Auto-Bottom Carton Erector

Senior Design Report submitted to the
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University of Cincinnati

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Bachelor of Science

in Mechanical Engineering Technology
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by

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Problem Statement

Halex, a subsidiary of Scott Fetzer Consumer Brands, is in need of a machine that will automatically erect cardboard cartons and drop them onto a conveyor-controlled packing line. The cartons that they use are called auto-bottom cartons, which use a tab/lock system and does not require tape to be erected. The machine must be able to keep up with the current speed of the conveyor belt, which brings empty cartons to a bagging machine to be filled with product. We will be designing a machine that will be totally automated, configurable to multiple different carton sizes, and can be replicated and integrated into many other packing lines.

Figure 1: Conveyer belt leading to Vertical Bagger machine

Research

Background of the Problem

When running their bagging machines, Halex currently uses an operator to manually construct each carton and place them onto a conveyor. This is an auxiliary task for a worker whose primary responsibility is ensuring that once product is dropped into the cartons, that the product is nested properly inside for the carton to close. The operator has brought it to management's attention that the frequency at which cartons have to be erected interferes with their responsibility to nest the product properly, resulting in the packing line having frequent down time. According to Operations, it is estimated that the packing line has about 90 minutes of downtime per 8-hour shift. Approximately 8 cartons pass through the packing line per minute. This means that this unnecessary downtime results in the loss of over 700 filled cartons per day, which can equate to up to $15,000 depending on the product. This loss occurs every day. The amount of ground an operator has to has to cover between the front of the line, where cartons are constructed, and the back of the line, where product is nested, is concerning. In order to prevent the operator from quitting, which has been threatened, the company has decided to implement an automated system for erecting the cartons.

Applicable Standards

Being that this project is not for a product used by consumers, there are no product standards for consumer safety that this project must adhere to, from an agency such as Underwriters Laboratories or Canadian Standards Association. However, this project will have to follow both International Electro-Technical Commission (IEC), and OSHA standards for electrical machine safety. According to IEC60204-1, in order to properly protect the operator from an injury due to an electrical or sensory error, this machine must be equipped with an emergency stop button.(1) Furthermore, according to OSHA 29 CFR 1910, all moving aspects of the machine must be enclosed or out of reach from the operator, to prevent any sort of personal injury.(2) Lastly, since the operator will have to periodically interact with the machine, there must be no sharp edges or corners.

State of the Art

Halex has looked into hiring an outside company to construct an auto-bottom cardboard carton erector for them. The first machine that we researched for Halex was made by a company called Econocorp.(3) A pro of this machine would be that it is prebuilt, so it does not cost Halex any labor. Another benefit would be the speed in which it is able to pump out erected cartons. A con of this option would be that because it is prebuilt and comes as is, it would be unable to be easily integrated into the current packing line's configuration. Another downside would be the cost. The next machine that we researched was the Pearson CE35 Carton Erector.(4) This erector featured a PLC user interface as well as status lighting. Cons for this machine include the needing 30 feet of floor space, as well as also being out of Halex's budget. We also examined the possibility of hiring another pair of hands for this specific task. This obviously would be the easiest option, and cost Halex little to no upfront investment. However, this worker would not have a full day's work to accomplish if they were dedicated to this task only. Also, Halex's labor cost would go up now that there is another operator on the payroll Hiring another company was deemed inadequate because their designs would cost anywhere between thirty and fifty thousand dollars. At that level of monetary investment, it would take the company a year to see any cost benefit from the erectors. There are numerous companies that have designed carton erector machines in the past, but Halex needs something tailored to their specific cartons, as well as their very tight dimensional constraints.

End User

The operator and Halex are both impacted by the inefficiencies of the packing line. The operator has too many responsibilities and is unhappy with their current position because of this. Halex has six total packing lines that are inefficient. These inefficiencies affect the amount of available product for sale by slowing down production. A solution to this will increase the company's output and keep their employees happy.

Summary of Research

Halex is in need of an automated machine that will erect auto-bottom cardboard cartons before releasing them onto a conveyor. The machine must be adjustable for multiple different carton sizes, and must comply with the constraints presented by the conveyor's configuration and operation. Currently these cartons are erected by hand, which means an operator must leave their station any time more cartons are needed on the line. Other companies have developed machines such as this before, whether it be for their own production or as a contracted developer for another. These machines are expensive and aren't usually adjustable to accommodate changes. Halex is in need of a flexible automated system that can be used for multiple different carton sizes, and can also be placed at the head of multiple conveyor lines within the plant. This machine must adhere to both IEC and OSHA's mechanical and electrical standards. We hope that the implementation of this project will increase Halex's output and efficiency, which will help them achieve optimal product fill rates; as well as relieve the already occupied operator.

Quality Function Deployment

To develop a QFD, the team consider customers and engineering characteristics. The customer characteristics considered were: Safety, Cost, Efficiency, Speed, Flexibility, Adjustability, Noisiness, Ease of Use, Lifespan, and Maintenance. The engineering characteristics considered were: Emergency STOP button, Enclosure for moving parts, Automatic carton-loading position, Adjustable carton feeder, Pneumatic (air-controlled) moving parts, Simple control panel, Mounts directly onto conveyor.

House of Quality

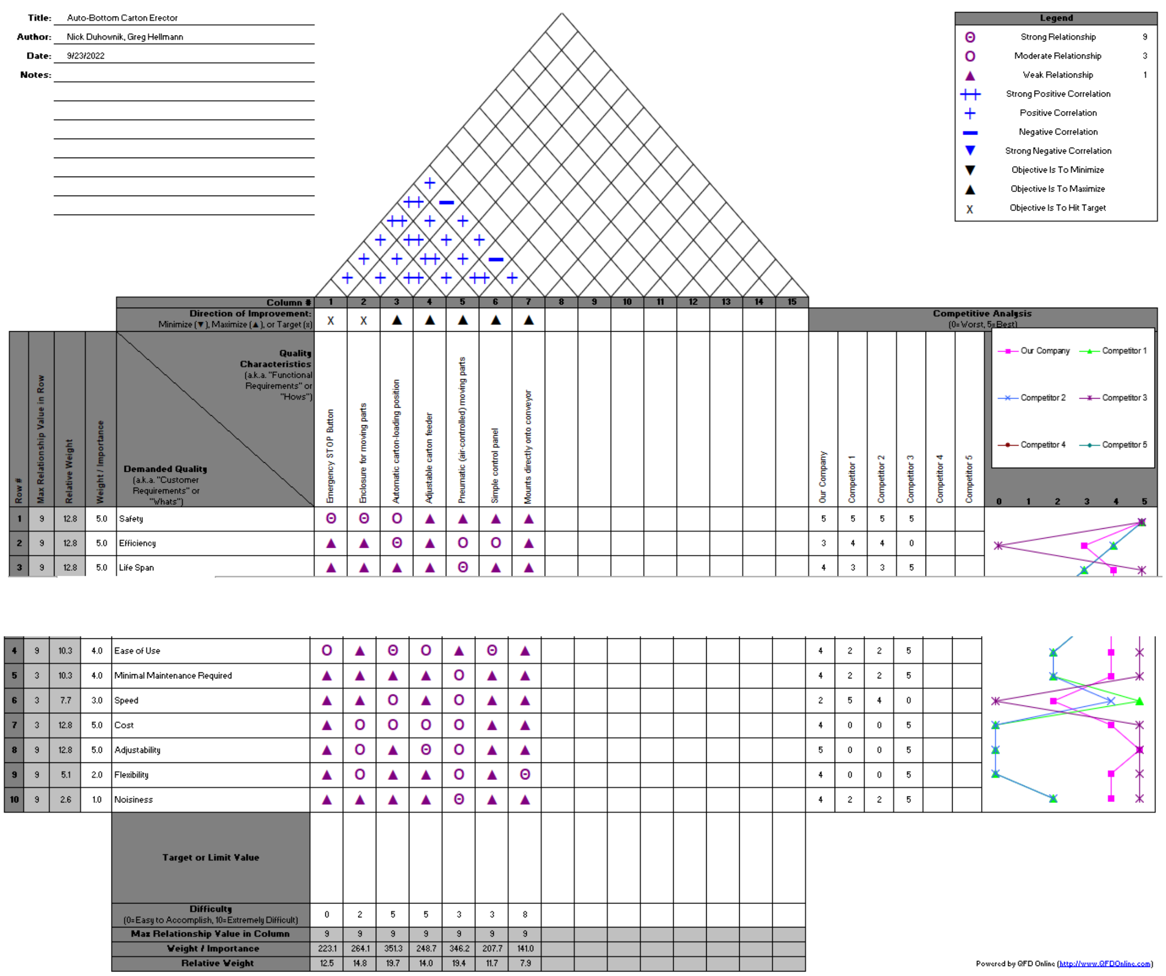


Figure 2: House of Quality

Product Objectives Ranking

Based on 1-5 Scale from Survey

1. Safety (Average Score: 4.64, 12.7% of Total)
2. Efficiency (Average Score: 4.27, 11.7% of Total)
3. Life Span (Average Score: 4.09, 11.2% of Total)
4. Ease of Use (Average Score: 4.00, 10.9% of Total)
5. Minimal Maintenance Required (Average Score: 3.91, 10.7% of Total)
6. Speed (Average Score: 3.64, 10.0% of Total)
7. Cost (Average Score: 3.45, 9.5% of Total)*
8. Adjustability (Average Score: 3.36, 9.2% of Total)*
9. Flexibility (Average Score: 3.18, 8.7% of Total)
10. Noisiness (Average Score: 1.91, 5.2% of Total)

*Note that even though Cost and Adjustability are weighted relatively low according to the survey, these are things that are quite important to the sponsor and end user of this product. Therefore, Cost and Adjustability will be focused on as well as Safety, Efficiency, and Life Span.

Concepts Drawings

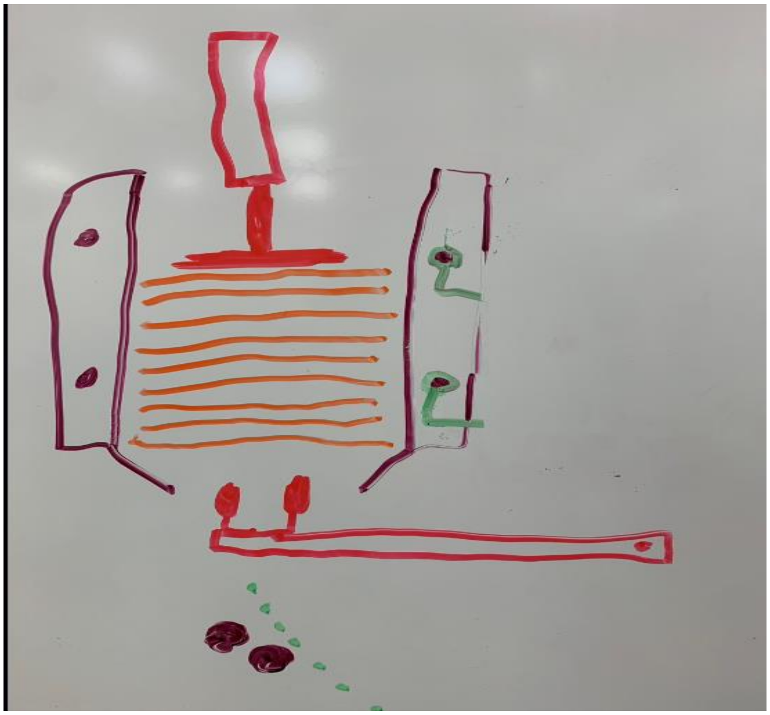


Figure 3: Overhead sketch of initial Carton Erector Concept

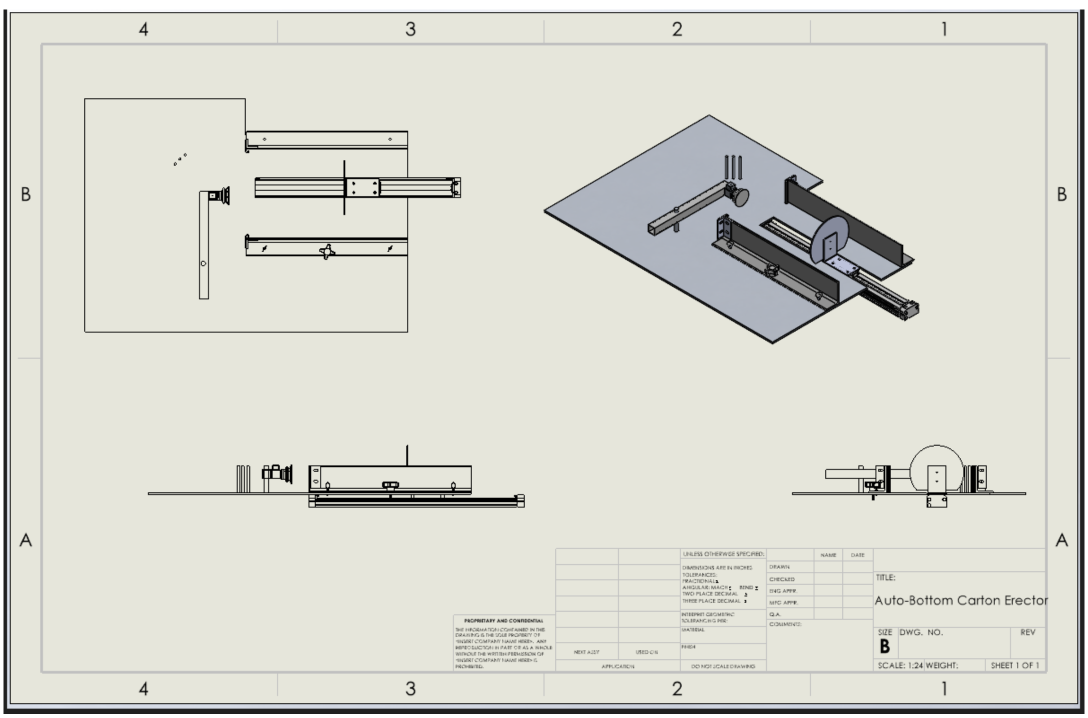


Figure 4: SOLIDWORKS drawing of Concept 1

This initial concept was inspired by Econocorp's carton erector machine. There will be a feeder of flat cartons that are stood up by applied pressure from an air cylinder. The air cylinder will continuously push cartons to the front of the feeder where there will be an arm equipped with a vacuum-powered suction cup. The arm will be powered by a motor similar to what powers a car's windshield wipers. This was deemed more suitable than a servo motor because of the larger life span due to no having to constantly stop and start. The suction cup will grab the carton, and pull it out of the feeder while rotating it by 90 degrees. During this process, the edge of the carton will make contact with stationary rollers. These rollers are intended to make contact with the creased edge of the carton, popping it open without impeding the motion of the arm. After the carton is erect, the vacuum pump will cut off, disengaging the suction cup and allowing the carton to be dropped onto the conveyer line.

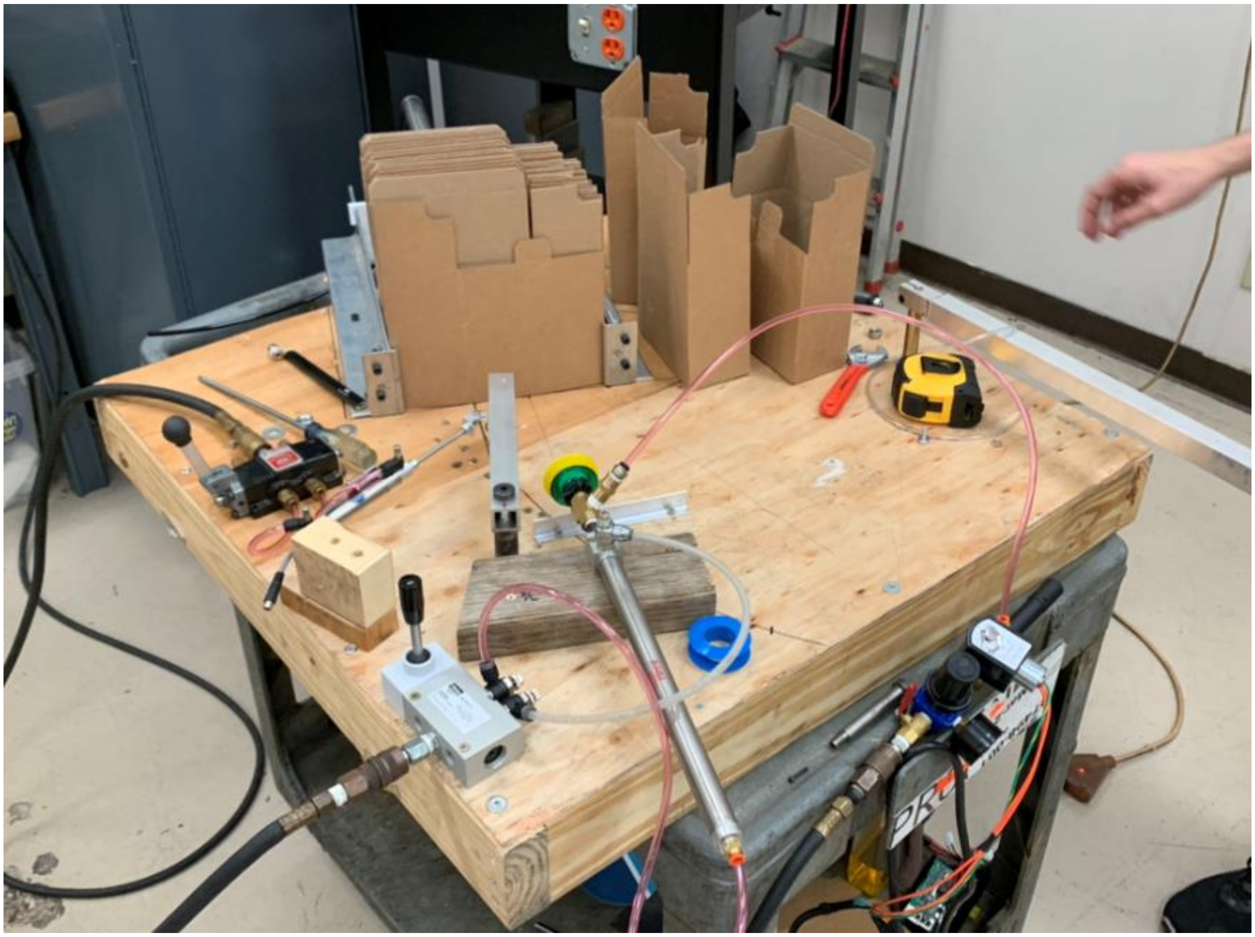


Figure 5: Actual assembly of Concept 2

This concept uses a second air cylinder instead of a motor-powered arm to engage with the flat cartons. The cylinder will now be equipped with the suction cup. The carton will be grabbed and pulled out of the feeder. Adjacent to the suction cup's home position will be a third cylinder that is hooked up to an arm, pivoting via a clevis-like connection. We wanted all of our moving parts to be air-powered, in order to have a longer life span and less maintenance than electric motors. When the carton is pulled out of the feeder, the arm will physically erect the box by applying pressure to the side. This concept was also equipped with a manual joy-stick-like controller for the feeder's air cylinder, allowing you to disengage in order to reload more flat cartons.

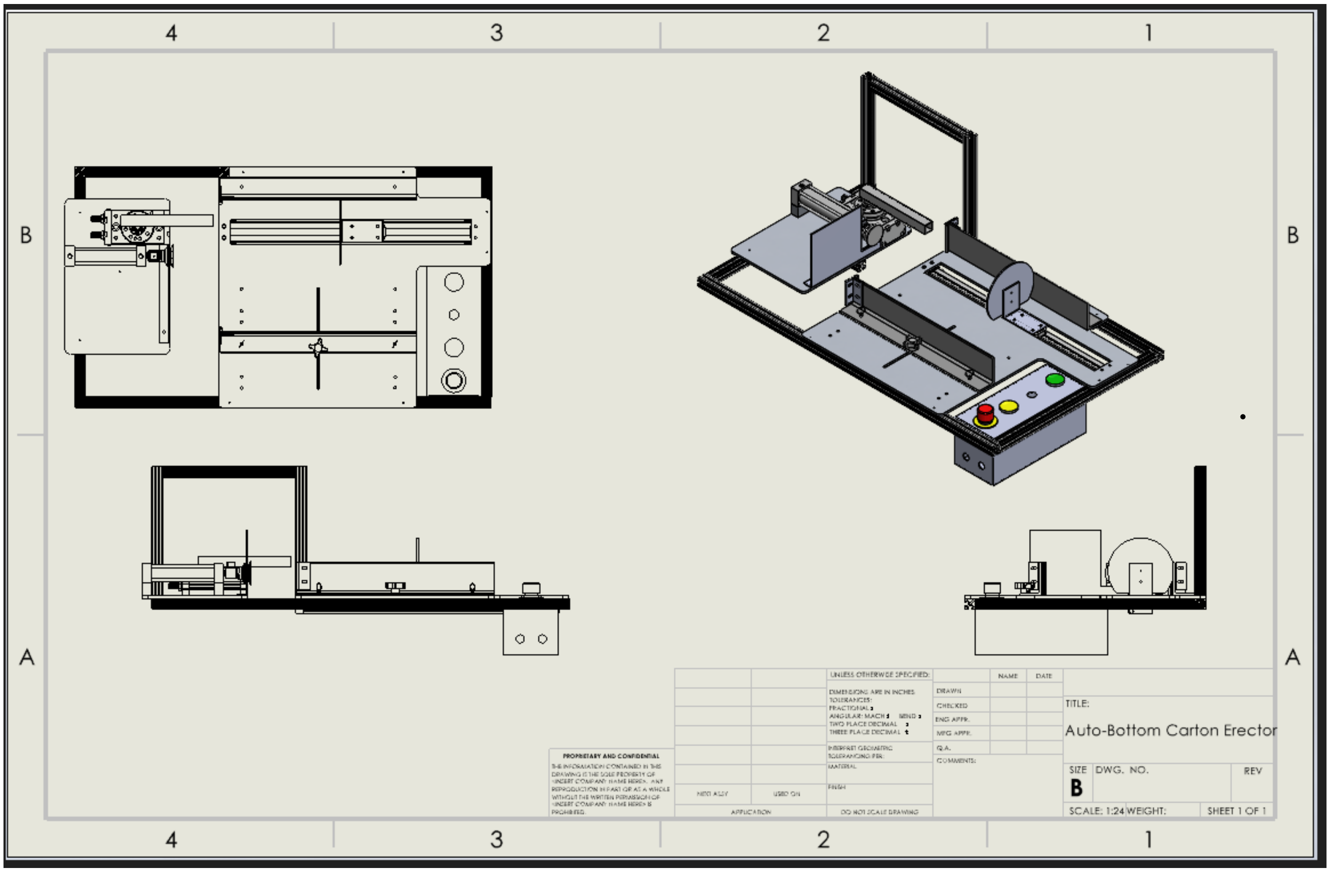


Figure 6: SOLIDWORKS drawing of Concept 3

This concept will likely be the final configuration of our carton erector. Instead of a third air cylinder, the swiveling arm will now be powered by a pneumatic rotary air actuator. The feeder for the cartons is also now adjustable, to include multiple different carton sizes used in production. This concept is also equipped with a control panel including an Emergency Stop button. All of the moving parts are also surrounded by T-slot framing. This will allow the addition of a cover to be installed to protect operators. The frame will also be utilized to be mounted directly onto the conveyor.

Project Management

Project Budget Limit

Electrical Components	$1,605.46
Mechanical Components	$1,258.73
Base Plate and Frame, Miscellaneous Hardware	$685.44
Total	$3,549.63

Figure 7: Budget broken into key components

Key Milestones

Date	Milestone to Complete
10/11/2022	Senior Design II
10/31/2022	Force Analysis of CAD Assembly
11/27/2022	Prototype Built
11/28 - 12/02/2022	Presentation I
01/09/2023	Senior Design III
02/28/2023	Integration into Production
03/14/2023	Documentation
04/06/2023	Tech Expo

Figure 8: Key Milestones for the final months of the project

Design Decision

Chosen Concept: Concept 3

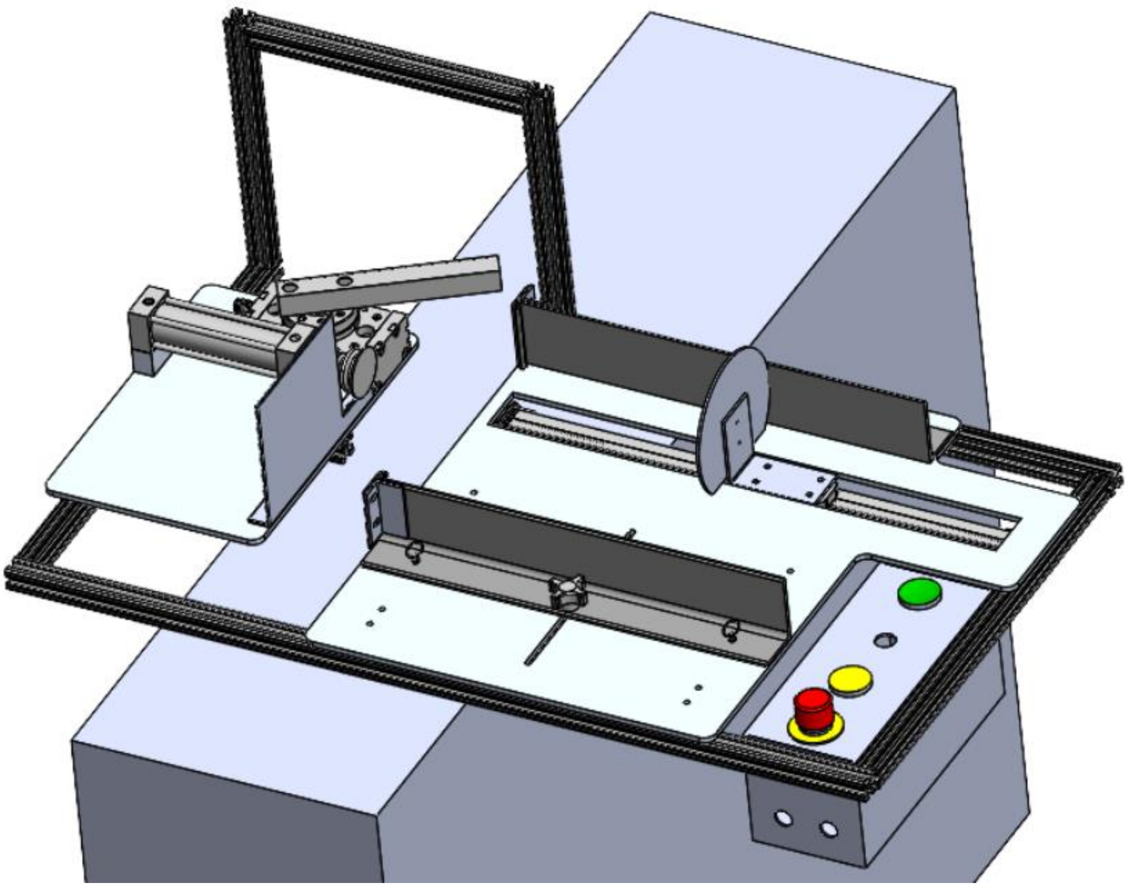


Figure 9: SOLIDWORKS assembly of the Carton Erector machine

This was the optimal design choice because it met the most requirements given buy Halex. It will utilize the pressurized air already available in the shop to power all of the moving parts. The base plate will consist of two separate pieces, which allows it to be place right over the conveyer line. The frame of the machine will serve multiple purposes: keeping the assembly together and allowing it to be mounted directly to the conveyer system. And in order to adhere to IEC and OSHA standards, the frame will also allow is to attach a covering to protect operators from moving parts. The mechanical components have been specifically chosen to comply with the dimensional constraints presented.

Loading and Storing Folded Cartons

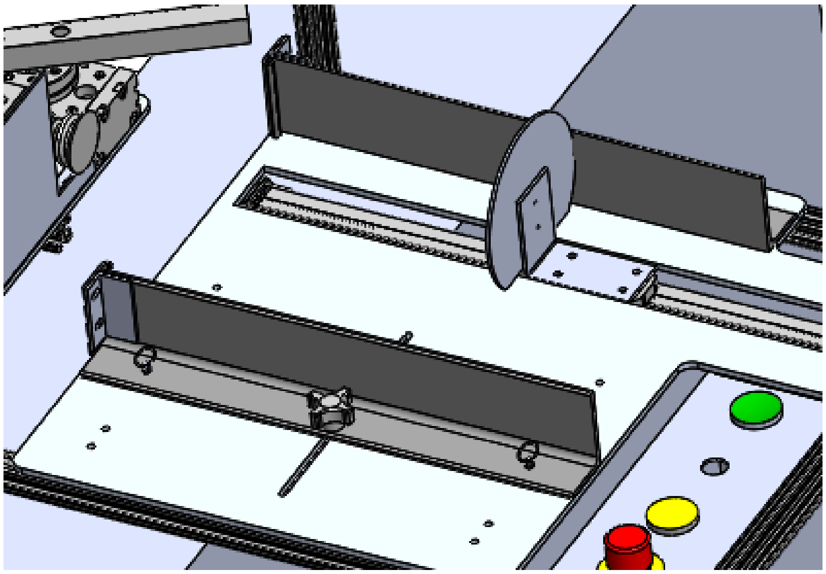


Figure 10: SOLIDWORKS assembly of the custom feeder mechanism

Figure 11: Real life concept for the feeder mechanism, storing folded cartons

The first challenge was coming up with a feeder mechanism to store the folded cartons while they are waiting to be erected. The mechanism would have to keep the cartons standing upright, and ensure that there was always a carton present at the workstation (grabbing point). Our first prototype consisted of two pieces of angle iron that would squeeze the folded cartons on either side. To apply pressure from the back of the stack, we used pneumatic air cylinder. We preferred this mechanism as well as most of this machine to be air powered. That way, it can run off of the shop's already installed air hoses located all around the warehouse. The final model will have a low-profile air slide instead of a cylinder. This was needed because an air cylinder would take up too much horizontal space behind the feeder, which would become a hazard for passing workers. With our low-profile slide, we were able to use the same stroke length of our original cylinder while taking up much less space.

Another requirement that out feeder had to satisfy was the ability to store five differently sized cartons, each having five different widths. We accomplished this by making one of the two pieces of angle iron stationary, while the other piece would be able to be adjustable. There will be a rail system machined into our baseplate, as well as holes at each of the five positions. Our piece of angle iron will be able to slide along the rail when the twist-latch is loosened. And to secure it at each location, there will be pull-ring spring plungers attached to the iron, that will fall into the set of holes once in the correct location.

Grabbing Folded Cartons

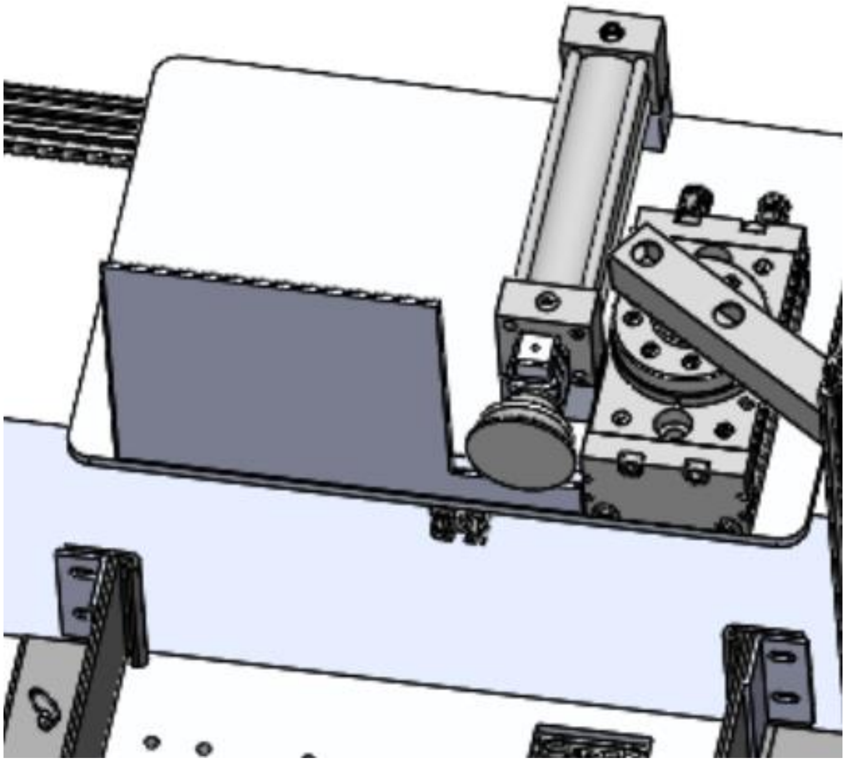


Figure 12: SOLIDWORKS assembly of the air-powered cylinder, with suction cup attached

Figure 13: Cardboard-specific suction cup

In order to be erected and dropped onto the conveyer, the folded carton must be grabbed and pulled out of the feeder mechanism. We concurred that the best way to grab the carton would be a suction cup powered by a venturi-style vacuum pump. The vacuum pump will also utilize the shop's compressed air. We acquired a suction cup that was specifically designed to handle cardboard. We also needed to choose something that was flexible and durable. Since the carton will be erected while the suction cup was attached, the cup must be able to remain secured while the carton is manipulated.

In order to pull the carton away from the feeder mechanism, we will be using a pneumatic air cylinder. The cylinder will be installed on the opposite side of the conveyer, across from the feeder. It was important that we used a cylinder that was not too long, because we were dealing with limited space on that side of the conveyer. This cylinder will extend out over the conveyer belt, grab the carton with its suction cup, and pull the carton out of the feeder and let it hang in space over the conveyer.

Erecting Cartons

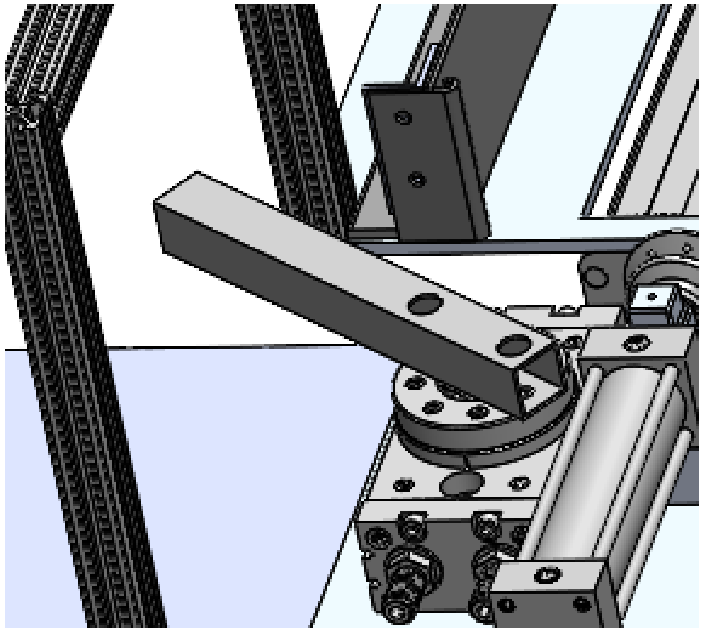


Figure 14: SOLIDWORKS image of rotary air actuator, with arm attached

Once the carton is attached to the suction cup, and removed from the feeder mechanism, something must physically manipulate it so that it snaps into an erect, open cardboard box. We decided that a mechanical arm rotating into the side of the carton was the best way to accomplish this. For the arm, we used a piece of square aluminum tubing. To control the motion, we decided to use a rotary air actuator. Again, this decision was influenced by the desire to utilize compressed air to power this system. Furthermore, we felt that an air-powered rotational device would have a longer lifespan than something like a servo motor. Once the arm swings into the carton and erects it, the suction cup will release and the carton will fall onto the conveyer system. Since the carton will be travelling toward the actuator, the arm will have to rotate back, allowing it to pass.

Enclosing Moving Parts and Mounting to Conveyer

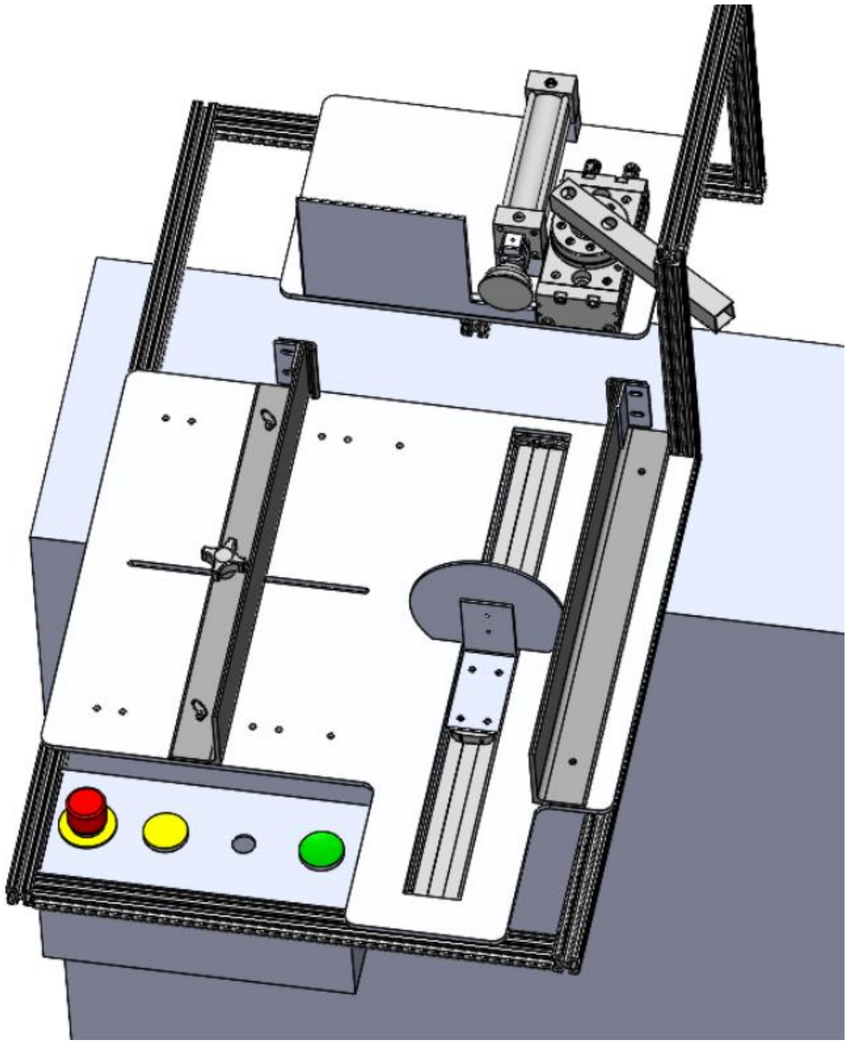


Figure 15: SOLIDWORKS assembly showing the T-slot framing around the entire machine

In order to comply with mechanical safety standards, we had to figure out a way for the moving parts of this machine to be enclosed. We decided that our machine would have a skeleton made of T-slot framing, that would go around the entire system. That way, a plastic enclosure can be attached to the frame, and keep all moving parts away from the operators. This skeleton of T-slot framing also will help us install our machine. There is not a lot of space on the ground for our machine to occupy, so the solution to that will be attaching our system directly onto the conveyer line. The various runs T-slot framing will be necessary to accomplish this.

Maintenance

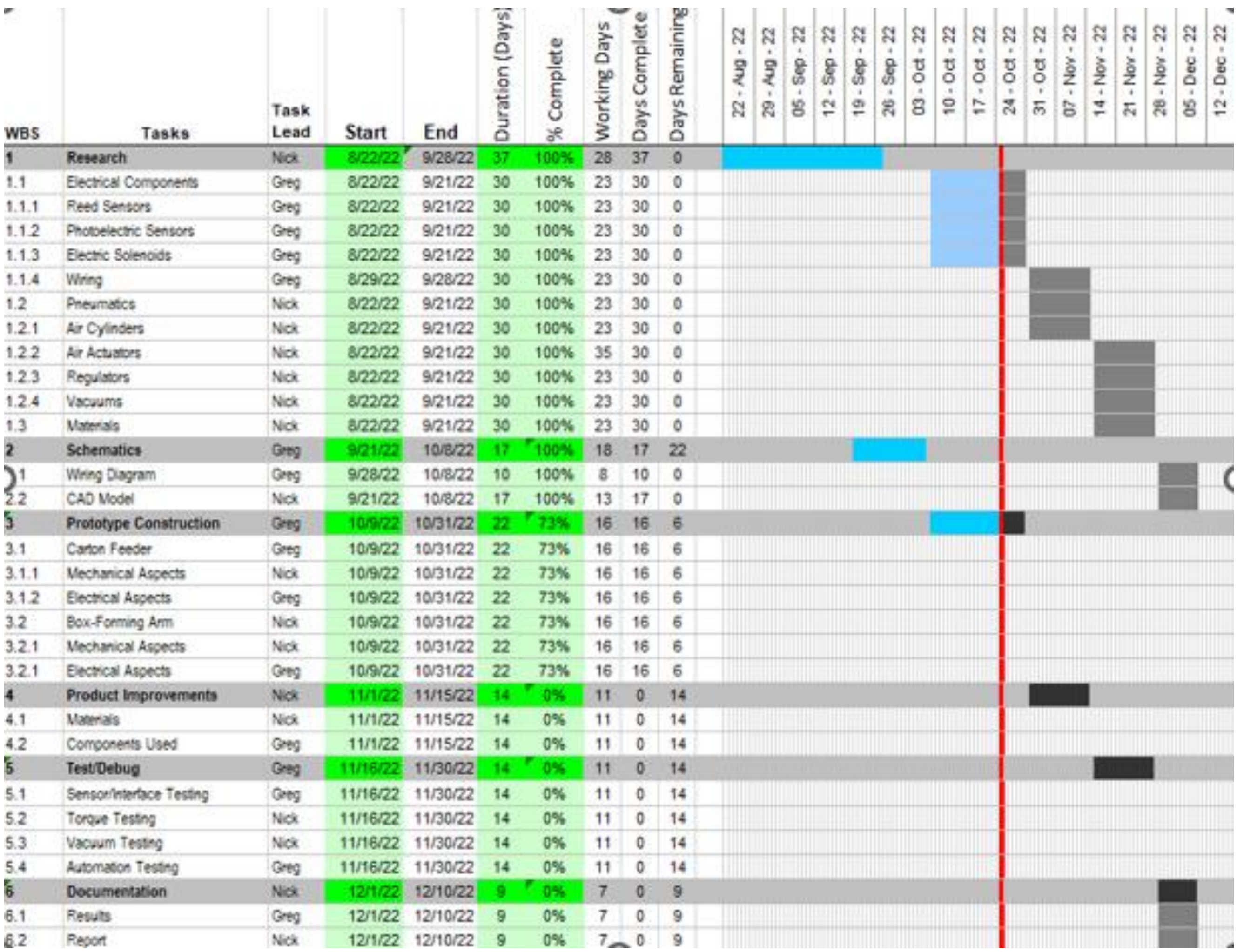
Some of the identifiable parts that will have to be maintained and checked on regularly:

- Due to all the moving parts rotation points will have to be lubricated
- Airline will have to be checked for condensation build up
- Airlines will have to be inspected for wear and aging
- The suction-cup will have to be inspected for wear and addressed accordingly
- Cylinder sensors should be inspected to ensure erector function properly \
- The entire erector should be nut and bolted regularly

Some daily actions required for the erector:

- Photo optical sensors need to be wiped off and cleaned
- The use of the pneumatic magazine lever to load boxes
- Loading of boxes (amount to be determined)
- Before and after the erector is utilized a visual inspection should be conducted to see if there are any preventable breakdowns

Gantt Chart



WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	**Research**	Nick	8/22/22	9/28/22	37	100%	28	37	0
1.1	Electrical Components	Greg	8/22/22	9/21/22	30	100%	23	30	0
1.1.1	Reed Sensors	Greg	8/22/22	9/21/22	30	100%	23	30	0
1.1.2	Photoelectric Sensors	Greg	8/22/22	9/21/22	30	100%	23	30	0
1.1.3	Electric Solenoids	Greg	8/22/22	9/21/22	30	100%	23	30	0
1.1.4	Wiring	Greg	8/29/22	9/28/22	30	100%	23	30	0
1.2	Pneumatics	Nick	8/22/22	9/21/22	30	100%	23	30	0
1.2.1	Air Cylinders	Nick	8/22/22	9/21/22	30	100%	23	30	0
1.2.2	Air Actuators	Nick	8/22/22	9/21/22	30	100%	35	30	0
1.2.3	Regulators	Nick	8/22/22	9/21/22	30	100%	23	30	0
1.2.4	Vacuums	Nick	8/22/22	9/21/22	30	100%	23	30	0
1.3	Materials	Nick	8/22/22	9/21/22	30	100%	23	30	0
2	**Schematics**	Greg	9/21/22	10/8/22	17	100%	18	17	22
2.1	Wiring Diagram	Greg	9/28/22	10/8/22	10	100%	8	10	0
2.2	CAD Model	Nick	9/21/22	10/8/22	17	100%	13	17	0
3	**Prototype Construction**	Greg	10/9/22	10/31/22	22	73%	16	16	6
3.1	Carton Feeder	Greg	10/9/22	10/31/22	22	73%	16	16	6
3.1.1	Mechanical Aspects	Nick	10/9/22	10/31/22	22	73%	16	16	6
3.1.2	Electrical Aspects	Greg	10/9/22	10/31/22	22	73%	16	16	6
3.2	Box-Forming Arm	Nick	10/9/22	10/31/22	22	73%	16	16	6
3.2.1	Mechanical Aspects	Nick	10/9/22	10/31/22	22	73%	16	16	6
3.2.1	Electrical Aspects	Greg	10/9/22	10/31/22	22	73%	16	16	6
4	**Product Improvements**	Nick	11/1/22	11/15/22	14	0%	11	0	14
4.1	Materials	Nick	11/1/22	11/15/22	14	0%	11	0	14
4.2	Components Used	Greg	11/1/22	11/15/22	14	0%	11	0	14
5	**Test/Debug**	Greg	11/16/22	11/30/22	14	0%	11	0	14
5.1	Sensor/Interface Testing	Greg	11/16/22	11/30/22	14	0%	11	0	14
5.2	Torque Testing	Nick	11/16/22	11/30/22	14	0%	11	0	14
5.3	Vacuum Testing	Nick	11/16/22	11/30/22	14	0%	11	0	14
5.4	Automation Testing	Greg	11/16/22	11/30/22	14	0%	11	0	14
6	**Documentation**	Nick	12/1/22	12/10/22	9	0%	7	0	9
6.1	Results	Greg	12/1/22	12/10/22	9	0%	7	0	9
6.2	Report	Nick	12/1/22	12/10/22	9	0%	7	0	9

Figure 16: Gantt Chart for the Fall Semester

Assembly

The first step of the assembly process was to design the baseplate for the carton erector machine. The baseplate will support all of the major components, as well as provide a surface or mounting. Because of this, there were many holes to machine to attach the hardware. There were also some size constraints to consider, as there is limited space to install this machine. Because the primary operation of the machine is to drop constructed cartons onto a conveyer line, there needed to be a gap designed into the middle of the baseplate so there was somewhere for the carton to fall. It was determined that the baseplate would need to be two pieces: one piece that would hold the feeder mechanism and store the flat cartons, and a second piece to hold the mechanical components that will manipulate the carton. The team opted to have the custom baseplate laser cut by a third-party company. The material used for the baseplate was ¼ inch aluminum.

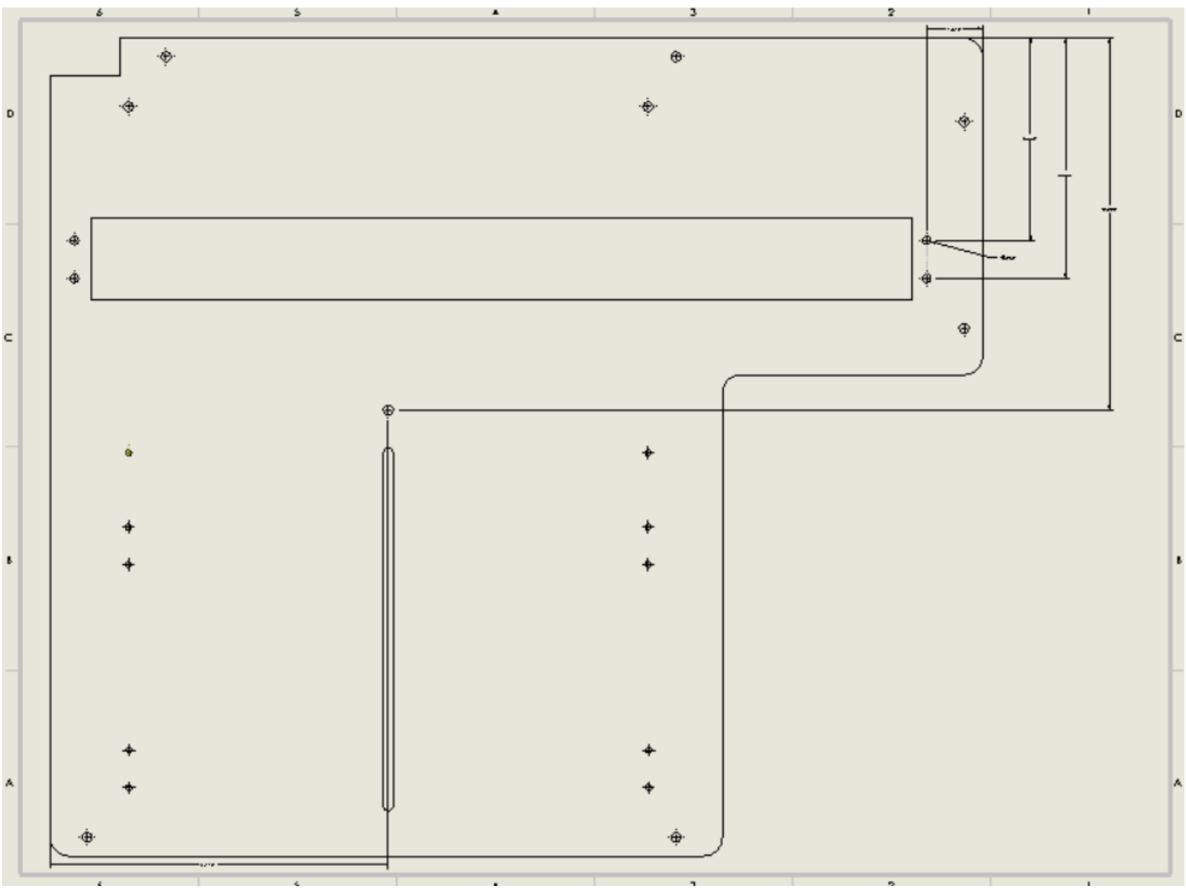


Figure 17: SOLIDWORKS drawings of the first piece of the baseplate

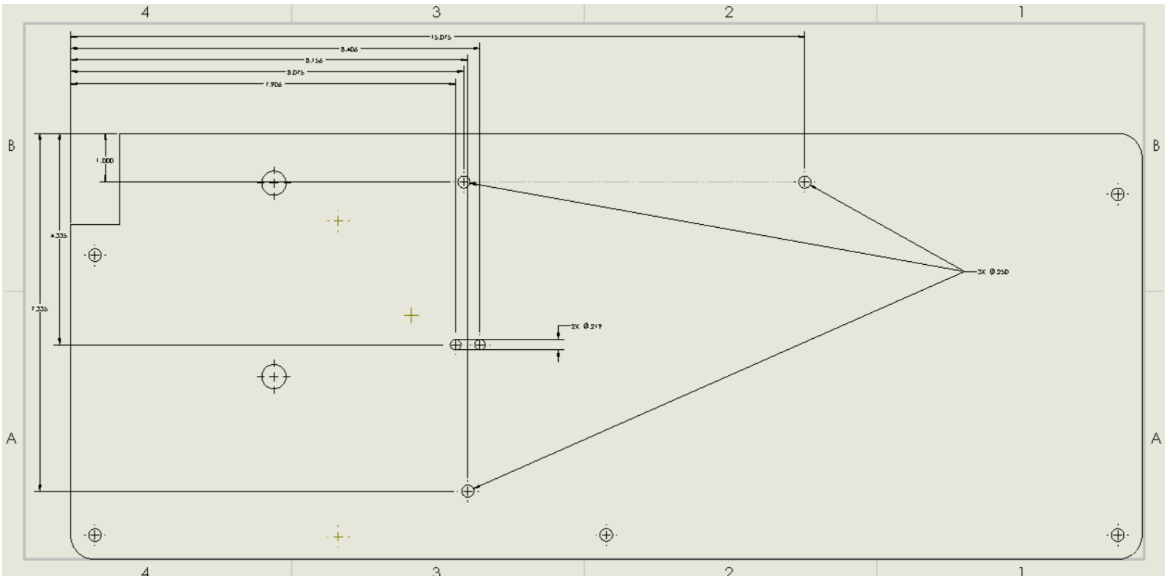


Figure 18: SOLIDWORKS drawing of the second piece of the baseplate

After receiving the custom baseplate, it was time to start mounting the mechanical components. Some of the components required custom mounting brackets and adapters. The air cylinder used for grabbing cartons from the feeder mechanism needed to be slightly elevated off of the baseplate surface, in order to make contact in a more optimal position of the folded carton. This required designing its own mounting bracket. The same cylinder needed a T-fitting attachment in order to be connected to both the suction cup and the compressed air used to power it. Because of the dimensional constraints inherited by the location of the cylinder, most of the T-fittings available were too large for the assembly. A custom T-fitting needed to be designed and implements into the cylinder’s assembly. The T-fitting connected to the stroke of the air cylinder, the airline, and the suction cup.

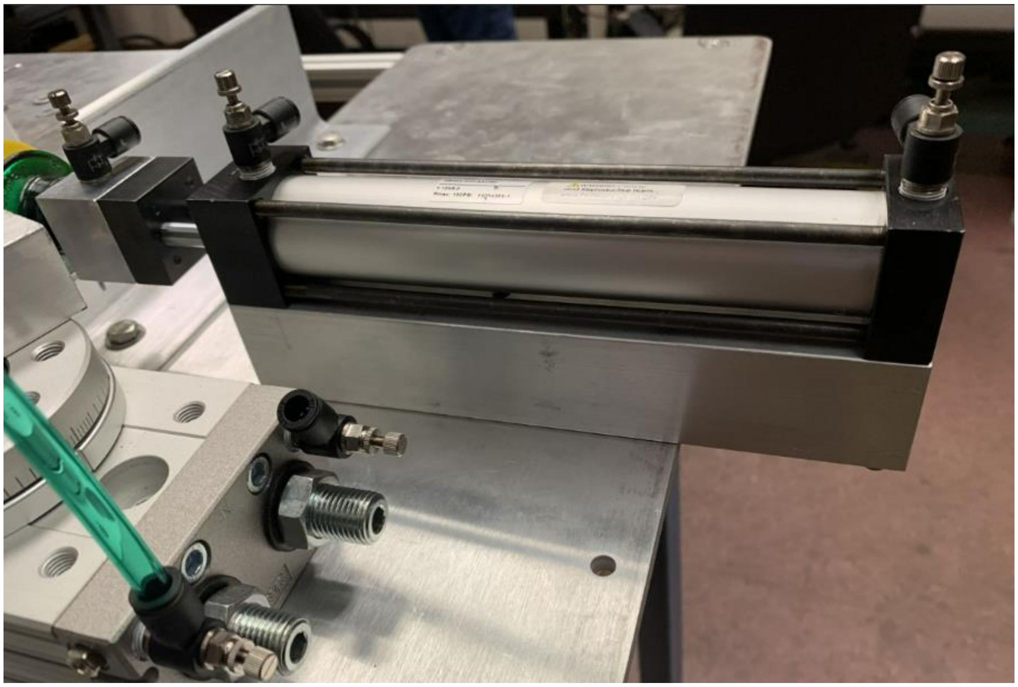


Figure 19: Air cylinder with custom mount allowing it to be raised above the baseplate surface

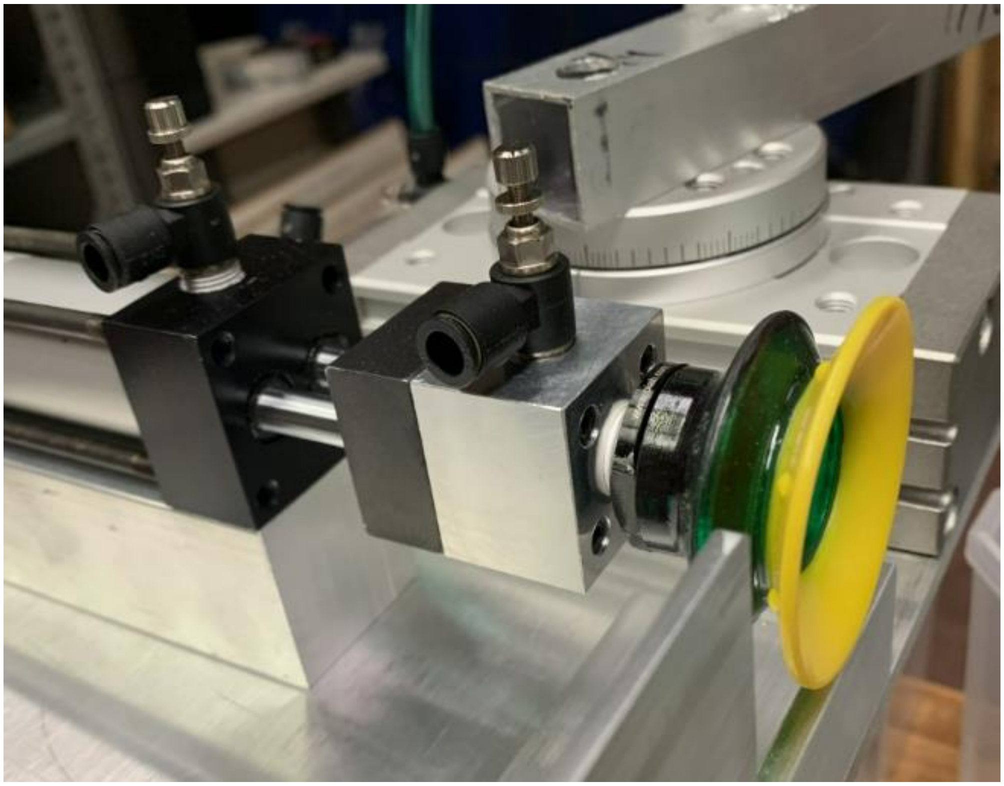


Figure 20: Custom T-fitting connecting the air cylinder, suction cup, and air intake

After the hardware was mounted to the baseplate, it was time to attach both pieces to the frame of the machine. The frame is made out of T-slot rails. The T-slot framing is important to maintain the proper distance between both pieces of the baseplate. This framing will also crucial when it is time to integrate the machine and mount it to the conveyer system. The frame will also be used to attach the OSHA-required covering for the moving parts, as well as the electrical box that will control the machine. On the side where the erected cartons will travel down the conveyor belt, the framing had to be elevated in order to not interfere with the traveling cartons.

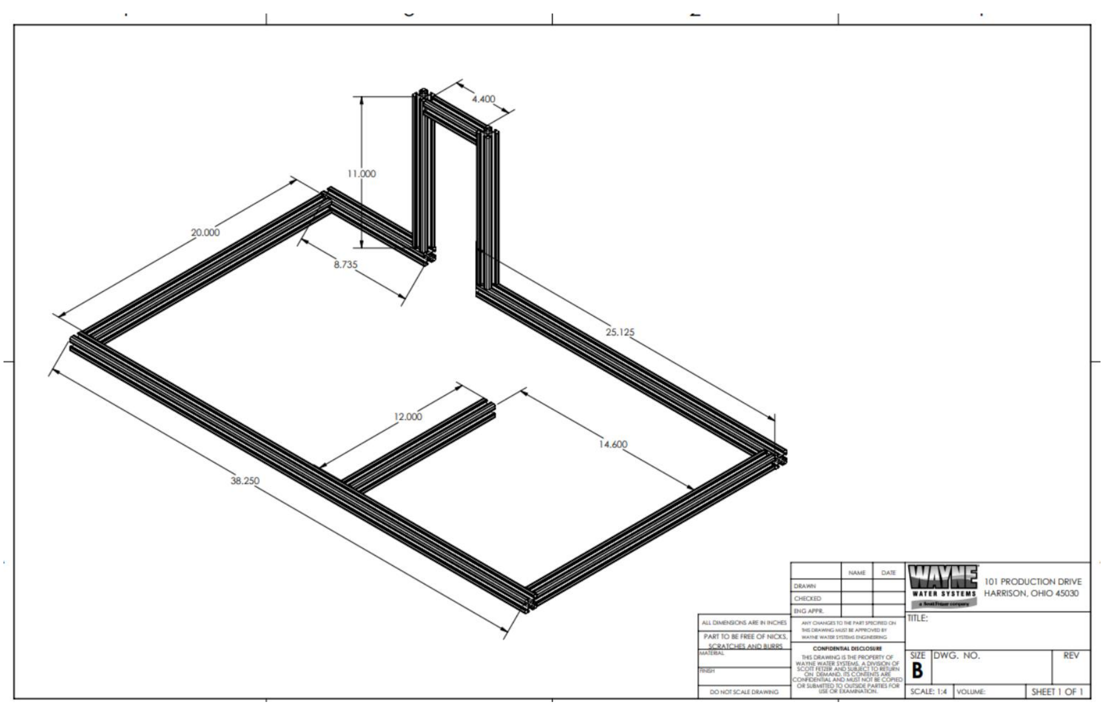


Figure 21: SOLIDWORKS model of T-slot framing

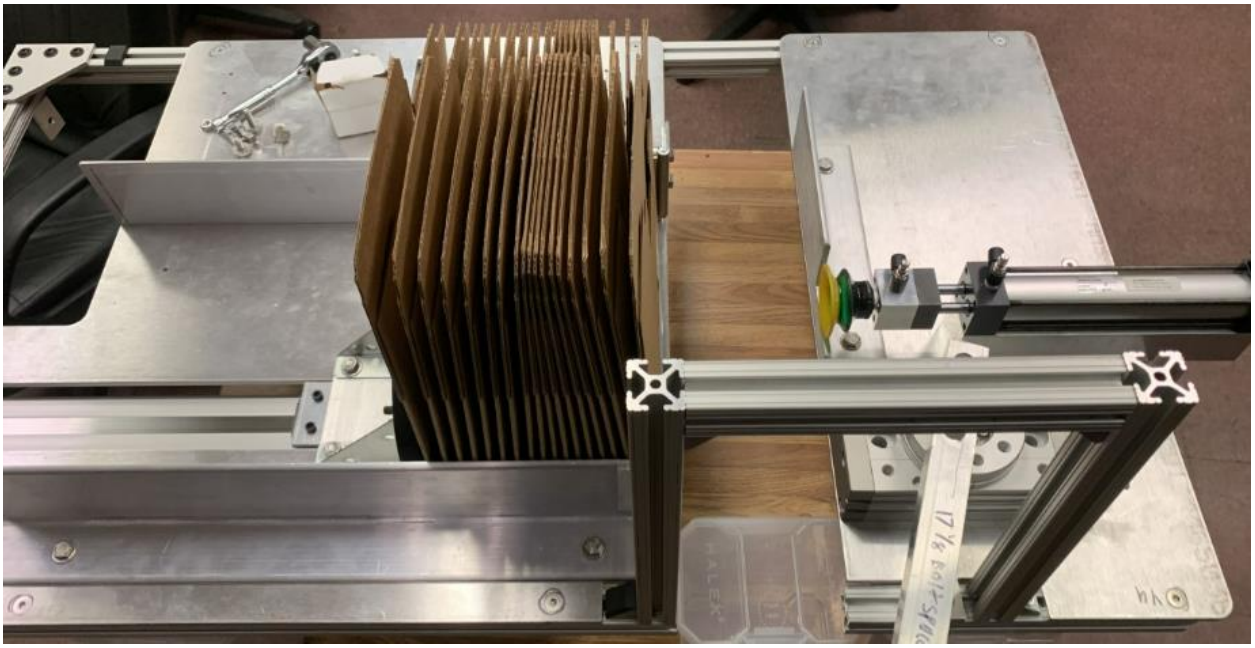


Figure 22: Partial assembly of the case erector machine, showing the T-slot framing attached

After all of the mechanical components of the machine were attached and mounted, it was time to start integrating the electrical components of the case erector. A custom electrical box had to be designed and built in order to hold everything needed to control the machine, as well as be mounted to the T-slot framing in the available space. The electrical box contains the pressure regulators, the relays, and the wiring. Mounted to the box are the solenoids and the vacuum pump. There are ports built into the electrical box to attach the compressed air line, as well as an electrical cord to plug in and power the machine. The top of the box will have an emergency STOP button, per OSHA regulations.

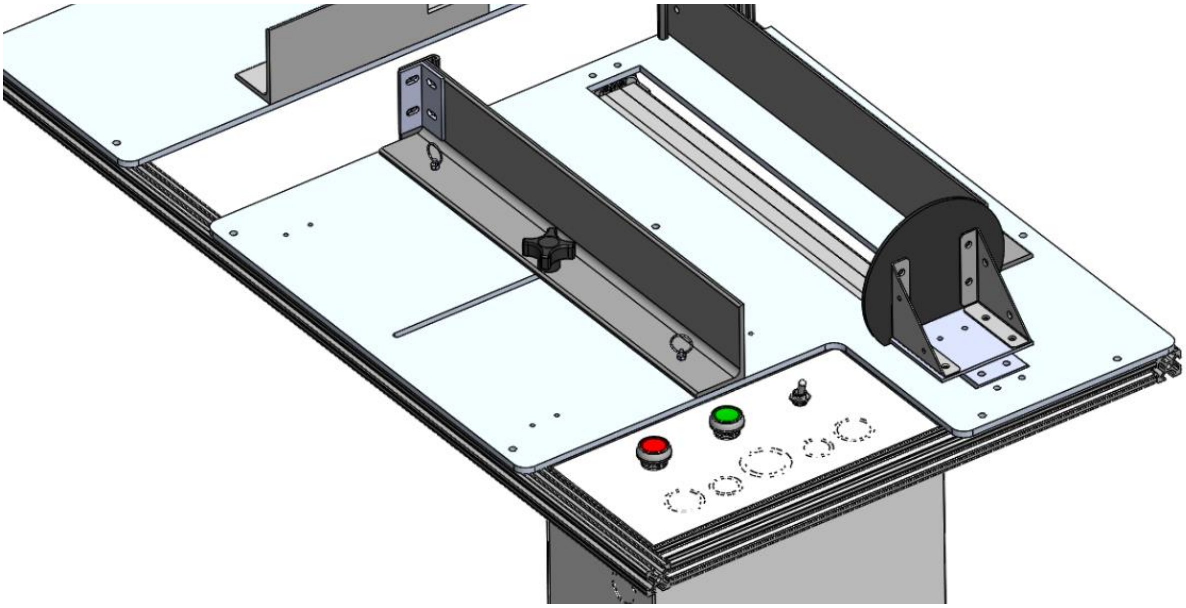


Figure 23: SOLIDWORKS assembly showing the electrical box mounted to the machine, towards the bottom of the image

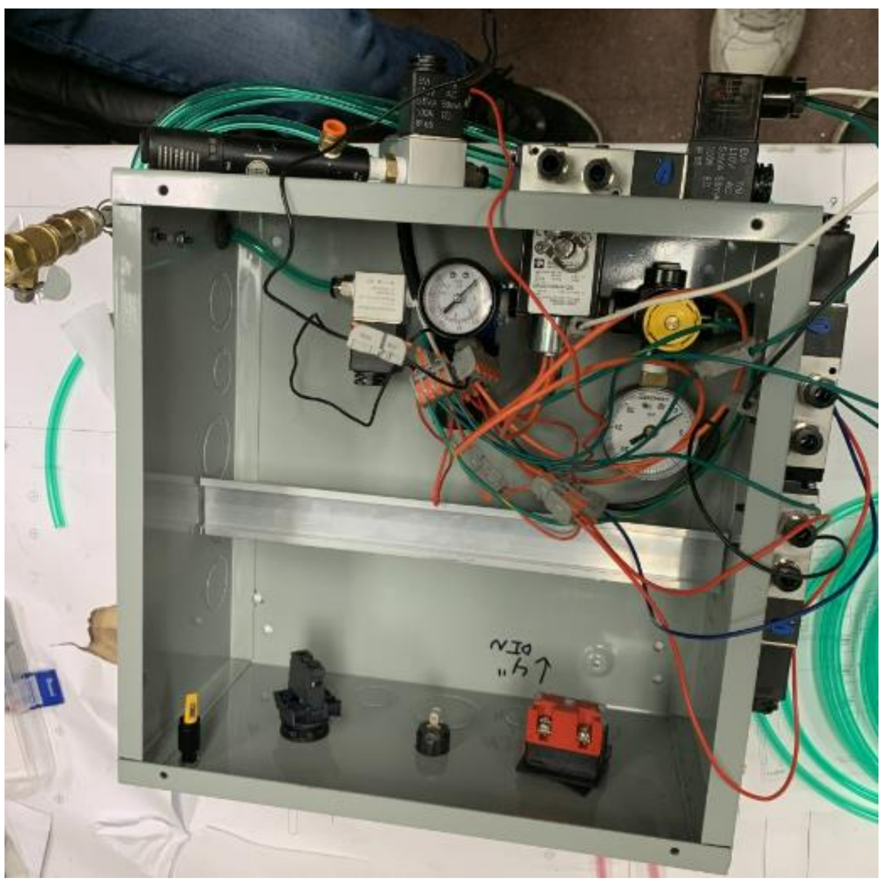


Figure 24: The inside of the electrical box

Once the electrical box was mounted to the frame it was time to wire the sensors to the relays and solenoids. Sensors were mounted to the air cylinder, air slide, and rotary air actuator. After all of the wiring is complete, the next step was to hook up all of the pneumatic air lines. Compressed air going to the box will run through the pressure regulators and the vacuum pump. The air will then travel to the air cylinder, the air slide, and the rotary air actuator, in order to control those mechanical components. Once everything was connected electronically and pneumatically, it was time to test the carton erector.

Testing

When testing the feeder mechanism, it was important that all sizes of the cartons were able to fit into the mechanism. This was tested and proved. The combination of loosening the twist latch and pulling up on the pull-ring spring plunger allows the feeder mechanism to be adjusted with ease. It was also important that air slide will be able to push against the folded cartons so they will be in the optimal position to be grabbed by the suction cup. But the slide also couldn’t apply too much pressure on the cartons, or else they would get pushed out of the feeder mechanism prematurely. This was accomplished by using a pressure regulator to reduce the pressure of the compressed air being supplied to the air slide. The slide was provided with the optimal amount of pressure in order to keep the cartons in the feeder mechanism and ready to be erected.

The air cylinder with the suction cup attachment is the component of the machine that must pull the cartons out of the feeder mechanism. A force gauge was used to determine the amount of force necessary to remove a carton consistently. The cartons required an average of 14 pounds of force in order to be pull out ed of the feeder mechanism. The air cylinder selected is able to exert of a force of 62 pounds at 50 psi, so it was deemed an adequate mechanism to remove the cartons.

To test the consistency of the erector machine, it was decided see if the machine was able to erect 20 consecutive cartons of each size. After testing, it was determined that the erector machine was successful in constructing all of the cartons. This test was duplicated so that all 5 sizes of cartons were tested.

The conveyer belt that the erector machine is being integrated into leads cartons to a vertical bagging machine. This vertical bagger is able to fill 6 cartons a minute with product. So, in order for the erector machine to work for this operation, it would have to be able erect at least 4 cartons a minute. After timing the machine while it was operating, it was determined that the erector machine was able to erect up to 15 cartons more minute. This is obviously more than enough cartons to keep up with the current speed of production. This was anticipated, and to ensure that there isn't a backup of cartons on the conveyer belt causing a blockage, a photelectric senser was attached to the bottom of the erector machine. That way, the sensor will detect if there is still a carton underneath the machine, and will stop the machine from erecting more cartons.

Dimensionally, the one section of the baseplate that holds the air cylinder and the rotary air actuator will be in a compromised position. On that side of the conveyer line, there is another packing line very close, that would be interfered with if the machine had too much overhang. It was determined that this section of the baseplate could not be over 14 inches long. This affected some of the design decisions as well as the component selection. The air cylinder was only able to have a 4- or 4.5-inch stroke because of this. This dimensional constraint also impacted the choice of using the rotary air actuator, because it would be one of the more concise ways to erect the carton. The assembly of the final machine was able to successfully adhere to this dimensional constraint.

In order to be compliant with OSHA safety standards, there needed to be an emergency STOP button attached to this machine. The button was tested while the carton erector was running, to see if it would shut down all operations immediately. When the STOP button was pushed, all mechanisms returned to their home positions. The air cylinder retracted, the air slide released the folded cartons, and the rotary air actuator rotated back to its original orientation. This was deemed a successful and viable safety measure for the machine.

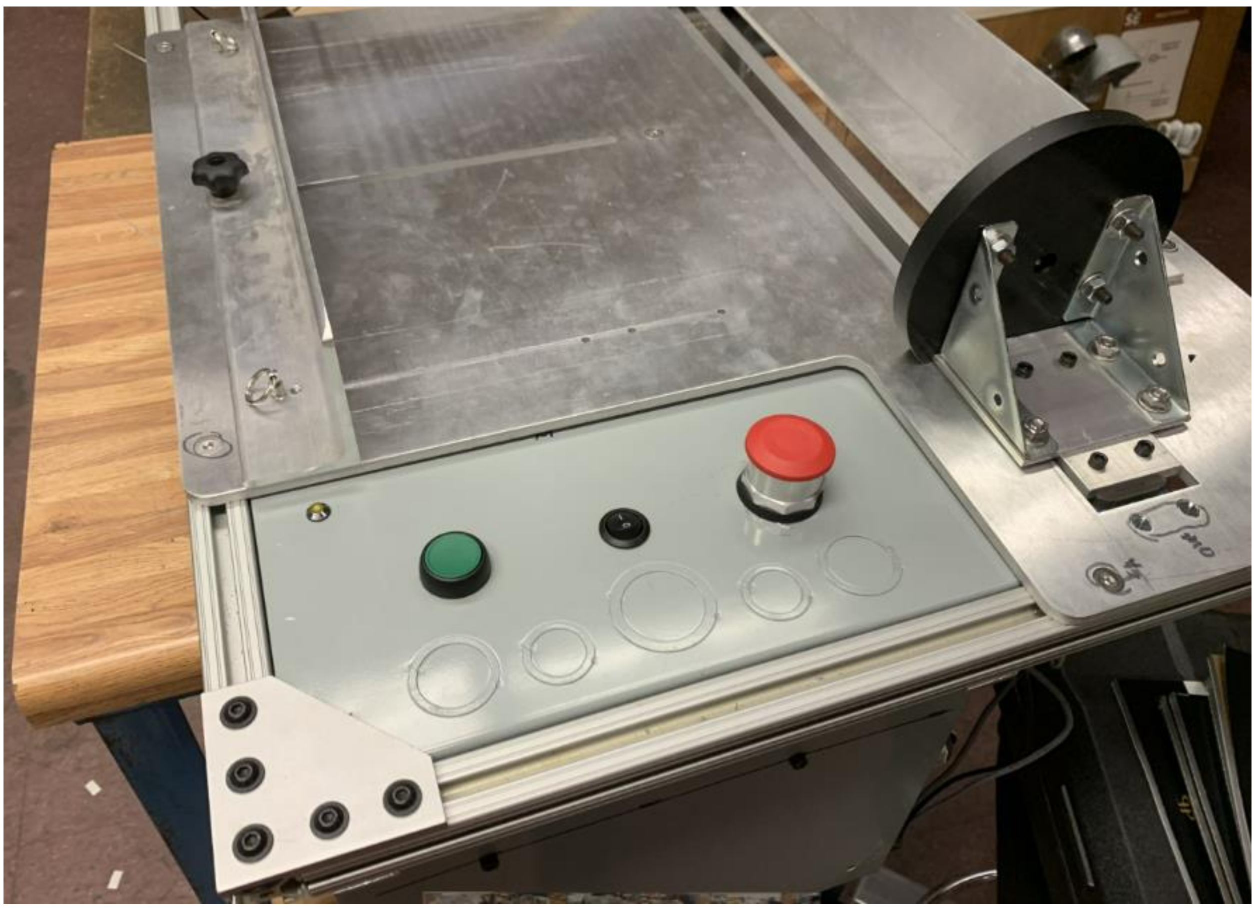


Figure 25: Emergency STOP button

Along with being able to stop the machine in case of an emergency, OSHA requires all moving parts of the machine to be covered so that an operator could not get their clothes snagged any of the mechanisms. This was accomplished by cutting pieces of plexiglass and using them to build a shell that would cover the air cylinder and the rotary air actuator. This plexiglass cover was mounted to the machine via the T-slot rail system used as the frame for the case erector. The cover was put to the test by having someone lean on it while the machine was operating. There were no injuries to report, and no articles of clothing were snagged by the machine.

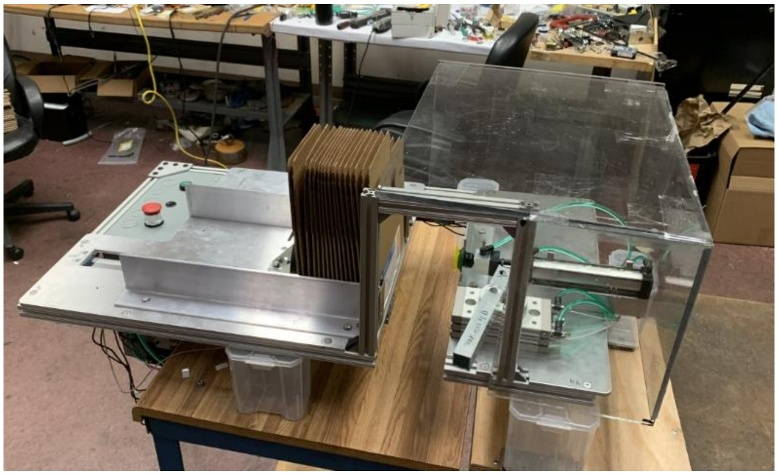
Figure 26: Plexiglass covering

Conclusion

The team successfully designed, built and tested a device to automatically erect cardboard cartons and drop them onto a conveyor belt. The machine:

- Met all OSHA safety requirements
- Successfully assembled boxes of all 5 sizes without issue
- Erected cartons at a rate of 15 cartons per minute

This project produced many challenges, but it was an enjoyable experience to be apart of. It was very fulfilling to see a machine that was designed and built from scratch assembled and operating in real life. Halex is very happy that the project was able to be completed and was a success. I learned a lot about automation and other electrical components while working on this project, as well as the importance of safety standards with moving parts. If I had to do it over again, I may have made some different decisions pertaining to some of the mechanical components. For instance, instead of using a rotary air actuator to manipulate the cartons once removed from the feeder mechanism, I would have selected a servo motor or a step motor. This is because these motors allow you to very precisely adjust the degree of rotation, whereas the air actuator was a lot more sensitive, and reliant on consistent air pressure. All in all, it felt great to complete a project that not only satisfied the University of Cincinnati's requirement for my degree, but also something that will help one of my favorite company's that I have worked for.



Figures 27 & 28: The fully assemble Auto-Bottom Carton Erector

Figure 29: Me at the Tech Expo

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Appendices

Cardboard Carton Erector Machine

We are developing an automated system that will erect "auto-bottom" cardboard cartons, and drop the boxes onto a conveyor line to be filled with product. Our machine will function similarly to this https://www.youtube.com/watch?v=Ku1JRs_ZMh0

Safety

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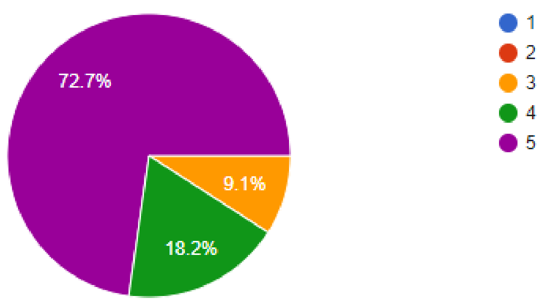
11 responses



Cost

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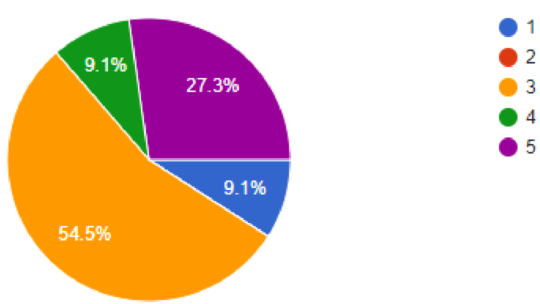

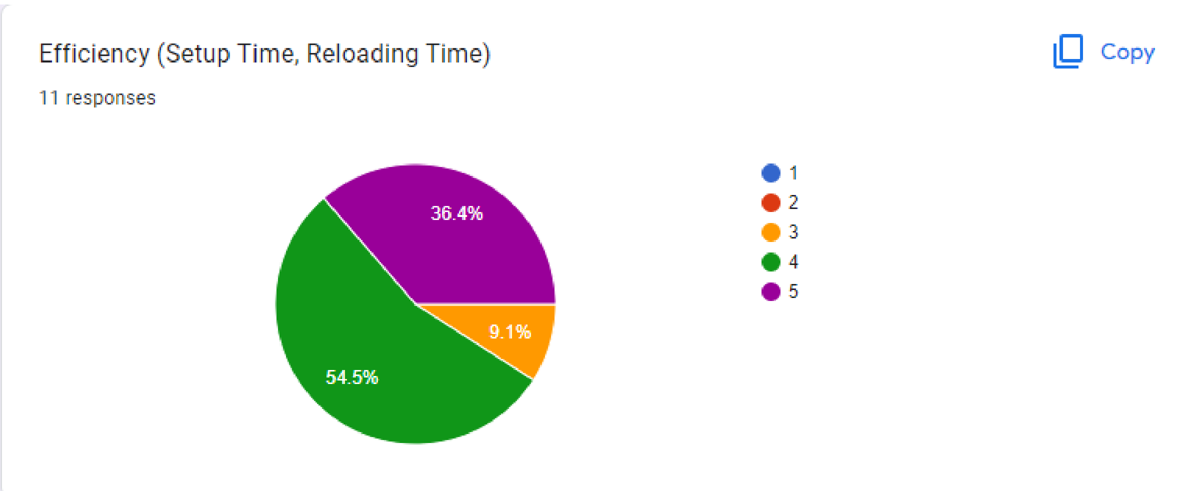
Efficiency (Setup Time, Reloading Time)
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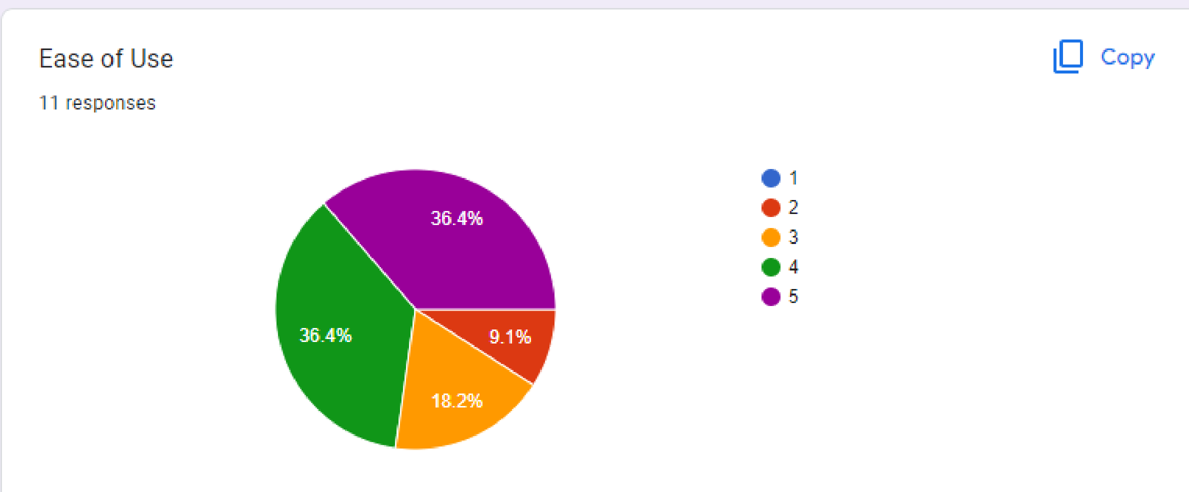
Ease of Use
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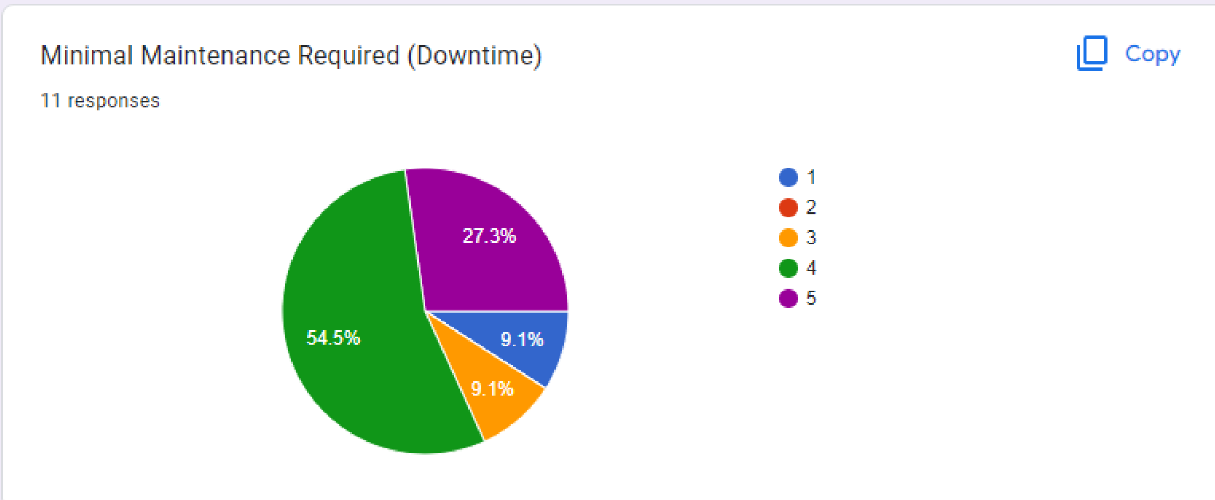
Minimal Maintenance Required (Downtime)
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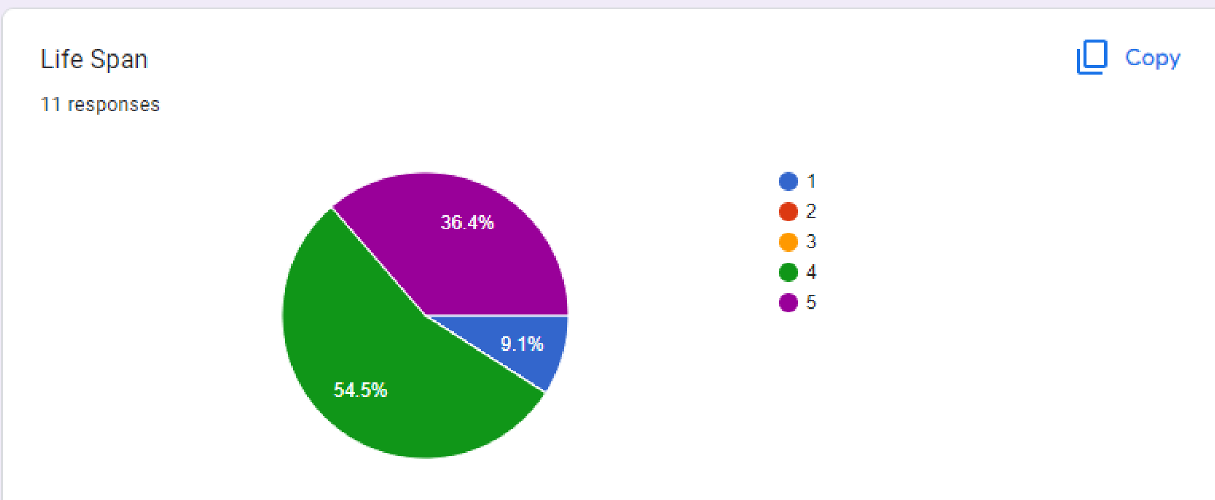
Life Span
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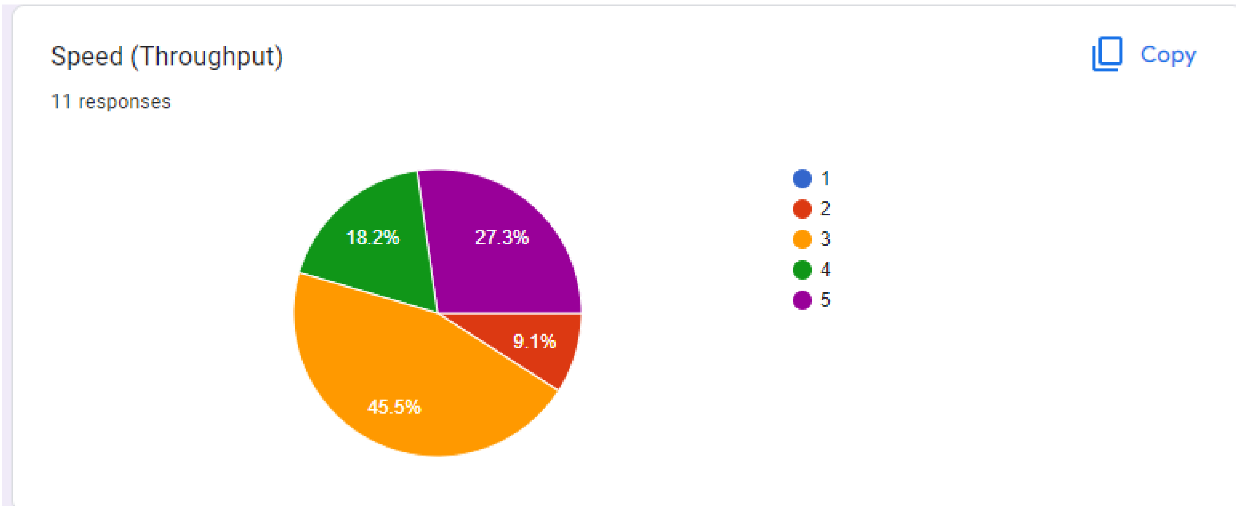
Speed (Throughput)
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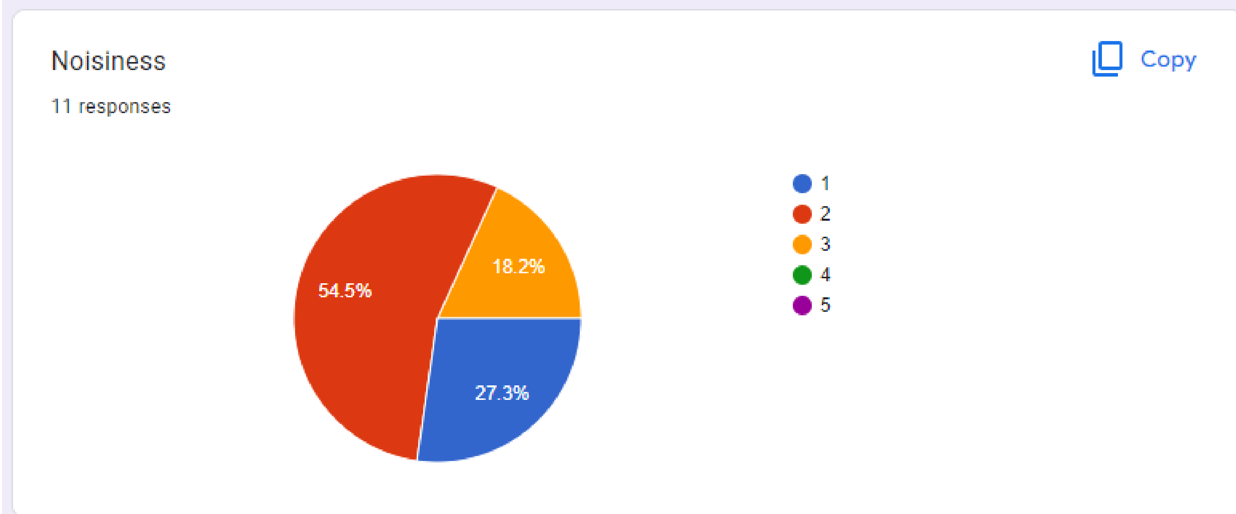
Noisiness
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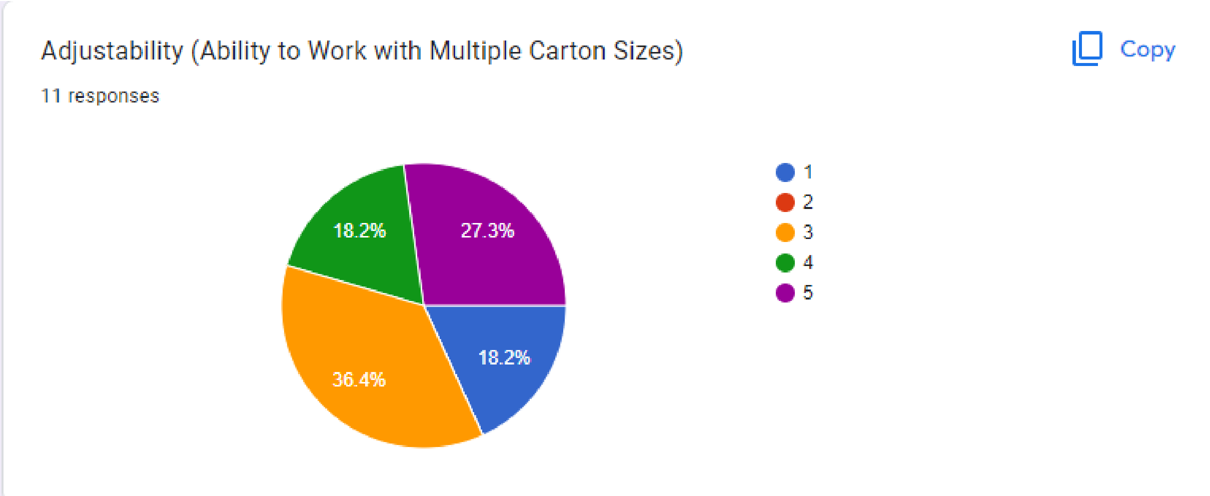

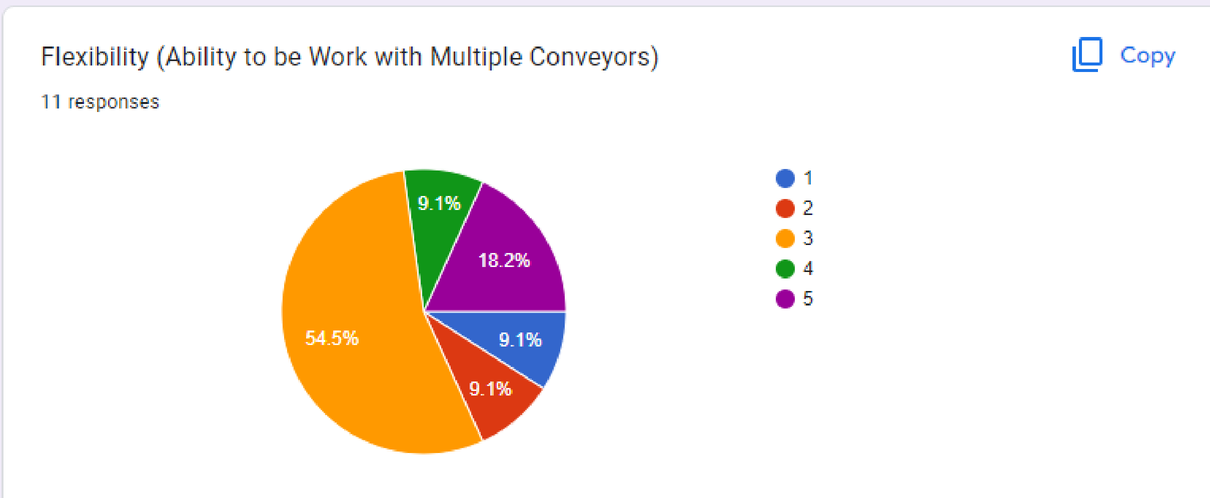

Figures 30-35: Quality Function Deployment Survey

Case Erector Life Cycle								
Part number	Part name	life cycle	cost per unit	Max psi	expected force	voltage	amps	cycle per dollar
1299k33	Rotary Air Actuator	10000000.00	$ 430.21	145	23.9-34.5 in lbs	N/A	N/A	23244.46
1358tr12	Latching relay 9 teminal	10000000.00	$ 75.80	N/A	N/A	120ac	10A	131926.12
7098k12	Thin spade termial relay	10000000.00	$ 17.89	N/A	N/A	120ac	10A	558971.49
59675k137	rodless aire slide 16"	3750000.00	$ 587.63	116	38-76	N/A	N/A	6381.57

Figure 36: Component Life Cycle Data

Name	Part Number (McMaster-Carr)	Quantity	Price / Unit	Total
Latching Relay, 120VAC	1358T12	5	$ 75.80	$ 379.00
9 Terminal Latching Relay Socket	1358T21	5	$ 16.46	$ 82.30
DIN 3 Rail, 1m	8961K31	1	$ 23.29	$ 23.29
DIN 3 Cable Clips, Qty. 25	7443N112	1	$ 23.06	$ 23.06
Reed Sensor, Rotary Air Actuator	1299K21	2	$ 17.56	$ 35.12
Reed Sensor, Air Slide	2738T114	1	$ 12.92	$ 12.92
Reed Sensor, Air Cylinder	6648K78	2	$ 66.62	$ 133.24
Push Button, Green	6749K101	1	$ 16.67	$ 16.67

E-stop	9235K345	1	$ 93.38	$ 93.38
Electrical Box	N/A	1	$ 250.00	$ 250.00
Latching Relay, 120VAC	6784T112	3	$ 29.37	$ 88.11
Photoelectric Switch, OWOP	6584K46	1	$ 115.08	$ 115.08
Signal Relay	7098K42	1	$ 25.02	$ 25.02
Flow Control Valve, 1/8 NPT x 1/4"	45045K32	6	$ 21.70	$ 130.20
Solenoid, NC	Link	3	$ 28.99	$ 86.97
Solenoid, 5/2	Link	3	$ 16.99	$ 50.97
Misc. Nuts, Bolts, & Washers		1	$ 30.00	$ 30.00
Fuse	Link	1	$ 12.99	$ 12.99

Multipurpose 6061 Aluminum 90 Degree Angle, 4ft	8982K252	1	$ 57.68	$ 57.68
Strut Channel	33085T33	1	$ 22.33	$ 22.33
Rodless Air Slide	2738T56	1	$ 489.10	$ 489.10
Carton Pusher	8573K121	1	$ 12.79	$ 12.79
18-8 Stainless Steel Pull-Ring Retractable Spring Plunger	8500A16	2	$ 13.81	$ 27.62
Height-Adjusting Vacuum Cup	6049A66	1	$ 36.87	$ 36.87
Sensor Ready Tie Rod Air Cylinder	4917K108	1	$ 145.80	$ 145.80
Back Stop	89015K236	1	$ 25.56	$ 25.56

Adjustable-Angle Rotary Air Actuator	1299K34	1	$ 489.47	$ 489.47
Laser Cut Plates, 1/4", ~24"x36"	89155K11	1	$ 350.00	$ 350.00
Corner Brace	47065T216	16	$ 6.11	$ 97.76
T-Slot Framing, 1"x1", 10'	47065T101	2	$ 48.76	$ 97.52
Air Manifold	5779K318	1	$ 21.57	$ 21.57
Cylinder Bracket	9246K51	2	$ 53.45	$ 106.90
				$ 3,614.61

Figures 37-40: Extended Bill of Materials

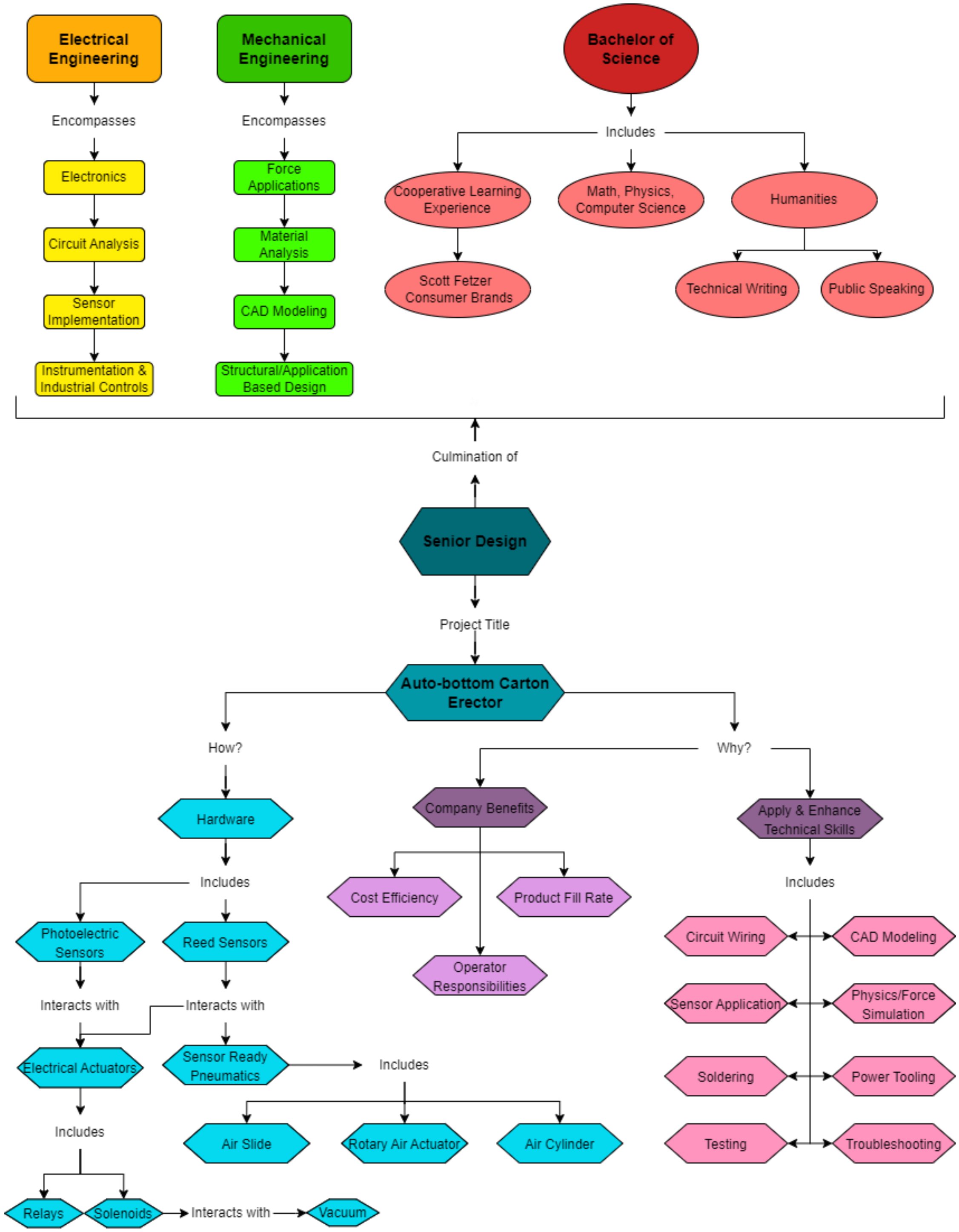

Figure 41: Concept Map