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STUDENT INTERNSHIP TECHNICAL REPORT

Automation of the Receipt Inspection of Criticality Control Overpacks (CCO)

DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

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EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Development Initiative, an innovative program developed by the U.S. Department of Energy's Office of Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the spring of 2022, a DOE Fellow intern, Philip Moore, spent 16 weeks doing a spring internship at Savannah River National Lab under the supervision and guidance of Corey Hopper. The intern's project was initiated on January 24, 2022, and continued through April 2, 2022, with the objective of contributing to a robotic system for automation of CCO inspection.

Savannah River National Laboratory (SRNL) has been developing an automated method for processing the receipt of CCOs. The goal is to reallocate as many full-time employees as possible to tasks that require more manpower. Proof of this technology could later lead to applications that could help reduce dose in the workforce.

At the beginning of the internship, the robotic arm was the focus of the team. Tasks covered over the course of the internship include a new CCC bolt alignment tool, a lid ring restrictor, a new holder for the CCC lid, and a bracket for a new laser scanner. While not all these projects were completed by the end of the internship, they were at least brought to the point of having a functioning design ready to be manufactured.

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1. INTRODUCTION

Nuclear waste bound for the Waste Isolation Pilot Plant (WIPP) is transported in a criticality control overpack (CCO). This packaging comprises a 55 gallon drum, two plywood dunnages, and a criticality control container (CCC) (Figure 1). These packages are purchased by WIPP and shipped to nuclear sites as needed. When they arrive at a nuclear site, these packages must be inspected for damage or imperfections. Currently this process is done by hand. This can be problematic as the CCC, which must be removed for the inspection, weighs over 100lbs.

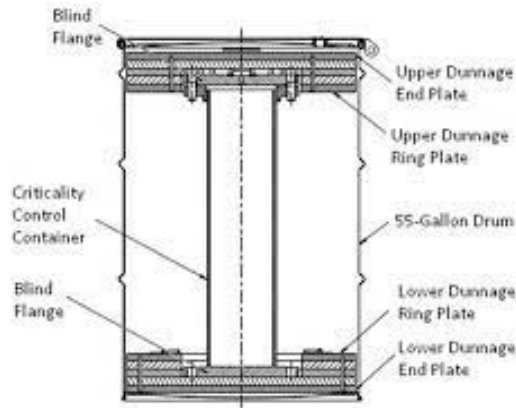


Figure 1. CCO diagram [1].

The DOE is determined to make the safe disposal of waste more efficient as well as remove repetitive tasks that could lead to chronic injuries in DOE workers and contractors. The solution to these issues is automation. The CCO inspection is a good opportunity to develop a technology to handle CCOs. In the immediate future, successful deployment of this technology would allow the reallocation of 6 full time employees per year. In the long term, this could be used as a proof of concept to allow a similar system to pack and unpack radioactive material from CCOs. This could help workers avoid 340 REM over the course of 30 years [2].

The proposed solution is to utilize a singular robotic arm alongside two Autonomous Guided Vehicles (AGVs) to handle the receipt and inspection of CCOs at Savannah River Site (SRS). The AGVs were supplied by a company called Amerden but were not the primary focus of the internship as the only one completed was awaiting repairs from the vendor. The robotic arm was from a company called Fanuc [2]. The state of the systems that support the Fanuc robot were much more advanced. The layout of the inspection robot at the beginning of the internship can be seen below (Figures 2 and 3).

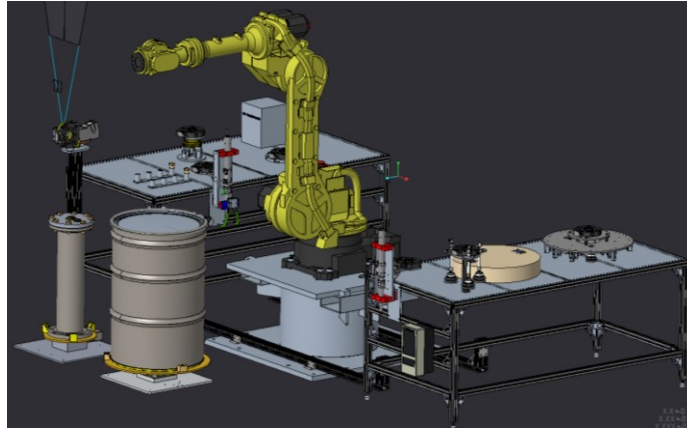


Figure 2. Fanuc robot at beginning of internship.

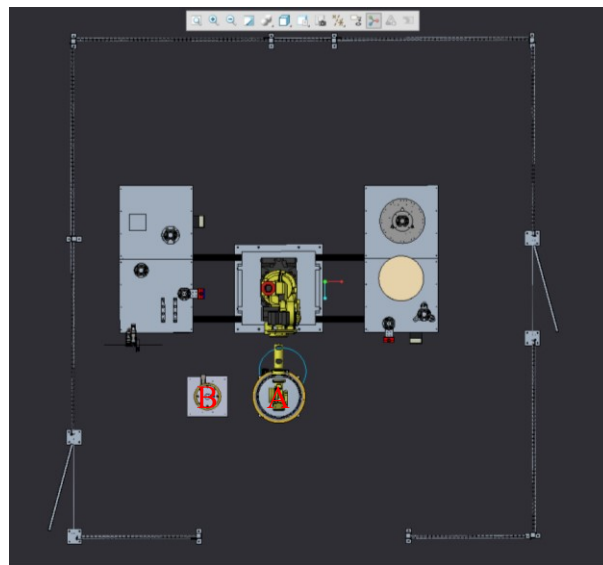


Figure 3. Fanuc robot layout at beginning of internship.

The AGVs handle the receipt of the CCO pallets. They unload a singular CCO and place it on a turntable (Figure 3: A). After the lid and top dunnage are removed, the CCC is placed on a secondary turntable (Figure 3: B). The two containers are graded on a number of pass/fail criteria. If a package fails any of these criteria it is rejected and sent back to the WIPP.

At the time that the internship began the robot could complete every motion involved in the inspection but was not actually checking the criteria. This is because it was still suffering from a few repeatability issues. Repeatability was the focus of the work done over the course of the internship.

The research conducted was to complete a variety of tasks that could not take the primary focus of the team. These included a tool to align the CCC Lid, a weight to place on the CCO drum lid, a new lid rest for the CCC lid, and a bracket to mount a laser scanner. Each of these was conceptualized, designed, and prototyped in an iterative process.

During the inspection of the CCC unit, the CCC lid is removed, examined, and replaced. When the CCC lid is being replaced by the gripper tool, it can become misaligned. If not addressed, this can lead to cross threading in the bolts used to seal the lid. A tool was to be created that the robot was used to realign the bolt holes.

[illegible]

Figure 4. Drawing of initial bolt alignment tool design.

3



Figure 5. 3D printed bolt hole alignment tool with steel pintle.



Figure 6. 3D printed bolt hole alignment tool in CCC.

Therefore, a new design (Figure 7) was devised that would use 4 bolt holes, an outer ring to register with the CCC lid and a pintle located at the center of the tool.

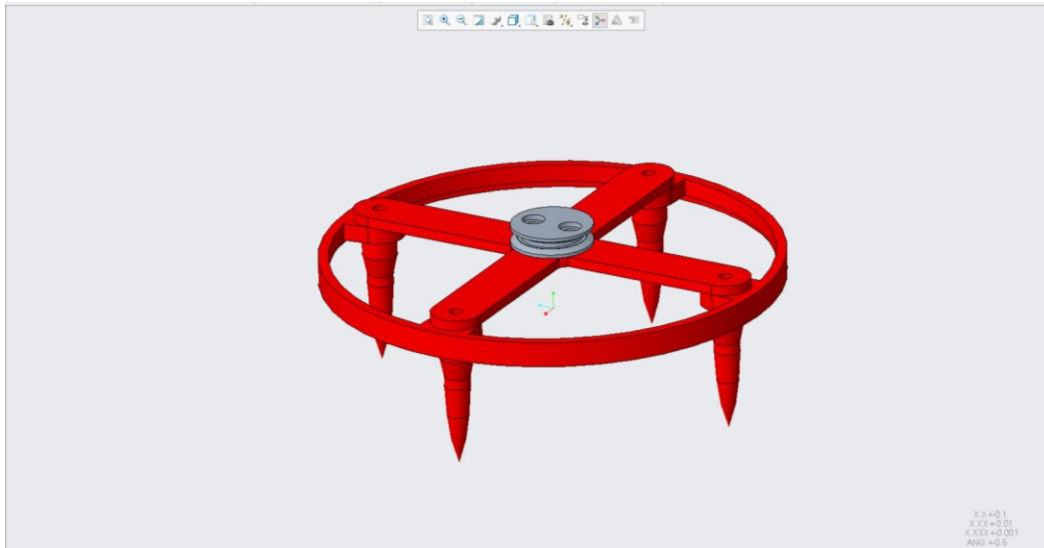


Figure 7. Redesigned CCC bolt hole alignment tool.

The additional ring of registration was removed in the final design (Figure 8), as it was found to be redundant.

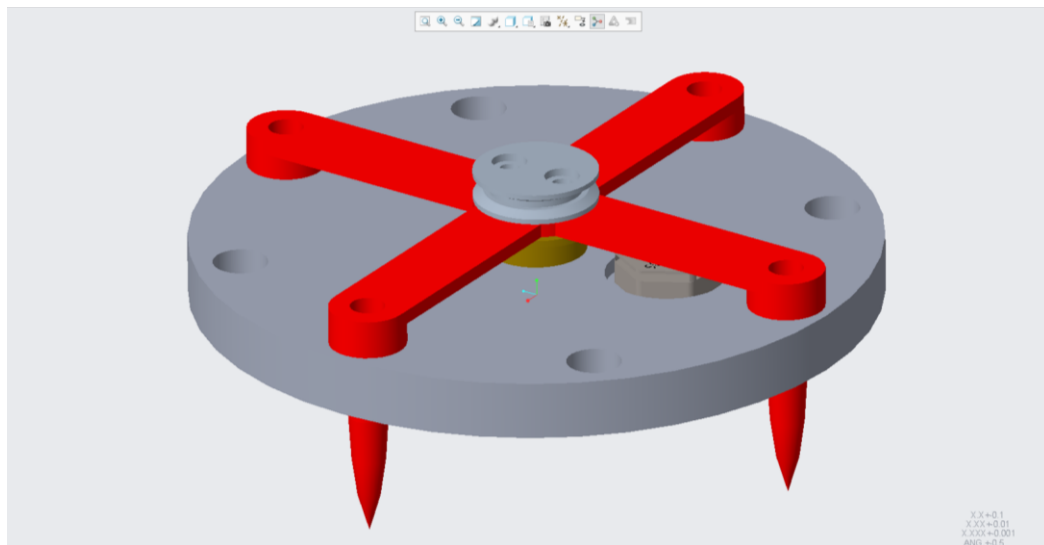


Figure 8. Final bolt hole alignment tool design.

CCO LID RING RESTRICTOR

The vendor that supplies the CCOs was in communication with SRNL and making adjustments to the CCO design. There is a gasket located between the lid and the lip of the drum. The vendor decided to replace the flat gasket with a more effective round gasket. However, the round gasket made it so that the lid could not be closed by the arm. The vendor therefore agreed that the gasket was to be shipped with the CCO but separately, to be installed after the inspection. However, the lack of a gasket removed much of the friction between the lip of the drum, the lid, and the lid ring. Without this friction, the lid ring would often rotate while the nut runner was removing the lid ring bolt. A weight could be placed on the lid ring to prevent this from happening. To aid testing, a mockup was made of aluminum extrusions (Figure 9).

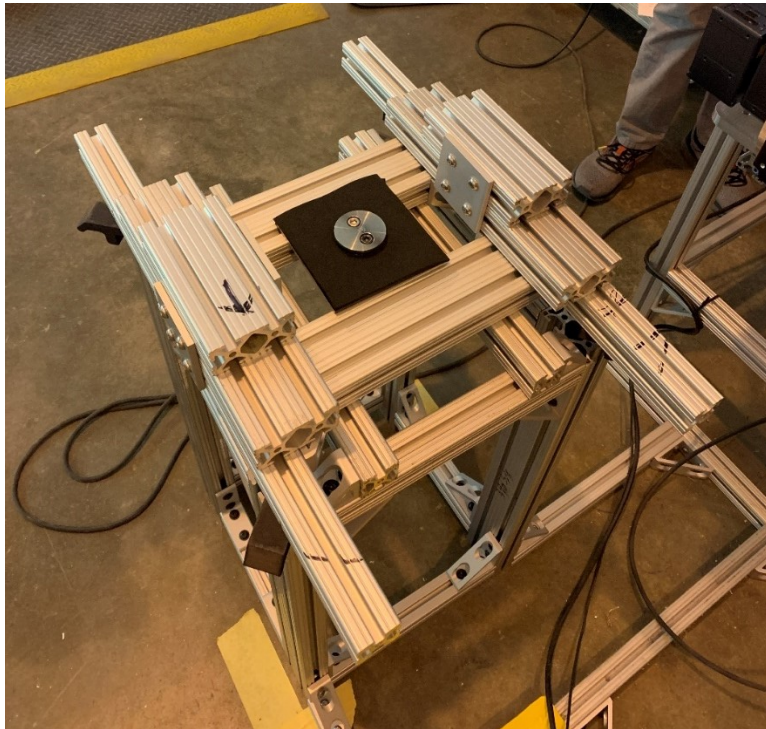


Figure 9. Aluminum extrusion lid ring restrictor.

The mockup was adjusted until it fit the lid ring tightly. The mockup weighed approximately 20lbs and functioned as intended. A stand was also constructed of aluminum extrusions and mounted to the frame of the robot (Figure 10) so that the robot could place and retrieve this new tool.

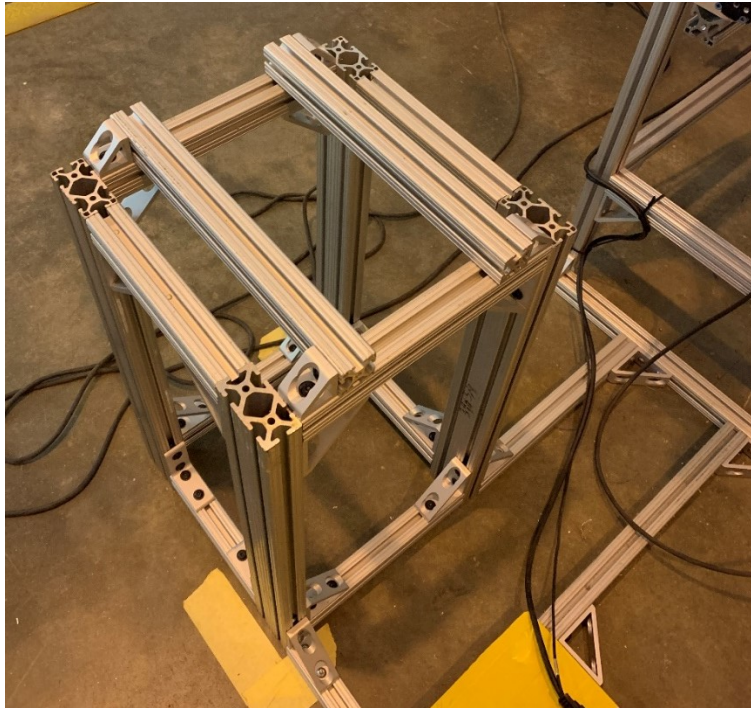


Figure 10. Aluminum extrusion lid ring restrictor stand.

A final design was made with a 30lb body made from 3/8" stainless steel (Figure 11) using the measurements taken from the mockup. This design has slots for adjustable feet and holes to mount weights in case it becomes necessary during testing.

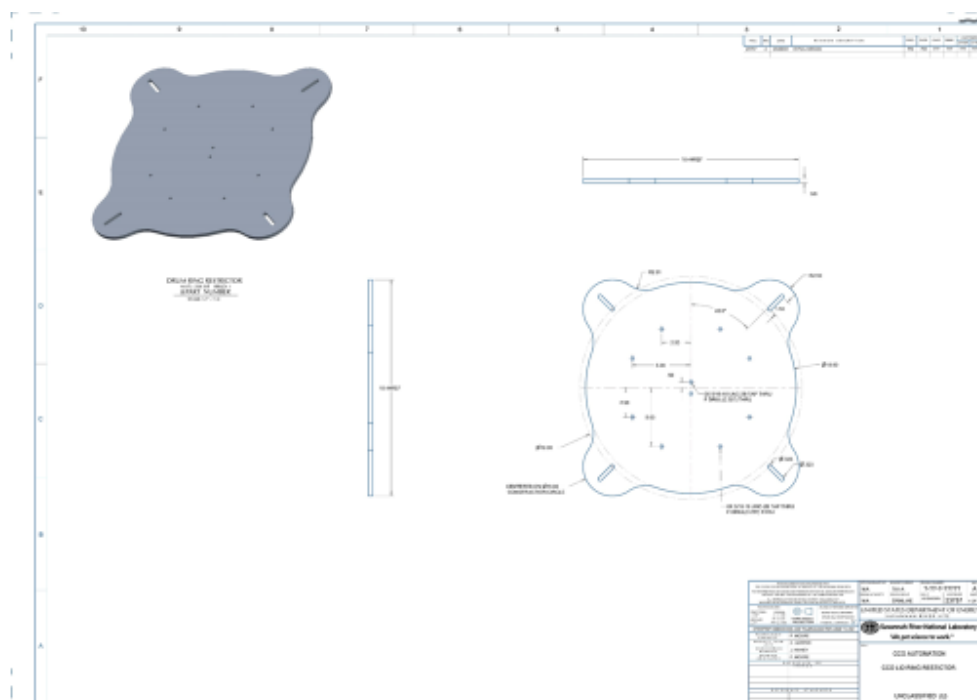


Figure 11. Drawing of final lid ring restrictor body.

A pintle is located in the center of the assembly. The feet that restrict the CCO lid ring are mounted using custom washers (Figure 12).

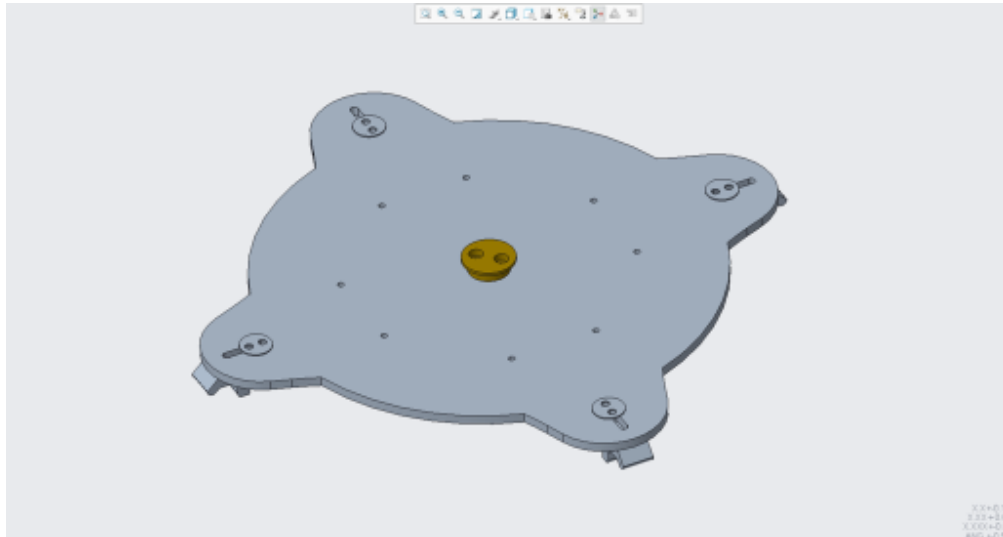


Figure 12. Final lid ring restrictor assembly.

This design could not be manufactured by the end of the internship but was completed and submitted for manufacturing.

CCC LID HOLDER

The starting design for the CCC lid holder was a 3d printed cylinder for the lid to rest on (Figure 13). Due to its size and lack of registration it is not the most secure place to store the lid (Figure 14).

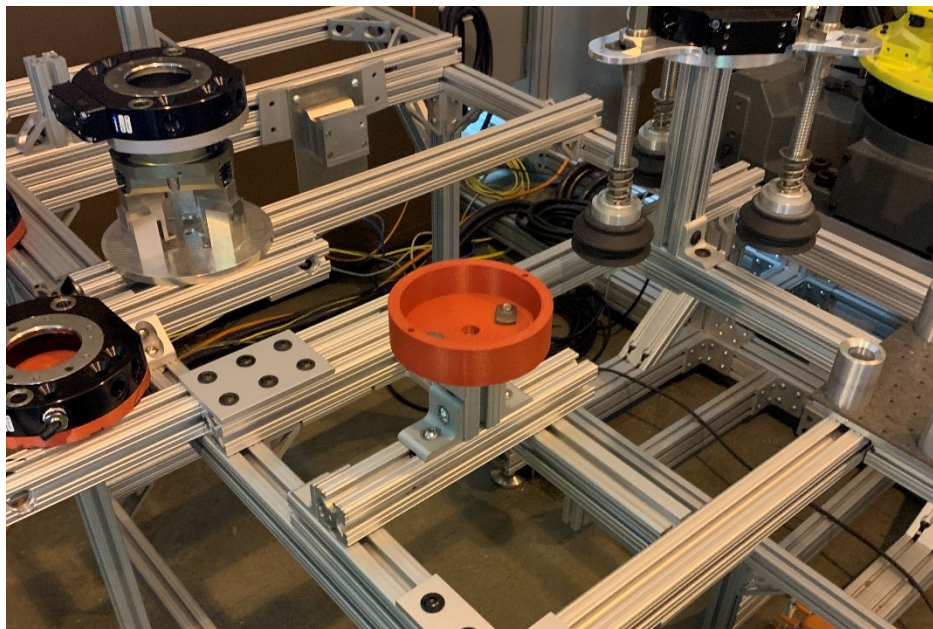


Figure 13. Original CCC lid holder.

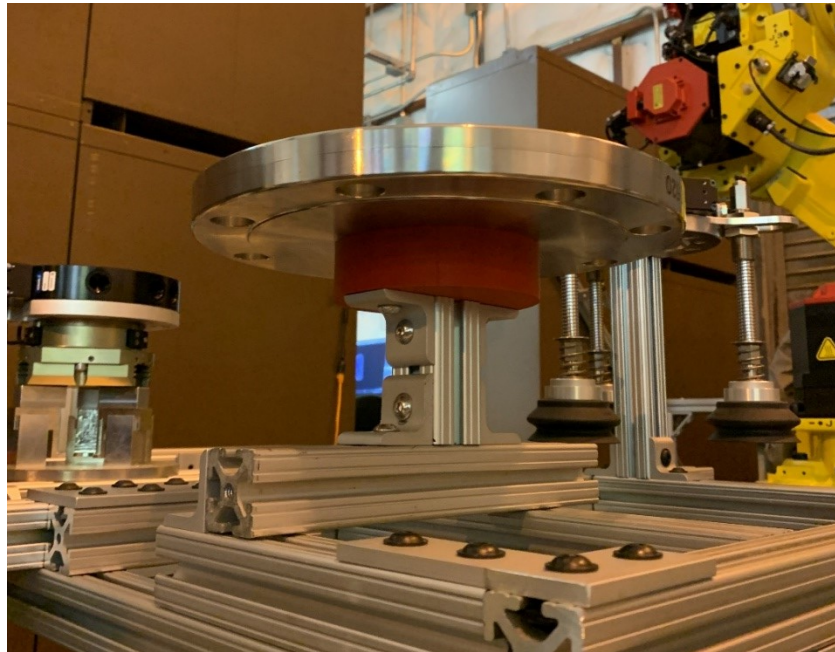


Figure 14. CCC lid resting on the original CCC lid holder.

A more permanent stand was needed to ensure repeatability. This design uses a series of lead-ins to ensure the CCC lid is always returned to its center (Figure 15). It also has a hole to allow the robot's vision to identify its center more easily. Like the previous version, it mounts to the aluminum extrusion frame with two T-nuts.

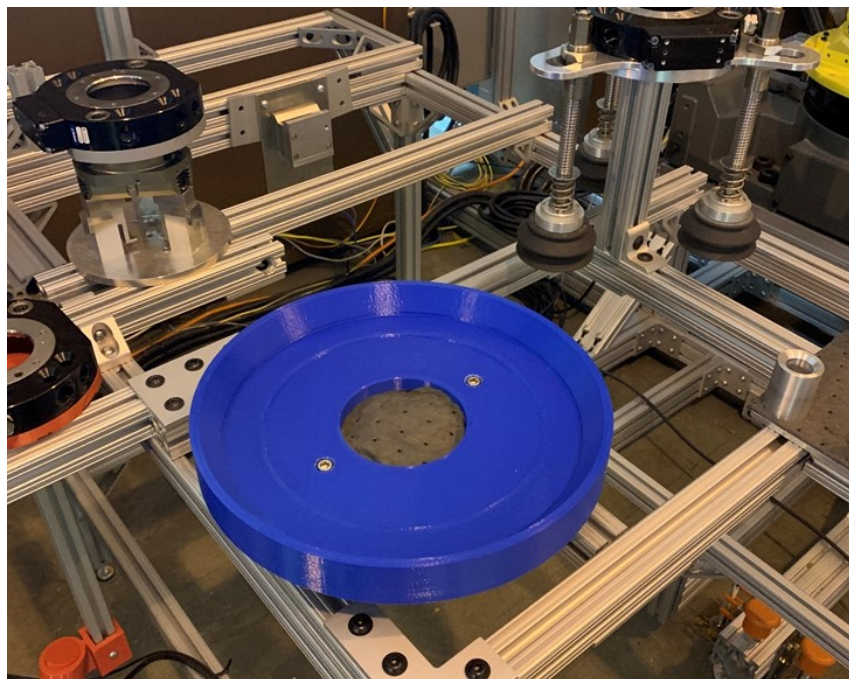


Figure 15. Redesigned CCC lid holder.

This redesign makes it impossible for the CCC lid to fall and ensures that it is always placed precisely in the same location.

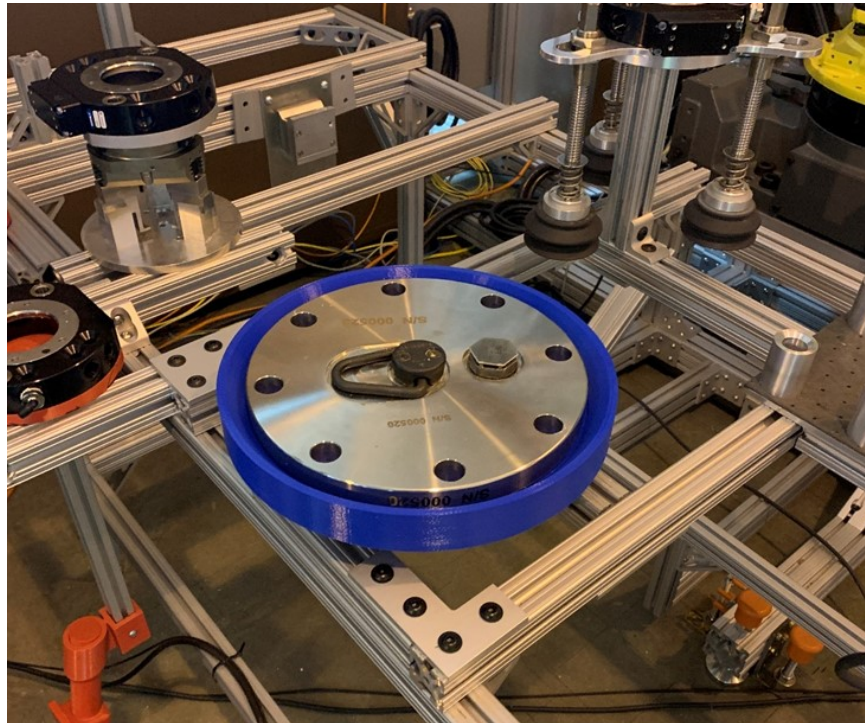


Figure 16. CCC lid resting in the redesigned CCC lid rest.

Q5X BANNER LASER SCANNER BRACKET

The addition of a Q5X Banner Laser Scanner (Figure 17) to the robot would allow detection of abnormalities such as whether a tool was dropped. It would allow the robot to stop if such an error occurred. A bracket was needed to mount it to the wrist of the robot.

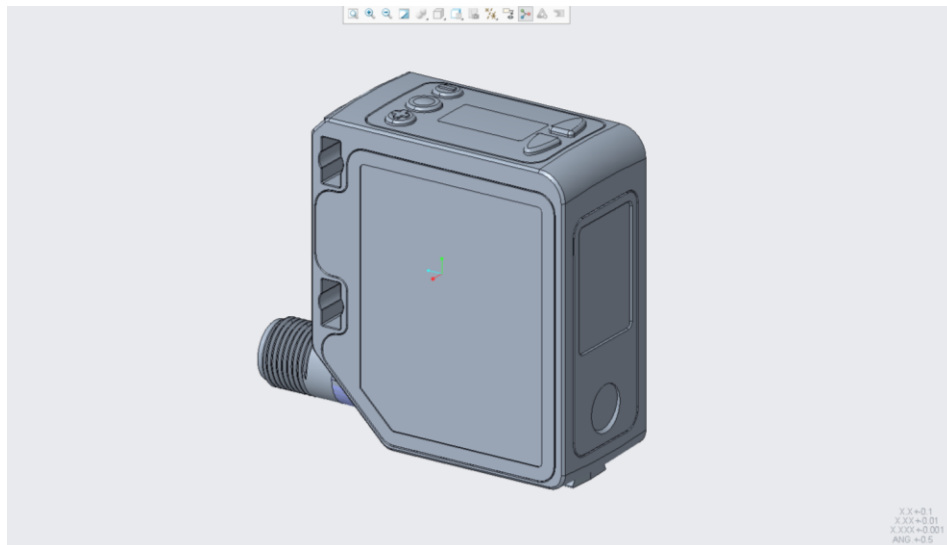


Figure 17. Q5X Banner Laser Scanner

The scanner had a number of possible mounting points. The bracket designed makes use of the two slots at the back of the scanner. A custom nut is placed in each of the slots so that a screw can be used to mount it. The bracket has two mounting points to connect it to the frame (Figure 18: 1), a single hole for the scanner to pivot about (Figure 18: 2) and a slot to adjust the angle of the scanner (Figure 18: 3).

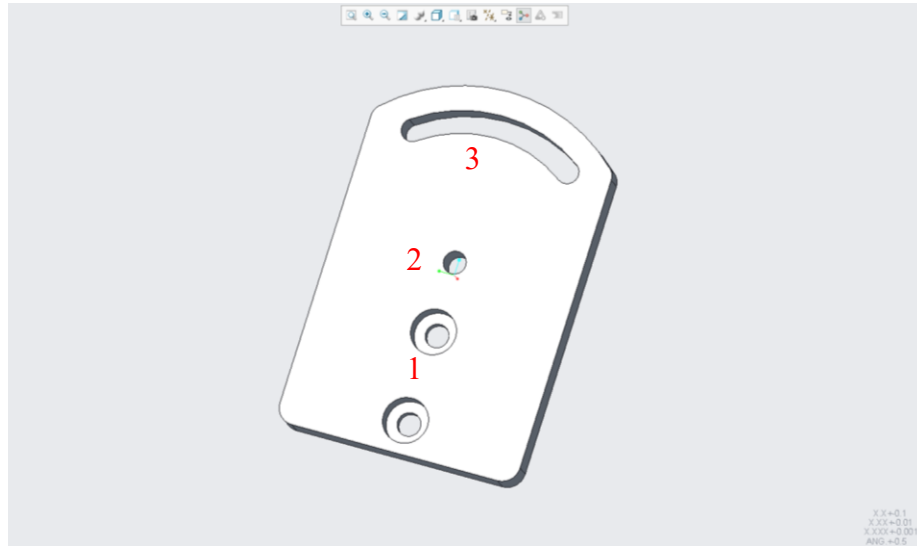


Figure 18. Banner scanner bracket mounting points (1), pivot (2), and slot (3).

The mount for the bracket works by sealing around the vision system bracket with 6 M4 screws and securing with 2 M6 screws (Figure 19).

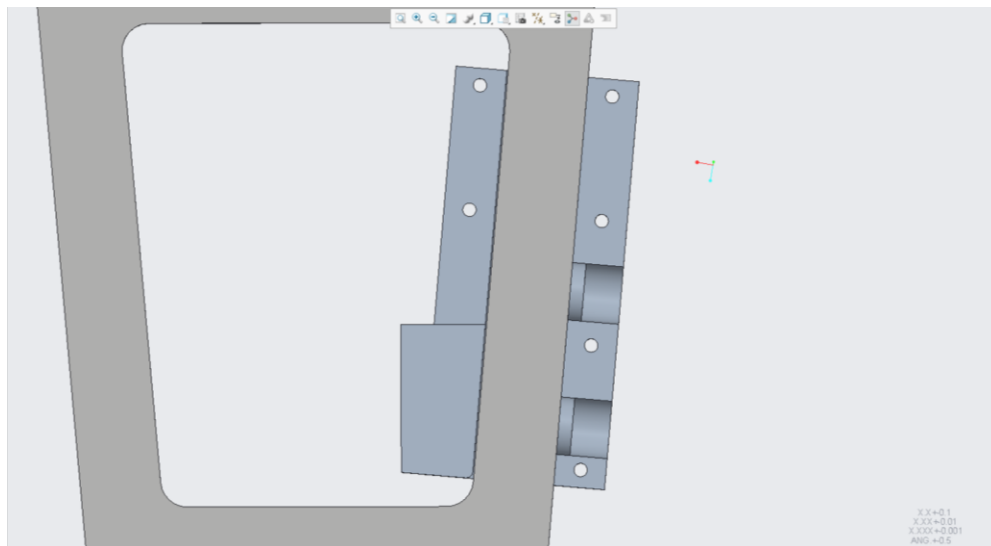


Figure 19. Bracket mount bottom on the vision system bracket.

The mount also serves as a bracket for an LED bar to improve visibility for the vision system (Figure 20). The mount for the LED bar was made to be strong but lightweight.

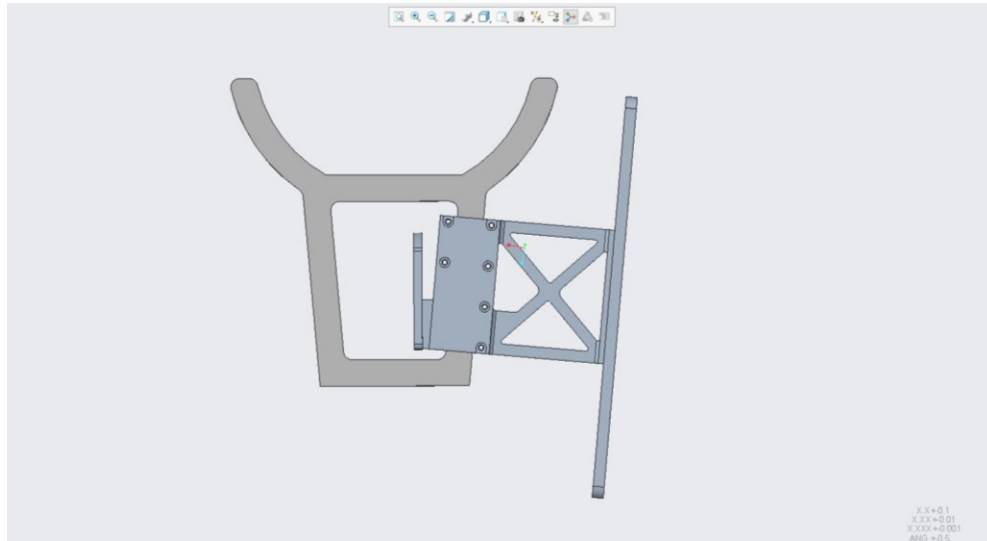


Figure 20. Complete final design of the Q5X bracket.

This prototype was 3D printed and mounted to the robot for testing (Figure 21).



Figure 21. 3D printed Q5X bracket.

While the bracket was test for fit on the robot, it was not fully tested due to it not being wired or programmed.

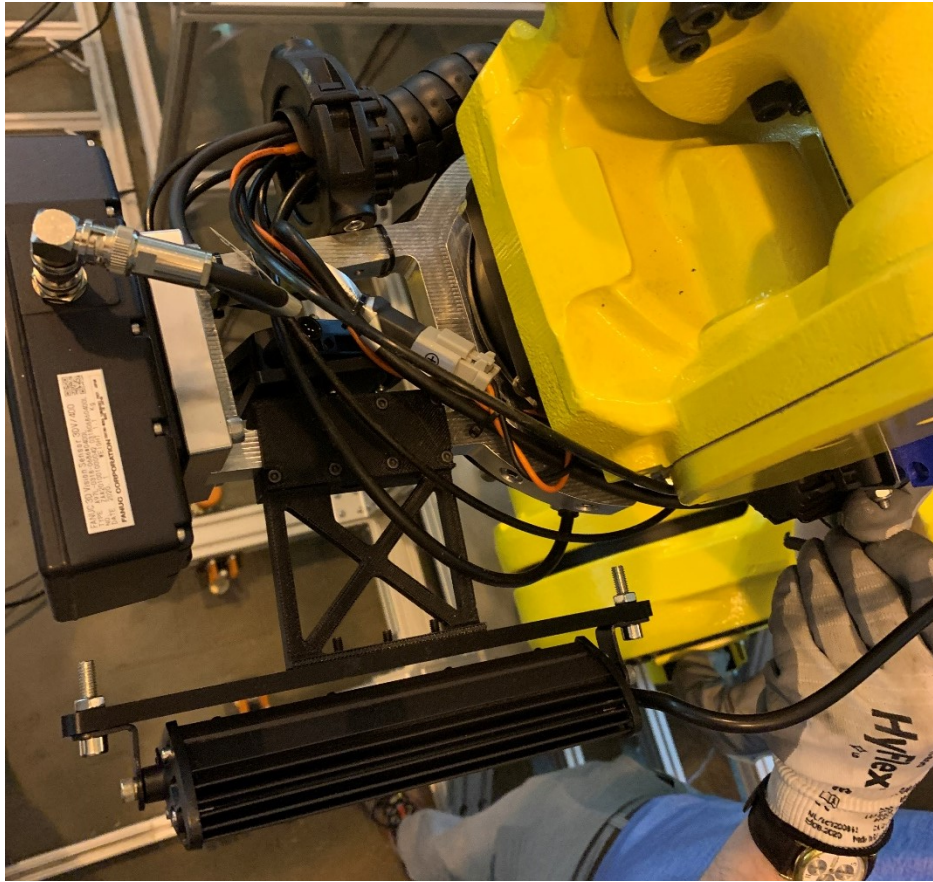


Figure 22. Q5X bracket with an LED bar mounted on the wrist of the robot.

3. RESULTS AND ANALYSIS

At the time of this report, only two of the items developed of the course of the internship were implemented. A 3D printed version of the CCC lid holder replaced the previous, more precarious lid holder. Due to necessity, the prototype lid ring restrictor made of aluminum extrusions was implemented. A drawing of the final design was made, but it was not able to be machined before the end of the internship but was otherwise ready for testing.

The final design CCC bolt hole alignment tool could not be 3D printed or programmed before the end of the internship. The Banner laser bracket was completely made and assembled but needed to be implemented into the robot's code. The Robot at the end of the internship can be seen bellow (Figure 23).



Figure 23. Final layout of the Fanuc robot.

4. CONCLUSION

Although not every project came to fruition, each at least had a design ready to be printed and tested. In the future, the CCC bolt alignment tool must be printed and tested. Once that is happened an alignment subroutine must be added to the robot's program. The final design for the CCO lid ring restrictor must be machined and the code adjusted to accommodate it. Finally, the BQ5X Banner laser scanner must be implemented into the robot's code so it can interpret the data. Future projects for the inspection robot include designing a Tamper-Indicating Device (TID) instillation process and programming the arm to collaborate with the two AGVs that will move the CCOs and CCO pallets.

5. REFERENCES

- [1] SCAGLIONE J.M. OVERVIEW OF DILUTE AND DISPOSE WASTE FORM CRITICALITY ANALYSIS FOR DISPOSAL AT THE WASTE ISOLATION PILOT PLANT. 17 April, 2019.
- [2] KOENIG, RICHARD E. K-AREA SIX-YEAR AUTOMATION IMPLEMENTATION PLAN. United States: N. p., 2021. Web.

APPENDIX
