Design Project 2 – Get a Grip

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial 10

Team Fri-06

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Submitted: December 6, 2023

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Executive Summary

The motivation of the project is to have the team design a secure system for the transfer of surgical instruments to an autoclave for sterilization. The project gives the students an opportunity to 3D print objects and hands-on programing. The main idea of the project is to develop a computer program that controls a robotic arm (Q-Arm), enabling it to pick up and move the 3D printed container to the autoclave while securely holding a surgical tool inside. The project was mainly focused on four main tasks for the teams (modelling and computing), which were to secure a transfer method that is safe to pick up and move a container to the autoclave, design a container that securely holds a surgical tool which could firmly hold a surgical tool to be picked up by the Q-Arm and ensuring that the tool stays in place during the transfer, design a computer program that controls the Q-Arm for the pick-up, drop-off, and rotation functions, and finally, demonstrating functionality and correctness of the design which was demonstrated during the Q-Arm challenge. In conclusion, the project gave both teams the opportunity to get hands-on experience with advanced technology, letting them apply what they have learned to solve a real-world problem. In the end, the project was a success, showcasing the skills and knowledge gained throughout the project.

Summary of Design Objectives

The goal of the project was to create a combined program and container design that would be able to pick up and move a specified tool into an autoclave to be cleaned while fulfilling various objectives and constraints. These objectives included efficiently picking up and moving the designed container, securing the tool inside designed container during movement, accurately placing that container in the corresponding autoclave, and being able to repeat this task indefinitely. Some constraints were placed onto the design by these objectives and the limitations of the system a part of it. These constraints included limitations placed on the size of the container to ensure it fits in the autoclave, limitations on the orientation of the sterilization container to ensure it can be placed in the autoclave, limitations on the weight to be less than or equal to 350g, and limitations placed by the 3D printer requiring that features of the container must be greater than 2mm in size. The goal of the project is achieved through the functions of the system, which are to move around freely, strongly grip containers and lift them from the group, release grip of container putting it down at the desire location, and to open autoclave drawers.

Background and Research Summary

Autoclaves are heated containers used to sterilize objects through high temperatures, killing any bacteria, and then later with steam to cleanse the object and cool it down, with the waste being collected at the bottom of the autoclave [1]. Containers are commonly used to secure objects during sterilization, commonly with perforations at the top and bottom to allow for the flow of steam and the disposal of waste out of the base. These containers must withstand temperatures in excess of 405.15 kelvin for extended periods of time, usually 30 minutes for healthcare supplies [2] .It is important for this container to minimise contact with the tool in order to reduce the chance of contamination between the container and tool. It is important to note that most. The apparatus being used to transport the sterilization container is a mechanical arm consisting of a pivot, 4 joints, and at the end a retractable claw [3]. The tool that is being transported in this project is a retractor. The program is to control the movement of the arm is known as Q-arm and uses python to receive commands. The design of the container itself was created using Autodesk inventor, and would be constructed with a plastic 3D printer able to print to accuracy within 2mm [3].

Figure 1: Orthogonal View of Retractable Claw

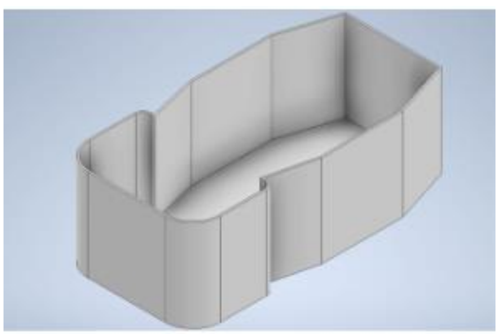


Figure 2: Orthogonal view of dimensions in which the container had to fit

Description of Proposed Solution

The Proposed container used to store the specified tool takes the appearance of a rectangular box with a bulge protruding from either side of the container. The general shape of the container is designed to follow the profile of the tool being stored to minimise cost. A sliding lid apparatus is located at the top of the container in order to contain the tool during transportation, while still allowing the lid to be secured at high angles that would otherwise cause it to fall off. Both the lid and the base of the container are filled with perforations in order to facilitate air circulation. At the bottom of the container, a series of bevels are included at the base of the container, which separates the tool from the bottom of the container. Corners are rounded both on the inside and outside of the box and lid in order to minimize the buildup of condensation and contaminants in the corners of the container.

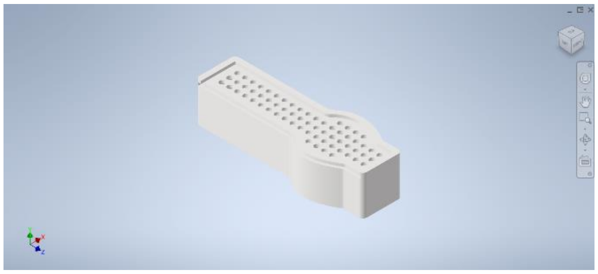


Figure 3: Orthogonal view of combined container and lid

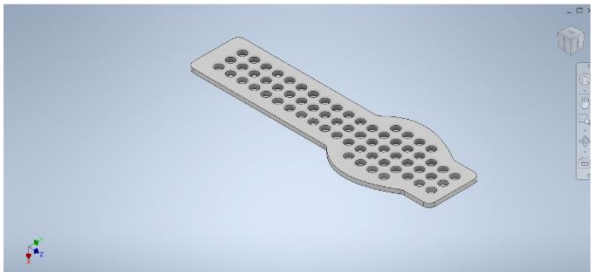


Figure 4: Orthogonal view of container lid

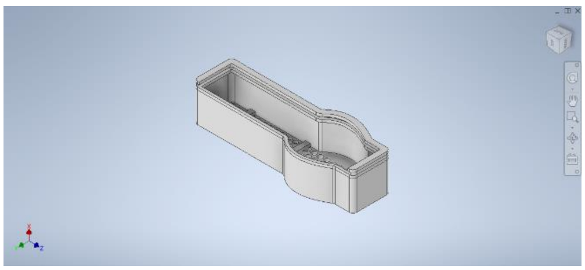


Figure 5: Orthogonal view of container base

A computer program, which is comprised of five different user-defined functions, was created to control a robotic arm that transfers the container created by the modelling sub-team into its corresponding autoclave using left and right potentiometers. The first function is the pick-up function which moves the robotic arm to the coordinates of the container's location and closes its gripper around the container. The second function is the return home function which moves the robotic arm to the coordinates of its starting position. The third function is the rotate function which takes the change in values of the right potentiometer, multiplies the change by 350 degrees and uses the resulting product to rotate the base of the arm. A constant of 350 degrees is used since the base's range of motion is limited to +/- 175 degrees. The fourth function is the drop off function which activates all the autoclaves, checks which colour autoclave the arm is nearby, moves the arm to the coordinates of either the top or bottom of the autoclave depending on the value of the left potentiometer (between 0.5 and 1 for the top; 1 for the bottom), opens the bottom drawer if the arm is at the bottom, opens the arm's gripper, closes the bottom drawer if the arm is at the bottom and deactivates the autoclaves. The final function is the main function which uses the previously mentioned functions to complete a cycle of picking up a container, returning home, rotating, dropping off the container and returning home again. Additionally, the main function spawns a list of containers in a random order and repeats the container transfer cycle until all containers have been transferred.

Strengths and Limitations of Design

After multiple thorough revisions and modifications to the program code, the finalized program is one that satisfies the desired function of the Q-Arm; to transport containers into the autoclaves for sterilization. A strength of the program is that there are set coordinates within the code for the home location, container spawning locations, and locations of all the autoclaves, this is a strength because it makes the program very user friendly as it is easy to use as long as the user understands the set thresholds for the arm to properly adjust and move the arm for transporting the containers, as the program will automatically check if the arm is close enough to the container to drop off in addition to automatically picking up the container as it spawns. Another strength of the program design is that it accounts for if the arm is about to collide with the autoclave and automatically moves the arm such that no collision happens. With the strengths of the program design there also comes limitations, areas that could have been further improved on. The coordinates of all the autoclaves being stored in the program is a strength but at the same time a limitation due to the fact if the colour of the autoclaves or the location of the autoclaves were to change, the program would have to be modified for the arm to drop the containers off at the proper locations. Another limitation with the program design is the fact that the user must manually move both the potentiometers to 100 to spawn another container, this could have been improved on by making the program automatically spawn in the next container as in the real world, having the user manually spawn in containers could reduce the efficiency of the overall system.

The design of the proposed container has many strengths. The specific shape of the container allows it to securely contain the tool with as little resources as possible by conforming to the shape of the tool. The perforations at the top and bottom of the container allows for the flow of steam into the container and waste out of the bottom of the container, while still keeping the tool inside secure. The small pedestals mounted along the bottom helps minimize contact between the tool and container, reducing contamination. Rounded edges help prevent the buildup of steam and contaminants in corners. Finally, the tight sliding lid design ensures that even at extreme angles, the lid and by extension the tool inside the container is secure. That said, there are multiple areas in which the proposed container could be improved going forward. Most notably, the fit between the lip surrounding the top of the container and the lid was too tight, and due to small printing inaccuracies didn't initially fit. Additionally, Airflow could be improved further by removing the base of the container, as the 3 pedestals are enough to prevent the tool from falling through the container.

Summary of Contributions

Deliverable	Contributions				
	Reid (Modelling)	**Sam (Modelling)**	**Andy (Computing)**	**Kyle (Computing)**	**Fahd (Computing)**
Milestone 1	Contributed to list of functions, objectives and constraints and morph chart.	Contributed to list of functions, objectives and constraints and morph chart	Contributed to list of functions, objectives and constraints and morph chart	Contributed to list of functions, objectives and constraints and morph chart	Contributed to list of functions, objectives and constraints and morph chart
Milestone 2	Created low fidelity model of Sam's Design, created prototype virtual model	Implemented Reid's design choice to create a low fidelity model	Provided feedback for teammates' flow charts and contributed to pseudocode	Provided feedback for teammates' flow charts and contributed to pseudocode	Provided feedback for teammates' flow charts and contributed to pseudocode
Milestone 3	Refined and modified shared design for sterilization container	Discussed possible improvements to the box design	Provided feedback for teammate's preliminary programs	Provided feedback for teammate's preliminary programs	Provided feedback for teammate's preliminary programs
Milestone 4	Refined and modified shared design for sterilization container	Further improved the box design	Added drop off and pick up functions to the team's program	Added rotate and main functions to the team's program	Added drop off and return home functions to the team's program

Sterilization Container Design	Contributed in creating finalized container design	Contributed in making edits to fianl design	N/A	N/A	N/A
Computer Program	N/A	N/A	Made drop off and pick up functions	Made rotate and main functions	Made drop off and return home functions
Design Project Report	Summary of Design Objectives, Background and research summary, Description of proposed container, Strengths and limitations of Container, Agenda	Source Materials Database, as well as appendix C (additional information), Edits across all typed sections.	Logbook of additional meetings and discussions, Strengths and limitations of Program	Description of proposed solution (computing), Summary of contributions table, Final Gantt chart	

References

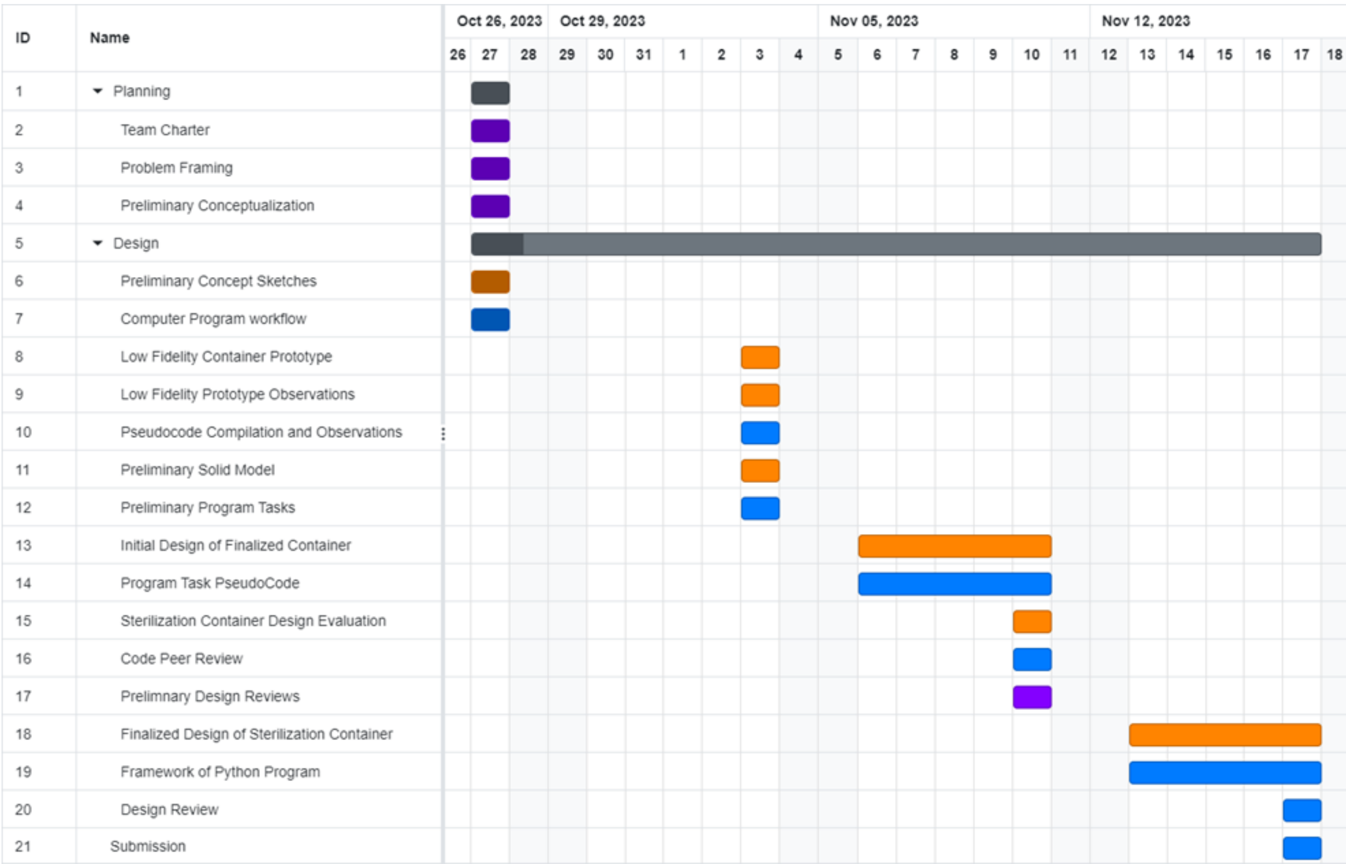
[1] A. Gupta, "Consolidated Sterlizer Systems," Consolidated Sterlizer Systems, [Online]. Available: https://consteril.com/how-does-a-laboratory-autoclave-work/#:~:text=Similar%20to%20a%20pressure%20cooker,chamber%20have%20been%20sufficiently%20sterilized.. [Accessed 6 December 2023].

[2] Centers for Disease Control and Prevention, "Centers for Disease Control and Prevention," Department of Health and Human Services, 2008. [Online]. Available: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/sterilization/steam.html#:~:text=The%20two%20common%20steam%2Dsterilizing,minimal%20time%20to%20kill%20microorganisms.. [Accessed 2023].

[3] McMaster Univseriity, "Avenue to Learn," October 2023. [Online]. Available: https://avenue.cllmcmaster.ca/d2l/le/content/553675/viewContent/4379646/View. [Accessed October 2023].

Appendices

Appendix A: Project Schedule

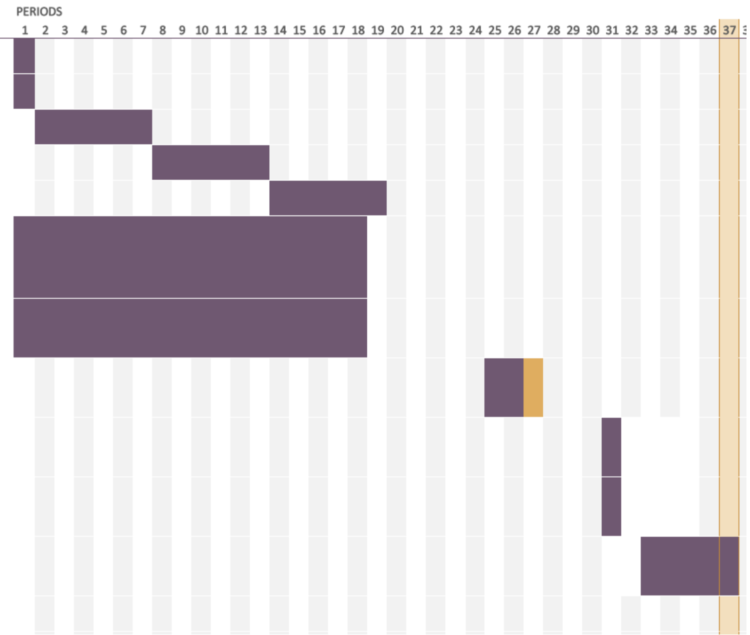


Project 2 - Fri-06 - Final Gantt Chart

Final Day 37

Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	2	6	2	6	100%
Milestone 3	8	6	8	6	100%
Milestone 4	14	6	14	6	100%
Sterilization Container Design	1	19	1	18	100%
Computer Program	1	19	1	18	100%
Research Summary	25	2	25	3	100%
P2 Q-Arm Challenge	31	4	31	1	100%
Project Interview	31	4	31	1	100%
Design Project Report	31	7	33	5	100%



Appendix B: Scheduled Weekly Meetings

Weekly Design Studio Agenda

Date	Objectives		
	Both sub teams	Modelling Team	Computing Team
October 24th, 2023	Distribute administrative roles and document personel - Sub team choice - Project leads Problem framing Preliminary Conceptualization	Preliminary Concept Sketches	Computer program workflow
November 1st, 2023		Observations based on low fidelity prototypes Preliminary solid model	Pseudocode compilation and observations Preliminary Program Tasks
November 8th, 2023	Preliminary design reviews	Sterilization container design evaluation	Coding peer review
November 15th, 2023	Design Review		
November 28th, 2023	Project 2 Q-Arm challenge Project 2 interview		

Logbook of Additional Meetings and Discussions

Date, Time, and Duration:	**Purpose & Topics Discussed**	**Members Present**
Oct 27th, 2023 9:15 AM – 9:20 AM 5 Minutes	Teams channel for P2 was made with channels for computing and CAD teams, and channel for sharing important files with each other.	All
Nov 1st, 2023 Online, All day	CAD team exchanged sketches for initial design and discussed the 3D model of design	Reid and Sam
Nov 3rd, 2023 9:30 AM – 11:20 AM During Design Studio	Computing team exchanged flowcharts and discussed similarities and differences as well as plans for the final program.	Andy, Kyle, Fahd
Nov 16th, 2023 Online, All Day	CAD team work together to create container design in inventor	Reid and Sam
Nov 17th, 2023 9:30 AM – 11:20 AM 10 minutes During Design Studio	Check-in meeting with TA to receive feedback and approval for program code and container design. Feedback for CAD team: Reduce size of model, include more perforations at bottom for steam to drain, add more creative features. Feedback for Computing team: Change the way the coordinates of the container are stored in a	All

	bunch of lists and add more comments.	
Nov 24th, 2023 9:30 AM – 11:20 AM 10 minutes During Design Studio	Check-in meeting with TA: Both sub-teams had no issues and both were looked over and got approvals. CAD team was approved for 3D printing the container design.	All
Nov 30th, 2023 11:20 AM – 11:30 AM 10 minutes	Met in preparation for P2 interview to discuss and prepare for the interview.	All
Dec 4th, 2023 Online, All day	Discussed everyone's responsibilities for the final design report and planned out who will do what.	All

Appendix C: Additional Documentation

Source Materials Database

- “Ansys Granta EduPack | Software for Materials Education.” Accessed: Nov. 29, 2023. [Online]. Available: https://www.ansys.com/products/materials/granta-edupack
- “Project 2 Module,” class notes for ENG1P13, Department of Engineering, Fall, 2023.
- “Autodesk Inventor Professional | Software for Mechanical Design.” Accessed: Nov. 3, 2023. [Online]. Available: https://www.autodesk.com/products/inventor/overview
- “Footprint #2,” class notes for ENG1P13, Department of Engineering, Fall, 2023.
- “Tool-3 (Retractor),” class notes for ENG1P13, Department of Engineering, Fall, 2023.
- “Quanser Interactive Labs | Software for Interactive Virtual Hardware.” Accessed: Oct. 26th, 2023 [Online]. Available: Quanser Interactive Labs Platform - Enhance Online Learning

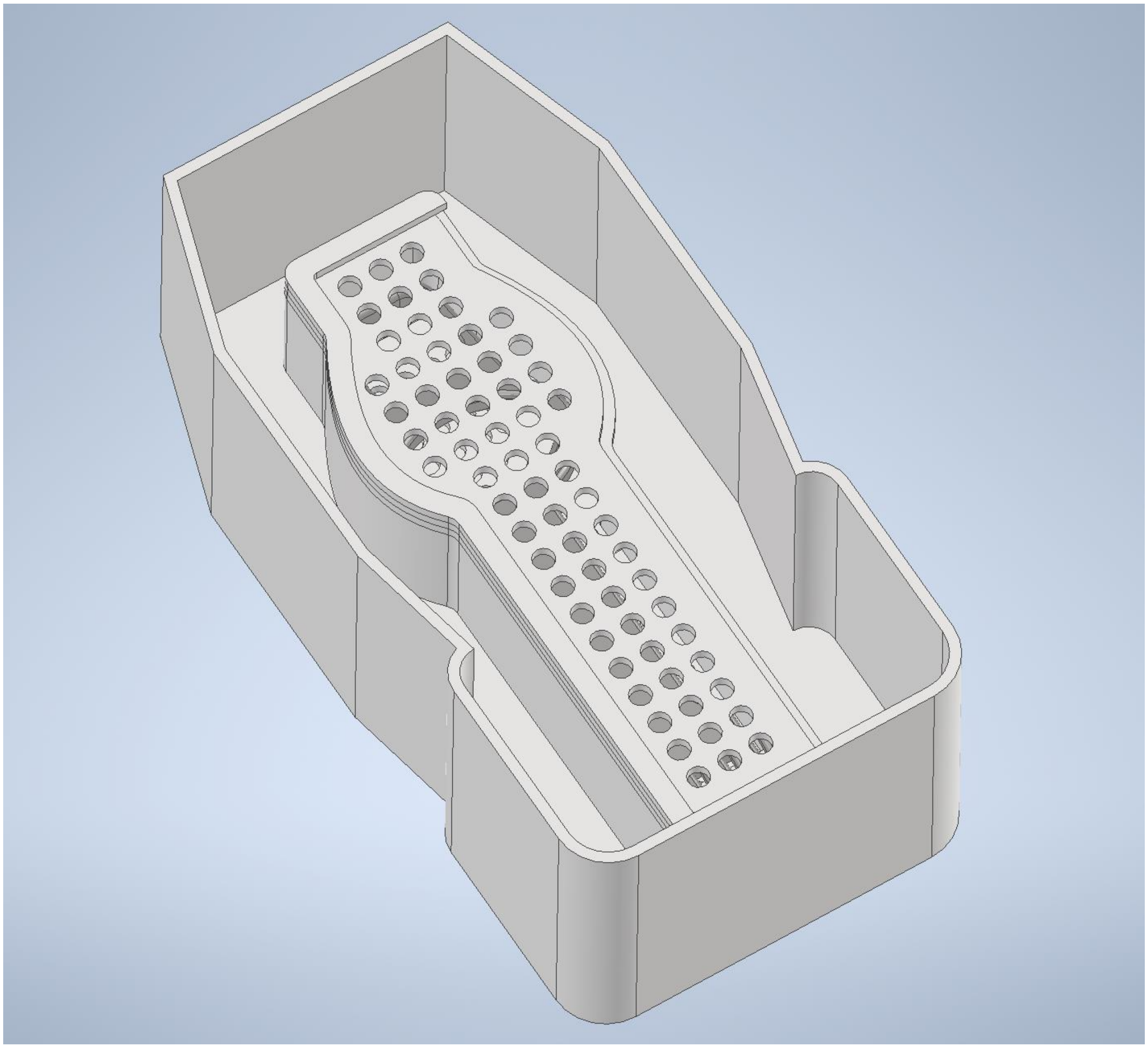
Finalized Code:

```
#-------------------------------------------------------------------------------
# STUDENT CODE BEGINS
#-------------------------------------------------------------------------------


# Made by Kyle
def rotate_q_arm():
    """Rotates the base of the Q-arm based on the change in right potentiometer values."""
    current_value = potentiometer.right()
    while potentiometer.left() == 0:
        previous_value = current_value
        current_value = potentiometer.right()
        angle = (current_value - previous_value)* 350   # Keeps the rotation angle within Q-arm's range of motion
        arm.rotate_base(angle)
```

```python
# Made by Andy
def pick_up():
    """Picks up the container at its spawn location."""
    container_location = (0.59, 0.05, 0.05)
    arm.move_arm(container_location[0],container_location[1],container_location[2])
    time.sleep(2)
    arm.control_gripper(45)


# Made by Fahd
def return_home():
    """Moves the Q-arm to its home location."""
    home = (0.406, 0.0, 0.483)
    arm.move_arm(home[0], home[1], home[2])


# Made by Kyle
def main():
    """Spawns all 6 containers in a random order and sorts them into their correct autoclaves."""
    import random
    container_list = [1,2,3,4,5,6]
    random.shuffle(container_list)
    for id in container_list:
        arm.spawn_cage(id)
        pick_up()
        time.sleep(2)
        return_home()
        transferring_container = True
        while transferring_container:
            while potentiometer.left() != 1 or potentiometer.right() != 1:
                if potentiometer.left()==0:
                    rotate_q_arm()
                if potentiometer.right()==0:
                    drop_off()
                    return_home()
                    transferring_container = False


#---------------------------------------------------------------------------------
# STUDENT CODE ENDS
#---------------------------------------------------------------------------------
```

```python
# Made by Andy and Fahd
def drop_off():
    """Drops off the container at its corresponding autoclave based on left potentiometer values and colour."""

    # Initial Q-arm location, and target autoclave locations.
    initial = arm.effector_position()
    R1 = (0, -0.625, 0.317)
    R2 = (0, -0.406, 0.171)
    G1 = (0, 0.625, 0.317)
    G2 = (0, 0.406, 0.171)
    B1 = (-0.621, 0.239, 0.317)
    B2 = (-0.417, 0.161, 0.171)

    # Activates the autoclaves, and determines which colour autoclave the Q-arm is near.
    arm.activate_autoclaves()
    colour = None
    if arm.check_autoclave('red'): colour = 'red'
    elif arm.check_autoclave('green'): colour = 'green'
    elif arm.check_autoclave('blue'): colour = 'blue'

    # Moves the Q-arm to the container's corresponding autoclave using left potentiometer values and colour.
    at_top, at_bottom = False, False
    while potentiometer.right() == 0:
        # Moves the Q-arm to the top of the autoclave.
        if 0.5 < potentiometer.left() < 1:
            if  at_bottom:
                arm.move_arm(initial[0], initial[1], initial[2])  # Prevents the Q-arm from passing through the autoclave.
                time.sleep(2)
            if colour == 'red': arm.move_arm(R1[0], R1[1], R1[2])
            elif colour == 'green': arm.move_arm(G1[0], G1[1], G1[2])
            elif colour == 'blue': arm.move_arm(B1[0], B1[1], B1[2])
            arm.open_autoclave(colour, False)
            at_top, at_bottom = True, False
        # Moves the Q-arm to the bottom of the autoclave, and opens the autoclave drawer.
        elif potentiometer.left() == 1:
            if at_top:
                arm.move_arm(initial[0], initial[1], initial[2])
                time.sleep(2)
            if colour == 'red': arm.move_arm(R2[0], R2[1], R2[2])
            elif colour == 'green': arm.move_arm(G2[0], G2[1], G2[2])
            elif colour == 'blue': arm.move_arm(B2[0], B2[1], B2[2])
            arm.open_autoclave(colour, True)
            at_top, at_bottom = False, True

    # Opens the gripper, closes the autoclave drawer, and deactivates the autoclaves.
    if colour != None:  # Prevents the gripper from opening if not near any autoclaves.
        arm.control_gripper(-45)
        time.sleep(2)
        arm.open_autoclave(colour, False)
        arm.deactivate_autoclaves()
```

Finalized Container:



Appendix D: Design Studio Worksheets

https://acrobat.adobe.com/id/urn:aaid:sc:VA6C2:a90dab4f-7eb7-457a-bafc-4d263cfdeb76