.0	Ease of Use		Θ		Θ	Θ			Θ							
2	9	10.0	3.0	Ease of Assembly	O	O			Θ			Θ	Θ						
3	9	13.3	4.0	Load Capacity	Θ	Θ	Θ			Θ	Θ								
4	9	13.3	4.0	Space Utilization	Θ	O	Θ			O		Θ							
5	9	16.7	5.0	Cylce Time	▲	Θ	Θ			Θ	Θ		Θ						
6	9	16.7	5.0	Safety				Θ	Θ		O	O	Θ						
7	9	13.3	4.0	Mainenance				Θ		Θ		O							
8																			
9																			
10																			
Target or Limit Value					7ft^3	One Orientation	30-100 parts running on the machine	6 count	30 lbs	120 pounds	1 ft/sec	exact posistion each time							
Difficulty (0-Easy to Accomplish, 10-Extremely Difficult)					3	5	3	5	7	2									
Max Relationship Value in Column					9	9	9	9	9	9	9	9	9						
Weight / Importance					286.7	490.0	390.0	420.0	390.0	430.0	320.0	450.0	390.0						
Relative Weight					8.0	13.7	10.9	11.8	10.9	12.1	9.0	12.6	10.9						

Appendix F – Meeting Minutes

10/25/19: Initial visit with Dr. Dong to go over the problem statement and scope of the project.

11/1/19: Initial visit with the ILSCO engineering team to have a demo of the current laser marker and develop an understanding of the project including scope, current issues, timeline, equipment availability, deliverables, and next steps.

11/18/19: Review of the three initial design concepts.

11/22/19: Meeting with Dr. Dong to discuss tray design.

12/2/19: ILSCO Safety Orientation for general plant safety, reviewed tray and insert designs, and reviewed changes required to the conveyor and guarding.

12/5/19: Meeting with Dr. Huston to give a status report.

1/20/20: Review fabricated tray design, reviewed the detailed design of two concepts (in/out conveyor, load/unload station, controlled placement on conveyor), run parts off using the tray design.

2/6/20: Meeting with Dr. Dong to discuss the concepts that would be reviewed at the next ILSCO meeting.

2/7/20: Infeed and outfeed conveyor concept review at ILSCO.

2/26/20: Meeting with Dr. Dong to discuss deliverables and a contingency plan if the project does not get built. This included a simulation and/or 3D printed model.

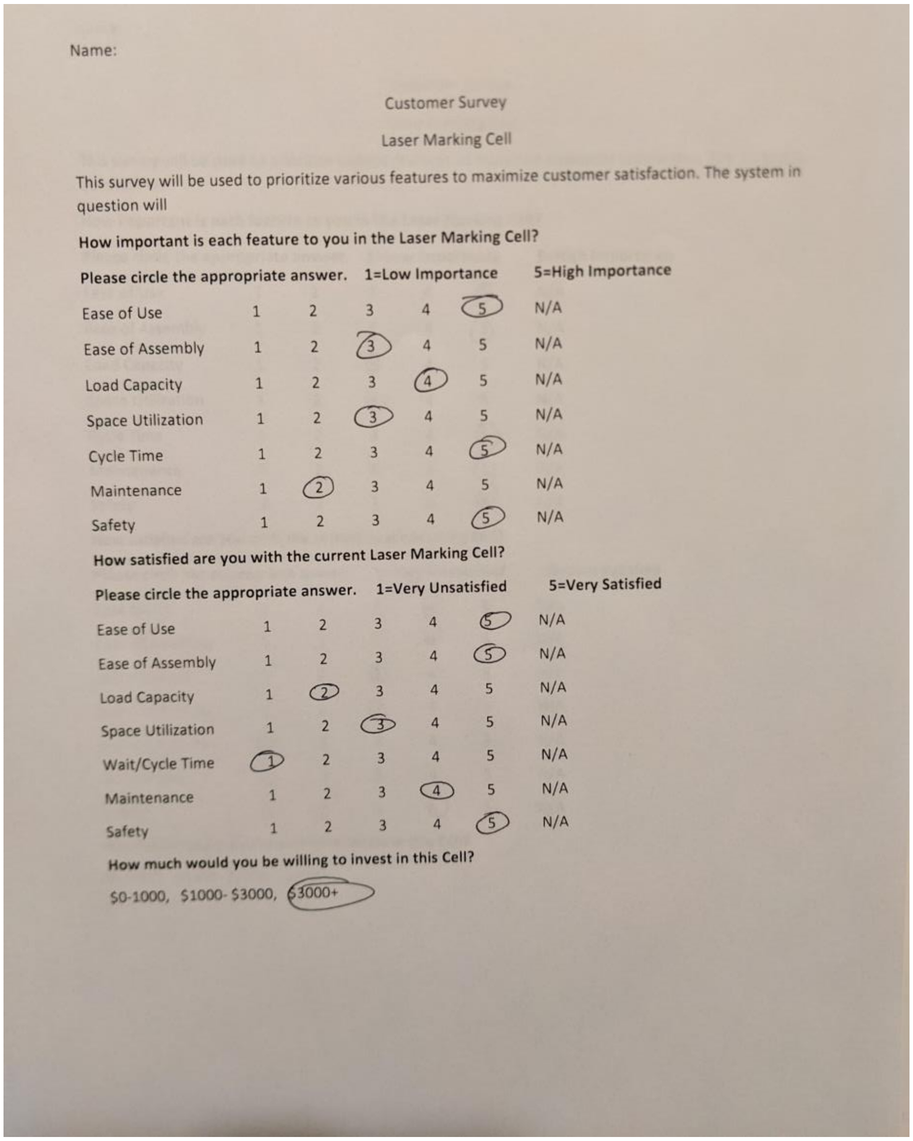
3/24/20: Meeting with Dr. Huston to give a progress report of operations at ILSCO and requirements going forward.

4/2/20: Meeting with Dr. Dong to discuss simulation progress.

4/16/20: Meeting with Dr. Dong to discuss the presentation and need to include planned fabrication, testing, report, and assembly instructions.

4/20/20: Meeting with Dr. Huston to discuss submission of the report and presentation.

Appendix G – Customer Surveys


Name:

Customer Survey

Laser Marking Cell

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will

How important is each feature to you in the Laser Marking Cell?

Please circle the appropriate answer.	**1=Low Importance**				**5=High Importance**	
Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

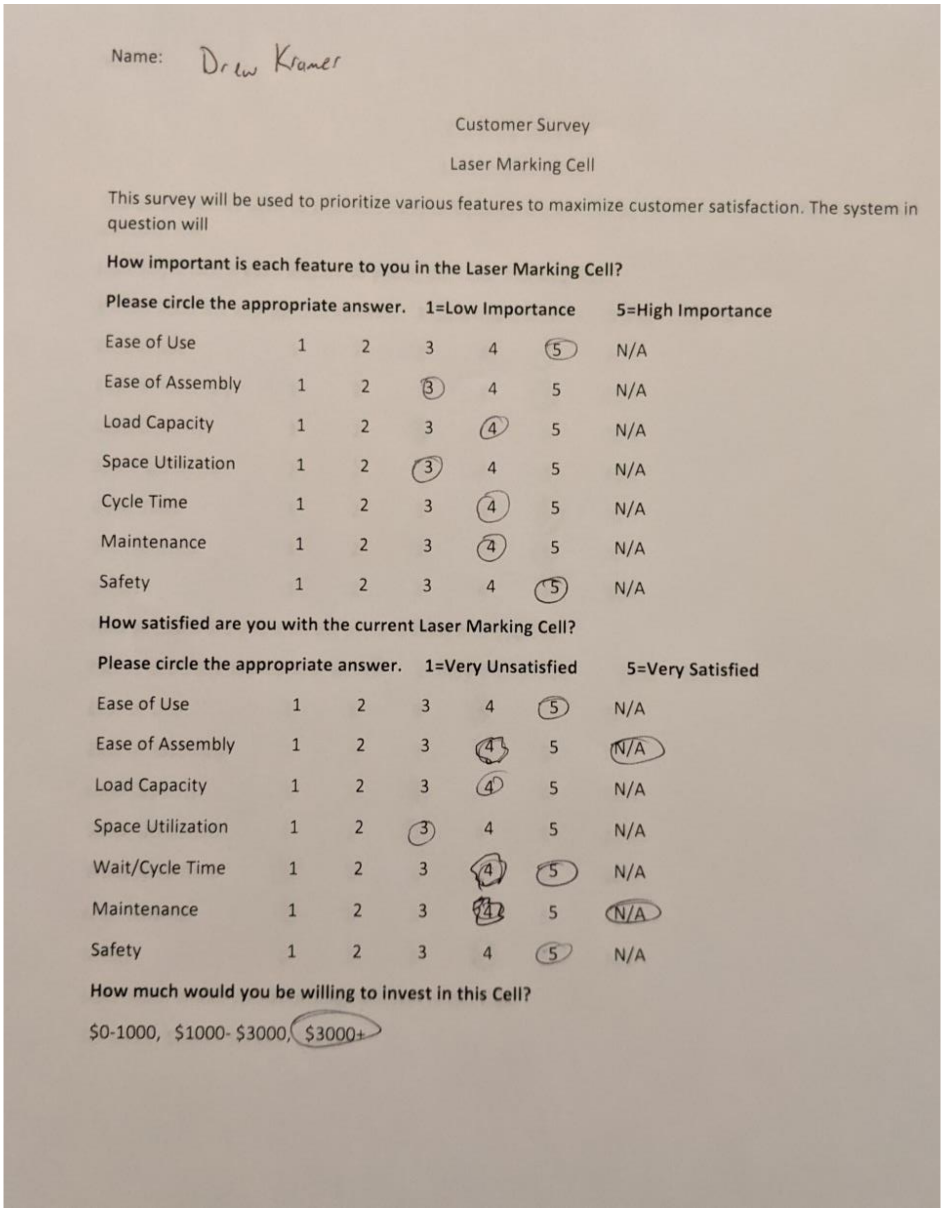
How satisfied are you with the current Laser Marking Cell?

Please circle the appropriate answer.	**1=Very Unsatisfied**				**5=Very Satisfied**	
Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Wait/Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

How much would you be willing to invest in this Cell?

$0-1000, $1000- $3000, $3000+

Note: Second sentence should say "The system in question will help prioritize the product objectives for this project."



Name: Drew Kramer

Customer Survey

Laser Marking Cell

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will

How important is each feature to you in the Laser Marking Cell?

Please circle the appropriate answer. 1=Low Importance 5=High Importance

Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

How satisfied are you with the current Laser Marking Cell?

Please circle the appropriate answer. 1=Very Unsatisfied 5=Very Satisfied

Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Wait/Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

How much would you be willing to invest in this Cell?

$0-1000, $1000- $3000, $3000+

Name:

Customer Survey

Laser Marking Cell

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will

How important is each feature to you in the Laser Marking Cell?

Please circle the appropriate answer.	**1=Low Importance**				**5=High Importance**
Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

How satisfied are you with the current Laser Marking Cell?

Please circle the appropriate answer.	**1=Very Unsatisfied**				**5=Very Satisfied**
Ease of Use	1	2	3	4	5	N/A
Ease of Assembly	1	2	3	4	5	N/A
Load Capacity	1	2	3	4	5	N/A
Space Utilization	1	2	3	4	5	N/A
Wait/Cycle Time	1	2	3	4	5	N/A
Maintenance	1	2	3	4	5	N/A
Safety	1	2	3	4	5	N/A

How much would you be willing to invest in this Cell?

$0-1000, $1000- $3000, $3000+