Fanuc Robot Cell Automation

Senior Design Proposal submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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1. Problem Statement

Our proposal is to design and build robot cells for the new Robotics and Automation labs being held in High Bay. The cell will allow students to go beyond the limitations of simulation software by giving them hands on experience with robots. The result will be the creation of several cells that can be used to build a curriculum around for the Robotics and Automation labs at the University. The cells will be fully programmable and will focus on highlighting robotic assembly and the different styles of feeders and sensors used in cells.

2. Research

a. Background of the Problem

It is safe to say that manufacturing today is a lot different than it was 50-100 years ago. With the implementation of technology and automation, the growth opportunities are endless. Industrial robots started being implemented in the early 1960s (1). The main goal of industrial robots/automation is to ultimately perform specific tasks without the need for humans to intervene. Automation through robotics aims to increase efficiency, productivity, and accuracy in the production process, reducing manual labor and minimizing human error (1). The University of Cincinnati is currently offering robotics courses and opportunities for a variety of different minors and a few majors related to robotics. To greatly impact education and aid the students, the University recently purchased six Fanuc robots to be used in the robotics courses that are offered. FANUC robots have played a key role in advancing automation by improving efficiency, reducing costs, enhancing safety, and supporting the transition to more intelligent and adaptable manufacturing systems. Their widespread use across industries has driven significant progress in automation technologies. Students will be exposed to the Fanuc robots in lecture and lab by obtaining hands on learning that they will immediately be able to implement in their future careers in the manufacturing field. FANUC's educational robots help students by providing hands-on experience with industrial automation technologies, preparing them for careers in robotics and manufacturing. These robots are designed for easy programming and safe use, allowing students to learn real-world applications such as robotic programming, material handling, and automation system integration. Through practical learning, students gain valuable skills in robotics, helping bridge the gap between academic knowledge and industry needs. An issue that students are facing is a lack of hands-on robotics experience in college which limits students' ability to apply theoretical knowledge to real-world problems, which is critical in a field like robotics. It can hinder their problem-solving skills, creativity, and technical competency, making them less prepared for industry jobs that require practical expertise. Additionally, without hands-on experience, students miss out on opportunities to work with cutting-edge technology, which could affect their innovation and competitiveness in the job market. Employers and new hires/recent grads in the manufacturing industry are impacted by this problem, more so because robotics and automation are a new and quickly grossing field. Due to said lack of experience, it is vital that students get as much exposure as possible to these concepts; solving this issue will help students by bringing hands-on experience to the workplace, enabling them to solve real-world problems efficiently and apply their practical skills.

The manufacturing industry is also facing a significant challenge finding people to work and do quality work, crushing industries production as well as the cost of the product for the end user (2). Students with robotics exposure can help operators and programmers by quickly understanding and troubleshooting robotic systems, reducing downtime, and improving efficiency. Their hands-on experience allows them to bridge the gap between design and execution, offering fresh insights for optimizing workflows. Additionally, they can assist in automating repetitive tasks, enhancing both productivity and safety, while collaborating effectively with experienced operators and programmers to integrate new technologies smoothly. The end user is greatly impacted by quality issues from human error. The use of industrial robots and automation are the answers to the shortages, but without people with proper knowledge and experience controlling/programming the robot, there is no use for the robots.

b. Applicable Standards

Below can be found at (3)

- OSHA 1910 Subpart D – Walking- Working Surfaces
- OSHA 1910 Subpart G – Occupational Health and Environment Control
- OSHA 1910 Subpart I – Personal Protective Equipment
- OSHA 1910 Subpart J – General Environment Controls
- OSHA 1910.212 - Machine Guarding
- OSHA 1910 Subpart S – Electrical Safety
- OSHA 1910.1200 - Hazard Communication
- OSHA Technical Manual - Section IV: Chapter 4 - Robotic System Safety
- OSHA 29 CFR 1910.211 - Emergency Stop Systems
- ISO/TS 15066:2016
- ISO/TR 20218-1:2018
- OSHA Technical Manual (OTM) Section IV: Chapter 4
    - Industrial Robot Systems and Industrial Robot System Safety

c. State of the Art

The current state of the art in robotics is advancing rapidly across all industries. Robotics is heavily used in automotive and electronics manufacturing for tasks such as assembly, welding, painting, and material handling. The cobot (Collaborative Robot) has been experiencing an increase in use, due to its ability to work alongside human workers, enhancing flexibility and efficiency.

Fig. #1 Cobot (4)

FANUC's cobots, such as the CR series, are known for their user-friendly design and ease of integration. They come with a lightweight and compact build, making them suitable for deployment in environments where space is limited. These robots are equipped with advanced sensors and safety features that allow them to operate safely in close proximity to human workers. Safety is a core component of FANUC's cobot design. Cobots are frequently used in assembly operations, where they can handle repetitive tasks such as component insertion, screwdriving, and part assembly. Their flexibility allows them to be quickly reconfigured for different tasks, making them ideal for small-batch production and customizable assembly lines. They are fitted with collision detection systems that automatically stop or slow down the robot if it encounters a human or an unexpected obstacle. This makes it a great asset for our use due to the safety features of this robot. Now due to the cobot's ability to work alongside humans, they aren't capable of the high speeds that other robots have (5). This can make them undesirable for production lines where cycle time and high production rates are crucial. Another downside is the payload. The lack of power that hinders the speed also affects the payload, which means that cobots aren't well suited for tasks with high payloads (5). The cobot really excels when the task isn't set in stone and humans need assistance.

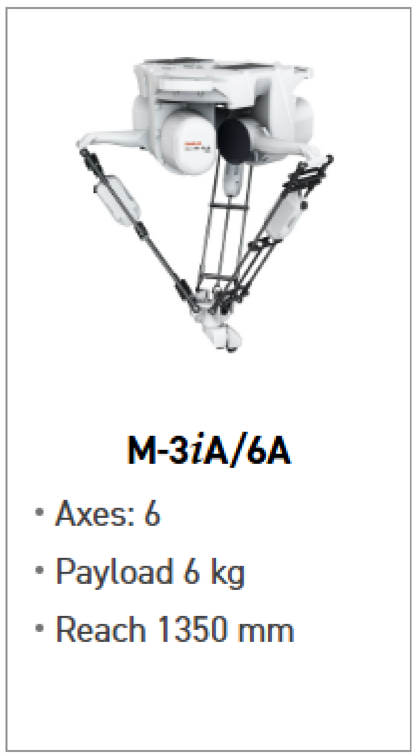

Fig. #2 M-3ia-Delta-Robot (6)

The M-3ia Delta Robots from FANUC are a remarkable example of high-speed, precision automation technology designed for industrial applications. Specializing in quickly and accurately picking items from one location and placing them in another, this type of robot is wildly used in pick and place applications. Despite their lightweight design, the M-3ia Delta

Robots can handle payloads up to around 3 kg. This makes them suitable for handling small to medium-sized parts, components, or products with ease.

Fig. #3 - ARC Mate 50iD/7L (7)

The ARC Mate 50iD/7L is commonly used in automotive production lines for welding components such as chassis parts, exhaust systems, and body panels. Its precision and repeatability are crucial for meeting the high-quality standards in this industry. Repeatability is a huge factor in manufacturing, especially in the assembly process. These types of Robots are very durable and versatile, excellent for long lasting manufacturing. Overall, the ARC Mate 50iD/7L is valued for its flexibility, speed, and precision, making it a popular choice across various manufacturing sectors that require high-quality and efficient processes. Even though this robot is popular for its wide range of capabilities and flexibility, this comes at a high cost (8). These robots are typically expensive when compared to other robots on the market. Another issue is the maintenance. Articulated robots have to be complex to achieve flexibility and repeatability, which makes them hard to repair (8).

d. End User

The person most affected by this will be the engineering students at UC. Creating a robot cell to display how robots are used in the field will enhance the student's learning experience. Students getting to see just some of the many skills these robots possess should help get students excited and interested in robotics. The faculty and staff will also benefit from the new robot cell. Creating a cell will help the faculty make use of the new robots that were just installed in Rhodes High Bay. The faculty that'll be working with the robots will need to have the necessary programming knowledge to be able to run the program. Along with this, if there are any changes that need to be made to the program, then having a good understanding of how to program the robot will be useful. The work we do on these new Fanuc robots can also help inspire faculty to come up with other similar ways to display the many capabilities these robots have. Failure to solve this issue would leave the university without a good way to display the capabilities of these robots. The current Manufacturing Automation Lab that uses these robots only serves as an introduction to the different features, but this new cell would show students something closer to what you'll see in industry.

e. Applicable Standards

- OSHA 1910 Subpart D – Walking- Working Surfaces (3)
- OSHA 1910 Subpart G – Occupational Health and Environment Control (3)
- OSHA 1910 Subpart I – Personal Protective Equipment (3)
- OSHA 1910 Subpart J – General Environment Controls (3)
- OSHA 1910.212 - Machine Guarding (3)
- OSHA 1910 Subpart S – Electrical Safety (3)
- OSHA 1910.1200 - Hazard Communication (3)
- OSHA Technical Manual - Section IV: Chapter 4 - Robotic System Safety (3)
- OSHA 29 CFR 1910.211 - Emergency Stop Systems (3)

f. Summary of Research/Conclusion

The evolving world of robotics and automation is transforming industries by increasing efficiency, reducing human error, and driving innovation. This shift impacts labor markets, requiring new skills while optimizing production processes, and enhancing safety and precision across sectors like manufacturing, healthcare, and logistics. The integration of AI into automation is further pushing the boundaries of what's possible in terms of smart, adaptive systems. The University of Cincinnati is currently offering robotics courses and opportunities for a variety of different minors and a few majors. The University recently purchased six Fanuc robots for the robotics courses offered. Before this year, students at the university lacked access to hands-on experience in regard to robotics and programming. FANUC education robots provide students with hands-on experience in robotics and automation, preparing them for careers in advanced manufacturing and technology. These robots simulate real-world industrial applications, allowing students to learn programming, troubleshooting, and robotic operation in a safe environment. By using FANUC's industry-standard technology, students gain valuable skills that are directly transferable to modern automated industries. These robots are designed for easy programming and safe use, allowing students to learn real-world applications such as robotic programming, material handling, and automation system integration. Hands-on experience with robots before entering the real world is essential because it equips students with practical skills, problem-solving abilities, and familiarity with industry-standard technology. This experience helps bridge the gap between theory and real-world applications, making students more confident and capable when working with automated systems in professional environments. It also enhances their employability by giving them a competitive edge in a rapidly evolving, technology-driven job market. This issue should be addressed because it leaves students unprepared for the demands of industries increasingly driven by automation and technology. Without hands-on exposure, graduates may struggle to adapt to modern workplaces that rely on robotics, reducing their competitiveness in the job market.

The end users affected most by this issue will be students in terms of experience and employers hiring qualified candidates. A new robotics lab can spark excitement in students by providing a dynamic, hands-on learning environment where they can engage with cutting-edge technology. The ability to build, program, and operate robots makes it hard to grasp lecture concepts more tangible and develops creativity and problem-solving. This experience not only makes learning more enjoyable but also ignites curiosity and passion for robotics, encouraging students to explore the field further and pursue careers in automation, engineering, and related disciplines.

Despite significant advancements in the robotics and automation world, there are still several gaps in the state of the art. Robots often struggle with understanding complex, dynamic environments in real-time, especially when dealing with unstructured or unpredictable scenarios. Robots also have limited ability to handle delicate tasks requiring fine motor skills, which is crucial for applications in healthcare, manufacturing, and service industries. Seamless, intuitive communication between humans and robots is also still a challenge, particularly in terms of natural language understanding, emotional recognition, and safety in shared spaces. Lastly, fully autonomous robots that can make complex, context-aware decisions without human intervention remain an ongoing challenge, particularly in highly dynamic and uncertain environments.

g. Customer features

- Aesthetics
- Collaboration
- Competitive
- Customizable
- Cycle time
- Ease of assembly
- Ease of use
- Fun
- Inspiring
- Safety
- Rewarding

3. Quality Function Deployment

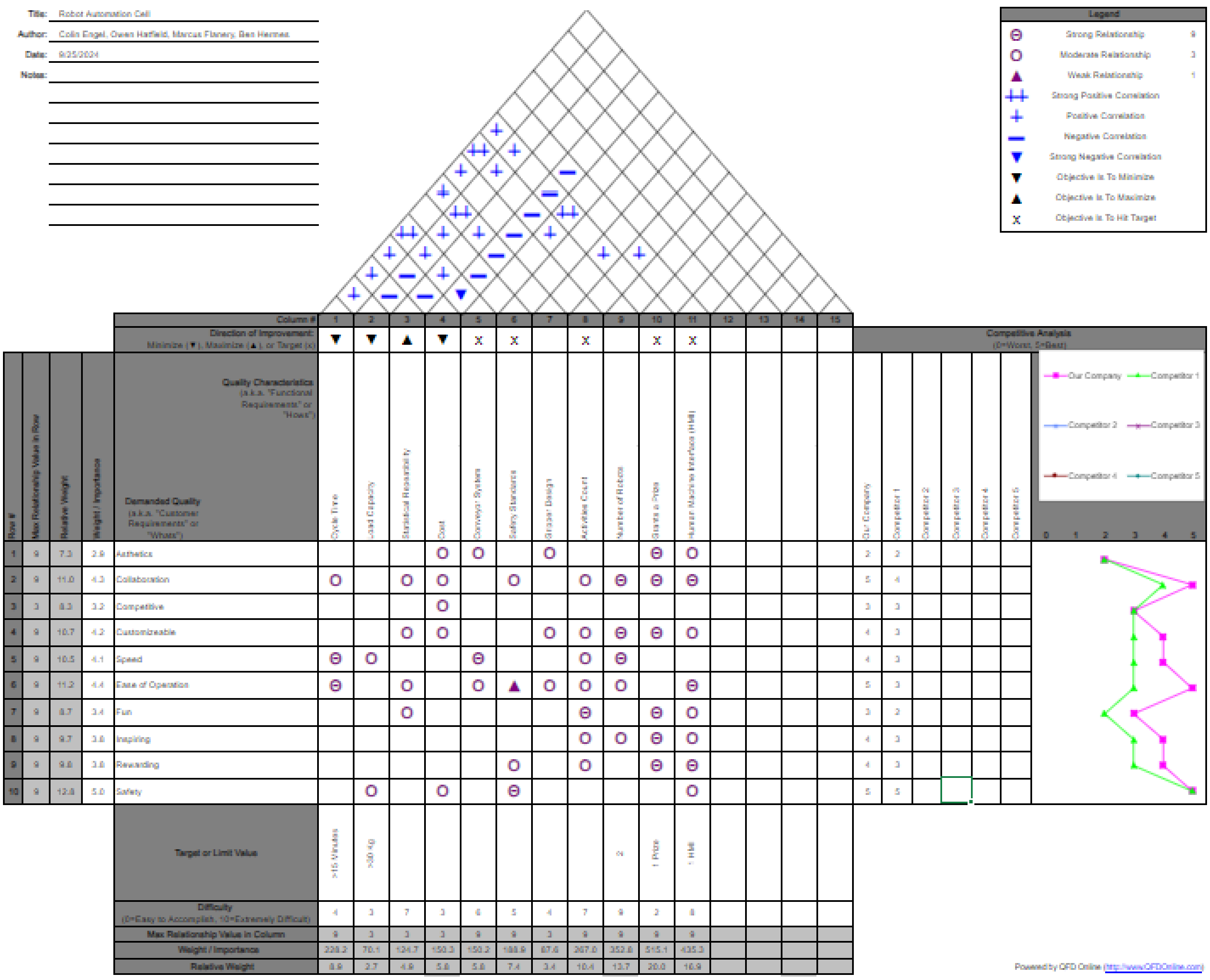

Fig. #3 – Quality Function Deployment

a. Survey Methodology and Results

Our survey was sent out to an entire manufacturing automation class. Out of 60 people surveyed, 46 responded, giving a response rate of 76.7%. Based on the survey, the data helps identify what aspects of what the manufacturing automation class prioritizes, which in our case will be our end users. By far, the data shows that the demand for collaboration, ease of use, and safety rank highest for our customers' wants and needs.

		Importance of the feature		Satisfaction with the feature in the current technology	
Customer Feature	Total Surveyed	Average Rank	Standard Deviation	Average Rank	Standard Deviation
Aesthetics	*46*	*2.85*	*0.903*	*3.35*	*0.22333*
Interactive	*46*	*4.28*	*0.5267*	*3.07*	*0.05667*
Competitive	*46*	*3.22*	*0.5344*	*2.76*	*0.36667*
# of Activities	*46*	*4.19*	*0.4365*	*3.09*	*0.03667*
Time to complete	*46*	*4.11*	*0.3565*	*3.35*	*0.22333*
Easy to Use	*46*	*4.35*	*0.5963*	*3.33*	*0.20333*
Fun	*46*	*3.39*	*0.3626*	*3.04*	*0.08667*
Inspiring	*46*	*3.78*	*0.0266*	*2.91*	*0.21667*
Rewarding	*46*	*3.83*	*0.0767*	*3.24*	*0.11333*
Card Game	*46*	*3.96*	*0.2066*	N/A	N/A
Dice Game	*46*	*3.28*	*0.473*	N/A	N/A
Board Game	*46*	*3.80*	*0.0467*	N/A	N/A

Fig. #5 – Survey Statistics

b. Engineering Characteristics

- Cycle time
- Load capacity
- Statistical repeatability
- Cost
- Conveyor system
- Safety standards
- Gripper design
- Activity count
- Number of robots
- Granting a prize
- Human machine interface (HMI)

c. Product Objectives:

Product Objective	Relative Weight
Cycle Time	8.9
Load Capacity	2.7
Statistical Repeatability	4.9
Cost	5.8
Conveyor System	5.8
Safety	7.4
Gripper Design	3.4
Activity Count	10.4
Number of Robots	13.7
Grants a Prize	20.0
Human Machine Interface (HMI)	16.9

Fig. #6 – Weight of Objectives

4. Concept Design

After thoughtful consideration the Centralized Assembly was chosen as our concept to pursue. Once the assembly begins and the base is set in the centralized assembly station, this ensures that the base is secured, and the following parts can be inserted precisely and properly, with a high factor of repeatability. Once the assembly is finished the finished product is then set on a conveyor system to our packaging station to then be delivered to the student.

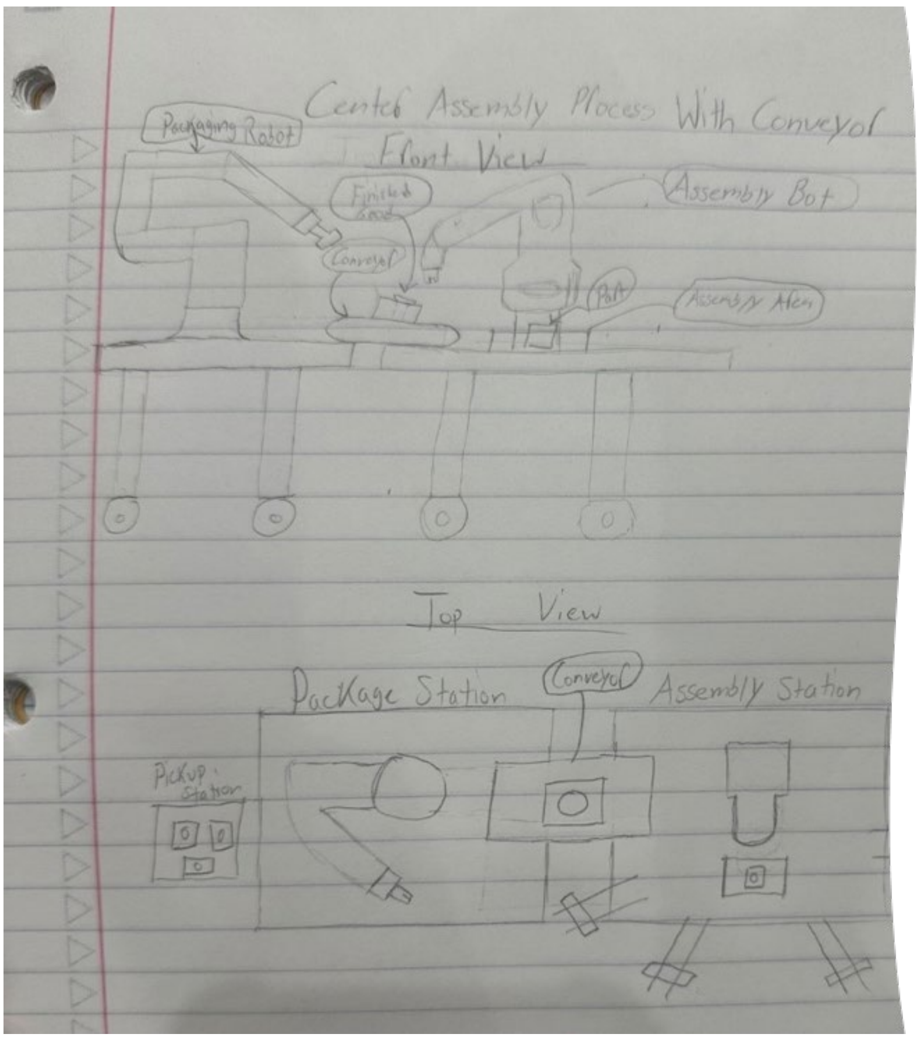

Fig. #7 – Assembly Process Rough Sketch

5. Designs

The following section entails initial feeder concepts, its final revisions and technical descriptions and their respective figures:

a. Base Feeder

i. Initial Concept design

The initial design was structured to hold five base blocks in a simple arrangement. The robotic gripper was programmed to pick up each part at a 90-degree angle, relying on the force of gravity to allow the remaining blocks to descend into position. The design lacked sensors, pneumatics, or additional automation.

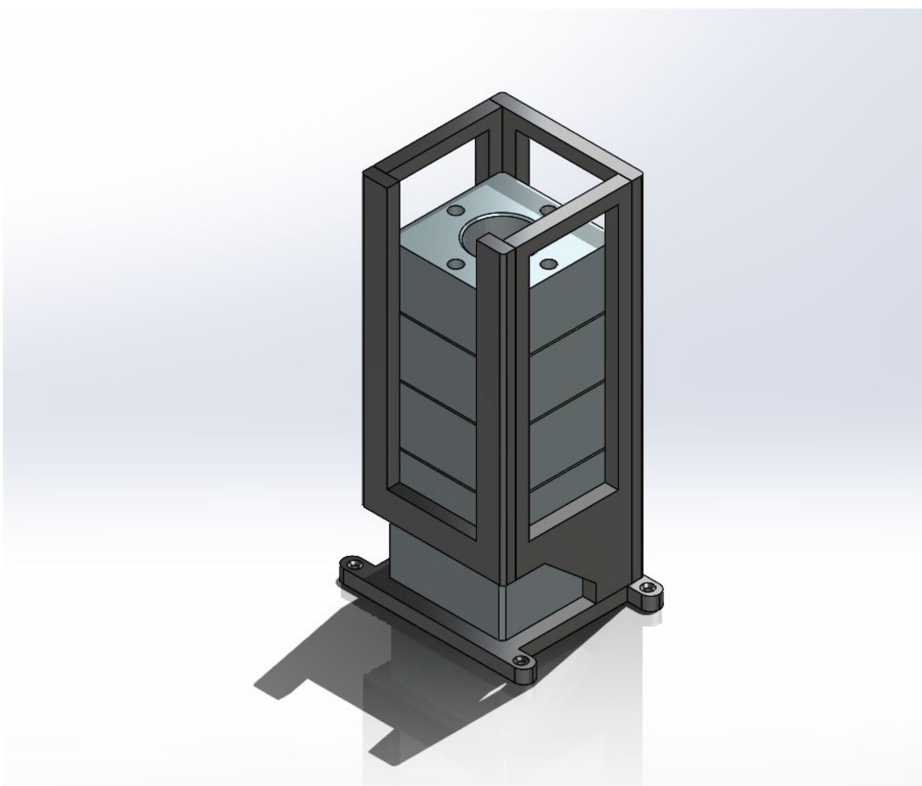

Fig. #8 – Initial Base Concept

ii. **Final Concept Design**

The revised design incorporates a rear-mounted pneumatic cylinder and front-mounted sensors for part detection. These sensors update the magnetic proximity sensors to identify when a new part is ready. A custom pusher mechanism is integrated to work with the gripper and gravity feeder. Additionally, the pusher block features a cutout tailored for a custom end-of-arm tooling (EOAT), removing the need for the robot to rotate 90 degrees.

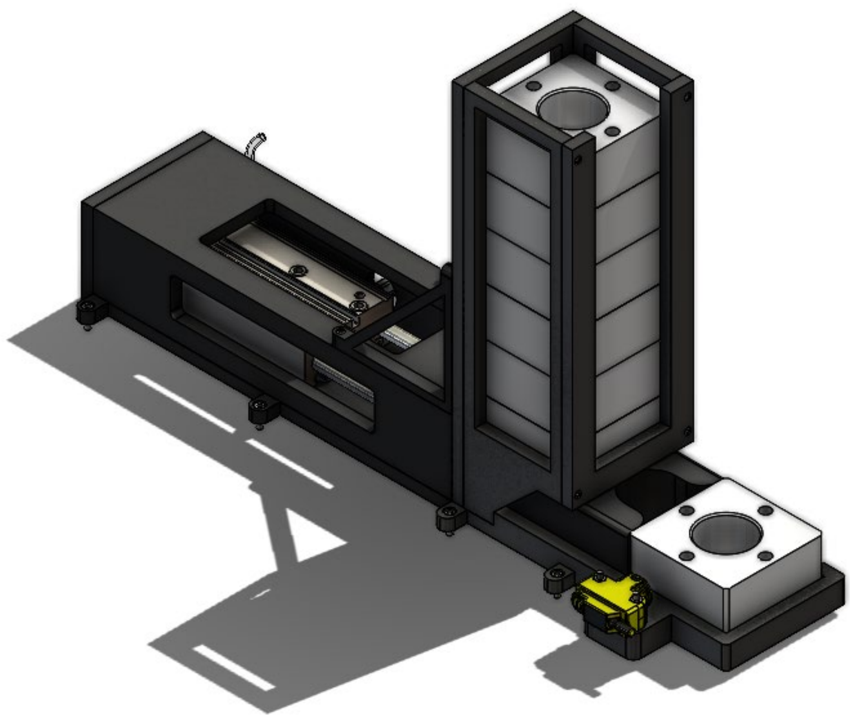

Fig. #8 – Final Base Concept

The housing for the feeder is split into multiple components (Front, side and rear panels, two base platforms and safety covering for the pneumatic piston. All of these will be 3D printed.

The revised final design includes a rear mounted pneumatic cylinder to move parts into the pickup zone. This specific piston was chosen due mainly to its stroke length of 100mm. The Length was vital to ensure the pusher arm was able to fully move the part into the pick-up zone as well as full retract to allow for a part to drop down from the feeder.

Fig. #9 – Pneumatic Piston

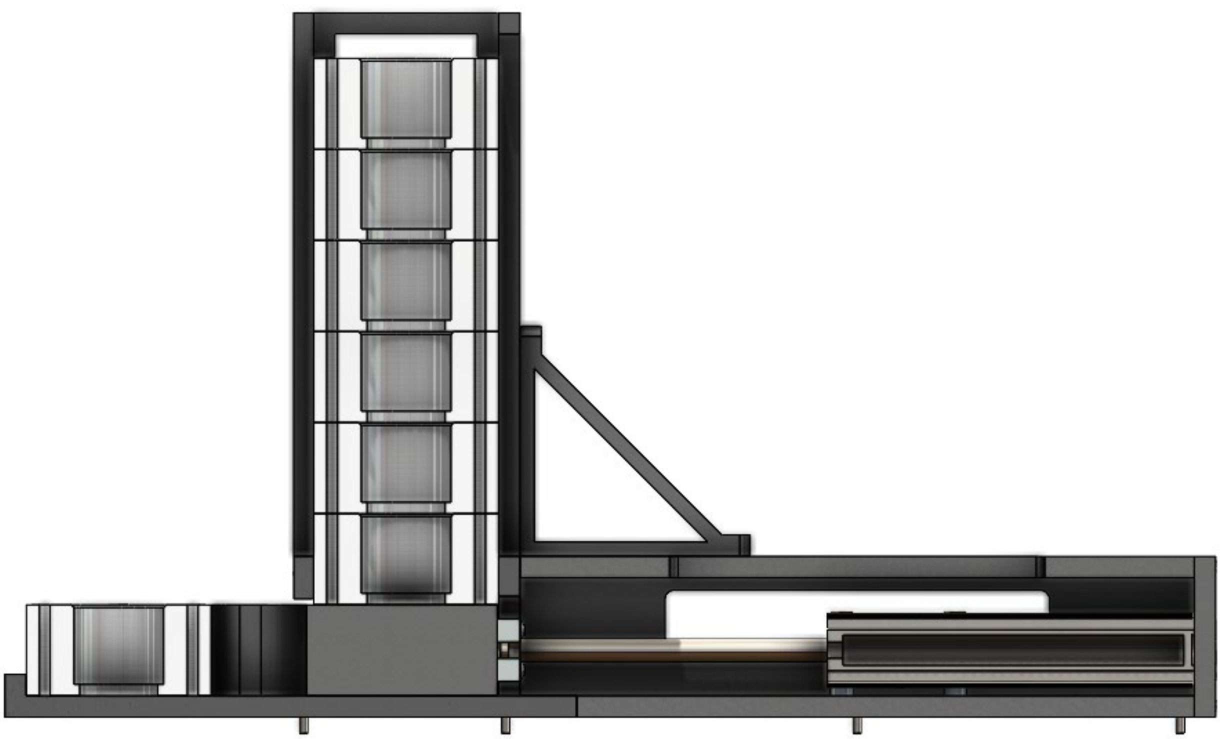

Fig. #10 – Right Section View

The revised final design includes a side mounted sensor detect part presence. The sensor will alert the piston whether or not to retract and move a new part forward. The Banner QS18 All-purpose scanner was chosen for this task. The Banner QS18 sensor is a photoelectric sensor that detects the presence or absence of an object by emitting a light beam and sensing its reflection. The QS18 sensor, along with a magnetic piston sensor and the pneumatic actuator will be used together to move parts in the Base Feeder.

Figure #11 QS18 Sensor

b. Bearing Feeder

i. Initial Concept design

The initial concept for the bearing feeder is a cylindrical tube stack for the inventory of the bearings to be stacked vertically on top of each other. Then a railing system would be implemented to separate the bearing from the inventory spot to the pickup spot. The way these two are separated is by a linear actuator with an attachment to push the bearing forward to pick up then retract to drop another bearing to repeat the process. Two photoelectric sensors were going to be used to communicate when the bearing is ready to be pushed, picked up, and when it needs replaced (refill of inventory).

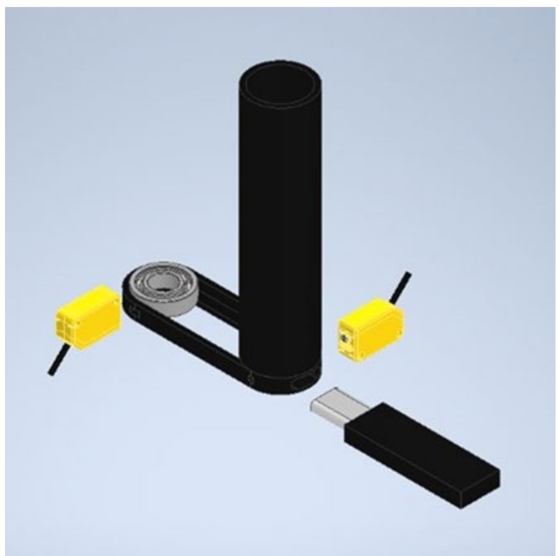

Figure #12 Bearing Feeder Concept Design

ii. Final Concept Design

The final design of the tubing system with four slots to visually ensure the bearings are properly oriented in the tube and giving visual aid to the operator of the amount of stock as well. The alignment rod is used in compatibility with the railing system to manually feed the bearings and ensure security for the operator that the feeding part of the process is as simple as possible

Figure #13 Tubing/Alignment Rod

The NEMA 17 Electric Cylinder Linear Actuator was chosen because of the great cost and the size of the actuator itself. The 2” stroke length of the actuator was a perfect fit for my railing system to ensure a perfect transfer of the bearing.

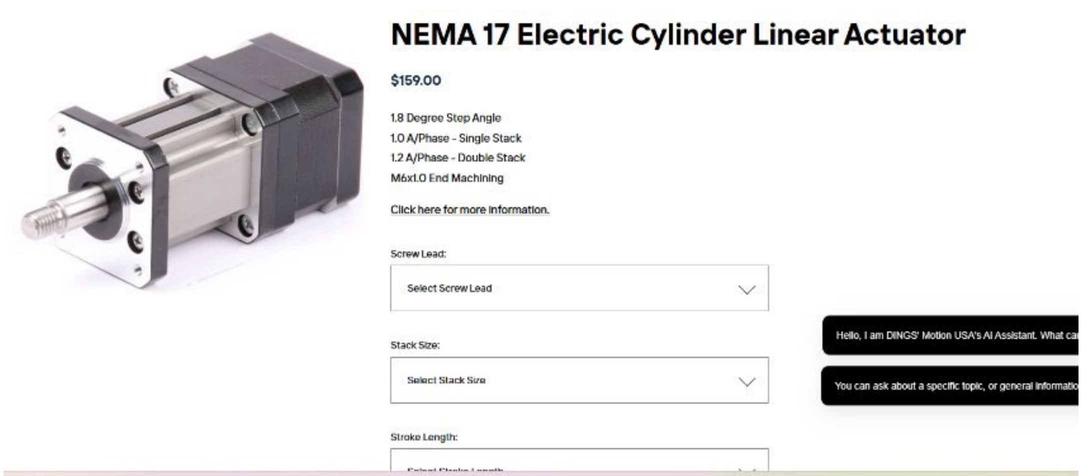

Figure #14 (9)

The simplicity and price that the photoelectric sensor brings to the assembly was a great fit for the bearing assembly process. The photoelectric sensor is great for detecting the presence/absence of a part which is perfect for this feeding process.

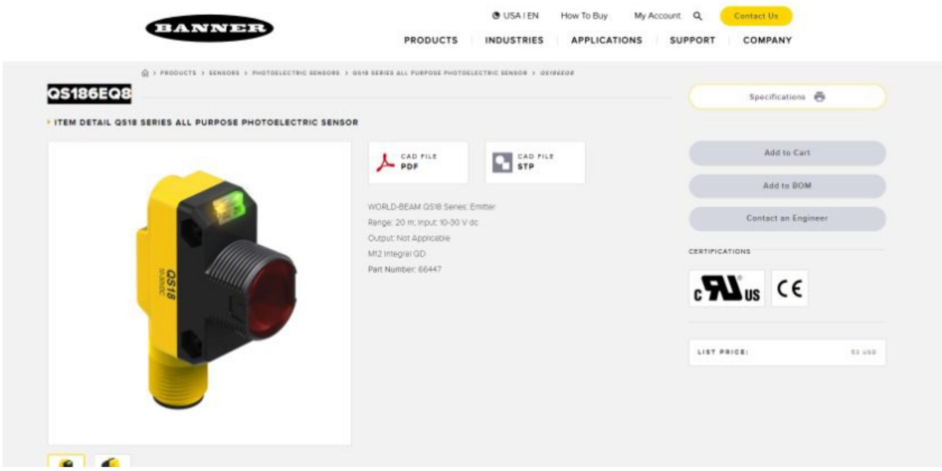

Figure #15 (10)

The railing system has an indent for the alignment rod that will be in the center of the cylindrical tube to ensure proper alignment for feeding. The railing will allow for a smooth transfer from inventory to pick up. The drop down at the pickup point will ensure that once the bearing is fully pushed by the actuator that the bearing will not be moving and can be picked up repeatedly in the same place.

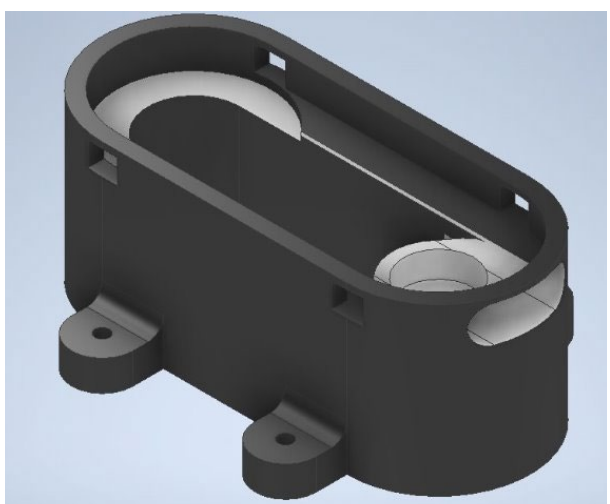

Figure #16 Railing System

The mount consists of a shell for the linear actuator so it can properly sit in the mount while also being aligned with the railing slot for the push rod. The two sensor brackets will be mounted to both sides of the base at the centerline of the bearing feeder sensor slots for precise part detection.

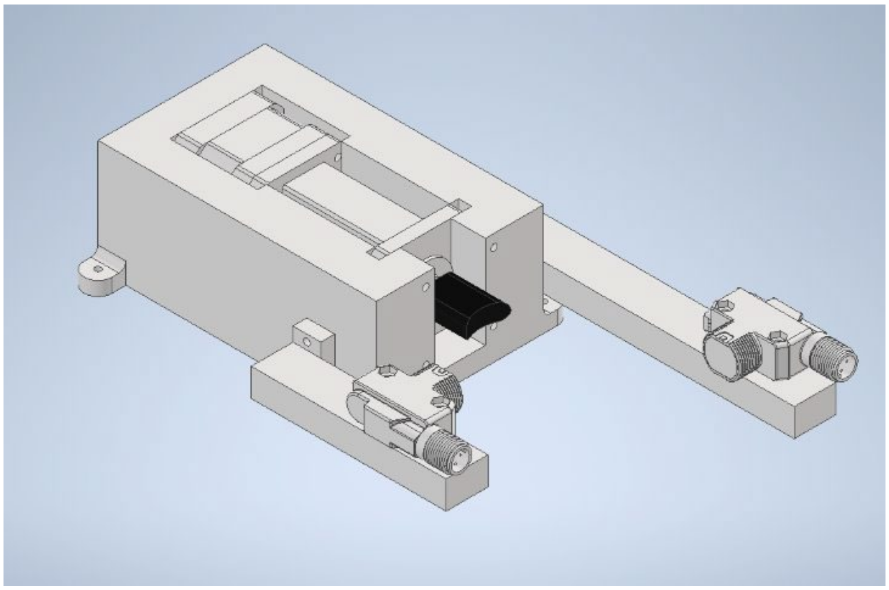

Figure #17 Actuator/Sensor Mount

c. Shaft Feeder

i. Initial Concept design

The initial design for the shaft feeder was a gravity feeder using a rotary actuator to dispense on shaft at a time. The shaft was going to be guided by the rails and stop at the bottom, where the camera would take an image and determine the correct pickup location. The pins are manually fed from the back through a slot that ensures they are fed horizontally. As we spent time breaking down the feeder designs, there were some major factors that the initial feeder failed to address. The first issue was that the rails were not sufficient at keeping the shaft attached and oriented correctly. The next issue was that there was no way to guarantee the shaft would be in the same position every time it reached the end of the track. There were also some minor issues regarding the rotary actuator system. The final concept took these factors into account, along with others not mentioned.

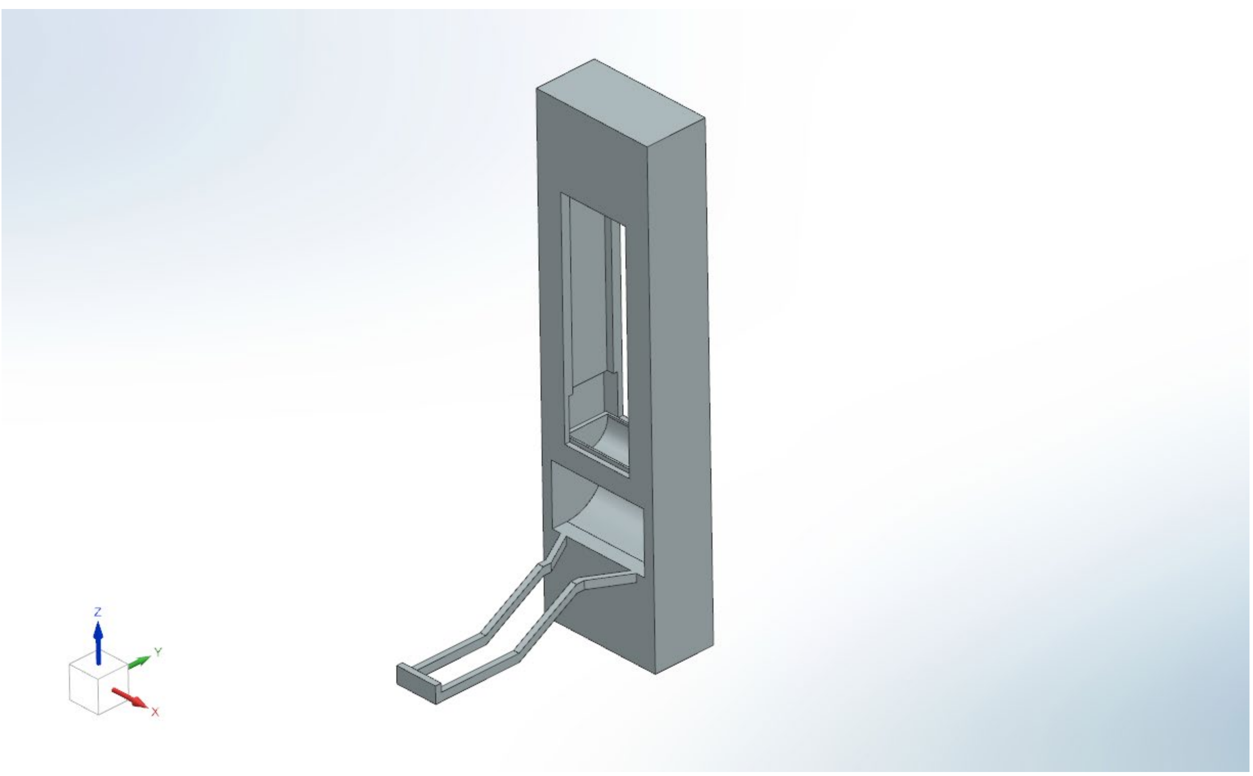

Figure #18

ii. Final Concept Design

The final feeder design features a linear actuator to dispense the shafts. The linear actuator will push one shaft through the door and onto the rails until it falls into place. Once in place, the robot will use a camera to take an image and determine how to orient the part in the intermediate pickup mount. In the end the robot will have picked up the shaft by the long end so it can be placed in the assembly.

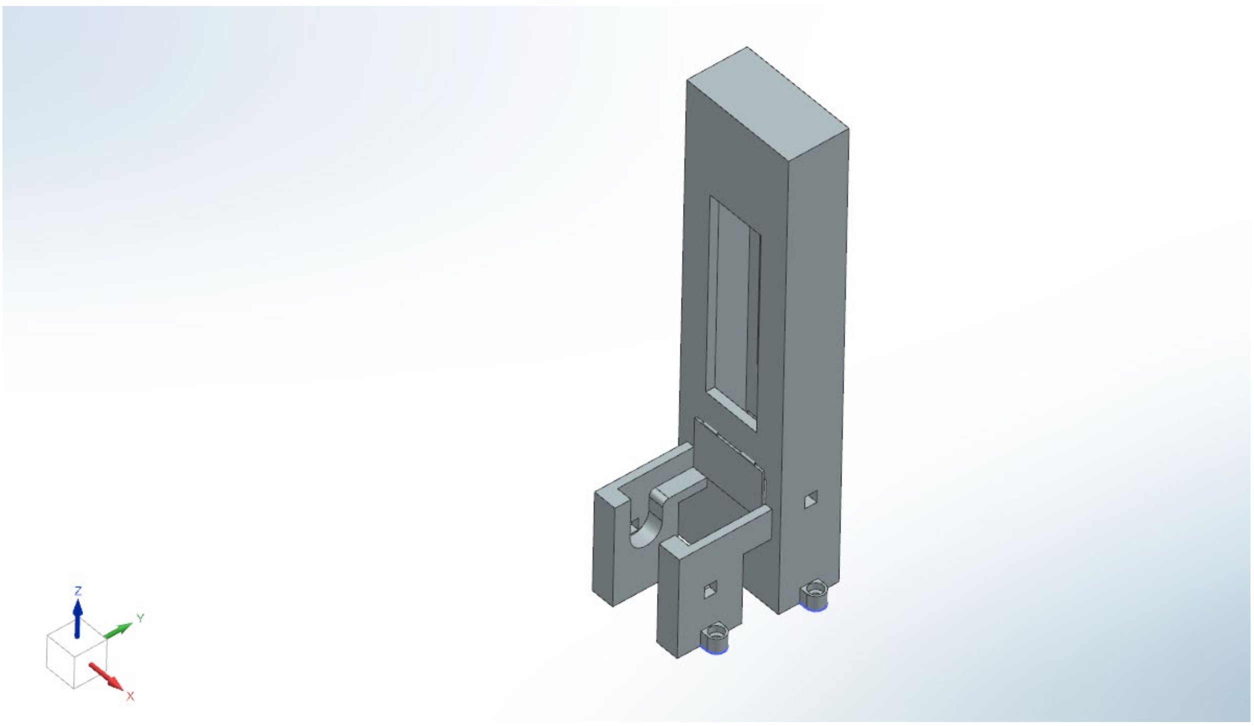

Figure #19

The actuator bracket features 2 flanges. The first flange connects the bracket to the feeder, and the second flange connects the bracket to the linear actuator.

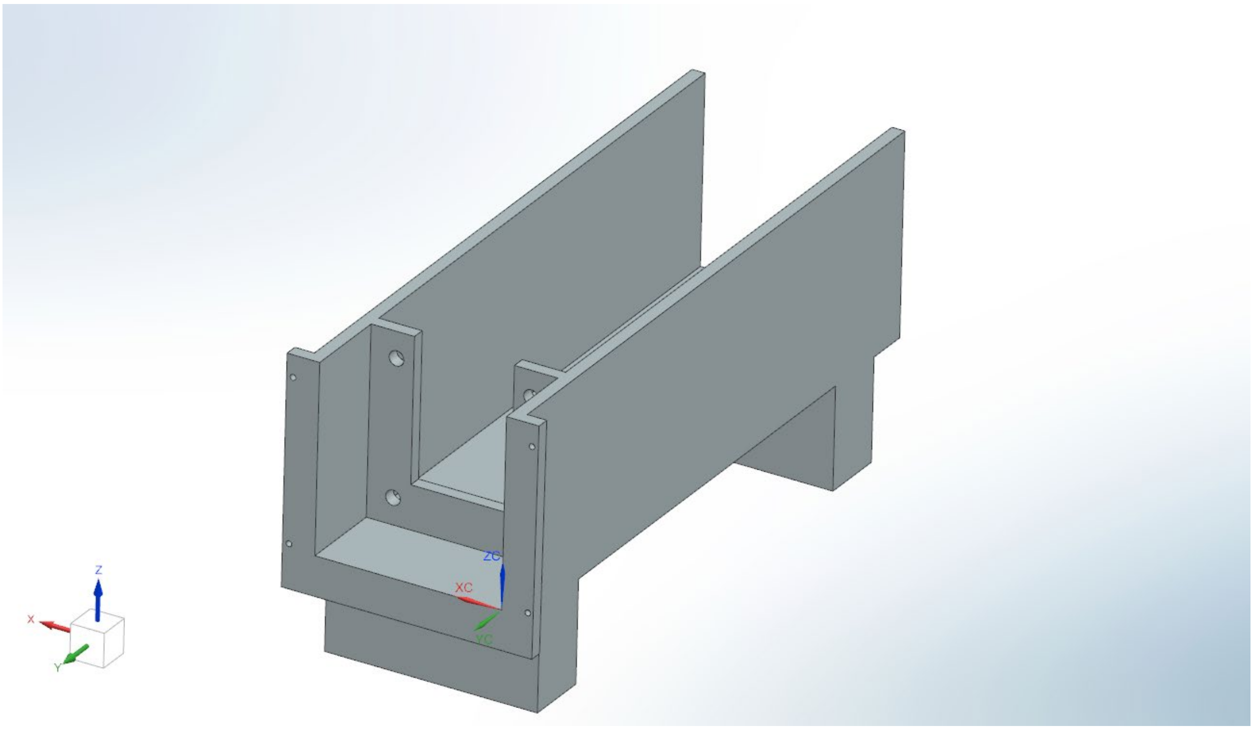

Figure #20

Sensor Brackets:

The sensor brackets both have two mounting faces. One face is mounted to the feeder and the other is used to mount the sensor to the bracket.

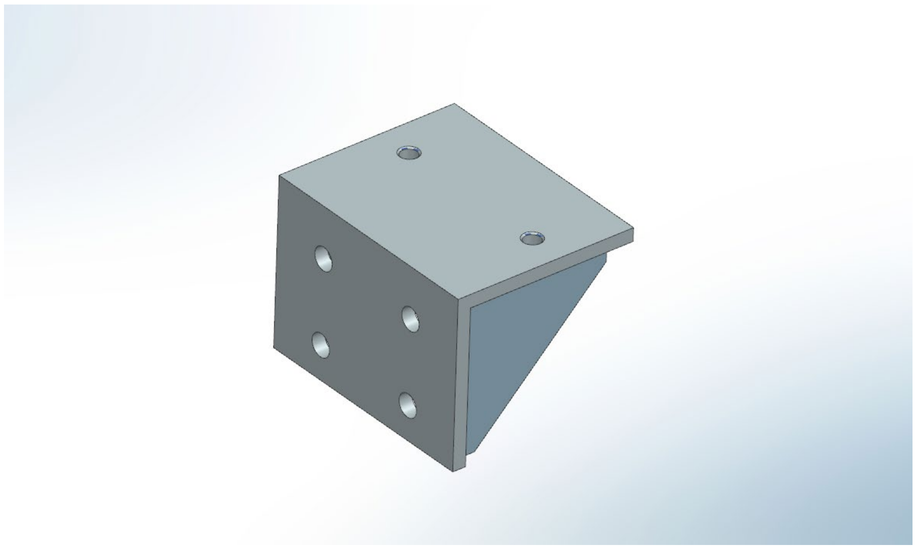

Figure #21

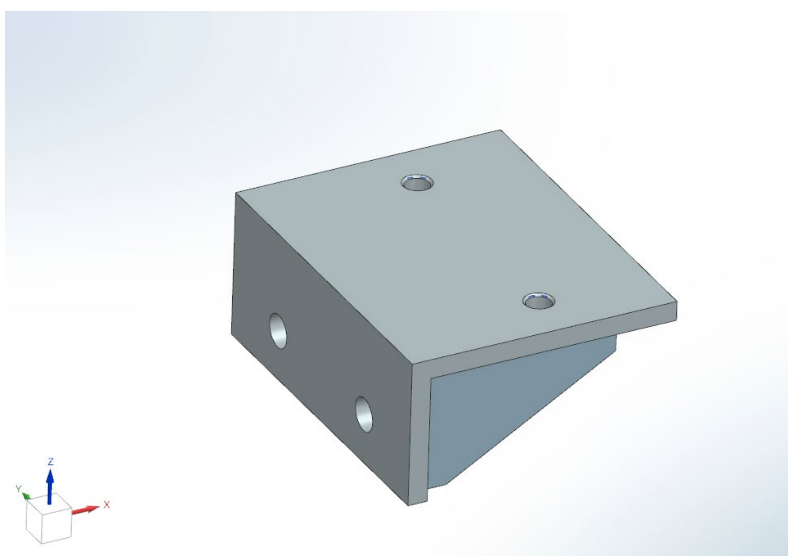

Figure #22

In the final design, sensors will check the status of the system. One sensor will let the linear actuator know when to activate and the second sensor will let the robot know when to come and take an image of the shaft.

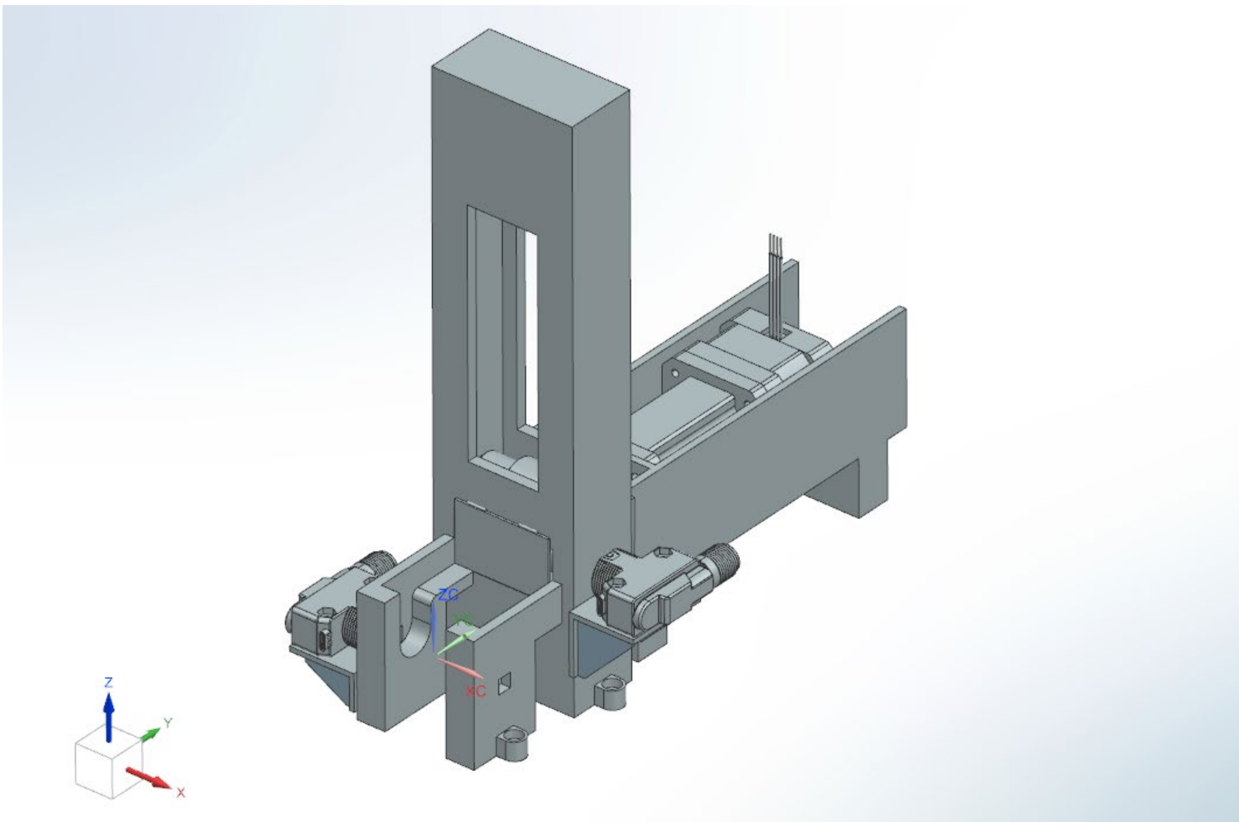

Figure #23

d. Cap Feeder

i. Initial Concept design

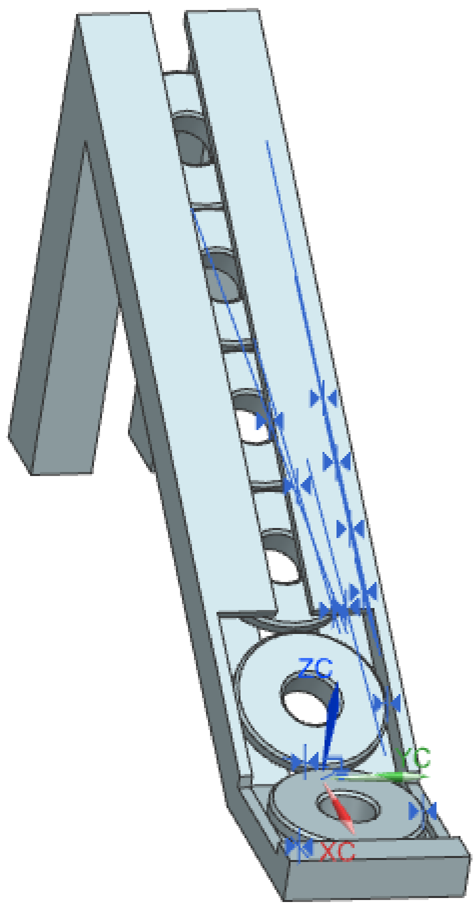

Fig. #24 – Initial Cap Feeder Concept

The original feeder design was a simple gravity feed design. Load the parts into a slide and then the robot would come and pick them up at the end. There was a high possibility of the part pickups being affected by the part next on deck so a re-design was to be considered. Top loaded design, manually Feed Caps through top

ii. Final Concept Design

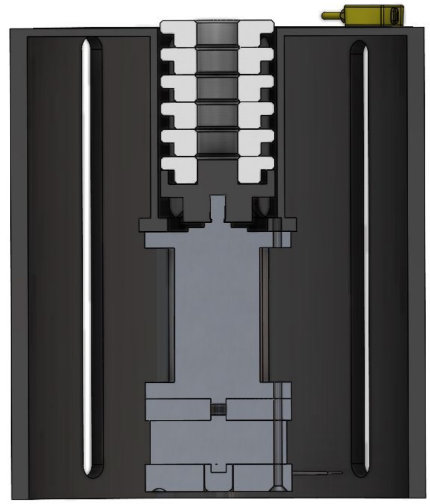

Fig.25 **Fig.26**

The final product is a top loaded feeder that uses a through beam to detect parts. As parts are taken the actuator will feed parts up until it needs to be reloaded, then the actuator will drop down for parts to be loaded. The main benefit of this design is that the parts do not get in the way of each other during the feeding process. There is a cap holder made from Polylactic acid (PLA) and that allows for the actuator to properly feed the parts up. In case of a part jamming, the cover is removeable so you can troubleshoot for a quick and easy repair. There are windows so the students can view the feeding process; there also is a removable shield for maintenance purposes. The cut outs are designed so that your fingers will not be able to reach the linear actuator.

e. Component Selection/Justification

NEMA 17 Electric Linear Actuator:

We chose this actuator mostly due to its flexibility and cost. The actuator rod is threaded on the end, which made it possible to use this actuator for 3 of the 4 feeders. This was because it gave us the option to create a custom pusher block for each feeder all while using one common actuator. It comes with 2” of stroke, which meets our requirements, and it is small enough to fit inside our layout area.

f. Table Layout

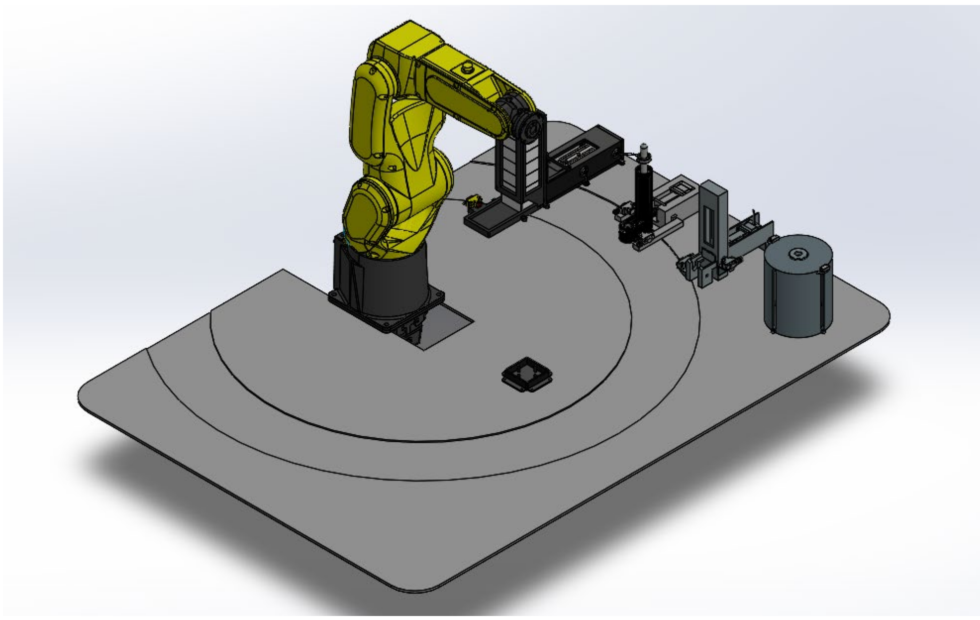

Figure #28 Assembly Layout Isometric View

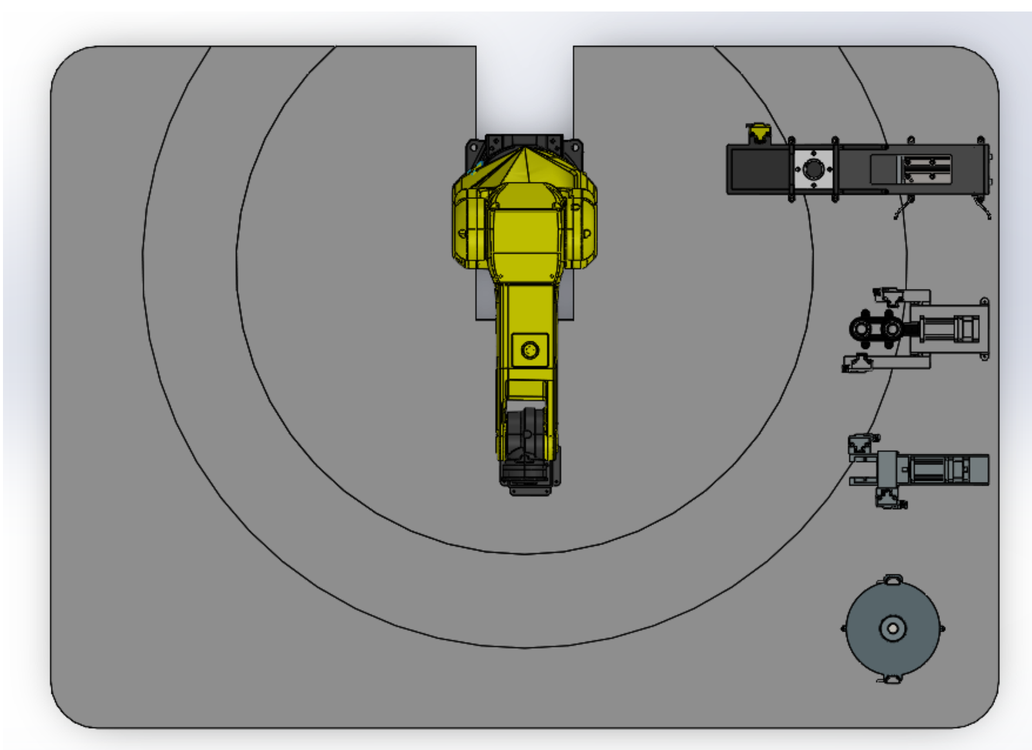

Figure #29 Top View Assembly Layout

g. Conveyor Design

Figure # 30 (11)

Conveyor Belt	
Payload	500 g
Effective Delivering Distance	600 mm
Maximum Speed	120 mm/s
Maximum Acceleration	1100 mm/s^2
Dimension	700 mm × 215 mm × 60 mm
Net Weight	4.2 kg
Weight (packing included)	5.34 kg

Figure #31 (11)

The Magician Conveyor Belt will connect the assembly and packaging stations to ensure the robots do not have an overlapping work envelope. The payload will not exceed 500g and the speed of 120 mm/s is fast enough to ensure a high transfer time of the finished part.

h. Gripper Design

a. Initial Gripper Design

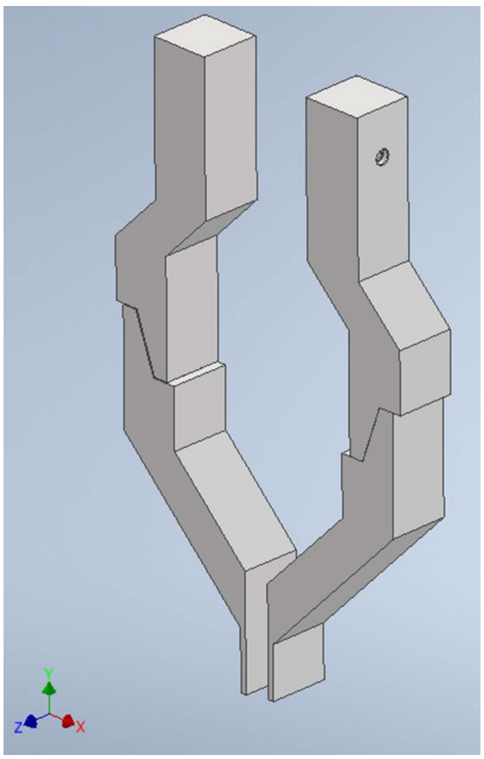

Fig #32

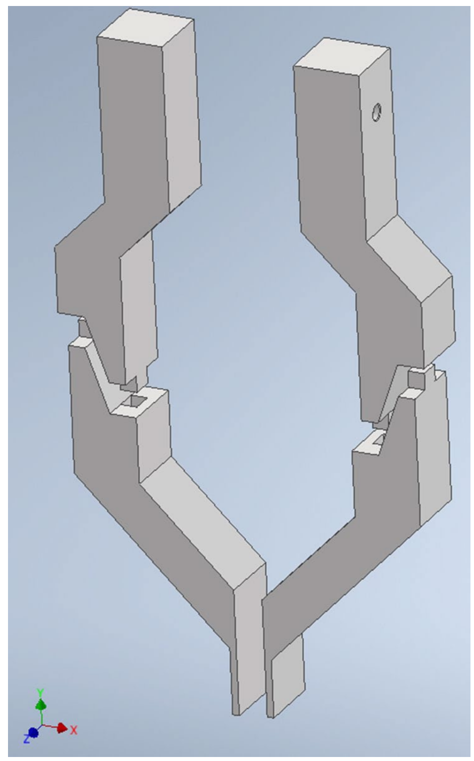

Fig #33

This two-phase gripper will allow us to take the 11 millimeters of linear open/close movement on the current setup and translate that to picking up every part. Limited by either fully opened, or fully closed, and 11mm of linear movement, designing one gripper to do all this is a big task. The biggest part is the 65mm base and the smallest is the 4mm inner diameter of the bearing. In order to meet these extreme conditions with only 11 millimeters of movement, we essentially need two different grippers. The secondary gripper, when it's attached, will only have one degree of freedom down. The pin slots, force of friction and the normal force of the inclined slope keep it locked in place until the gripper takes it back to its home position. The idea is to have the small gripper pick up the small parts and the big gripper pick up the base and completed assembly. This gripper in theory would work but ended up needing redesigned because we had no good way of changing the gripper besides by hand.

i. Final Gripper Design

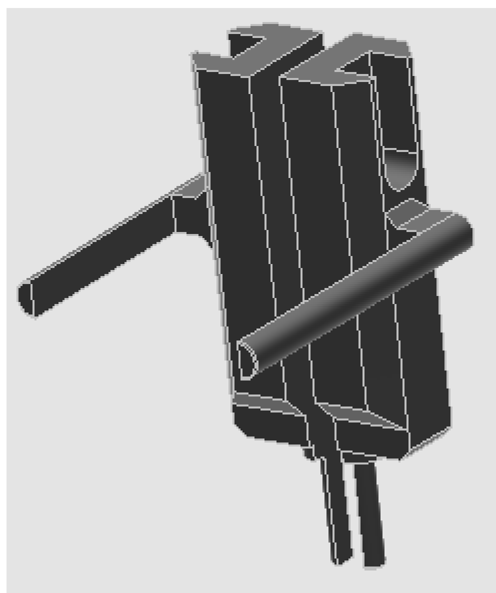

Fig #34

This dual gripper is designed to pick up the bearing and cap. The shaft and the base can be picked up by a suction cup, our other end of arm tooling. The first set of fingers is to pick up the bearing. The fully opened distance of the gripper is set to the inside diameter of the bearing. This is to ensure the least amount of pressure possible on our PLA gripper, while still holding the part. Then we used the fully closed position of the gripper and set the second set of fingers to the outer diameter of the cap. We are not able to use the inside diameter of the cap because the part must be placed onto the shaft of the assembly.

6. Fabrication & Assembly

a. Feeders

a. Base Final Assembly

The feeder system for our capstone project was fabricated using 3D printing and standard off-the-shelf hardware. All structural components were 3D printed with PLA material at the University of Cincinnati's 1819 Innovation Hub, providing a rapid and cost-effective method for prototyping. Fasteners including M2, M3, and M5 bolts, were sourced from McMaster-Carr to assemble the feeder frame and secure the moving elements. Hydraulic tubing was routed between the valve bank and both the input and output ports of the pneumatic piston integrated within the feeder. To reinforce structural integrity, 45-degree angled braces were installed at the rear of the assembly. A part detection sensor was mounted on the right side of the feeder to ensure convenient cable routing to the PLC and HMI interface. While PLA was sufficient for preliminary testing and validation, the current setup revealed issues with print quality and dimensional tolerance. For future iterations, industrial-grade materials and CNC-machined components are recommended to enhance reliability, part precision, and long-term durability in an industrial setting.

Fig #35

b. Bearing Final Assembly

The bearing assembly was printed at the 1819 Innovation Center out of PLA. The assembly process consists of six parts. There is an actuator bracket that you can slide the actuator into to keep it in place. This bracket is bolted onto the table using M3 screws. The bracket also has a mounting arm bolted to the side that holds a photoelectric sensor. A push rod is then screwed onto the end of the actuator so that the bearings could be pushed. The feeder base has a track to guide the bearing to its pickup location as it is pushed. The feeder tower was adhered to the base to store more bearings. Finally, a removeable alignment rod is inserted to ensure the bearings are fed correctly.

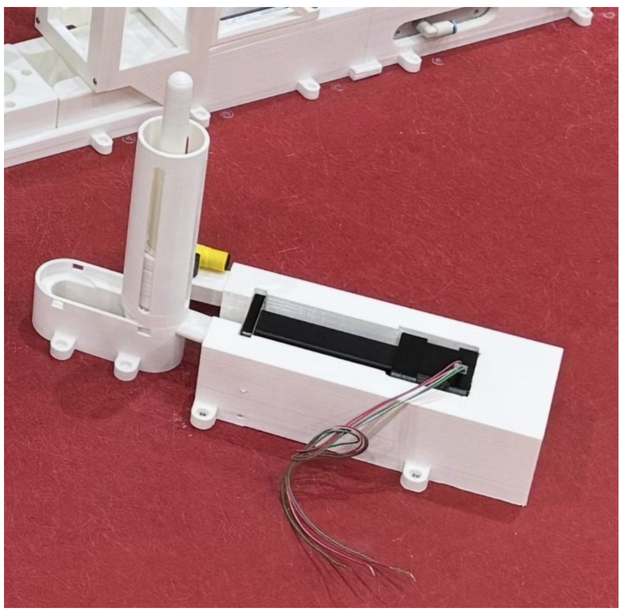

Fig #36

c. Shaft Final Assembly

The shaft assembly was also printed at 1819 Innovation Center out of PLA. The assembly consists of four parts. First is the shaft feeder. This piece is used to store parts and properly guide them to the pickup location. It is bolted to the table using M3 screws. This feeder has a bracket bolted to the side that holds a photoelectric sensor. A bracket for mounting the actuator is bolted to the back of the feeder. The actuator itself is bolted to the mounting bracket using an inner mounting flange. Finally, there is a push rod that is screwed onto the end of the actuator.

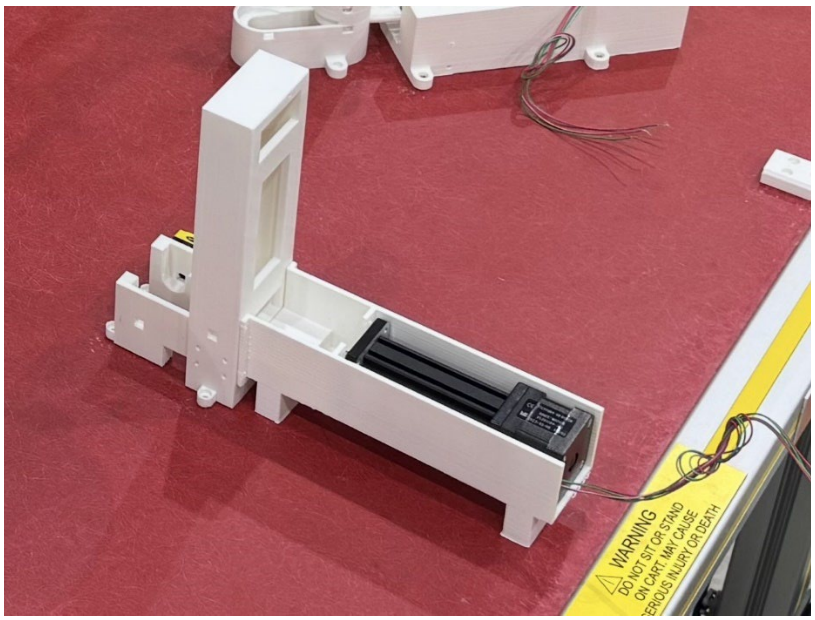

Fig #37

d. Cap Final Assembly

The cap assembly was fabricated at the 1819 Innovation Center along with the other 3 assemblies. This assembly consists of 3 parts. The first is the feeder itself, which stores and guides the caps to the pickup point. It is bolted to the table using M3 screws. The next piece is the cover shield. This piece slides onto the edge of the feeder and provides an easy way to get into the feeder for any maintenance issues. The last part of the assembly is the cap holder. The cap holder screws onto the linear actuator to properly seat the caps into place.

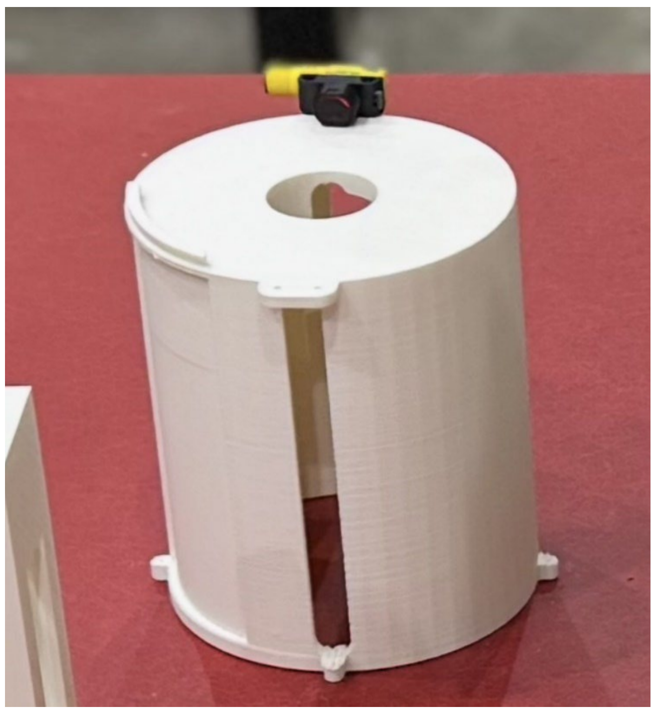

Fig #38

e. Final Assembly/Layout

The final layout consisted of 4 feeders plus a conveyor and an assembly station. A fiberglass plate is put on top of the cart table to avoid making any permanent changes to the robot cart. The plate was cut using a waterjet at the 1819 Innovation Center. Due to the materials nature, M3 inserts were pressed into the plate so that we can mount all the assemblies to the table. 2 mounting brackets were also used to locate the plate on the table for repeatability. The brackets slide into an aluminum tube on the cart and bolt onto the plate.

Fig #39

7. **Electrical Components**
    a. **Arduino Mega**

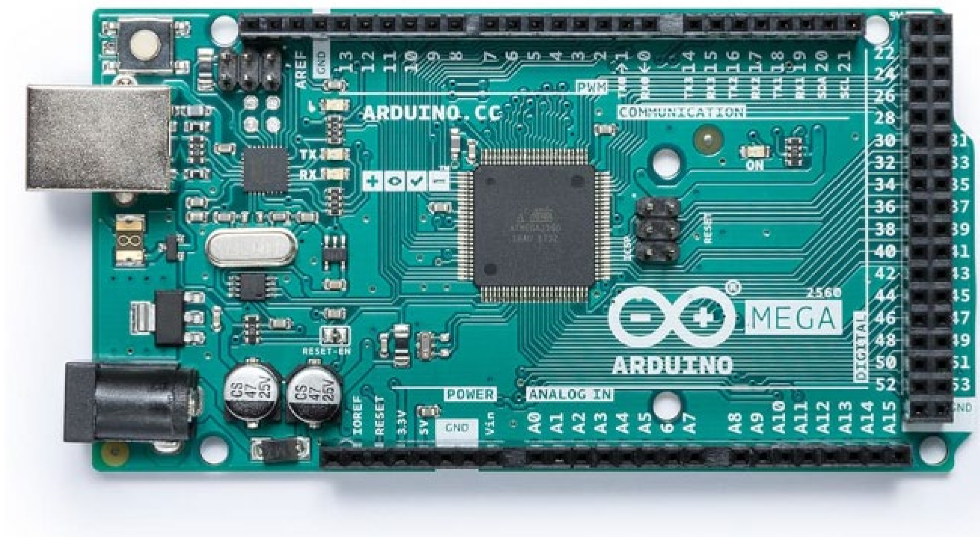

Fig #40

b. **NEMA 17 Linear Actuator**
    a. **Wiring Diagram**

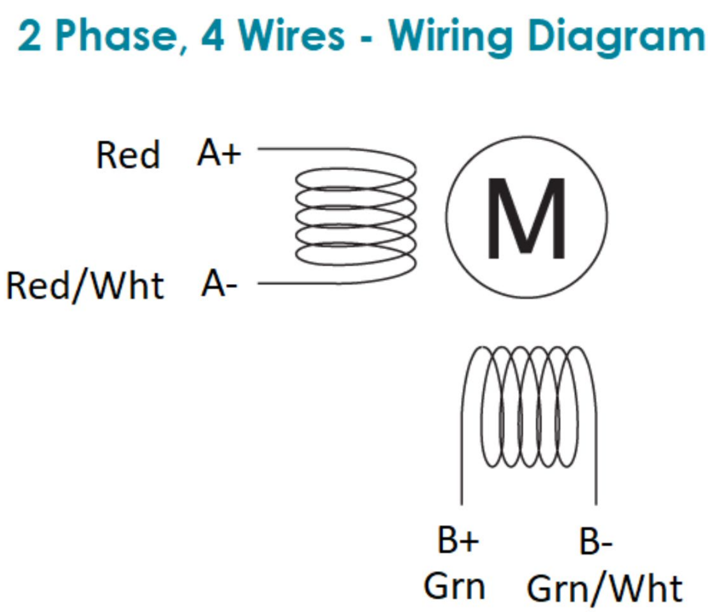

Fig #41

c. **TB6600 Stepper Motor Driver**

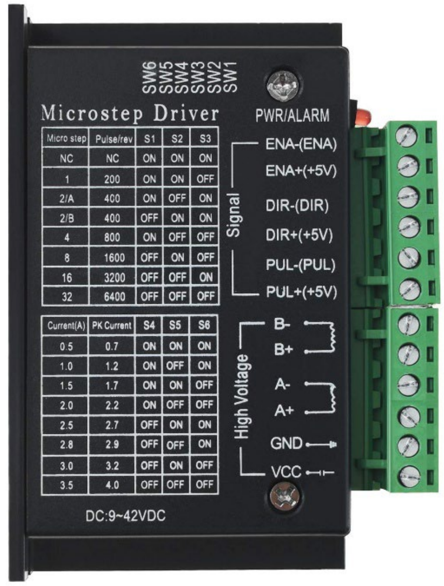

Fig #42

d. **Conveyor Belt**

a. **Wiring Diagram**

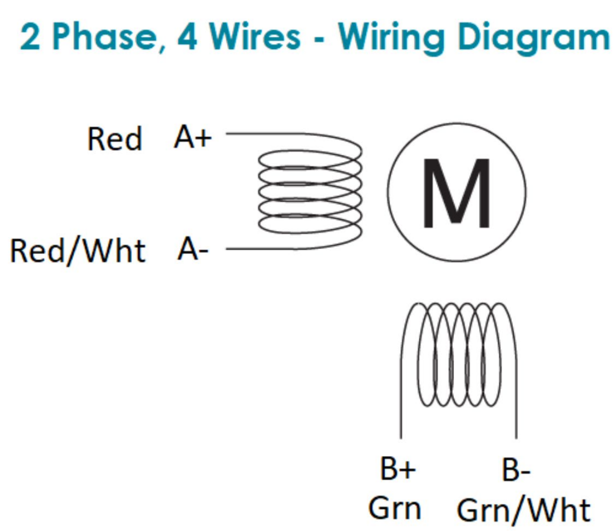

Fig #43

Fig #44

e. Overall Schematic

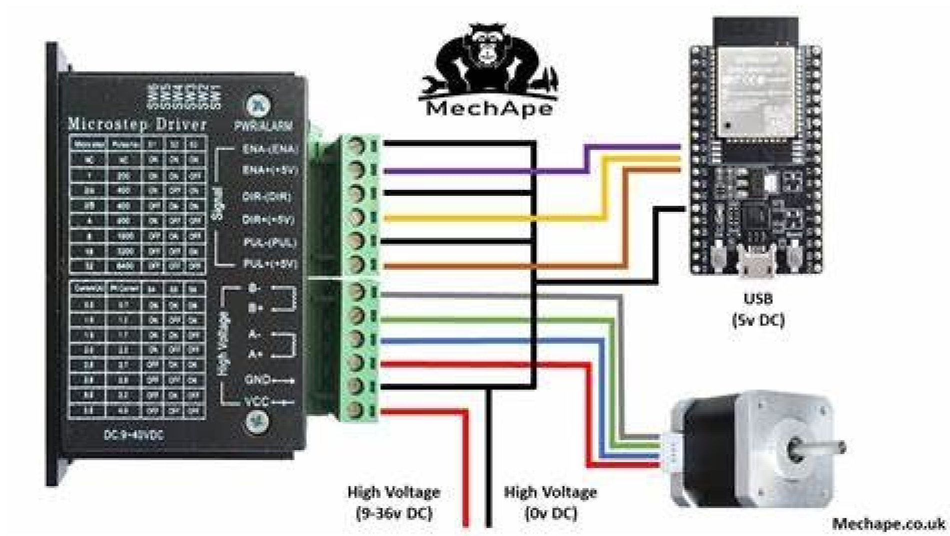

Fig #45

https://tse4.mm.bing.net/th/id/OIP.HAhfQRDw_ydXlerrATjauQHaEK?rs=1&pid=ImgDet

8. Testing

Cycle Time Test		
Project	Robot Automation Cell	
Units	Seconds	
Product	Bearing Assembly	
Station	Cycle Time	Mean
Base Feeder	50	-
Bearing Feeder	47	-
Shaft Feeder	72	-
Cap Feeder	40	-
Conveyor	3	-
Packaging	20	-
	232	38.66667
Total Cycle	3 minutes 52 seconds	

Fig #46

a. Roboguide

For testing, a combination of Roboguide software and robot programming was used. Roboguide is Fanuc's simulation software and was used to build out the major parts of the program. From there the program was taken to the robot and was touched up. This included updating positions, Adding the vision software programming, and adding anything we found while doing test runs. While testing, we recorded the cycle time for each sub-process. When comparing the initial Roboguide cycle time of 40 seconds to the final time of almost 4 minutes, it is clear that changes were made. A lot of this can be attributed to the programmed speeds. We did most of our testing on the robot at a lower speed than the simulation speed. This combined with all the additions/changes to the program are what attributed to this.

b. Programming

Utilizing our Arduino Mega we developed C++ code to control each of our actuators, controlled by push-button or sensor. Each actuator is assigned a specific button, for manual backup mode. When the button is pressed (active LOW), the corresponding actuator extends to a preset position and retracts back to its original position. This is used to simulate repeatable mechanical actions. One actuator moves stepwise across six distinct positions, incrementing its target with each button press. Once all positions are reached, it returns to its origin and resets for future cycles. The conveyor actuator is triggered by a sensor signal (also active LOW). Each time the sensor is tripped, the conveyor moves by a fixed distance. This movement is continuous and resets automatically, allowing it to respond repeatedly to part detection. Input buttons are configured using internal pull-up resistors to stabilize signals. Debounce delays and position checks are used to avoid unintended movement or false triggers. This setup provides reliable and modular control for multi-actuator automation tasks, suitable for integration into a larger robotic or manufacturing system.

c. Electrical

We spent a large majority of our time troubleshooting our electronics, because this was our first time doing something like this. We began by finding the wiring diagrams for the TB6600 Stepper Motor Drivers as well as our NEMA 17 Linear Actuators. Once everything was wired properly, we used a 24 Volt power source to supply our stepper motors. We then began wiring the stepper motors to the PWM and Digital ports on the Arduino Mega. The Arduino Mega was then powered by connecting to a laptop, which was also used for programming. Once everything was properly wired up and a full connection was established between the actuator, power supply, stepper motor, laptop, and Arduino testing could begin. We began by writing a basic program to turn on the linear actuator by using a simple button. Once we had figured one out, we began the wiring of the second with the same procedure, testing with programming to ensure it works and move to the next. By the end of our testing, we tied in 4 stepper motors to the power supply and Arduino with each having a separate ground, which allowed us to control all the actuators and the conveyor built by the push of a button!

9. Project Management

a. Colin:
   a. Gripper design and integration, cap feeder design, PLC/HMI Integration for sensors, actuators and conveyors, electrical wiring, and Arduino C++ programming

b. Owen:
   a. PLC/HMI Integration for sensors, actuators and conveyor, electrical wiring, and bearing feeder design

c. Markus:
   a. Vision system calibration & integration, Fanuc system programming, shaft feeder design

d. Ben:
   a. CAD Lead, finances & budgeting, layout design, & base feeder design

e. Project Budget Limit:

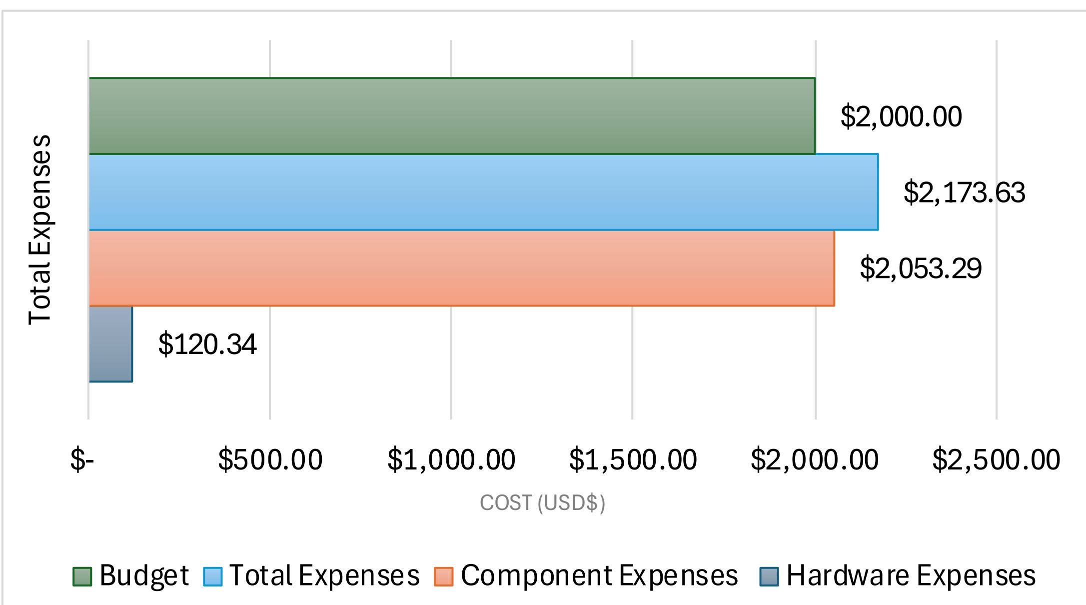

Figure #47

f. Key Milestones:

Fanuc Robot Cell Automation Gantt Chart 24/25	
Project Start Date:	8/26/2024
Group Members:	Owen Hatfield Colin Engel Ben Hermes Markus Flannery

Project Schedule

Class	Milestone Description	Assigned To	Progress	Due Date	September	October	November	December	January	February	March	April	May
Senior Design I	Background Research	Team	100%	9/15/2024									
	QFD	Team	100%	9/29/2024									
	Final Proposal	Team	100%	10/11/2024									
	Advisor Assigned	Team	100%	10/8/2024									
Senior Design II	Calculations	Team	100%	11/10/2024									
	Final Design	Team	100%	12/1/2024									
	Drawings Ready	Team	100%	12/8/2024									
	Senior Design 2 Report	Team	100%	12/6/2024									
	Senior Design 2 Presentation	Team	100%	12/7/2024									
	Parts List	Team	100%	12/8/2024									
	Bill of Materials	Team	100%	12/9/2024									
Senior Design III	Fabrication Start	Team	0%	1/8/2025									
	Fabrication Finish	Team	0%	3/3/2025									
	Testing Start	Team	0%	3/6/2025									
	Testing Finish	Team	0%	3/18/2025									
	Tech Expo	Team	0%	4/16/2025									
	Final Presentation	Team	0%	4/25/2025									

Figure #48 Gantt Chart

10. Future Work

While the current robotic assembly cell achieved its educational and functional objectives, several areas for improvement have been identified to further align the system with industry standards. Future iterations of the feeders—including the base, shaft, cap, and bearing units—should utilize industrial-grade materials and CNC-machined components rather than PLA 3D prints. Transitioning to precision-machined parts would significantly improve dimensional accuracy, durability, and overall system reliability, addressing the tolerance variations observed during testing. Additionally, the project validated the effectiveness of pneumatic actuation for part movement tasks. Pneumatics offer rapid cycle speeds, simple control logic, lower upfront costs, and high reliability in repetitive applications, making them a preferred choice in industrial feeder and assembly systems over electric actuators. In production environments, pneumatic systems excel for high-speed, low-complexity motions where durability and ease of maintenance are critical. Other improvements should include the development of a protective housing unit for the PLC and HMI systems to ensure equipment safety and to meet industrial electrical enclosure standards. Lastly, the integration of a dedicated packaging station, used by the collaborative robot, would expand the cell's functionality by allowing for completed assemblies to be sorted and prepared for shipment, closely simulating a full manufacturing workflow.

11. Conclusion

The Fanuc Robot Cell Automation project successfully addressed the initial problem statement by creating a fully functional, hands-on robotics cell for the University of Cincinnati's new Robotics and Automation Laboratory. Through the design and fabrication of a centralized assembly system with multiple custom feeders, integrated pneumatics, conveyor, and sensors, the project enabled students to gain direct exposure to real-world automation and robotic assembly practices. Fabrication was completed using PLA 3D printing at the 1819 Innovation Hub, along with outsourcing hardware, allowing for rapid prototyping and assembly testing. Pneumatic tubing and piston, electric actuators, and mounted sensors were incorporated to ensure efficient part movement and detection, seamlessly interfacing with the PLC and HMI systems. Although minor challenges related to material tolerances and print quality were encountered, the project achieved its primary goals of enhancing student engagement, improving technical competency, and bridging the gap between classroom learning and industry practices. Future iterations may incorporate industrial-grade materials and CNC-machined components to further improve durability and precision.

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