ENGINEERING

McMaster University

Project Two: Get a Grip

Designing a System for Sterilizing Surgical Tools using Remote Sensing and Actuation

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 11

Team: Fri-42

Aidan Gromek (gromea1)

Matteo Lonardi (lonardim)

Harikashan Thayeswaran (thayeswh)

Xiaoxiang Diao (diaox)

Submitted: December 9, 2020

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Matteo Lonardi 400310473 Click or tap here to enter text.

Matteo Lonardi

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Harikashan Thayeswaran 400326364 Click or tap here to enter text.

Hari.T

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Xiaoxiang Diao 400293294Click or tap here to enter text.

Xiaoxiang Diao

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Aidan Gromek 400317960 Click or tap here to enter text.

Aidan Gromek

Executive Summary

Modelling

This project was motivated by the desire to create an effective, safe and reliable transportation system for medical instruments. It was imperative that the container could be properly sterilized to prevent the transfer of disease-carrying microbes that may be left on the surface of the medical devices after use. The prototype was designed with specific dimensional constraints in mind so that it could fit inside a footprint, but also so that it could be 3D printed. The container was equipped with multiple sterilization holes that allow steam to enter and exit without getting trapped. The container also has extended ridges on the upper and lower portions of the side faces, creating an indent. This indent would allow the prongs of the gripper to get a more secure grasp on the container to reduce the likelihood that it is dropped in the transport process. A lid was also created that could be pulled open like a door, as it would be attached to the container via two hinges on its top. This lid would prevent the medical tool from coming out of the box during transport. The “seatbelt” was created in order to keep the medical instrument in place so it would not rattle around inside, which could cause irreversible damage to the tool. Theoretically, the friction between the seatbelt and the container would be enough to keep the seatbelt from sliding out of its placement in the hole in the side of the container.

Computing

Another motivation for this project was to design code that can effectively control the movement of a robotic arm to pick up, transfer and place a container for sterilization. The computer program was to interface with the two muscle sensor emulators from Quanser Interactive Labs to complete these objectives. The general workflow of this program was to start at the home position, pick up 1 of 6 unique containers, transfer the container to the corresponding unique drop-off location, return home and repeat this process for 6 containers. Various functions had to be created to assist this general process. “position_autoclave” returns the x,y,z coordinates of that container’s final position after knowing the container ID. “move_end_effector” takes 3 float values (x,y,z coordinates from the final position) and waits for the user to move both the right and left muscle sensor values past the threshold; then it moves the robot arm to this location. “control_gripper” checks whether the container is large or small, then if the left muscle sensor is above the threshold while the right is less than the threshold the gripper closes for the given size of the container and if both arms are less than the threshold the gripper opens. “autoclave_bin_drawer” is only applicable for the container 4, 5 and 6; it opens the corresponding drawer if the left is less than the threshold, the right is greater and closes if both are less. All these functions are integrated properly with “spawn_container” into a main function which iterates 6 times to complete our objective.

Project Schedule

Logbook:

Meeting:	**Description:**	**Participants:**	**Date:**
Sketches	Concept design of containers	everyone	November 7,2020
Quanser Simulation	Brainstorming the picking up function	Aidan and Shawn	November 10,2020
Prototype Design	Low-fidelity Prototype Observation	Matteo and Hari	November 10,2020
Prototype Design	Pugh Matrix	Matteo and Hari	November 13,2020
Peer Review of Code	Comparison of functions and overall workflow	Aidan and Shawn	November 13,2020
CAD Design	Completed the CAD design	Matteo and Hari	November 16,2020
Python Coding	Completing the functions and Putting it all together	Aidan and Shawn	November 18,2020
G-Code and CAD Design Review Meeting	Prepare for the interview	Matteo and Hari	December 3,2020
Python Code Review	Preparing for the interview	Aidan and Shawn	December 5,2020
Practice for Interview	Further analysis CAD design and code to prepare for questions	everyone	December 8,2020

Scheduled Weekly Meetings

ENGINEER 1P13

MEETING WITH Fri-42 – Friday, October. 30, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Xiaoxiang Diao**	**diaox**	**Yes**
Administrator	**Harikashan Thayeswaran**	**thayeswh**	**Yes**
Coordinator	**Aidan Gromek**	**gromea1**	**Yes**
Subject Matter Expert	**Matteo Lonardi**	**lonardim**	**Yes**
Guest			**No**

AGENDA ITEMS

1. Think of concept solutions to solve the problem
2. Complete the list of objectives constraints and function worksheet
3. Complete the morphological analysis worksheet
4. Complete the concept sketches worksheet
5. Complete the Team charter worksheet

MEETING MINUTES

1. Attendance and Updates
    a. Take Attendance
    b. Discuss the roles
    c. Talk about P2
2. Concept Sketches
    a. Thought of various types of designs
    b. Velcro, Electromagnets, Hooks, Springs
3. List of Objectives Constraints and Functions
    a. Worked as a group to complete this list
4. Morphological Analysis Worksheet
    a. Worked as a group to complete this analysis

POST-MEETING ACTION ITEMS

1. *Break into Sub teams [everyone]*
2. *Submit the Team work [**Harikashan Thayeswaran**]*
3. *Complete Initial Gantt Chart [**Xiaoxiang Diao**]*
4. *Finish the concept sketches [everyone]*
5. *Program workflow worksheet [Computing Sub-team]*
6. *Refined Concept Sketches worksheet [Modelling Sub-team]*

ENGINEER 1P13
MEETING WITH Fri-42 - Friday, Nov. 6, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Xiaoxiang Diao**	**diaox**	**Yes**
Administrator	**Harikashan Thayeswaran**	**thayeswh**	**Yes**
Coordinator	**Aidan Gromek**	**gromea1**	**Yes**
Subject Matter Expert	**Matteo Lonardi**	**lonardim**	**Yes**
Guest			**No**

AGENDA ITEMS

1. Conceptualize the sterilization container
2. Conceptualize the operation of the robotic arm
3. Update TA on team progress
4. Low-fidelity prototype observations worksheet (Modelling Sub-team)
5. Program Pseudocode Observations worksheet (Computation Sub-team)

MEETING MINUTES

1. Attendance and Update
   a. Discuss the sketches made last design studio
   b. Take Attendance
2. Gave TA an update
   a. Xiaoxiang gave the TA a debrief of our project
3. Low-Fidelity Prototype Observations Worksheet
   a. Worked on the Low-Fidelity Prototype Observations Worksheet (Modelling Sub-Team)
4. Program Pseudocode
   a. Worked on the pseudocode of the position_autoclave and move_end_effector function

POST-MEETING ACTION ITEMS

1. *Submit the team assignment [***Harikashan Thayeswaran***]*
2. *Complete the* pseudocode of the position_autoclave and move_end_effector function [Computing Sub-team]
3. *Complete the* Low-Fidelity Prototype Observations Worksheet [Modelling Sub-Team]
4. *Further plan out the final code and container [everyone]*

ENGINEER 1P13
MEETING WITH TEAM Fri-42 - Friday, Nov. 13, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Xiaoxiang Diao**	**diaox**	**Yes**
Administrator	**Harikashan Thayeswaran**	**thayeswh**	**Yes**
Coordinator	**Aidan Gromek**	**gromea1**	**Yes**
Subject Matter Expert	**Matteo Lonardi**	**lonardim**	**Yes**
Guest			**No**

AGENDA ITEMS

1. Create Preliminary Models of design in Autodesk inventor and Python
2. Evaluate and propose refinements/corrections
3. Peer Review the code the pseudocode worksheet and write down conclusions (Computational Sub-Team)
4. Pugh Matrix worksheet (Modelling Sub-Team)
5. Pseudocode for the remaining functions (Computational Sub-Team)
6. Update TA

MEETING MINUTES

1. Attendance and Update
    a. Discussed the prior week's Sub-Team work
    b. Took attendance
2. Pugh Matrix Worksheet
    a. Worked on the Pugh Matrix Worksheet (Modelling Sub-Team)
3. Code Peer-Review
    a. Worked on the coding peer review
    b. Discussed similarities and differences in the code
    c. Discussed different strategies to perform the same tasks, tried to further understand the code
4. Meeting With the TA
    a. Xiaoxiang lead the group discussion

POST-MEETING ACTION ITEMS

1. *Submits the team assignment [***Harikashan***]*
2. *Complete the G-code for 3-D printing [Modelling Sub-Team]*
3. *Complete one iteration of the process using Python code [Computational Sub-Team]*
4. *Prepare for presentations in Milestone 4 [everyone]*

ENGINEER 1P13
MEETING WITH Fri-42 - Friday, Nov. 20, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Xiaoxiang Diao**	**diaox**	**Yes**
Administrator	**Harikashan Thayeswaran**	**thayeswh**	**Yes**
Coordinator	**Aidan Gromek**	**gromea1**	**Yes**
Subject Matter Expert	**Matteo Lonardi**	**lonardim**	**Yes**
Guest			**No**

AGENDA ITEMS

1. Review the code and explanation with the computation Sub-Team
2. Review the G-code and the explanations for the CAD design
3. Meet with TA
4. Prepare for presentations
5. Present proposed design and document feedback on worksheet so changes can be applied

MEETING MINUTES

1. Attendance and Update
    a. Take Attendance
    b. Updated each Sub-Team
2. Meeting with a TA
    a. Xiaoxiang updated the TA about the progress of our project
3. Presentation
    a. The modelling group presented first Aidan wrote the feedback on the worksheet
    b. The computing group presented next, Aidan added their feedback to the worksheet
4. Meeting Review
    a. Both Sub-Teams met to discuss the feedback that needed to be implemented before submitted

POST-MEETING ACTION ITEMS

1. *Must complete the entire code for the interview [Computing Sub-Team]*
2. *Understand the CAD design and be able to answer question about it [Modelling Sub-Team]*
3. *Understand the code and be able to answer questions about it [Computing Sub-Team]*
4. *Upload python code and Autodesk inventor files in a zipped folder on avenue [Harikashan]*

Design Studio Worksheets

Milestone 0

Names and Portrait

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Harikashan Thayeswaran	thayeswh
Aidan Gromek	gromea1
Matteo Lonardi	lonardim
Xiaoxiang Diao	diaox

Insert your Team Portrait in the dialog box below

Previous Roles

Incoming Personnel Administrative Portfolio:

Prior to identifying Leads, identify each team members incoming experience with various **Project Leads**

	Team Member Name:	Project Leads
1.	Xiaoxiang Diao (Subject Matter Expert)	☐M ☐A ☐C ☐S
2.	Harikashan Thayeswaran (Team Coordinator)	☐M ☐A ☐C ☐S
3.	Matteo Lonardi (Administrator)	☐M ☐A ☐C ☐S
4.	Aidan Gromek (Manager)	☐M ☐A ☐C ☐S
		☐M ☐A ☐C ☐S

To 'check' each box in the Project Leads column, you must have this document open in the Microsoft Word Desktop App (not the browser and not MS Teams)

New Roles

Project Leads:

Identify team member details (Name and MACID) in the space below.

Role:	Team Member Name:	MacID
Manager	Xiaoxiang Diao	diaox
Administrator	Harikashan Thayeswaran	thayeswh
Coordinator	Aidan Gromek	gromea1
Subject Matter Expert	Matteo Lonardi	lonardim

Preliminary Gantt Chart

Full Name of Team Manager:	MacID:
Xiaoxiang Diao	diaox

Preliminary Gantt chart

Milestone 1

Pre-Project Assignment:

Name: Harikashan Thayeswaran | MacID: thayeswh

Copy-and-paste the pre-project assignment for one team member in the space below

Objectives

- Easy to lift up and lightweight
- High Durability
- Low cost (due to the fact that we are designing for less fortunate countries)
- The container manages to securely hold a tool
- High Efficiency
- Safety

Constraints

- Container (base) fits inside of the desired location of the autoclave
- Size of the objects
- The maximum mass the container can be is 350g
- Fits within $1m^2$
- No measurements can be below 4 mm (width of the container 80mm)

Functions

- Should be able to pick up and move containers to a desired location with precision.
- Should be able to identify the which the correct container
- Container should be able to sterilize tools
- The arm should be able to accurately grab the instrument and have a good grip on it without dropping the object

Name: Aidan Gromek	MacID: gromea1
Objectives • Safe • Sturdy grip • Efficient • Cost effective (minimize material used) • Lightweight • Durable *Constraints* • *The robot arm end effector is a 2-fingered multi-articulated gripper* • *Proximal gripping limits the size of objects to a maximum width of 80mm but allows for the entire end effector to grasp the object* • *Distal gripping allows for larger objects to be grasped up to a width of 150mm but less securely* • *No feature should be smaller than 4mm* • *The mass of the design cannot exceed 350 grams* • *Must 3-D print in less than 2 hours* *Functions* • The ability to open and close the 2-fingered gripper • The ability to move the robotic arm end-effector to a specified XYZ location • The ability to open and close the autoclave bin • The ability to flex/extend muscle sensor L only keeping muscle sensor R fully extended and vice versa. Flex and extend both muscle sensor L and R together • The ability to pick up and move containers to a desired location with precision • The ability to identify which is the correct container	

Name:Xiaoxiang Diao	MacID:diaox
Objectives • Stay unchanged during sterilization • Method of using is clear, easy and safe • Liquid inside can undergo correct sterilization *Constraints* • Mass should be smaller that 5kg • Liquid will not leak during the process of sterilization • Should not be too small that can't be hold by robot arm *Functions* • Can store most liquid and be rigid • Moved by the robot arm easily	

List of Objectives, Constraints, and Functions

Objectives	Constraints	Functions
• Box is easy to lift up and lightweight	• Container (base) fits inside of the desired location of the autoclave	• The ability to open and close the 2-fingered gripper
• Low cost (because we are designing for less fortunate countries)	• *Must 3-D print in less than 2 hours*	• Should be able to pick up and move containers to a desired location with precision.
• Secure Grip on the box	• *The mass of the design cannot exceed 350 grams*	• The ability to move the robotic arm end-effector to a specified XYZ location
• High Durability	• *No feature should be smaller than 4mm*	• The ability to open and close the autoclave bin
• High Efficiency (Modelling and coding)	• Fits within $1m^2$	• Should be able to identify which is the correct container
• Safety	• Max width of object to be grasped should be ~80 mm (if clamp is wrapping securely around object at the proximal) and ~150 mm (if clamp is just holding the object at the distal)	• The ability to flex/extend muscle sensor L only keeping muscle sensor R fully extended and vice versa. Flex and extend both muscle sensor L and R together

2. What is the primary function of the entire system?

• To deliver the tool to the correct autoclave container

3. What are the secondary functions?

• The ability to flex/extend muscle sensor L only keeping muscle sensor R fully extended and vice versa. Flex and extend both muscle sensor L and R together
• Should be able to identify which is the correct container
• The ability to open and close the autoclave bin
• The ability to open and close the 2-fingered gripper
• The ability to move the robotic arm end-effector to a specified XYZ location
• Should be able to pick up and move containers to a desired location with precision.

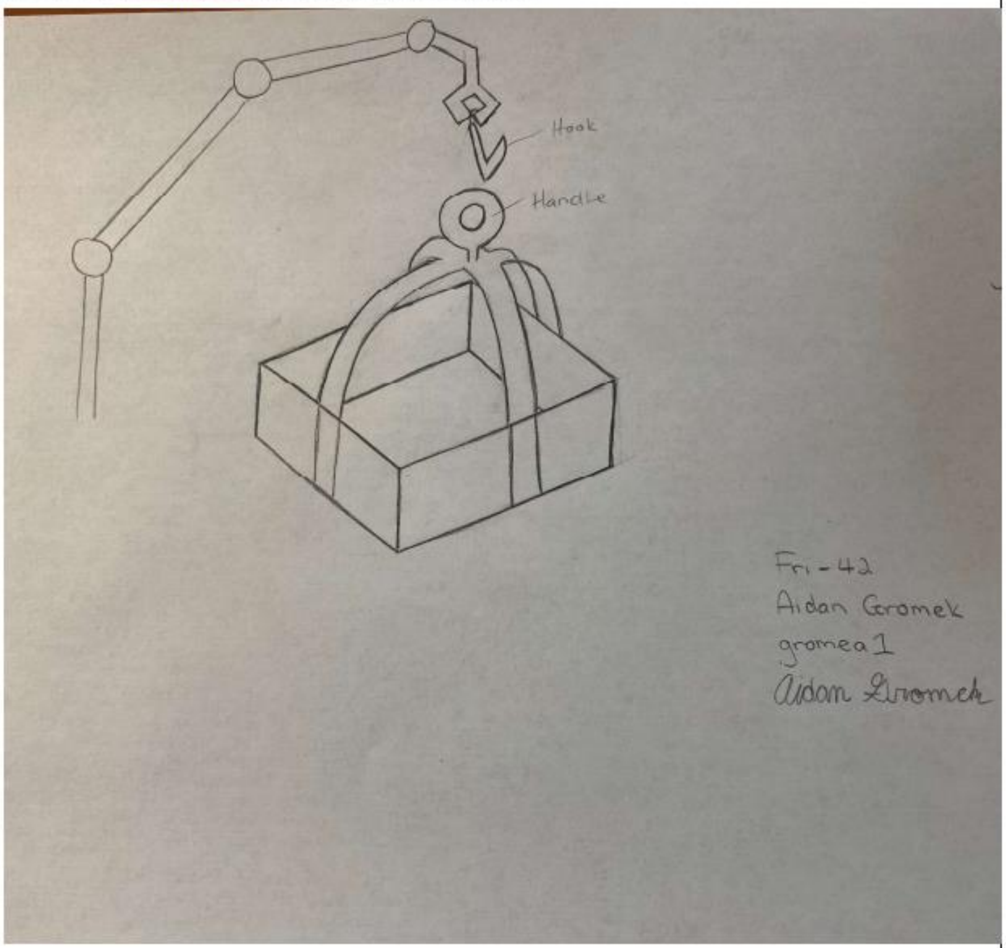
Morphological Analysis

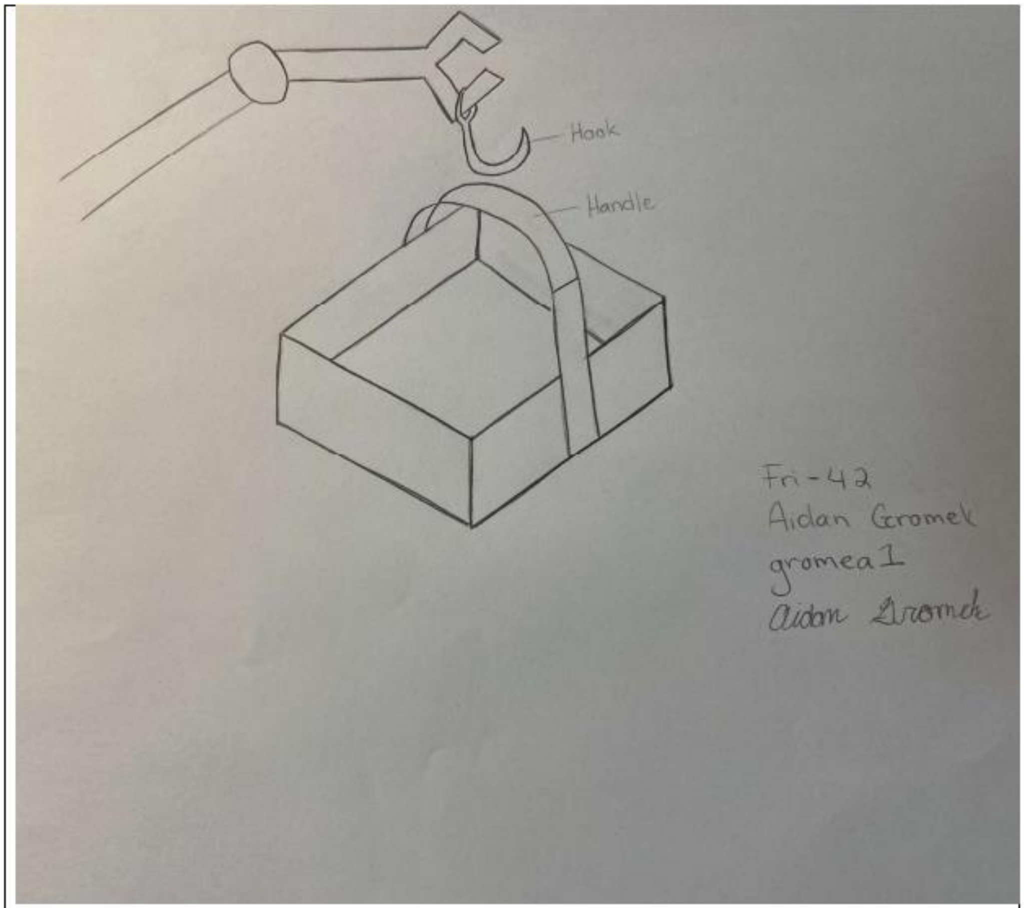
Function	Means					
Pick up/drop (for the gripper)	Electromagnets	Clamps	Spring-loaded fingers	Pulley (to pull on gripper fingers)	Velcro	Hooks and handles
Relocate box	Arm cannot rotate but can rise, and base of Q-arm has wheels	Rotating arm with stationary base	Q-arm base follows a circular conveyor belt with a rotating arm to distribute the box	Frictionless base of the Q-arm with 4 electromagnets set up in front, behind, to the right and left of the Q-arm which activate to slide the Q-arm to the bins	Q-arm situated on an elevated plane with 4 sides, with all the boxes. There will be slides which lead to the 6 bins (2 slides per each side at different slopes). The Q-arm will drop the appropriate box on the slide leading to the appropriate bin.	
Raise and Lower the arm	Hydraulics	Lever to rise the box	Gear system	Spring loaded	Pulley system	Magnets
Identify which is the correct container	Using visual software to differentiate between the 3 colours	Use a camera to measure the area/width of both sized boxes	Using echolocation to determine the size of each object	Label the bins from 1-6 and use a camera on the Q-arm to scan the numbers and identify the correct bin.	Use an infrared camera to distinguish between the colors then determine which bin is the larger and which is smaller.	

Concept Sketches Worksheets

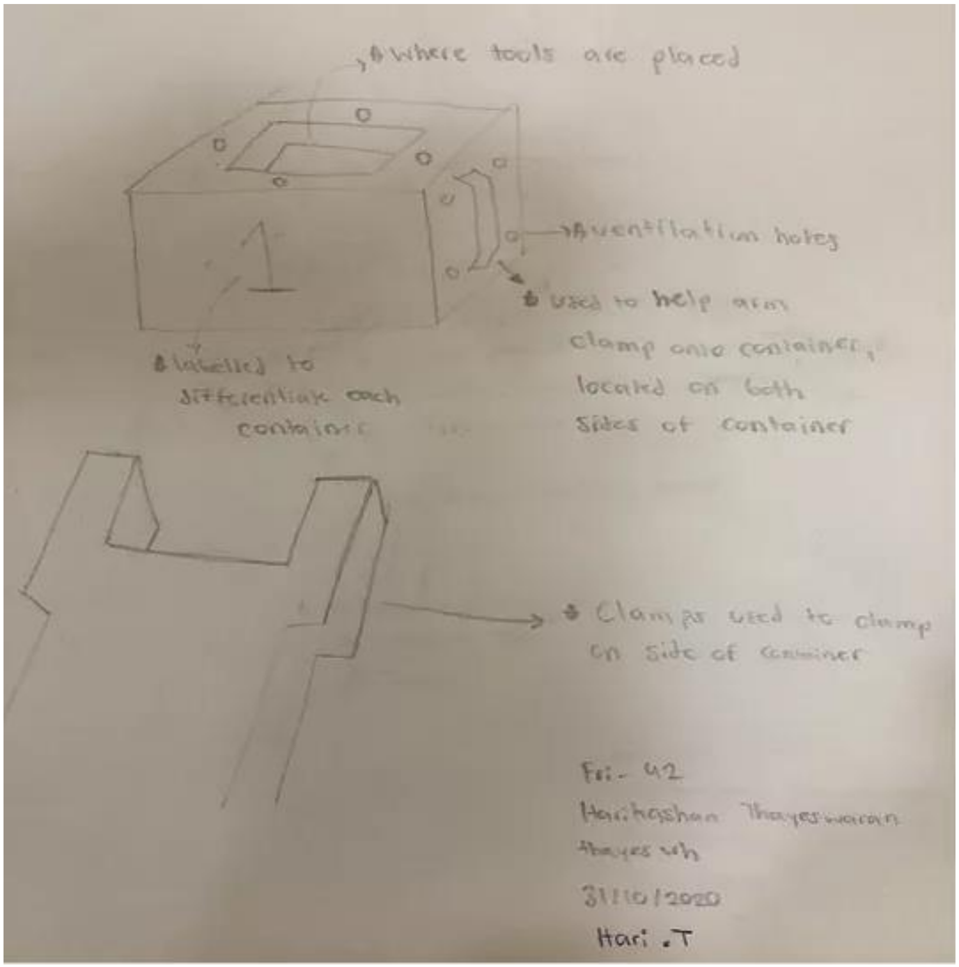
Aidan Gromek

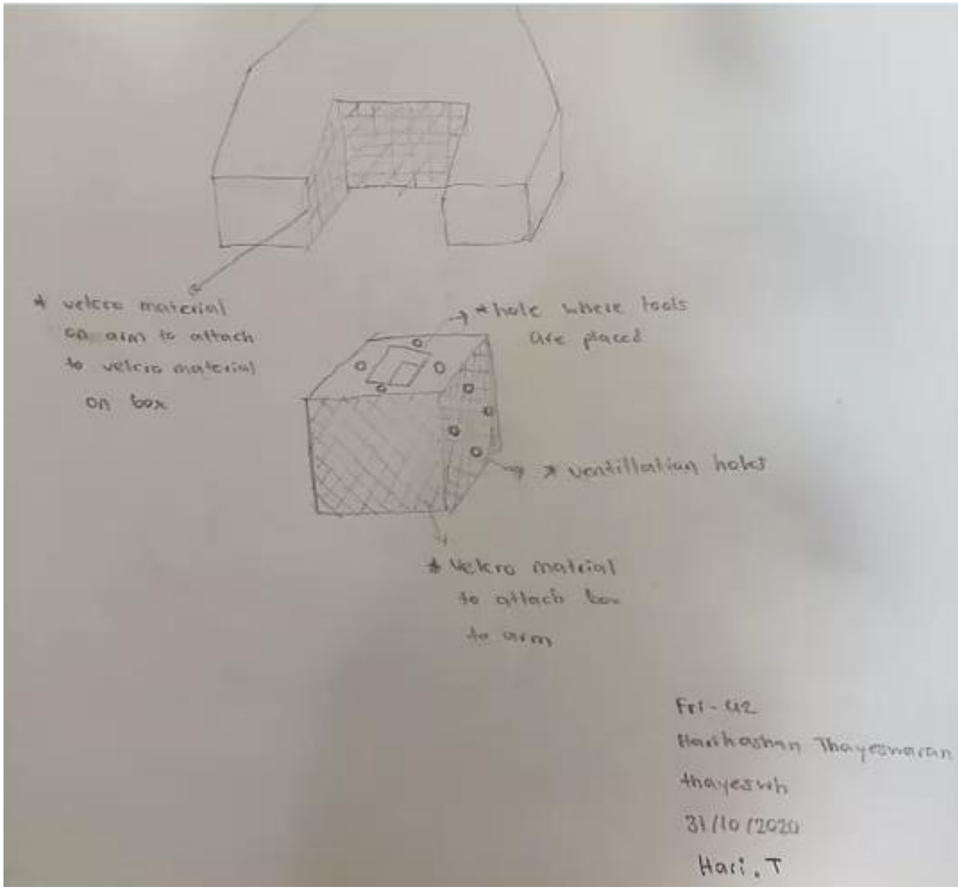
Name: Aidan Gromek	MacID: gromea1
Insert screenshot(s) of your concept sketches below	




Hook
Handle
Fri-42
Aidan Gromek
gromea1
Aidan Gromek

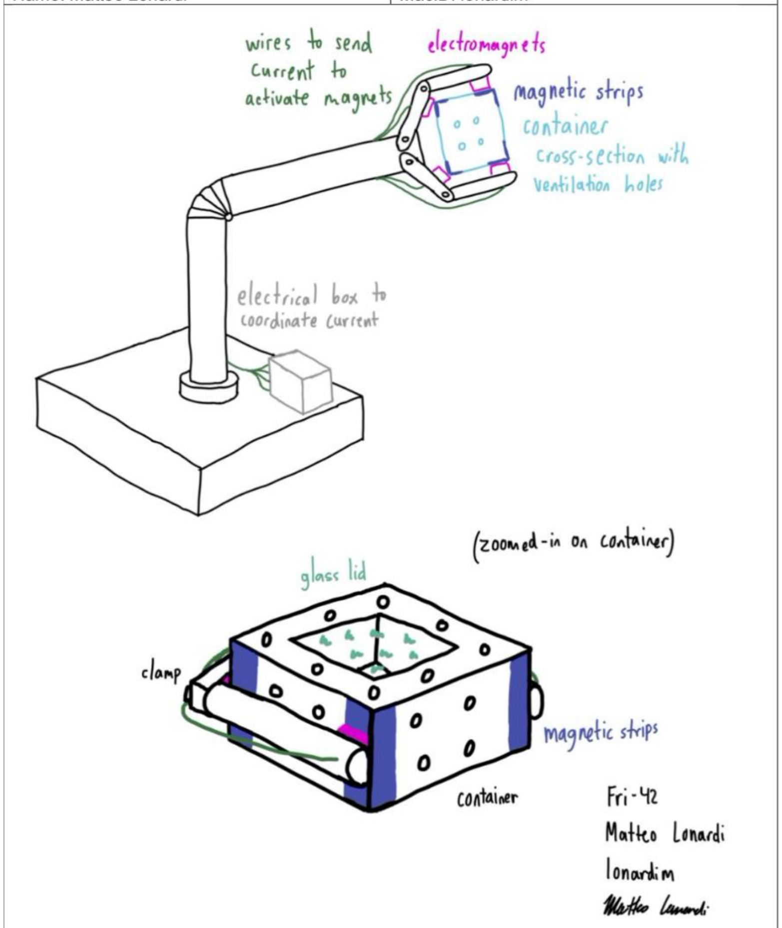
Harikashan Thayeswaran



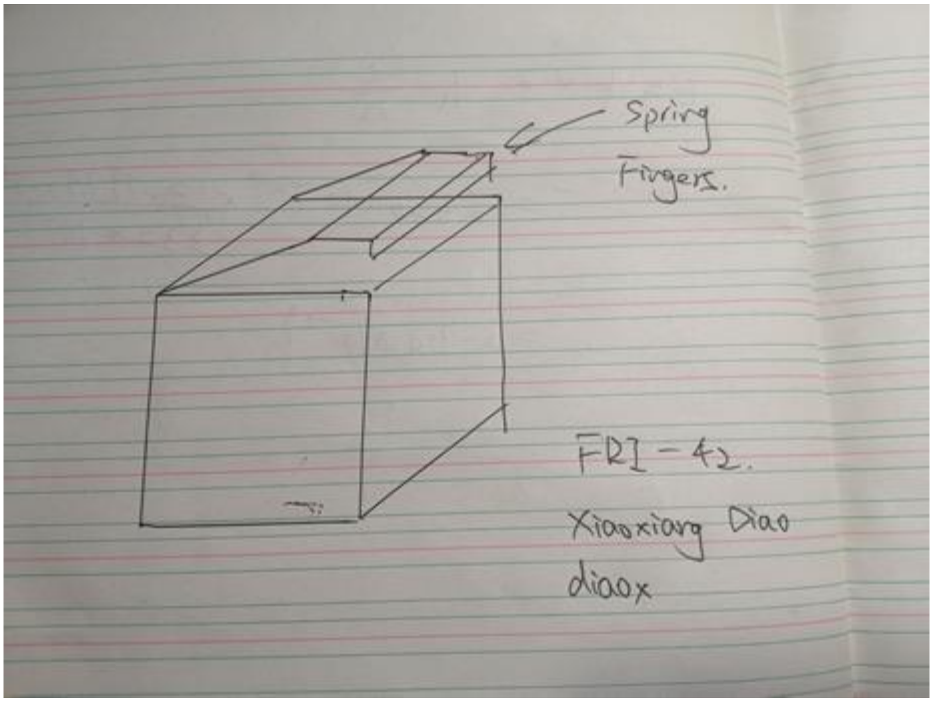

* velcro material on arm to attach to velcro material on box
* hole where tools are placed
* ventillation holes
* Velkro material to attach box to arm
Fri-42
31/10/2020
Hari.T

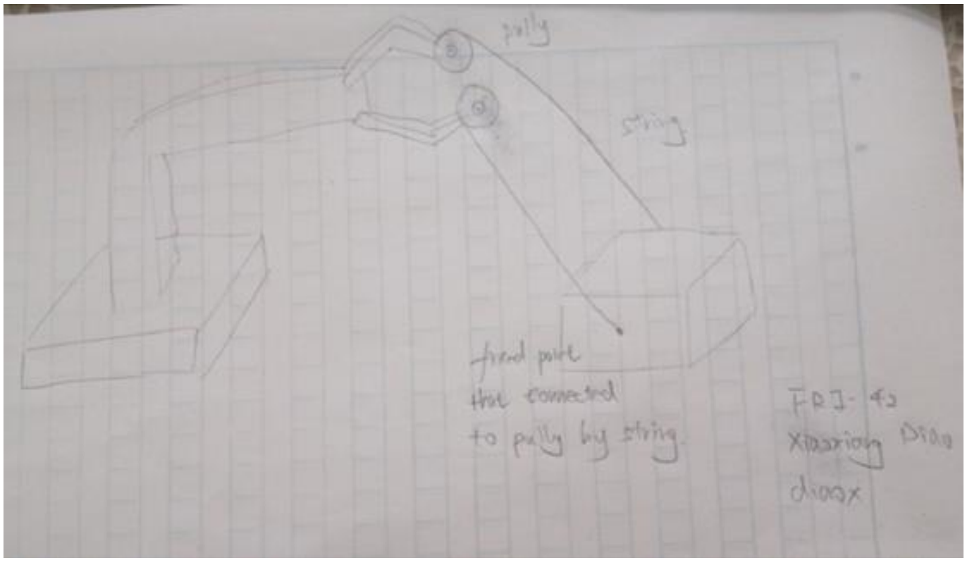
Matteo Lonardi

Name: Matteo Lonardi	MacID: lonardim



Xiaoxiang Diao

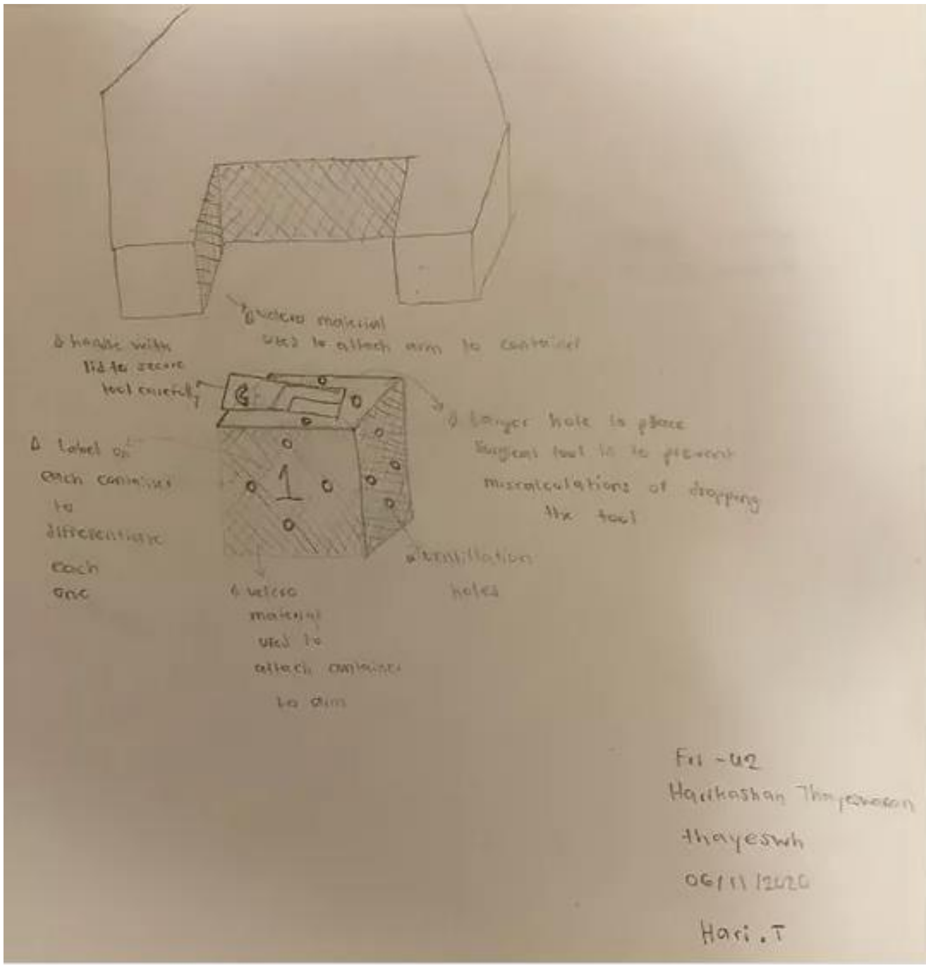




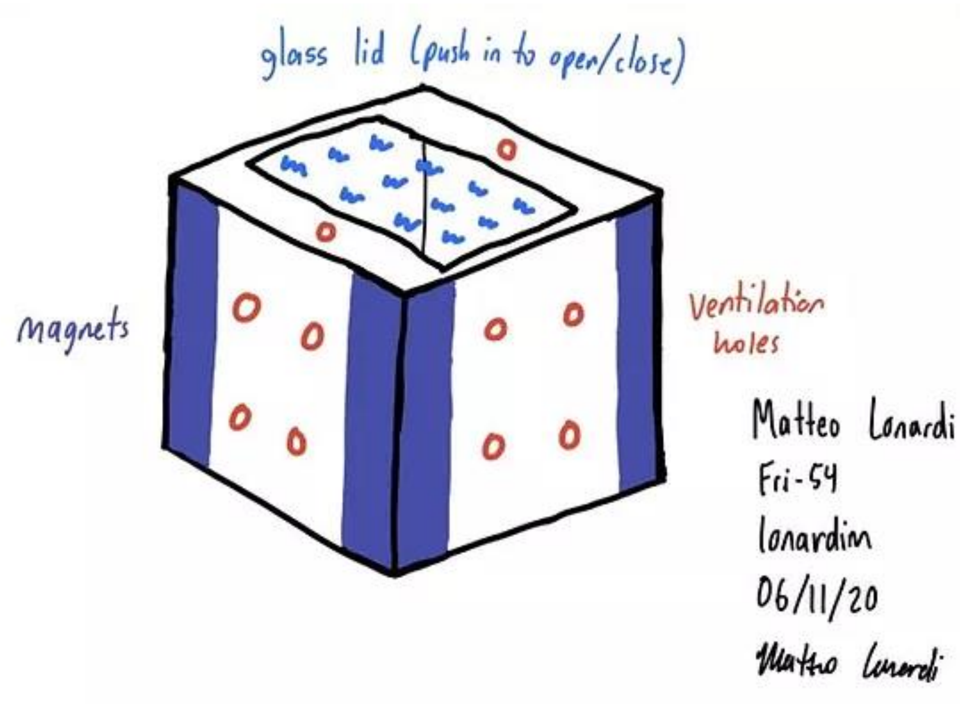
Milestone 2

Refined Sketches

Harikashan Thayeswaran

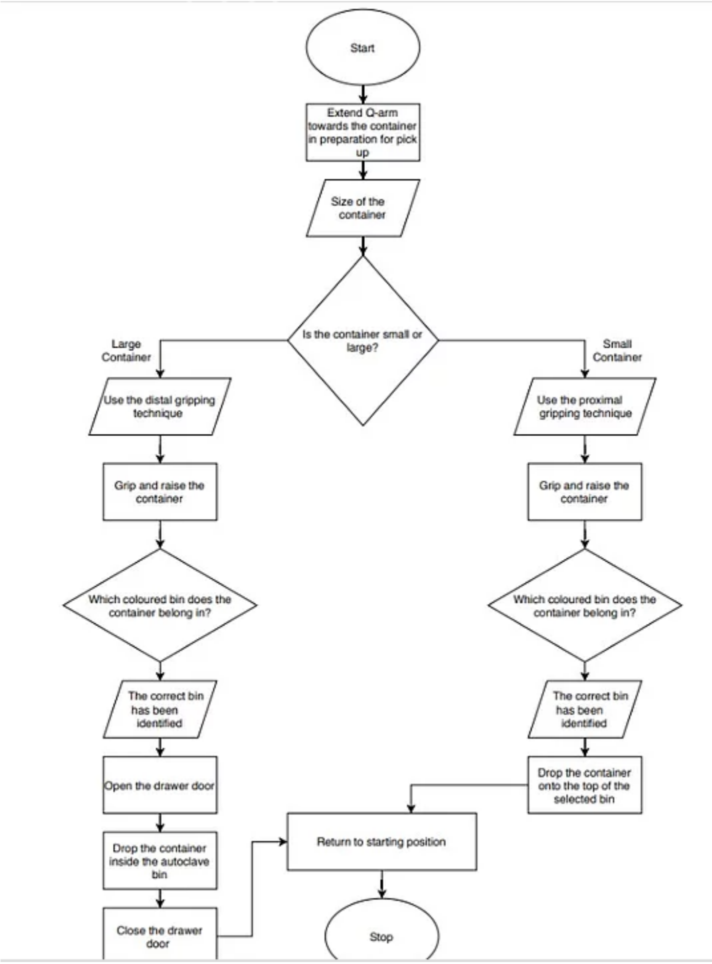


Matteo Lonardi

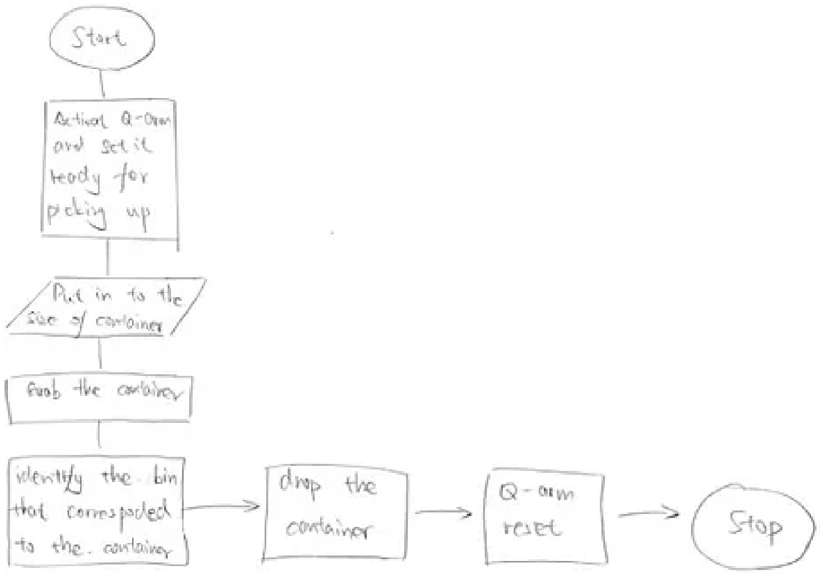


Computer Program Workflows

Aidan Gromek

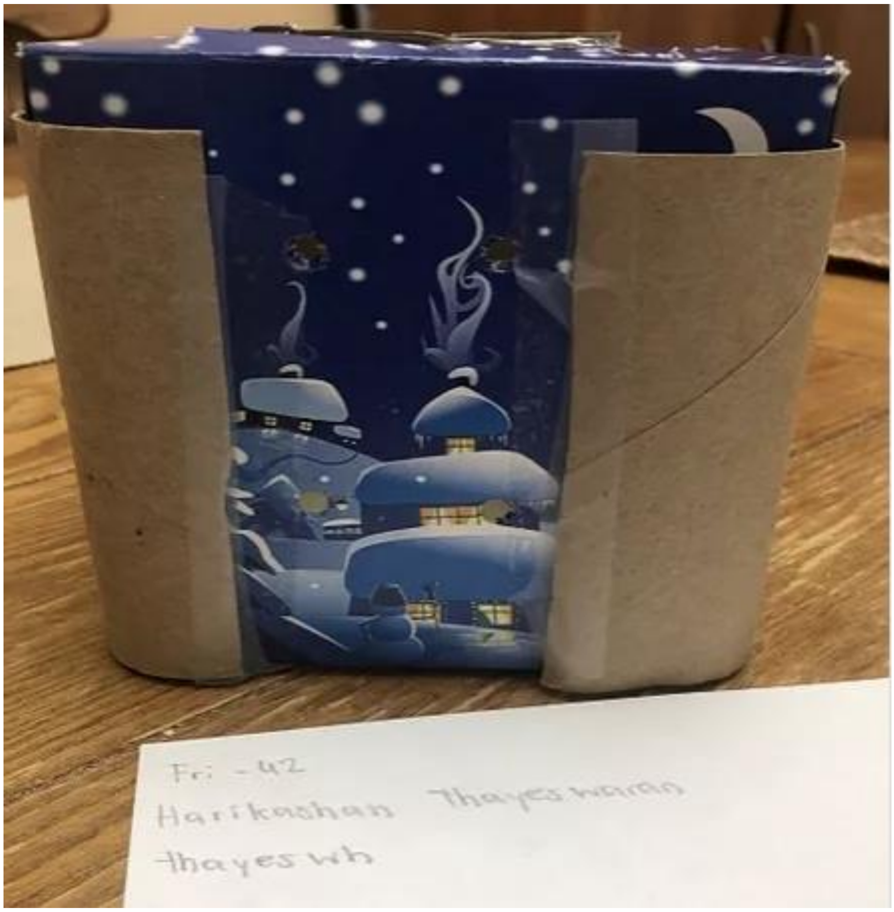


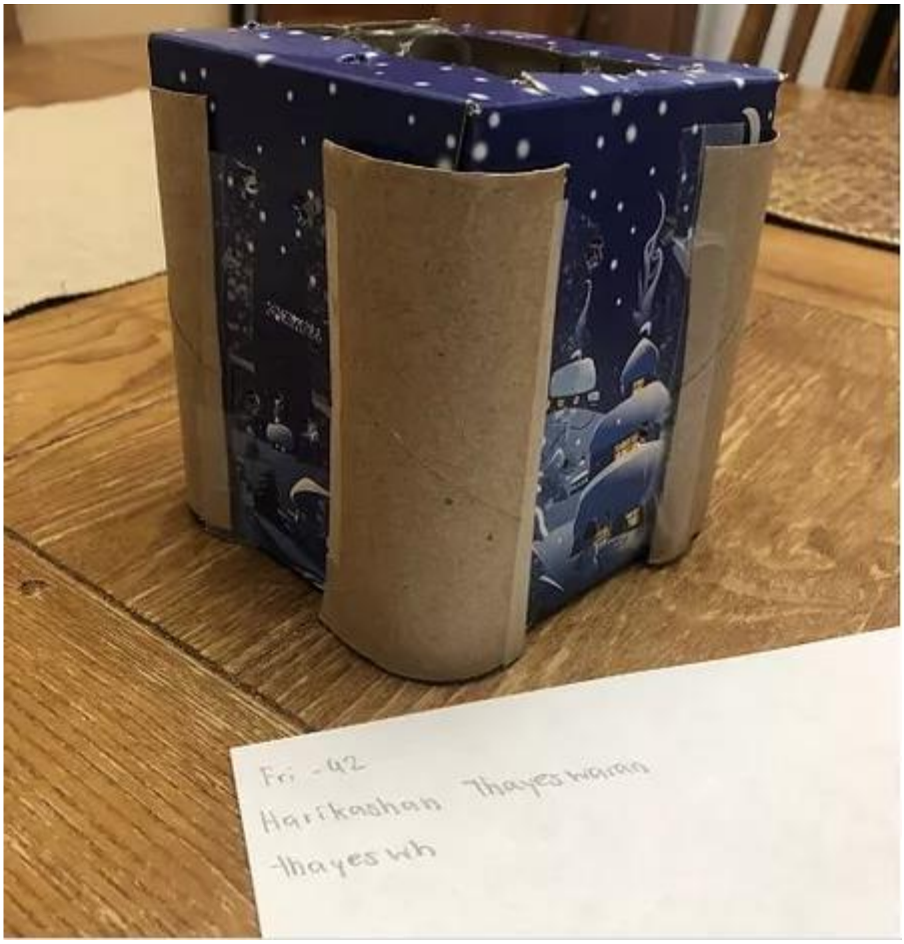
Xiaoxiang Diao



Low-Fidelity Prototypes

Harikashan Thayeswaran


Fri -42
Harikashan Thayeswaran
thayeswh

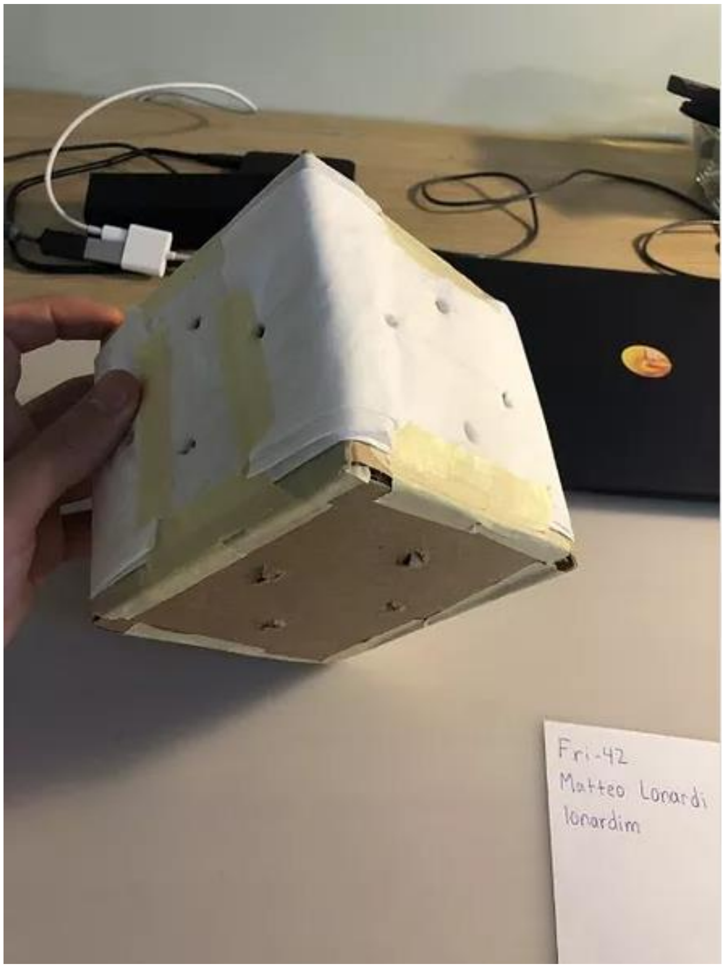

Fri -42
Harikashan Thayeswaran
thayeswh

- Saran wrap at the top represents the glass lid
- Half toilet paper rolls on corners represent the magnets
- Tissue box represents the overall container
- Holes in tissue box represents ventilation holes

Changes Made:

- There is now a glass lid added to the prototype that can only open from the outside to the inside
- Number of ventilation holes on top decreased to two due to size constraints

Matteo Lonardi


Fri-42
Matteo Lonardi
lonardim

- Tissue represents Velcro
- Holes in tissue box represents ventilation holes

Changes made:

- Velcro on top of container removed (redundant)
- Flap underneath the lid added to prevent it from falling into the container
- Number label on the side removed because the container will not need it to be identified

Low-Fidelity Prototype Observations

Electromagnets (Harikashan Thayeswaran):

- Disadvantages:
  - Possibility of magnets not being strong enough to hold the container
  - Possibility of the tool falling out the container
  - Since there are no holes at the bottom of the container, there is a possibility of the sterilization fluid getting trapped

- Advantages
  - Holds everything securely with glass lid and encloses the materials
  - The holes around the container allow for easy sterilization

- Alignment to List of Objectives, constraints and functions

  Objectives:
  - There is a secure grip on the box
  - The container has high durability
  - The container is safe and holds the tool carefully

  Constraints:
  - The container fits inside the desired location of the autoclave
  - The mass of the prototype would not exceed 350 g
  - Prototype would fit within 1m^2
  - The max-width of the object would be 150 mm

  Functions:
  - The robotic arms would be able to differentiate each container
  - The container should be able to open and close with the robotic arm as it has a lid
  - The robotic arm should easily be able to move the container to a specified location XYZ

- Reliability:
  - The container is reliable on picking up the surgical tools as the chances from the tool dropping are highly unlikely due to the container limiting the tool from moving around excessively.
  - The container uses material that is highly durable which reduces the amount of error for securely holding the tool.
  - The container is also reliable as it is enclosed from all sides (reducing the chances of the surgical tool from falling out the container)

- Sterilization:
  - Yes, the container can sterilize the surgical tool as it has ventilation holes on every side. These holes allow air to flow in and out of the container; however, the bottom of the container does not consist of ventilation holes, which may reduce the ability to sterilize the surgical tool effectively

Velcro Material (Matteo):

- Disadvantages
  - Possibility that only one of the sides of the clamp would become unattached from the Velcro, leaving the container stuck to the other side
  - Possibility of the tool falling out if the container is physically irritated (ie shaken)

- Advantages
  - Will hold tool securely without fear of it being damaged or becoming dirty
  - Container holes allow for easy and efficient sterilization
  - Velcro will ensure that the container is not dropped and will stick to the clamps securely

- Alignment to List of Objectives, constraints and functions
  Objectives:
  - There is a secure grip on the box
  - The container has high durability
  - The container is safe and holds the tool carefully

- Constraints:
  - The container fits inside the desired location of the autoclave
  - The mass of the prototype would not exceed 350 g
  - Prototype would take up a base area of max 1 m^2
  - The max width of the object would be 150 mm

- Functions:
  - The robotic arms would be able to differentiate each container
  - The container would be able to open and close while in the robotic arm as it has a lid with a handle
  - The robotic arm can move the container to a specified location

- Reliability:
  - The container can reliably hold the surgical tools; the chances of the tool dropping are highly unlikely because the container's compactness limits the tool's ability to move around excessively
  - The container uses material that is highly durable which lowers the chances that the tool is damaged in the moving process
  - The container is also reliable as it is enclosed from all sides (reducing the chances of the surgical tool from falling out the container)

- Sterilization:
  - Yes, the container can sterilize the surgical tool as it has ventilation holes on every side. These holes allow hot steam to flow in and out of the container, sterilizing the tools.

Workflow Peer-Review

- *One of our flowcharts was linear while the other was non-linear*
- *Both flowcharts used some type of "reset" function to reposition the Q-Arm after placing a container*
- *Both flowcharts used colour to identify the correct container*
- *Both charts' first step was to position the arm so that it could pick up the container*
- *Since the charts have a "reposition" step, both our algorithms would require some type of looping structure*
- *One flowchart checks for color and size while the other only checks for colour*
- *One flowchart opens and closes the drawer door for the large containers while the other does not*
- *To implement these ideas we would both need if structures when making decisions about identifying the colour and size*
- *We would both have to use similar functions to complete the tasks*

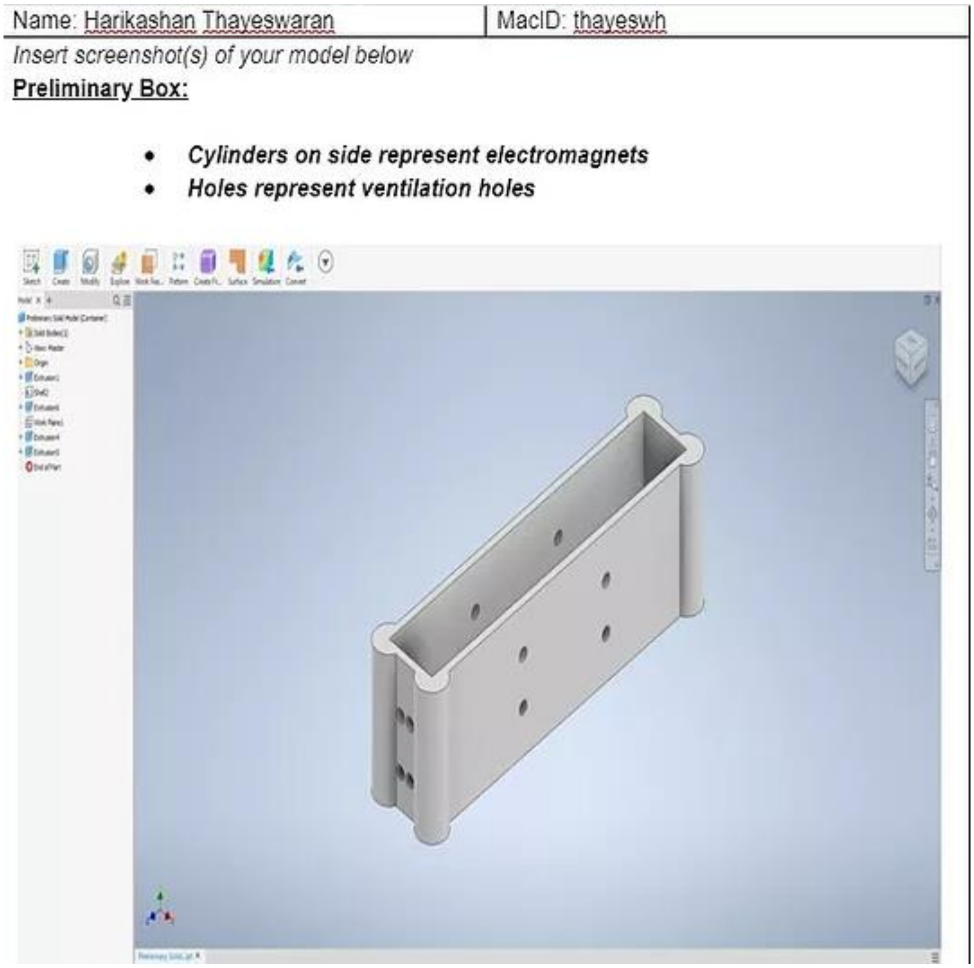
Program Pseudocode

```
For 6 Containers Being Distributed ##starting the loop to move 6 containers
    Call the move function to position the Q-Arm to pick up the container
    If the container is large
        Call the distal gripping function
        Call the raise and grip function
        If the container belongs to the RED autoclave bin
            Call the open red drawer door function
            Call the move large container to red function
            Call the close red drawer door function
        If the container belongs to the Blue autoclave bin
            Call the open blue drawer door function
            Call the move large container to blue function
            Call the close blue drawer door function
        If the container belongs to the Green autoclave bin
            Call the open green drawer door function
            Call the move large container to green function
            Call the close green drawer door function
    If the container is small
        Call the proximal gripping function
        Call the raise and grip function
        If the container belongs to the RED autoclave bin
            Call the move small container to red top function
        If the container belongs to the Blue autoclave bin
            Call the move small container to blue top function
        If the container belongs to the Green autoclave bin
            Call the move small container to green top function
    Call the reset position of Q-Arm function
    On to the next container ##reiterate through the loop until all containers are moved
```

Milestone 3

Preliminary Boxes

Harikashan Thayeswaran

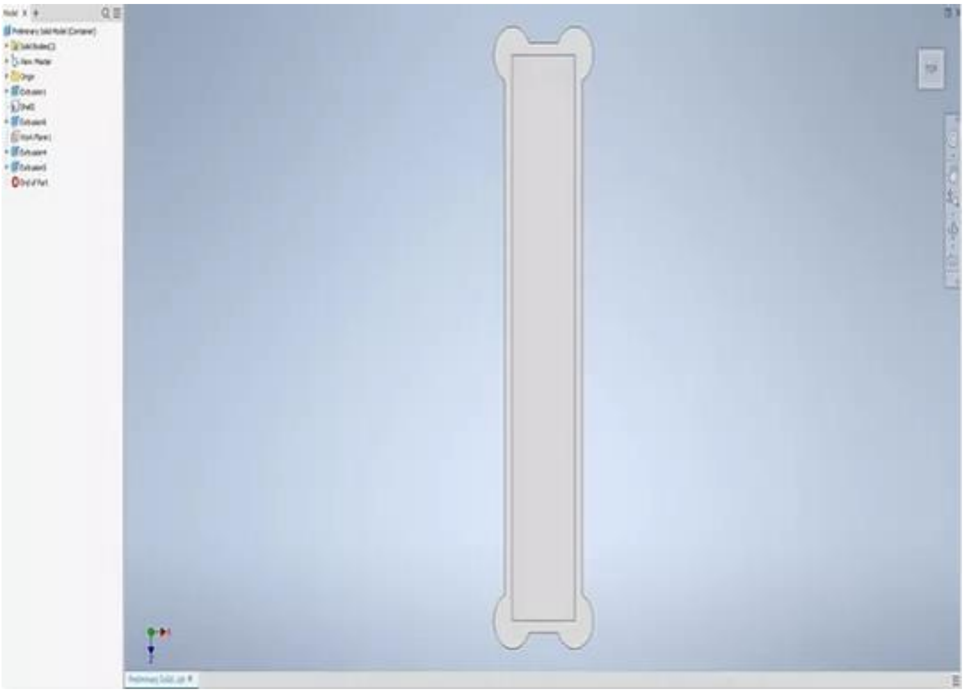


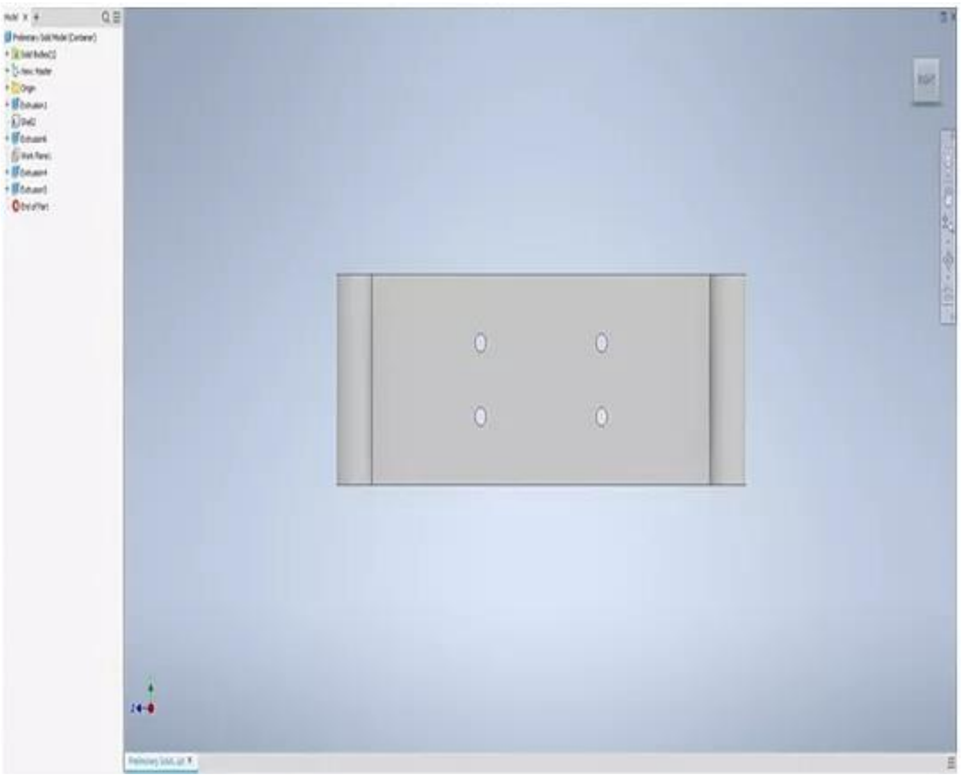
Name: Harikashan Thayeswaran	MacID: thayeswh

Insert screenshot(s) of your model below

Preliminary Box:

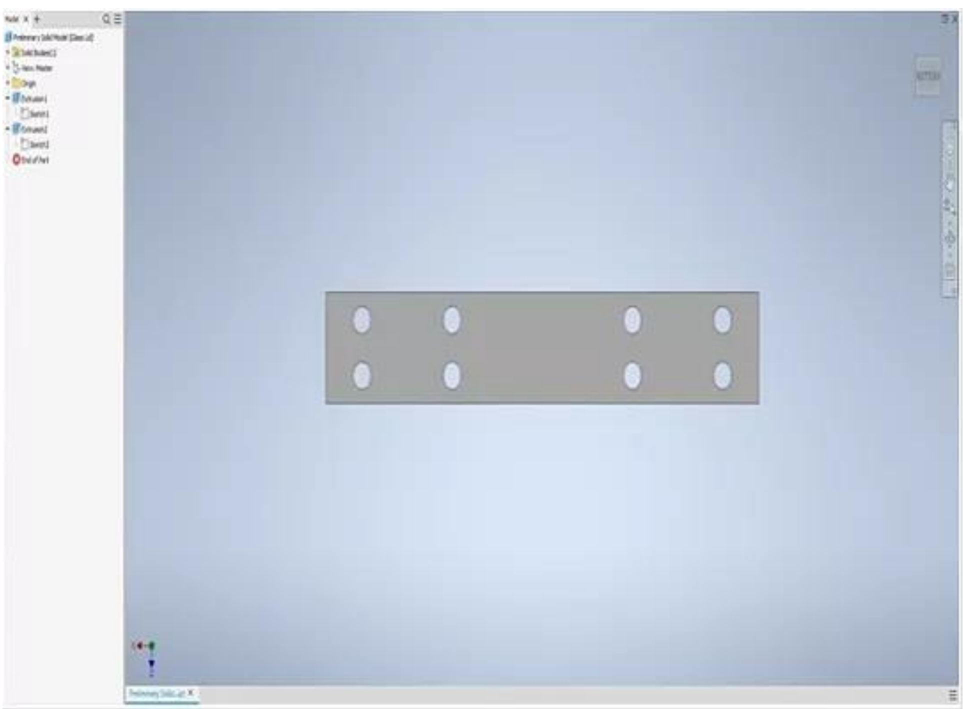
- ***Cylinders on side represent electromagnets***
- ***Holes represent ventilation holes***

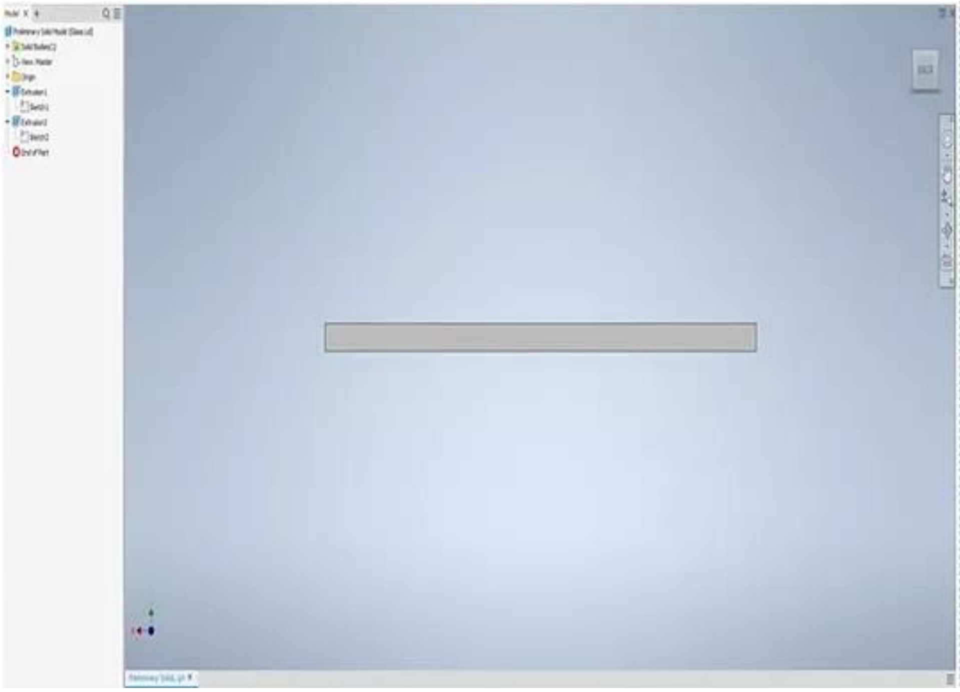




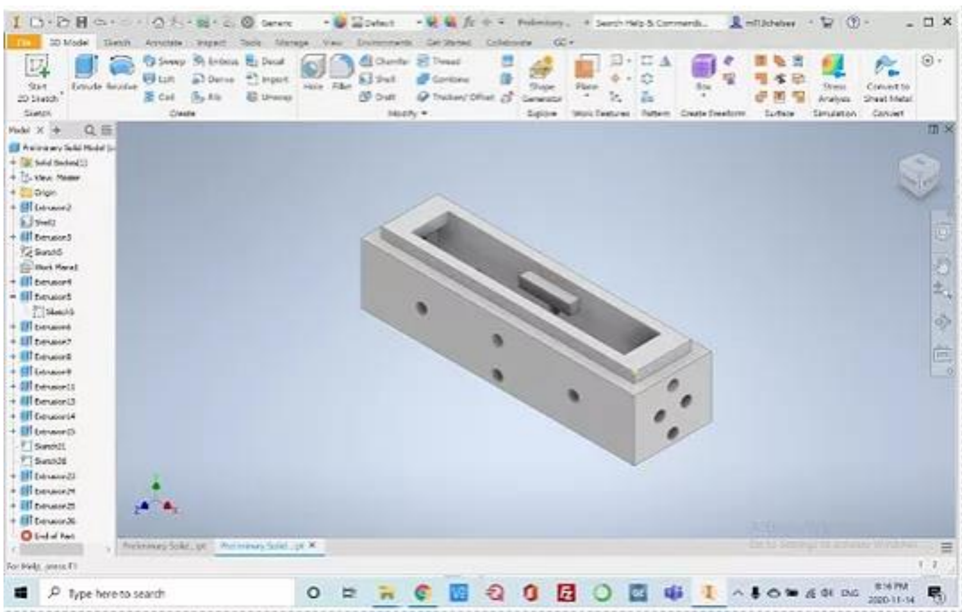
Preliminary Glass Lid:

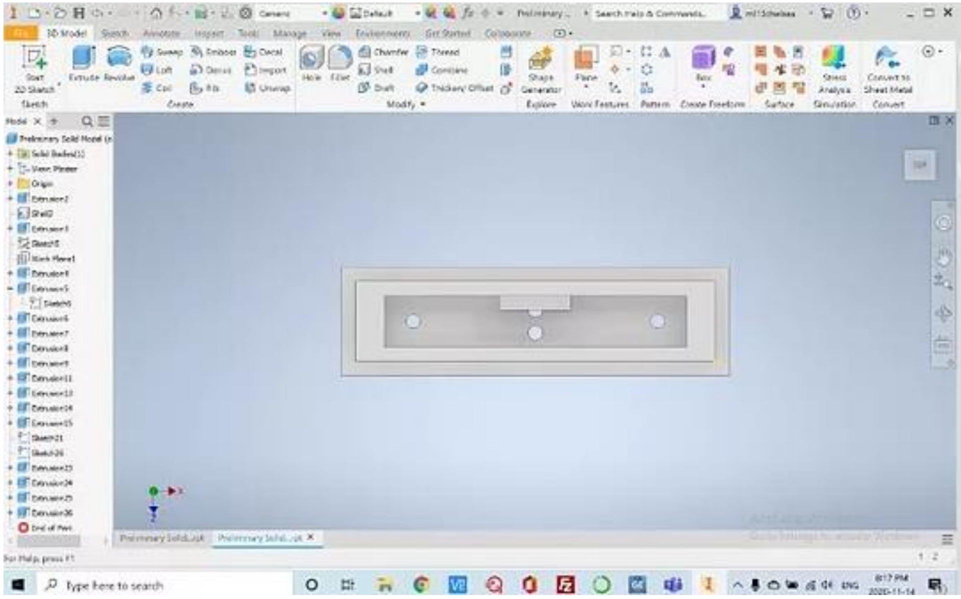
- **Holes represent ventilation holes**
- **Lid will be attached to the box using a hinge and is a push in lid**

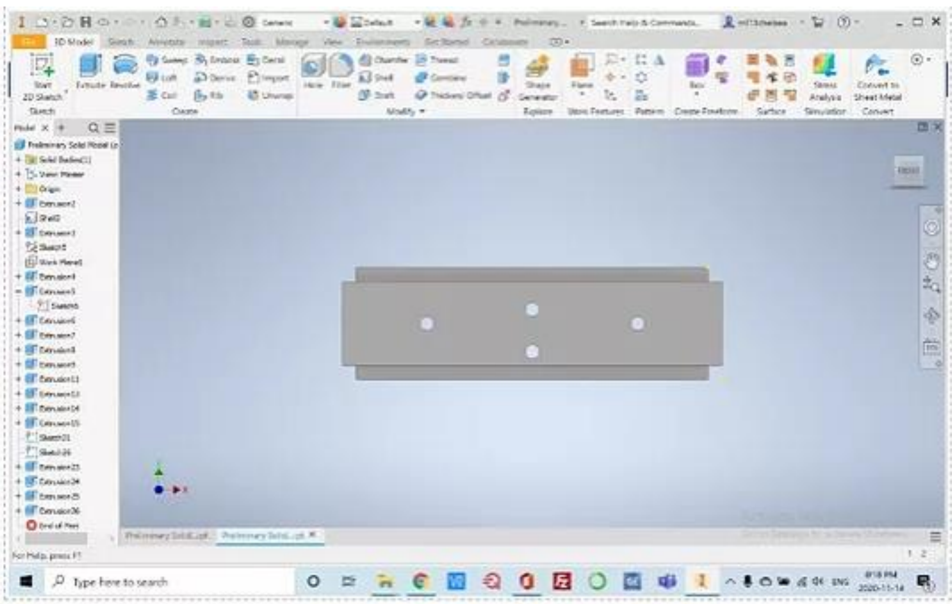




Matteo Lonardi

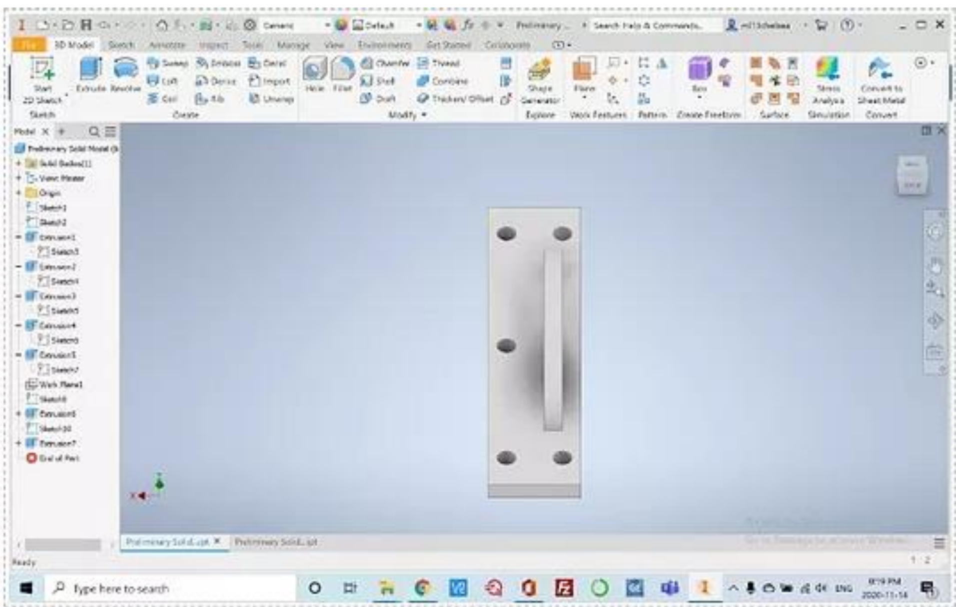






The rectangular extrusion along the side faces represents a Velcro padding. The holes are the ventilation openings, and the small indentation under the top opening represents a flap that will prevent the lid from falling in the box.

The picture can't be displayed.



This is the lid that would go on top of the container. There would be a hinge that connects the container to the lid, on the side opposite the handle.

Pugh Matrix

	Datum	Electromagnet	Velcro
Container has high durability	S	+	-
Container can be easily grasped	S	+	+
Container keeps contents secure	S	-	-
Container allows for efficient sterilization	S	-	-
Mass does not exceed 350 g	S	+	+
Pick-up and drop-off of container is reliable	S	+	-
Can fit inside an area of $1m^2$	S	S	S
Container can comfortably fit contents inside it	S	S	S
No features less than 4 mm	S	-	S
Width does not exceed 80 mm	S	S	S
Total +	0	+4	+2
Total –	0	-3	-4
Total Score	0	+1	-2

Explanation of Choice

The design that, according to the Pugh Matrix, should be considered the most successful would be the Electromagnet design. This design would work just as well as the Velcro design in many aspects, including size constraints, sterilization ability and how well it is securely holding the contents. However, the Electromagnet design would work better than the Velcro design would when it comes to durability. Electromagnets, while not perfectly durable over long periods of time, would last much longer than Velcro padding would. Velcro is very susceptible to wear over prolonged periods of usage; as the strips are ripped away from each other multiple times, their sticking capability slowly diminishes. If the container were dropped with the expensive surgical tools inside, there is a chance that the tools could break. The Electromagnet design also is more reliable than the Velcro design in picking up and dropping off the container. The electromagnets only need to be activated by an electrical current, and then the container would be picked up, and there is very little chance that it would be dropped or misplaced in the transfer to the drop-off location, where the current would need to be deactivated to initialize the drop-off process. However, for the Velcro design, there can be many errors. Along with the fact, as previously mentioned, that Velcro depreciates in durability over time, resulting in the increased chance that the container would be left behind during the pick-up process. Also, when dropping off the container, the two prongs of the arm would have to pull back on the Velcro at the exact same angle at the exact same time with the exact same force. If any of these did not happen, then the Velcro would become unattached from one of the Velcro pads on the prongs but would stick to the other pad. If this happened, it would become very difficult to remove it without human intervention. This problem is eliminated entirely in the Electromagnet design. Overall, the dimensions of the container on the Velcro design are much more effective than the electromagnet design; however, the electromagnets are much stronger than the Velcro. For the future, the combination of both the dimensions of the Velcro design and the electromagnets will be most effective as a final design.

Suggestions for the Future

For the future, the design should contain holders for the tool inside the container to limit the amount of movement from the tool. When observing the Datum, the Datum had holders in it, which was much more efficient in securing the tool compared to the designs for the container with electromagnets and Velcro. Another design feature that can be considered for the future is to add more ventilation holes into the box for easy sterilization (for the retractor). When examining the Datum, the number of ventilation holes was much greater than the number of ventilation holes on the preliminary designs. These ventilation holes allow the retractor to be sterilized much easier as there is more room for the steam to burn away the bacteria on the retractor. In the Velcro design, the material can be fragile and can wear off easily, so it would not be as efficient as the electromagnets. In the electromagnet design, the thickness is small and would not follow the constraint; thus, the Velcro design has better dimensions than the electromagnet design. For the future, the electromagnet design's thickness should be considered. In the electromagnet design, the ventilation holes on the front face can also be spread out more. In the future, the designs should take durability and efficiency as an essential requirement when being designed.

Preliminary Computation Programs

Aidan Gromek

```
def position_autoclave(number):
    greenbinsmall = [0.0,-0.67,0.3994]
    greenbinbig = [0.0,-0.35,0.47]
    redbinsmall = [-0.65,0.2172,0.4]
    redbinbig = [-0.35,0.13,0.48]
    bluebinsmall = [0.0,0.67,0.3994]
    bluebinbig = [0.0,0.35,0.47]

    if number == 1: ##greenbinsmall
        return greenbinsmall
    elif number == 2: ##greenbinbig
        return greenbinbig
    elif number == 3: ##redbinsmall
        return redbinsmall
    elif number == 4: ##redbinbig
        return redbinbig
    elif number == 5: ##bluebinsmall
        return bluebinsmall
    elif number == 6: ##bluebinbig
        return bluebinbig
```

Xiaoxiang Diao

```
def move_end_effector():
    while True:
        emg.update()
        print("Left:",emg.myoL,"Right:",emg.myoR)
        time.sleep(0.25)
        if 0.2<emg.myoL and emg.myoL<0.4:
            arm.move_arm(0,-0.635,0.3994)
        elif 0.4<emg.myoL and emg.myoL<0.6:
            arm.move_arm(-0.5967,0.2172,0.3744)
        elif 0.6<emg.myoL and emg.myoL<0.8:
            arm.move_arm(0,0.635,0.3994)
        else:
            arm.move_arm(0,0,0)
```

Code Peer-Review

Identify Autoclave Bin Location Task	**Team Member Name**: Aidan Gromek
Enter code errors and/or observations here • Different position for each container • Use of if and elif structure • (x,y,z) coordinates for the container positions recorded as a list • Function takes in the shape ID represented by an integer between 1 and 6 inclusive	
Move End-Effector Task	**Team Member Name**: Xiaoxiang Diao
Enter code errors and/or observations here • Need to def a function while moving the arm. • Sleep time of 0.25 may need to be increased so that we can move the q-arm to the desired location with no problems • Uses emg to obtain the values that will decide where the q-arm moves • Uses if, elif, else structure with ranges of values as conditions to move the q-arm • Does not use a threshold in function • Only concerned about left arm in emg	

Program Task Pseudocode

Control Gripper

```
Define a function that takes in a numerical value representing a small container or a large container
        Set different values for the amount of the gripper will close for a large container and another for the small container
        If the parameter value represents a small container
                Create an infinite loop
                        if the value of the muscle sensor exceeds the threshold value for both the right and left arms
                                Close the gripper to the amount set for a small container
                                Sleep for 2 seconds
                                Break from the loop
                        if the value of the muscle sensor exceeds the threshold value for just the right and not the left arm
                                Open the gripper
                                Sleep for 2 seconds
                                Break from the loop
        if the parameter value represents a large container
                Create an infinite loop
                        if the value of the muscle sensor exceeds the threshold value for both the right and left arms
                                Close the gripper to the amount set for a large container
                                Sleep for 2 seconds
                                Break from the loop
                        if the value of the muscle sensor exceeds the threshold value for just the right and not the left arm
                                Open the gripper
                                Sleep for 2 seconds
                                Break from the loop
```

Open Autoclave Bin Drawer

```
Define an opening bin drawer function that takes in a numerical value that represents either green, red or blue
        The function would determine whether this parameter value represents green, red or blue
        If the parameter value represents the Green bin
                Open the drawer of the green autoclave bin
        If the parameter value represents the Red bin
                Open the drawer of the red autoclave bin
        If the parameter value represents the Blue bin
                Open the drawer of the blue autoclave bin
```

Continue or Terminate

```
Define a function that takes in number of containers successfully placed in the autoclave
        if the parameter value is between 0 and 5
                Continue to run the program
        if the parameter value is 6
                Terminate the program
        If the parameter value is anthing else print that an invalid number of containers has been entered
```

Milestone 4

Modelling Sub-team feedback

Use the space below to document mentor feedback for your design.

- The container fits in the footprint (117mm, 21mm, 40mm) => without the lid (lid adds 10mm of height)
- All features all greater than 4mm
- The retractor width never exceeds 21mm
- Surgical Tool fits inside the container
- After scaling, spool length required is 4.19m
- Mass was 12.49g
- Mass constraint and print time constraint were met

Use the space below to propose design refinements based on the feedback.

- Make an assembly to ensure the retractor does not rattle or fall out
- Find a way to secure the tool if necessary
- How would you prevent the tool from moving around inside the container?
  ==> Maybe with a lid or hinges
- To make the 3-D printing easier fillet the underside of the overhanging nub piece inside the container

Computing Sub-team feedback

Use the space below to document mentor feedback for your design.

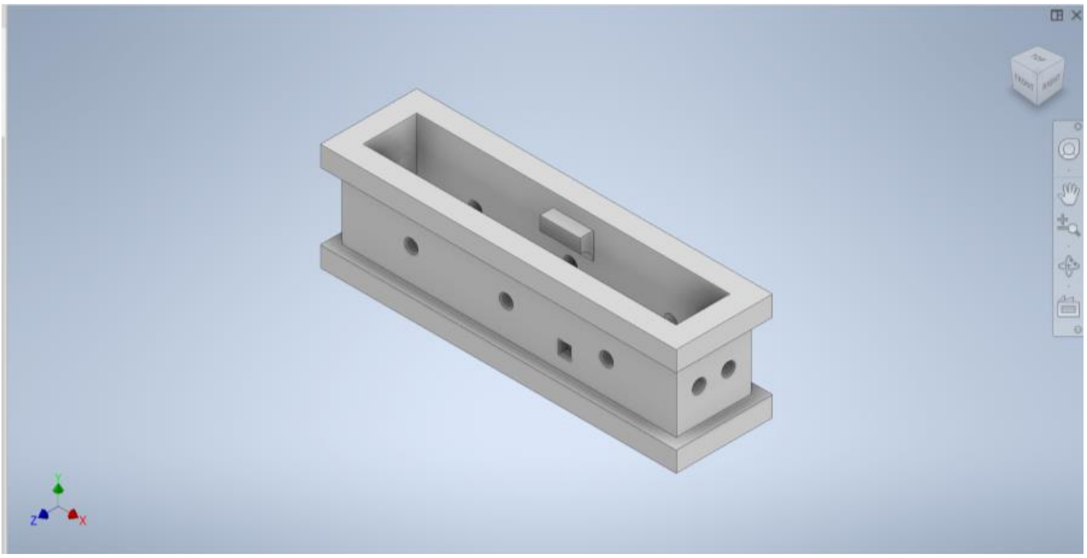
- Program successfully performs one cycle of pickup, grab and drop off

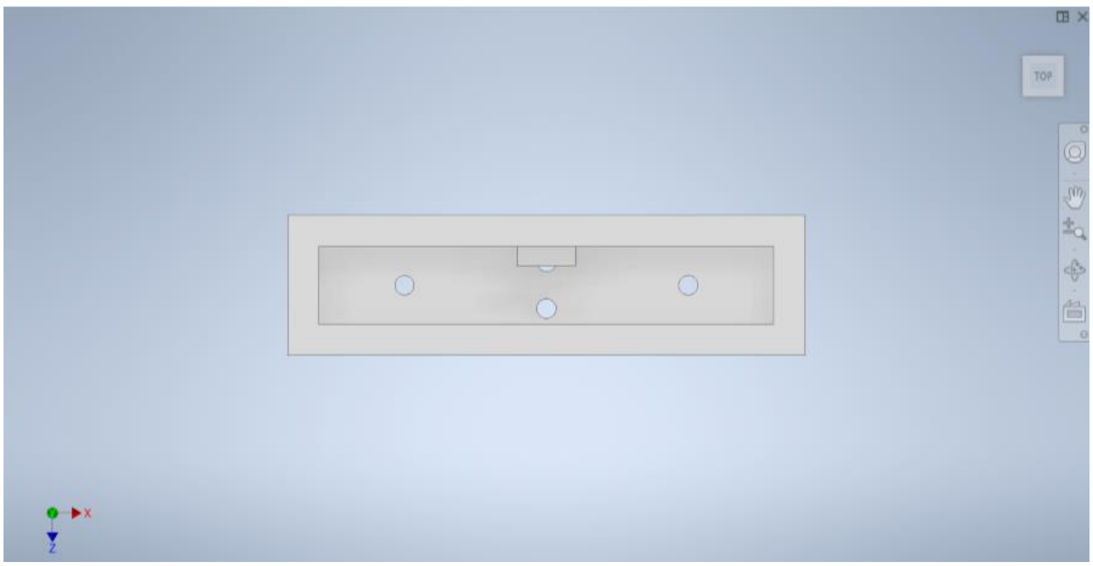
Use the space below to propose design refinements based on the feedback.

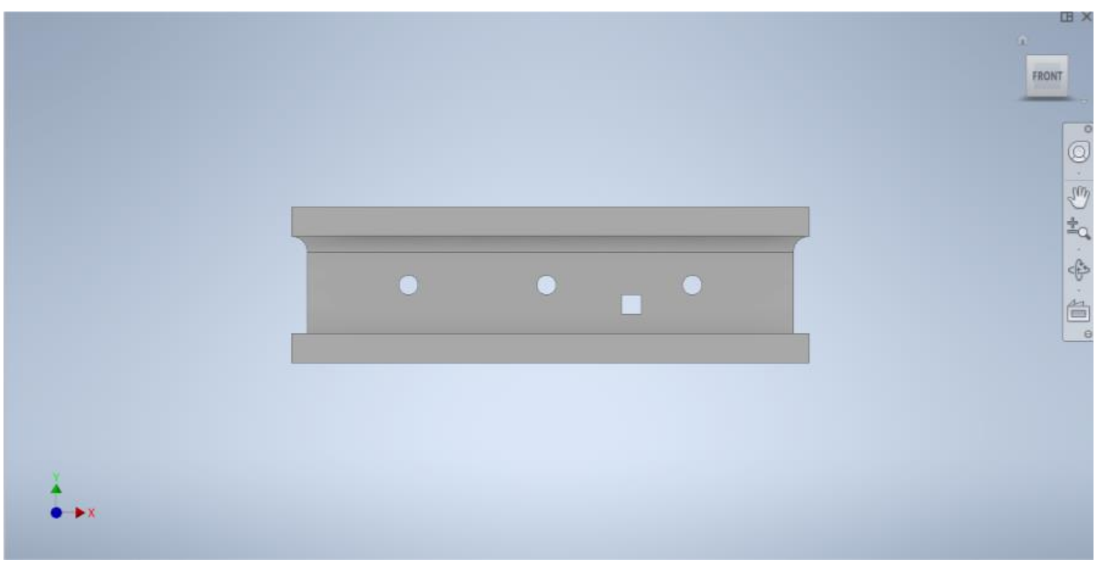
- Make a def main function instead of a large block of code representing the main to modularize the code
- Make the spawn container block of code into its own function since it is a stand-alone feature of the program just like the others
- Add comments to help those reviewing our code

Appendix A: Solid Model - Final Design

Container

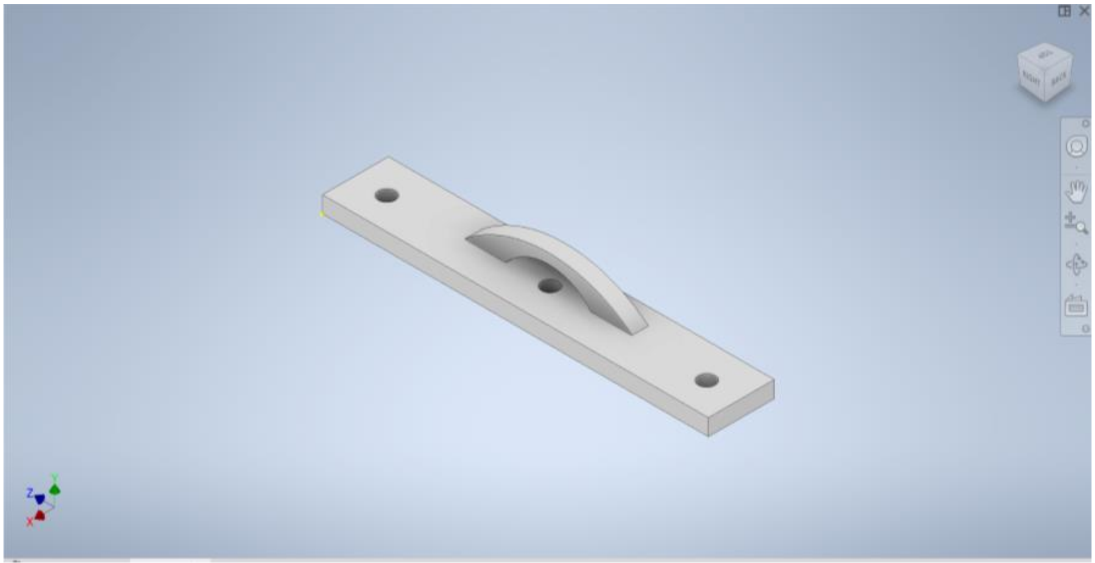






Lid

(would be connected to the container via hinges)



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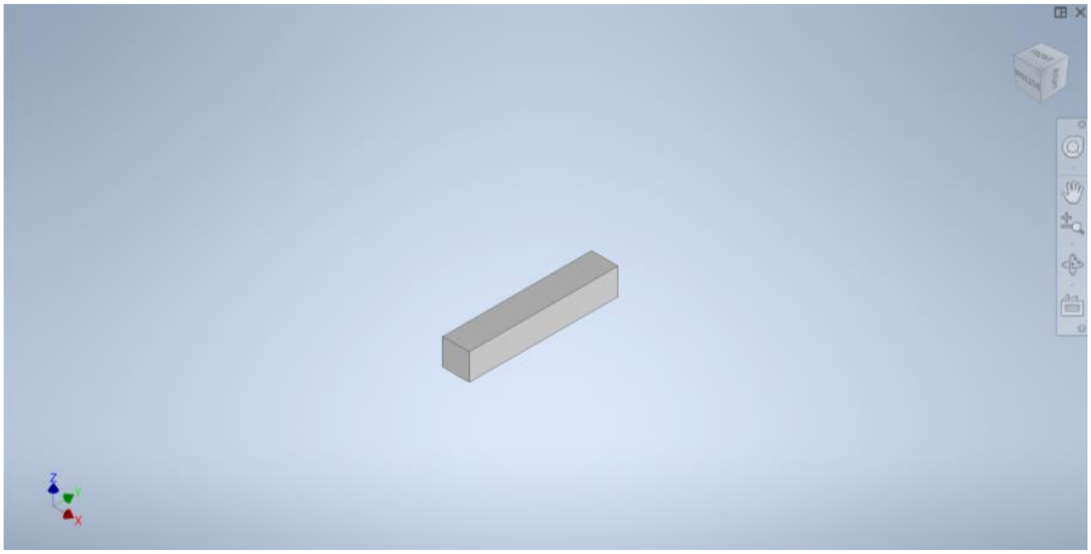
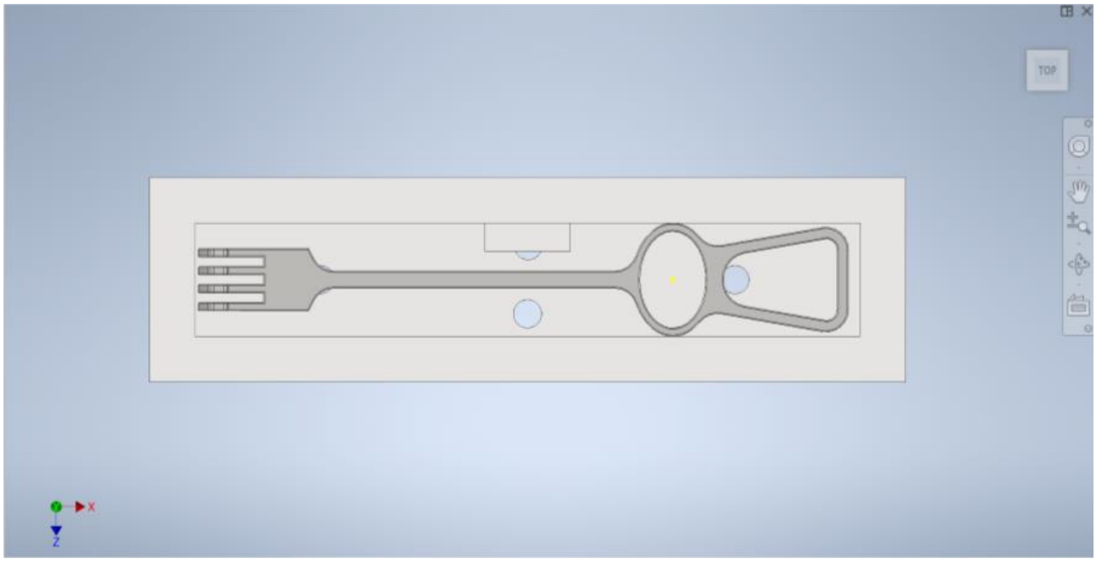
Seatbelt

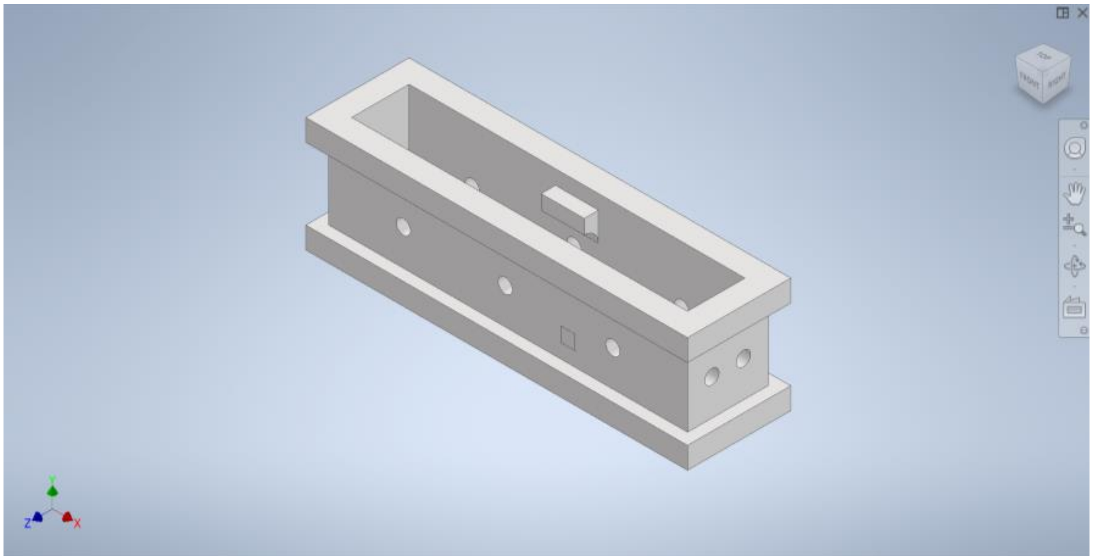
(holds the retractor in place)

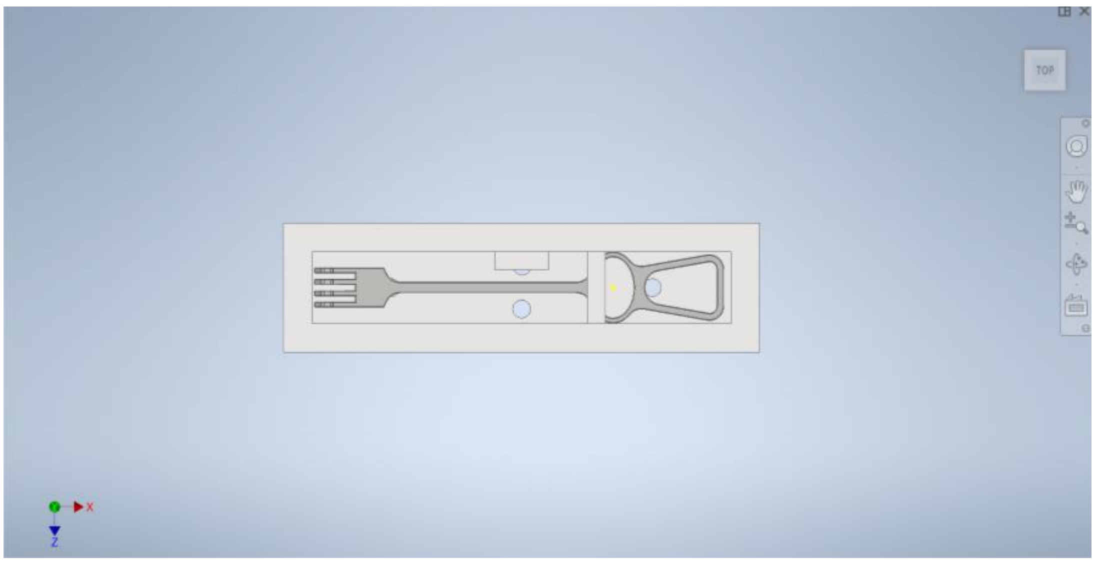


Retractor in Container



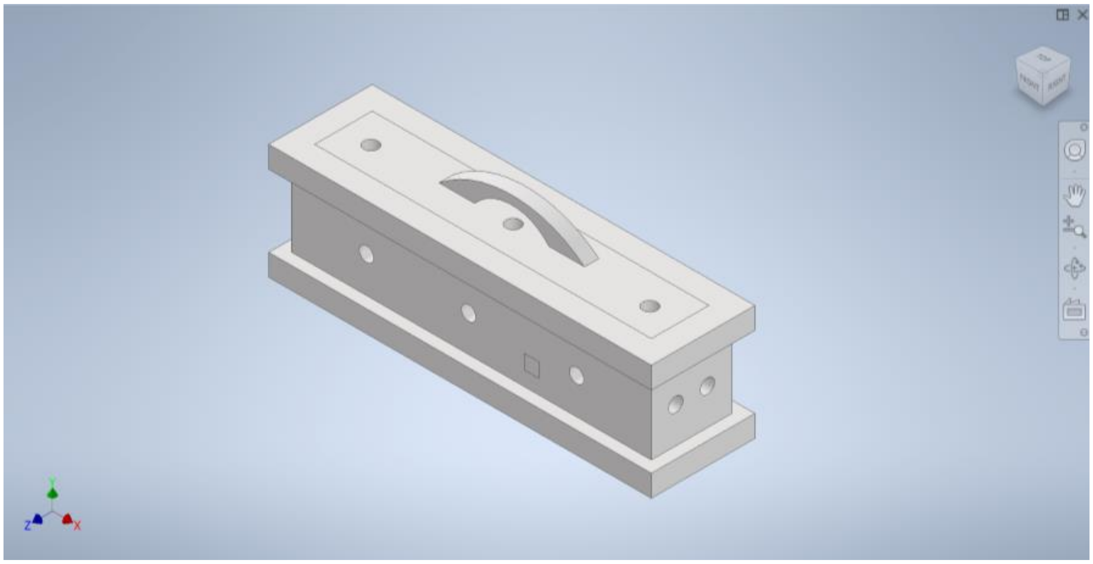
Seatbelt in, securing the retractor



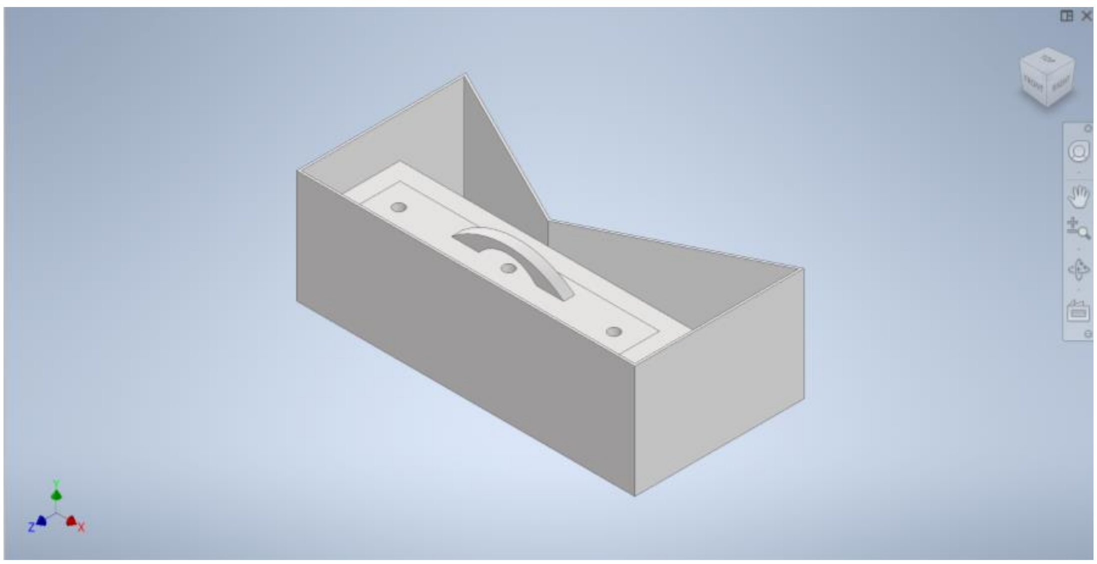


Lid securely on container

(hinges would be placed where the red markers are)

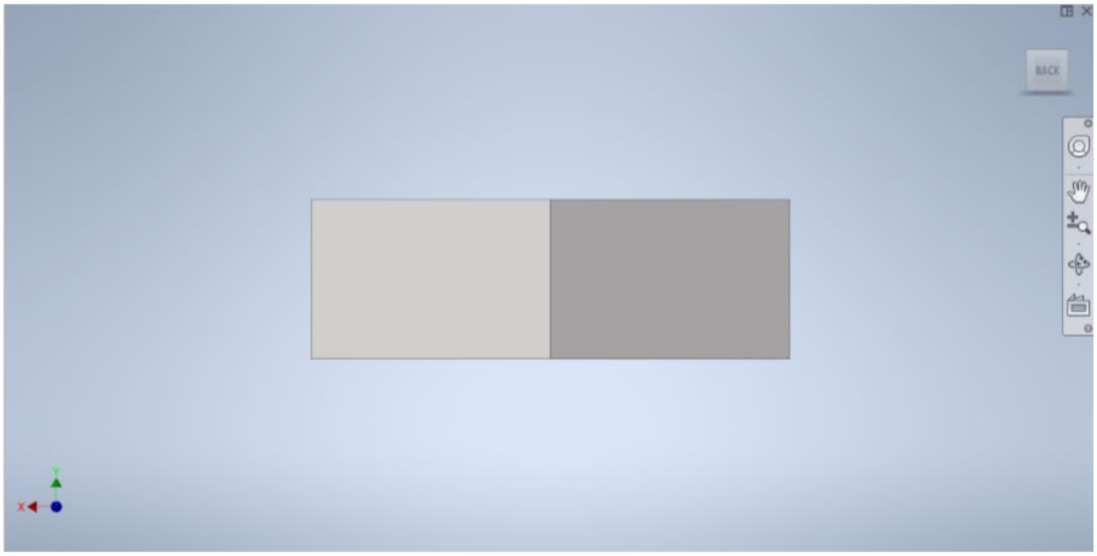


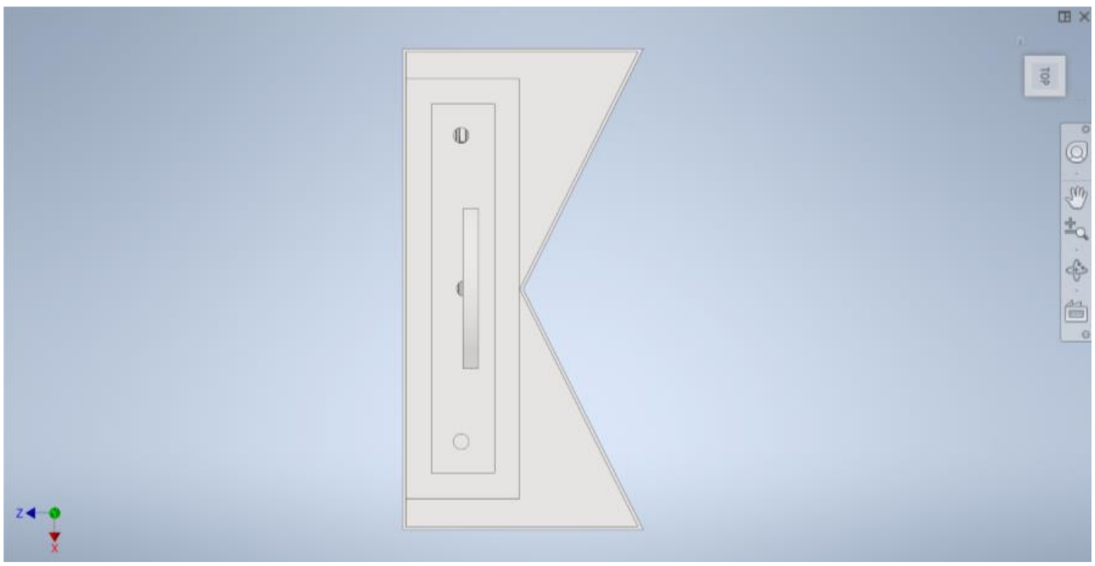
Container in footprint



Side views

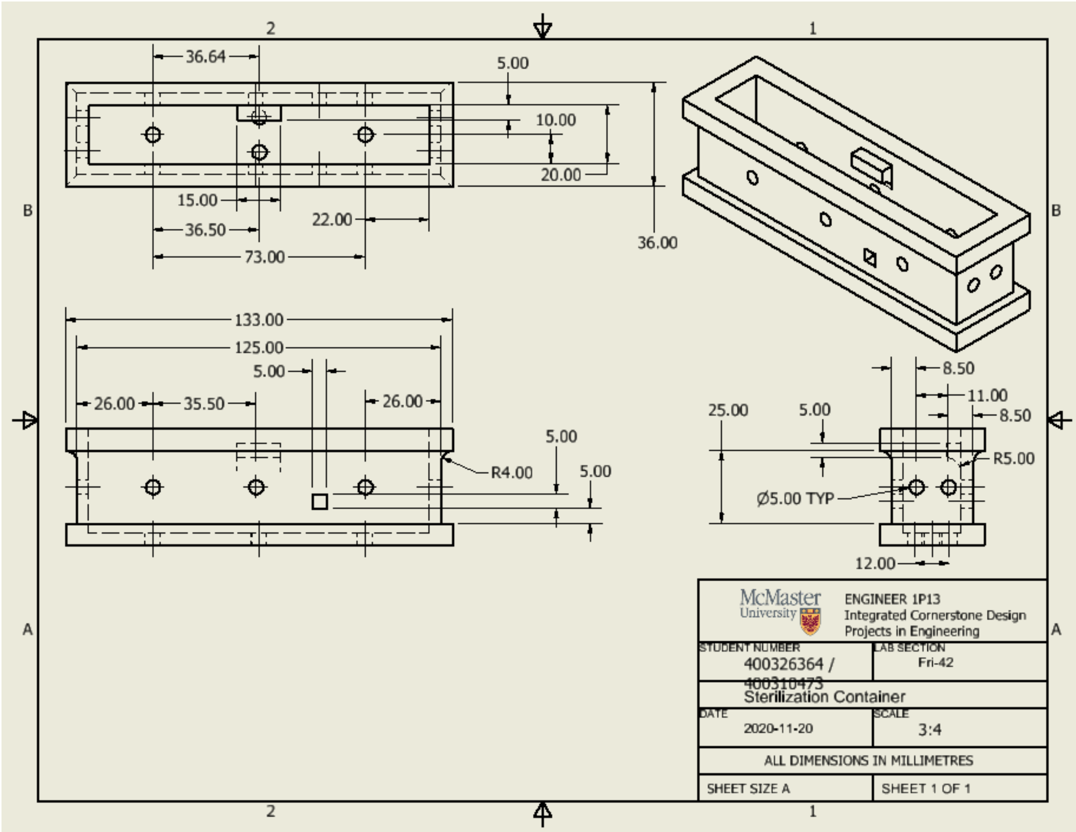
(making sure container is proper height (1) and proper length and width (2))





Appendix B: Engineering Drawings of Components

Container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5.00
10.00
20.00
15.00
36.50
22.00
73.00
36.00
133.00
125.00
5.00
26.00
35.50
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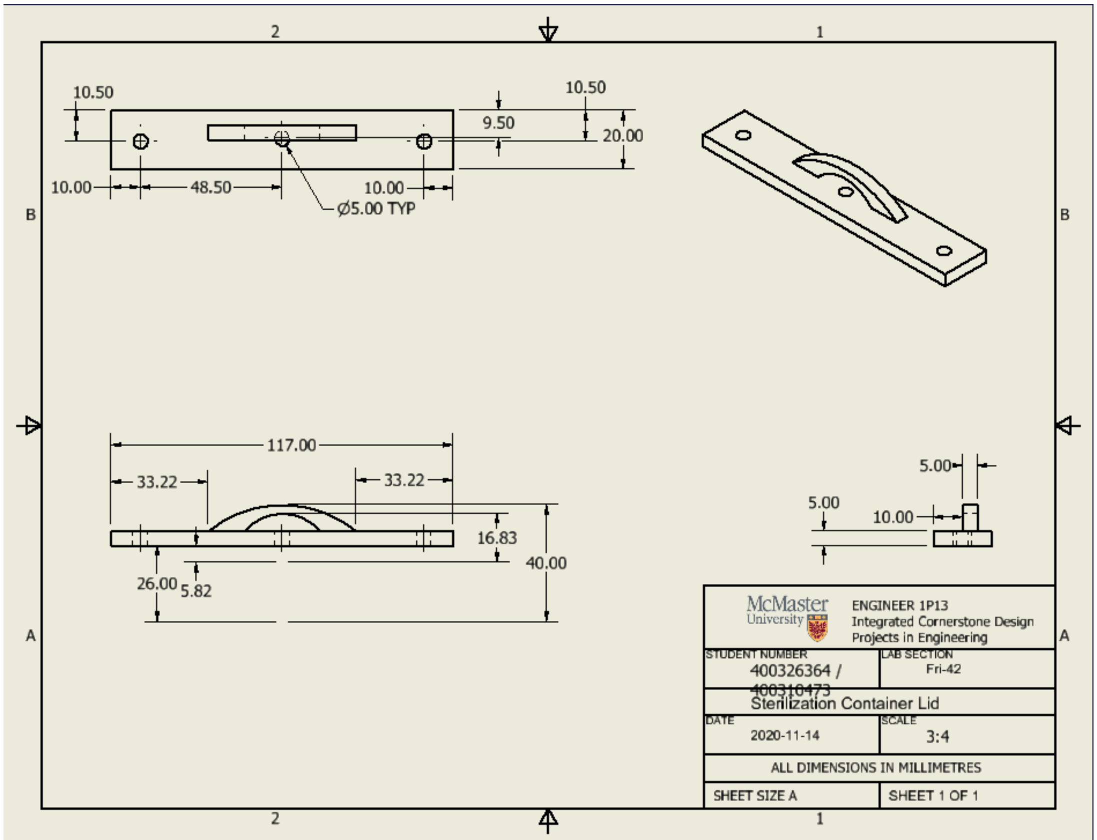
5.00
R4.00
5.00
8.50
11.00
8.50
25.00
5.00
R5.00
Ø5.00 TYP
12.00
McMaster University
ENGINEER 1P13
Integrated Cornerstone Design Projects in Engineering
STUDENT NUMBER
400326364 / 400310473
LAB SECTION
Fri-42
Sterilization Container
DATE
2020-11-20
SCALE
3:4
ALL DIMENSIONS IN MILLIMETRES
SHEET SIZE A
SHEET 1 OF 1

Lid: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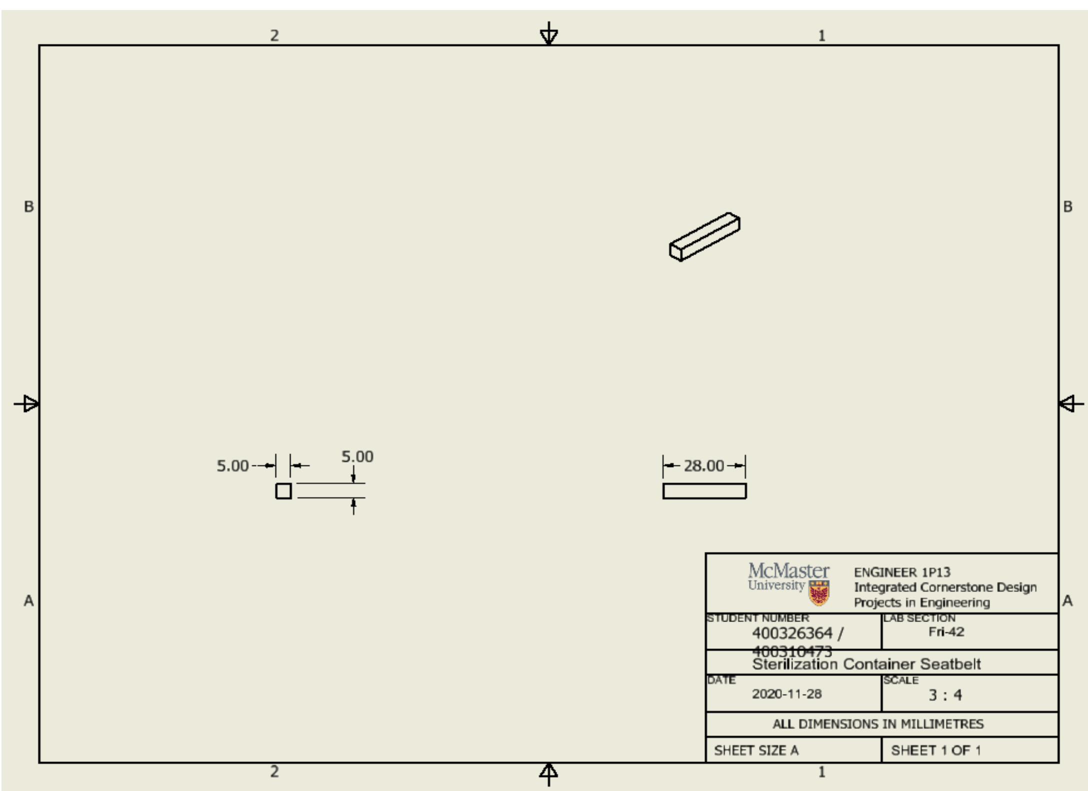
10.50
9.50
20.00
10.00
48.50
10.00
Ø5.00 TYP
117.00
33.22
33.22
16.83
40.00
26.00
5.82
5.00
5.00
10.00
McMaster University
ENGINEER 1P13
Integrated Cornerstone Design
Projects in Engineering
STUDENT NUMBER
400326364 /
400310473
LAB SECTION
Fri-42
Sterilization Container Lid
DATE
2020-11-14
SCALE
3:4
ALL DIMENSIONS IN MILLIMETRES
SHEET SIZE A
SHEET 1 OF 1

Seatbelt: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McMaster University
ENGINEER 1P13
Integrated Cornerstone Design
Projects in Engineering
STUDENT NUMBER
400326364 /
400310473
LAB SECTION
Fri-42
Sterilization Container Seatbelt
DATE
2020-11-28
SCALE
3 : 4
ALL DIMENSIONS IN MILLIMETRES
SHEET SIZE A
SHEET 1 OF 1

Appendix C: Final Computer Program

```
import random
import sys
sys.path.append('../')

from Common_Libraries.p2_lib import *

import os
from Common_Libraries.repeating_timer_lib import repeating_timer

def update_sim ():
    try:
        arm.ping()
    except Exception as error_update_sim:
        print (error_update_sim)

arm = qarm()

update_thread = repeating_timer(2, update_sim)
```

```
def position_autoclave(container_ID):

    if container_ID == 1: #redbinsmall
        position_final_list = [-0.5915,0.2362,0.4331]
        return position_final_list
    elif container_ID == 2: #greenbinsmall
        position_final_list = [0.0,-0.645,0.455]
        return position_final_list
    elif container_ID == 3: #bluebinsmall
        position_final_list = [0.0,0.645,0.455]
        return position_final_list
    elif container_ID == 4: #redbinbig
        position_final_list = [-0.3455,0.14,0.3436]
        return position_final_list
    elif container_ID == 5: #greenbinbig
        position_final_list = [0.0,-0.4030,0.3436]
        return position_final_list
    elif container_ID == 6: #bluebinbig
        position_final_list = [0.0,0.4053,0.3436]
        return position_final_list
```

```
def move_end_effector(positionx, positiony, positionz):
    thres = 0.5
    while True:
        time.sleep(0.4)
        if arm.emg_left()>thres and arm.emg_right()>thres: #both right and left
            arm.move_arm(positionx, positiony, positionz)
            time.sleep(0.25)
            break
```

```python
def control_gripper (container_ID):
    thres = 0.5
    while True:
        time.sleep(0.4)
        if container_ID < 4: #small containers
            if arm.emg_left()>thres and arm.emg_right()<thres:
                arm.control_gripper(35) #left arm greater than threshold and rig
                time.sleep(0.25)
                break
            elif arm.emg_left()<thres and arm.emg_right()<thres:
                arm.control_gripper(-35) #both arms less than threshold opens th
                time.sleep(0.25)
                break
        if container_ID > 3: #large containers
            if arm.emg_left()>thres and arm.emg_right()<thres: #left arm greater
                arm.control_gripper(25)
                time.sleep(0.25)
                break
            elif arm.emg_left()<thres and arm.emg_right()<thres:
                arm.control_gripper(-25) #both arms less than threshold opens th
                time.sleep(0.25)
                break
```

```python
def autoclave_bin_drawer(container_ID):
    thres = 0.5
    while True:
        time.sleep(0.4)
        if container_ID == 4: #Large Red Bin
            if arm.emg_left()<thres and arm.emg_right()>thres:
                arm.open_red_autoclave(True) #opens the red drawer
                time.sleep(0.25)
                break
            elif arm.emg_left()<thres and arm.emg_right()<thres:
                arm.open_red_autoclave(False) #closes the red drawer
                time.sleep(0.25)
                break
        if container_ID == 5: #Large Green Bin
            if arm.emg_left()<thres and arm.emg_right()>thres:
                arm.open_green_autoclave(True) #opens the green drawer
                time.sleep(0.25)
                break
            elif arm.emg_left()<thres and arm.emg_right()<thres:
                arm.open_green_autoclave(False) #closes the green drawer
                time.sleep(0.25)
                break
```

```python
        if container_ID == 6: #Large Blue Bin
            if arm.emg_left()<thres and arm.emg_right()>thres:
                arm.open_blue_autoclave(True) #opens the blue drawer
                time.sleep(0.25)
                break
            elif arm.emg_left()<thres and arm.emg_right()<thres:
                arm.open_blue_autoclave(False) #closes the blue drawer
                time.sleep(0.25)
                break
```

```
def spawn_container(container_ID):
    arm.spawn_cage(container_ID)
    time.sleep(2)



def main():
    pickup_position = [0.5035, 0.0, 0.0139] #pickup position
    position_final_list = [] #empty list to hold the x,y,z positions
    container_list = [1,2,3,4,5,6]
    random.shuffle(container_list)
    print("Whenever both arms are lowered make sure to lower the left arm first.
```

```
    for container_ID in container_list:
        print("Container ID is: ", container_ID)
        spawn_container(container_ID)
        position_final_list = position_autoclave(container_ID) #sets the final p
        move_end_effector(pickup_position[0], pickup_position[1], pickup_positio
        control_gripper(container_ID)
        move_end_effector(0.4064,0.0,0.4826) #moves home while still closed to a
        time.sleep(0.25)
        move_end_effector(position_final_list[0], position_final_list[1], positi
        if container_ID > 3: #used for large containers that need the autoclave
            autoclave_bin_drawer(container_ID)
            control_gripper(container_ID)
            time.sleep(0.5)
            autoclave_bin_drawer(container_ID)
            time.sleep(0.5)
        else: #these must be small containers so the autoclave drawer is not nee
            control_gripper(container_ID)
            time.sleep(0.5)
        arm.home() #return home

#Main Running
main()
```

Appendix D: References

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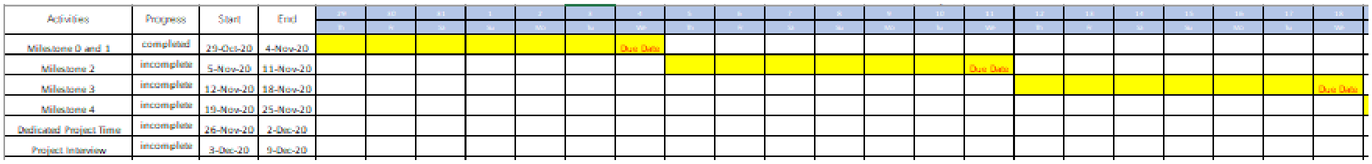
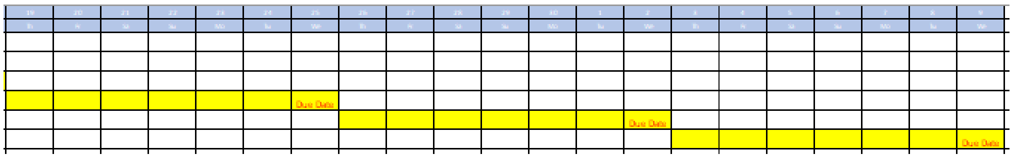
Appendix E: Gantt Chart

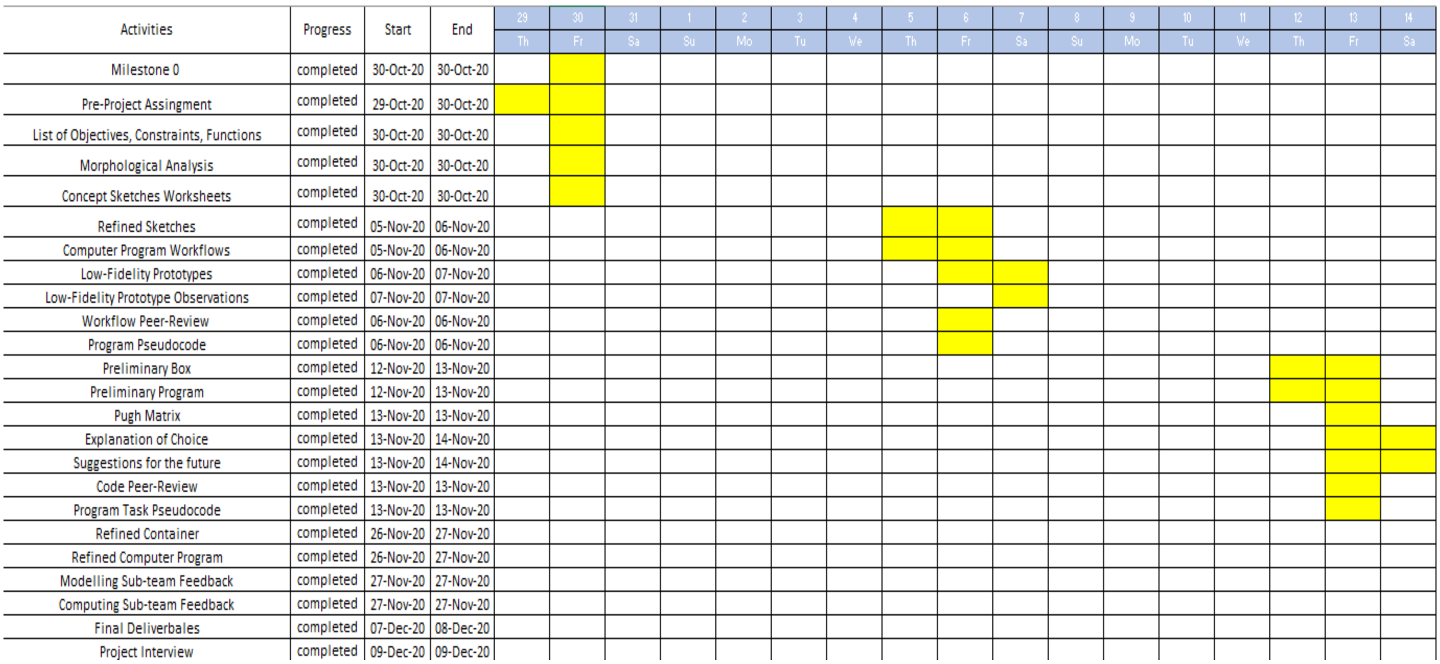
Preliminary Gantt Chart





Final Gantt Chart

(Dates located at top row of the Gantt chart)



Continuation of Final Gantt Chart

(Ranging from November 24th to December 9th)

21st row: Refined Container

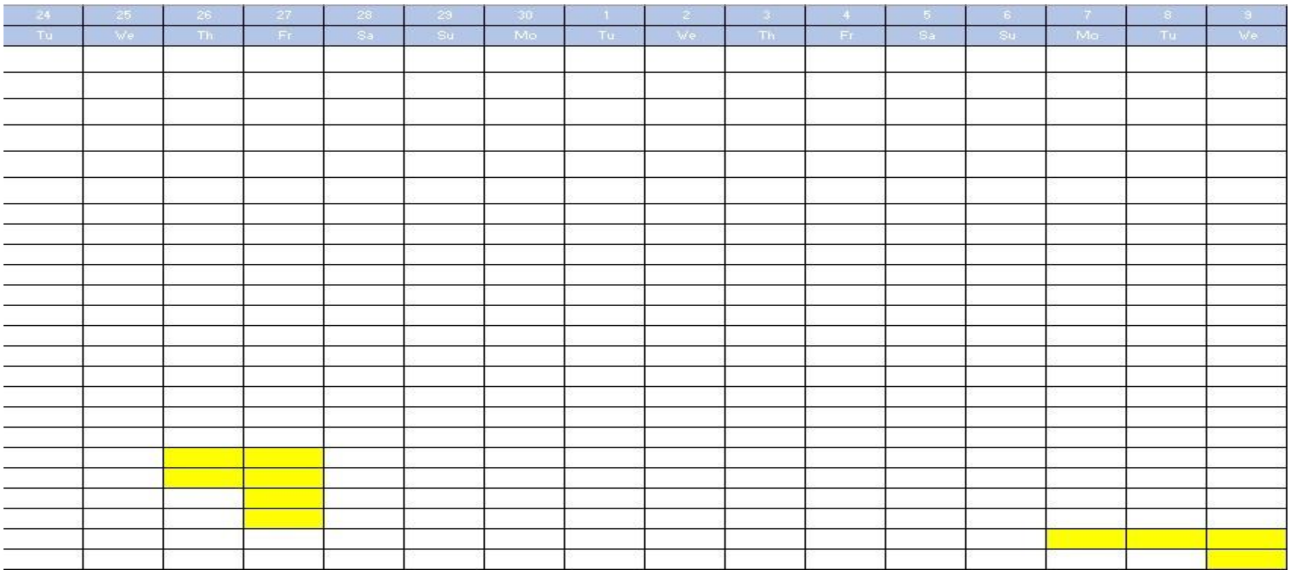
22nd row: Refined Computer Program

23rd row: Modelling Sub team Feedback

24th row: Computing Sub team Feedback

25th row: Final Deliverables

26th row: Project Interview



Appendix F: Scheduled Weekly Meetings

Activities	Meeting number	Meeting date
Milestone 0 and 1	1	30-Oct-20
Milestone 2	2	6-Nov-20
Milestone 3	3	13-Nov-20
Dedicated Project Time	4	20-Nov-20
Milestone 4	5	27-Nov-20