ENGINEERING

McMaster University

# Project Two – Get a Grip:

## Design a System for Sterilizing Surgical Tools Using Remote Sensing and Actuation

*ENGINEER 1P13 – Integrated Cornerstone Design Projects*

Tutorial 01

Team Mon-01

Marcus Cohoon (cohoom1)

Boshi Xu (xub35)

Xiang Zhang (zhanx326)

Eashwaar Mahibal (mahibale)

Aaryan Walia (waliaa9 )

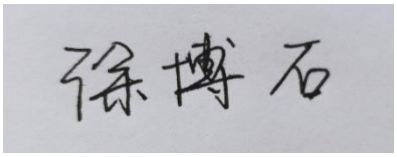
Submitted: November 4, 2020

# *Table of Contents*

## *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.

Boshi Xu 400314444.



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.

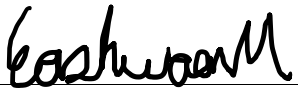
Xiang Zhang 400306856

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.

Marcus Cohoon 400297985

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.

Eashwaar Mahibal 400315190

x 

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.

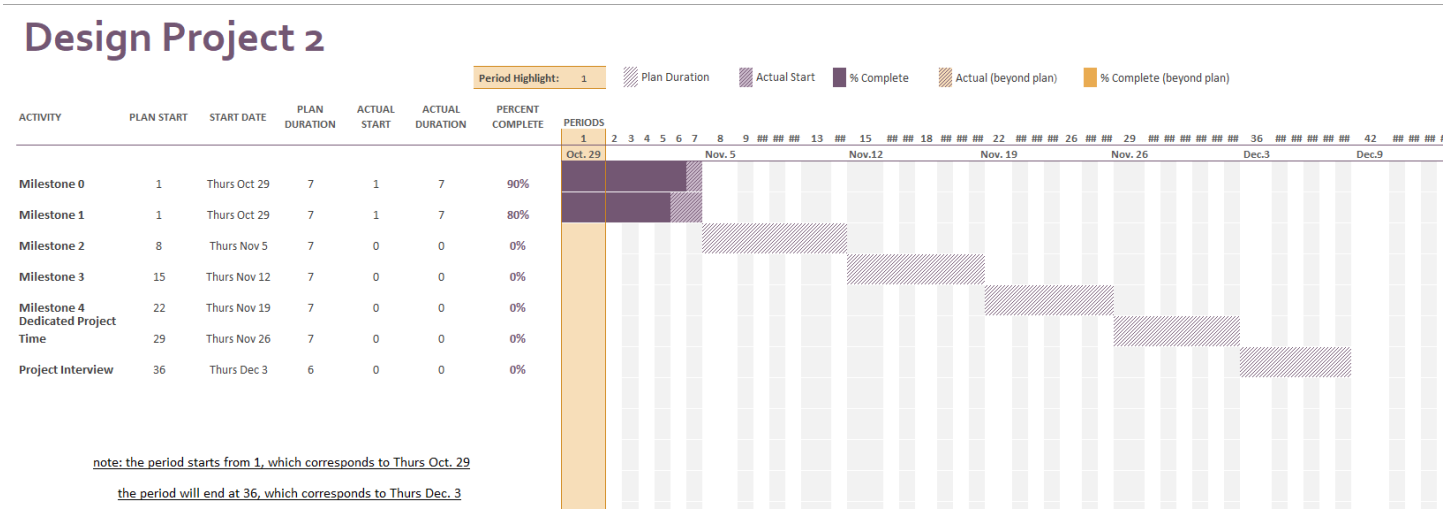
Aaryan Walia 400330671

## *Executive Summary*

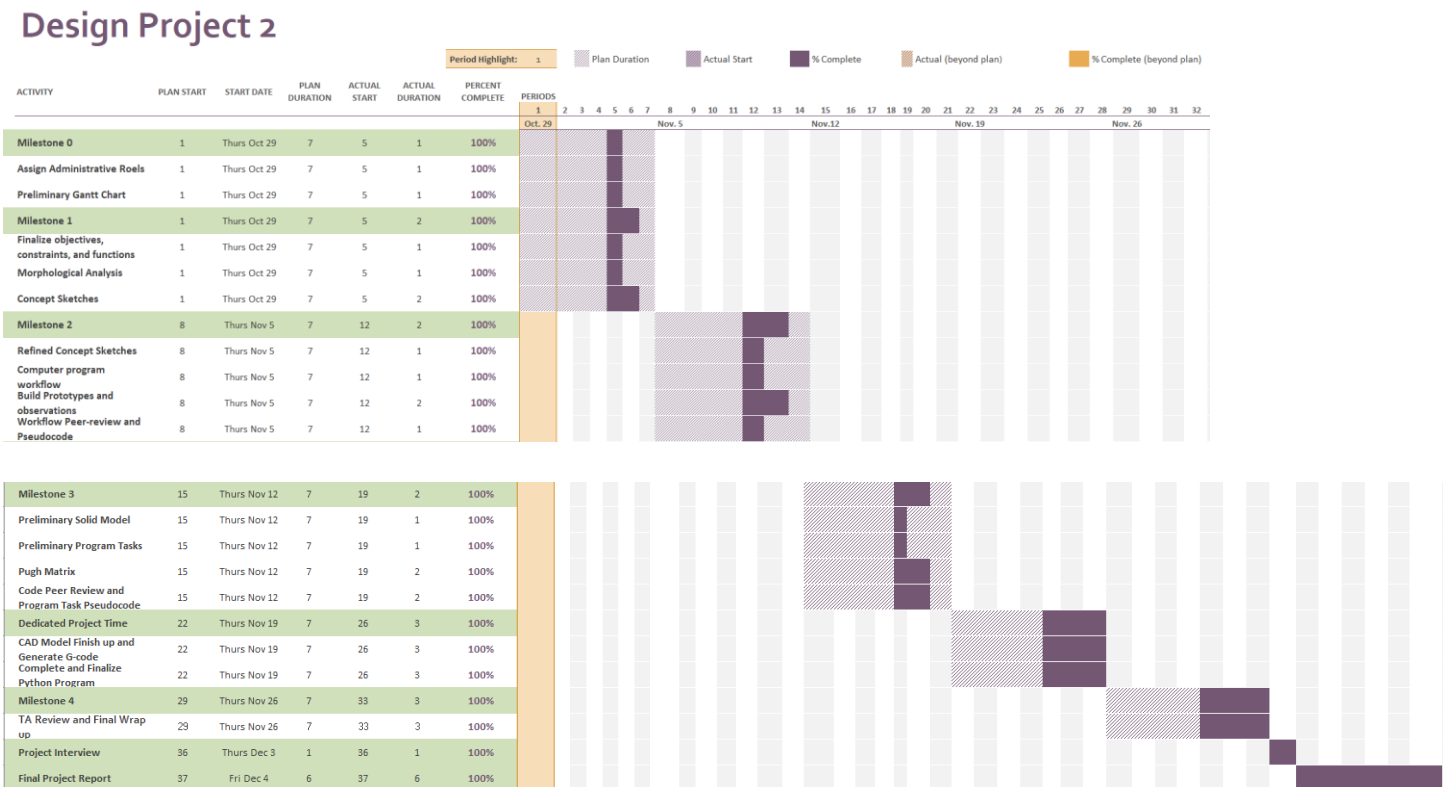
Throughout the course of this project we investigated the possibility of implementing a robot arm to facilitate the transfer of surgical instruments in a strategically designed container to various autoclaves for sterilization. This experiment is crucial to Canadian citizens living in rural areas because, according to Newfoundland and Labrador Medical Association, this demographic generally have a shorter life expectancy than those who live in more densely populated areas [1]. Rural Canadian Citizens make up a fifth of the total population, yet they only have access to 8% of the country's physicians [2].This is largely due to the simple fact that access to healthcare in these areas are extremely limited. This often leads to Canadian's living in these area's traveling great distances if they wish to receive any kind of care at all [1]! The Government of Canada creates policies that are often tailored solely toward urban healthcare, creating a consistent inequality for Indigenous people who make up the majority of the rural population [2]. A solution to this problem that is becoming increasingly more tangible is the implementation of remote healthcare, an option that is currently being implemented in Newfoundland and Labrador [3]. Remote healthcare includes things like telephone or video calls with a physician, recording and transmitting personal health indicators, and even remote surgery. With more research, remote surgery will allow a specialist to operate and control instruments with a robotic system without personally being there [4]. A key component of surgery that can also be facilitated remotely, is the sterilization of instruments which is often executed using autoclaves. Autoclaves are bins that sterilize objects through the use of pressurized steam [5]. This project proves that this solution is not a distant reality by both executing this crucial component of surgery and acting as a pre-cursor to future research in the development of the more complicated surgical system. Throughout the course of the project, a computer program was developed to control a robotic arm, in response to data from a bicep muscle sensor, in order to pick up and deliver containers of surgical instruments to their matching autoclave bins. In addition, a container was specially designed, using CAD modeling software, to securely hold instruments and allow for sterilization in an autoclave. After the completion of the project it was determined, using a virtual environment, that the program can successfully and remotely execute the pick-up and deliver of surgical instruments to their respective autoclave bins for sterilization. It was also determined that the container could successfully hold a surgical instrument using specially designed pegs and facilitate sterilization via a mesh sliding lid. Based on these successfully results, the Canadian government should look to fund remote surgery research in order to end the inequality in healthcare rural Canadians face everyday.

# *Project Schedule*

## Preliminary Gantt Chart




## Final Gantt Chart




## Logbook of Additional Meetings and Discussions

| **Date** | **Reason** | **Time** |
|---|---|---|
| **2020-11-5** | **Milestone 2 for Modelling team** | **12:30-2:30** |
| **2020-12-04** | **Finish Design project report** | **12:00pm-3:00pm** |

## *Scheduled Weekly Meetings*

### Weekly Design Studio Agenda's

| Week # | Milestone #/Activity | Agenda |
|---|---|---|
| Week 7 | Milestone 0 & 1 | No meeting |
| Week 8 | Milestone 2 | Work on the Low-Fidelity Prototype Observations and Program Pseudocode |
| Week 9 | Milestone 3 | Pugh Matrix and Code Peer-Review & Program Task Pseudocode |
| Week 10 | Dedicated Project Time | Finish Design |
| Week 11 | Milestone 4 | TA Review (Present work has been done) |
| Week 12 | Project Demonstration and Interview | Interview |

### Weekly Design Studio Meeting Minute's

# ENGINEER 1P13

## MEETING WITH TEAM Mon-01 – Monday Nov 9th

### ATTENDANCE

| Role | Name | Mac ID | Attendance (Yes/No) |
|---|---|---|---|
| Manager | Boshi Xu | xub35 | yes |
| Administrator | Xiang Zhang | zhanx326 | yes |
| Coordinator | Aaryan Walia | waliaa9 | yes |
| Subject Matter Expert | Marcus Cohoon/ | Cohoom1 | yes |
| | Eashwaar Mahibal | Mahibale | yes |
| *Guest* | **Omar Sanad** | | yes |

### AGENDA ITEMS

1. Update TA on team progress

### MEETING MINUTES (4MIN)

1. .
    a. Modelling team talks about why they choose their prototypes
2. .
    a. Computation team explains their workflow diagram
3. .
    a. Talk about next steps
4. .
    a.
5. .
    a.

### POST-MEETING ACTION ITEMS

1. *Create low-fidelity prototype [Modelling team]*
2. *Write out pseudocode [Computation team]*

# MEETING WITH TEAM Mon-01 – Monday Nov 16th

| Role | Name | Mac ID | Attendance (Yes/No) |
|---|---|---|---|
| Manager | Boshi Xu | xub35 | yes |
| Administrator | Xiang Zhang | zhanx326 | yes |
| Coordinator | Aaryan Walia | waliaa9 | yes |
| Subject Matter Expert | Marcus Cohoon/ | Cohoom1 | yes |
| | Eashwaar Mahibal | Mahibale | yes |
| *Guest* | **Omar Sanad** | | yes |

## AGENDA ITEMS

1.Update TA on team progress

## MEETING MINUTES(5MIN)

1.

a. Modelling team presents their preliminary solid model and explains why they choose that design

b. Discuss improvements to design and take input from TA and Computation team.

2. Computation team shows and explains their preliminary program tasks

## POST-MEETING ACTION ITEMS

3. *Complete Pugh matrix and finalize the most practical and useful design and make improvements from given input [Modeling team]*
4. *Peer review their preliminary program and make adjustments and finish design studio worksheets [Computation team]*

# ENGINEER 1P13

## MEETING WITH TEAM Mon-01 – Monday Nov 23rd

### ATTENDANCE

| Role | Name | Mac ID | Attendance (Yes/No) |
|---|---|---|---|
| Manager | Boshi Xu | xub35 | yes |
| Administrator | Xiang Zhang | zhanx326 | yes |
| Coordinator | Aaryan Walia | waliaa9 | yes |
| Subject Matter Expert | Marcus Cohoon/ | Cohoom1 | yes |
| | Eashwaar Mahibal | Mahibale | yes |
| *Guest* | **Omar Sanad** | | yes |

### AGENDA ITEMS

1.Update TA on team progress

### MEETING MINUTES(4MIN)

1. Modelling team presents Autodesk model for the container and receives feedback and critique
2. Computation team presents code and design to TA and receive feedback and critique

### POST-MEETING ACTION ITEMS

5. *Use feedback to make improvements and generate G-code[Modeling team]*
6. *Finish writing code in Python [Computation team]*

## MEETING WITH TEAM Mon-01 – Monday Nov 30th

### ATTENDANCE

| Role | Name | Mac ID | Attendance (Yes/No) |
|---|---|---|---|
| Manager | Boshi Xu | xub35 | yes |
| Administrator | Xiang Zhang | zhanx326 | yes |
| Coordinator | Aaryan Walia | waliaa9 | yes |
| Subject Matter Expert | Marcus Cohoon/ | Cohoom1 | yes |
| | Eashwaar Mahibal | Mahibale | yes |
| *Guest* | **Omar Sanad** | | yes |

### AGENDA ITEMS

2. Update TA on team progress
3. Ask any final questions

### MEETING MINUTES(3MIN)

1. Both teams demonstrated their models/code, and were approved by TA.

### POST-MEETING ACTION ITEMS

1. Be prepared for the meeting with IAI on Dec 3rd. (Team)

## *Design Studio Worksheets*

**Milestone 0**

Insert your Team Portrait in the dialog box below

Page Break

# MILESTONE 0 – TEAM CHARTER

Team Number: Mon-01

## Incoming Personnel Administrative Portfolio:

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

| | Team Member Name: | Project Leads |
|---|---|---|
| 1. | Marcus Cohoon | ☒M ☐A ☐C ☐S |
| 2. | Aaryan Walia | ☐M ☒A ☐C ☐S |
| 3. | Eashwaar Mahibal | ☐M ☐A ☒C ☐S |
| 4. | Xiang Zhang | ☒M ☐A ☐C ☐S |
| 5. | Boshi Xu | ☐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)**

## Project Leads:

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

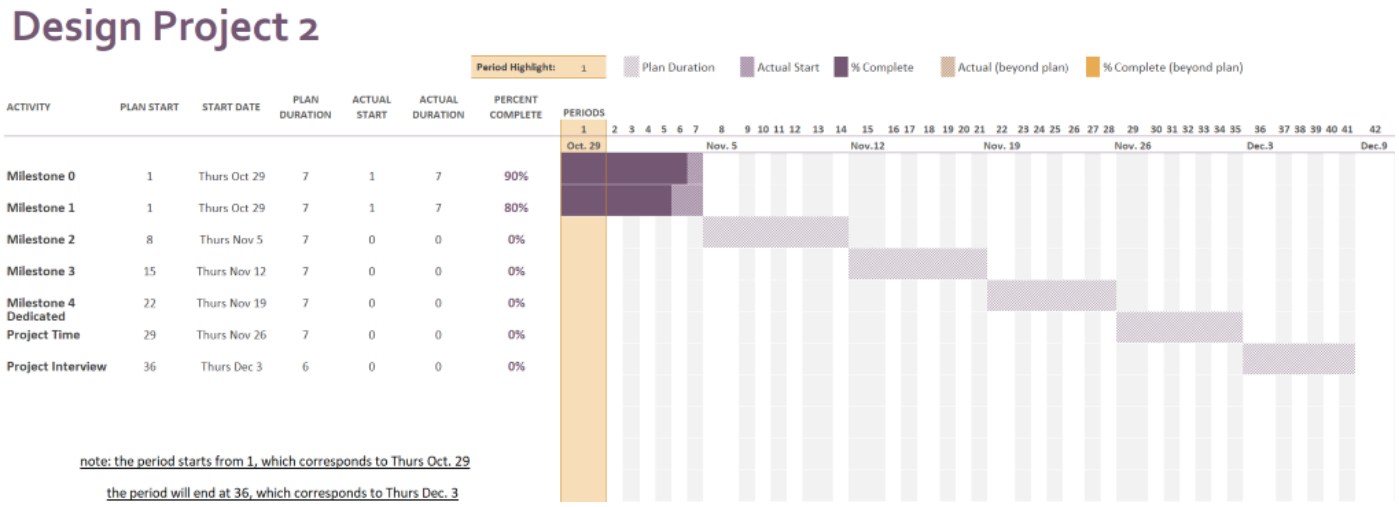
| Role: | Team Member Name: | MacID |
|---|---|---|
| **M**anager | Boshi Xu | xub35 |
| **A**dministrator | Xiang Zhang | zhanx326 |
| **C**oordinator | Aaryan Walia | waliaa9 |
| **S**ubject Matter Expert | Marcus Cohoon | Cohoom1 |
| **S**ubject Matter Expert 2 | Eashwaar Mahibal | Mahibale |

# MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team Number: Mon-01

| Full Name of Team Manager: | MacID: |
|---|---|
| Boshi Xu | xub35 |

Preliminary Gantt chart



**Milestone 1**

# MILESTONE 1 (STAGE 1) – PRE-PROJECT ASSIGNMENT

Team Number: Mon-01

You should have already completed this task individually prior to Design Studio 7.

1. Copy-and-paste each team member's list of objectives, constraints and functions on the following pages (1 team member per page)
    a. Be sure to indicate each team member's Name and MacID

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their list of objectives, constraints and functions with the **Milestone One Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone One Team Worksheets** document allows you to readily access your team member's work
    - This will be especially helpful when completing ***Stage 2*** of the milestone

Team Number: Mon-01

| Name: Xiang Zhang | MacID: zhanx326 |
|---|---|

*Objectives*

- Stable (secure)
- Time saving
- Low noise
- Easy to operate
- Energy saving
- Handle the equipment gently
- Not likely to be dirty
- Accurate

*Constraints*

- Length of the robotic arm
- Positions of autoclaves and the robotic arm is fixed
- The size of the gripper

*Functions*

- Find where the container is
- Pick up the container
- Transfer the container to corresponding autoclave
- Take the container out when finishing sterilization
- Determine the time required for sterilization
- Use the muscle sensor to control the robotic arm (i.e the gripper)

Page Break

Team Number: Mon-01

| Name: Marcus Cohoon | MacID: cohoom1 |
|---|---|

*Objectives*

- durable
- Low production cost
- Uncomplicated design
- Code efficient and fast
- Code should be Modular
- Well commented

*Constraints*

- Container must adhere to design outlined in footprint 1
- Base of container must fit in desired location in autoclave
- Size is limited to 80 mm if it is to be more securely gripped by the proximal end or 150 mm to be less securely gripped by distal end
- All features must be greater than 4mm in size
- Print time of model cannot exceed 2 hr
- Mass of model cannot exceed 350 g

*Functions*

- Prevent movement of retractor in transport
- Facilitate sterilization (allow steam to penetrate surface)
- Prevent contamination
- Easily grasped
- open or close gripper
- control movement of Q-arm
- Determine target location in correct autoclave
- open/close autoclave drawer for large containers

Page Break

Team Number: Mon-01

| Name: Boshi Xu | MacID: xub35 |
|---|---|

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

*Objectives*

- Design a project which is effective, easy to control, cheap, reliable and satisfy the requirments: able to pick us and transfer a stylization container

*Constraints*

- Dimensions, tenacity, length and material of the robotic arm
- Size of the model
- Mass of the model

*Functions*

- Find the position
- Pick up the container
- Transfer to the autoclave bin
- Stylization for a certain time and take it out of the container
- Use python to control it

Team Number: Mon-1

| Name: Eashwaar Mahibal | MacID: mahibale |
|---|---|

Objectives

- Design a program for a robotic arm to pick up and transfer a sterilization container
- Design a container that will hold a surgical item that will be carried by the robotic arm

Constraints

- The dimensions, strength, and speed of the robot arm
- The dimensions of the surgical tools
- The distance the robot arm must carry the container
- The dimensions and design of the autoclaves the surgical tool is placed in

Functions

- Arm: Pick up surgical container
- Arm: Carry container to autoclave
- Arm: Place container in autoclave bin
- Container: Securely hold a surgical tool while stationary and in motion
- Container: Can be picked up by the robotic arm

| Name: Aaryan Walia | MacID: Waliaa9 |
|---|---|

**Objectives:**
-Robotic arm that can safely and accurately transfer medical equipment into the autoclave.
-accurate movements
-easily controllable
-does not damage medical equipment

**Constraints**:
-mass below 350 grams
-Size of arm and containers

**Functions:**
-locate container
-securely grab container
-move container to autoclave
-release container

# MILESTONE 1 (STAGE 2) – LIST OF OBJECTIVES, CONSTRAINTS, AND FUNCTIONS

Team Number: Mon-01

1. As a team, create a final a list of objectives, constraints, and functions in the table below.
   - Use your individual *Pre-Project Assignment* to build your team's final list
   - The exact number you should have depends on what information you have gathered from the Project Pack.

| Objectives | Constraints | Functions |
|---|---|---|
| stable/secure | The dimensions of the container | Find the position of the container/autoclave |
| efficient | Container must fit in autoclave | Pick up the container |
| Easy to use | Mass of model must not exceed 350 g | Control the robotic arm |
| Accurate | Features must be greater than 4 mm | Transfer the container to the autoclave |
| Simple design | Print time cannot exceed 2hr | The container should be able to hold the surgical tool in place |
| | Size of the grabber | Allow for sterilization |

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

Transfer Surgical Container into the autoclave

3. What are the secondary functions?

| |
|---|
| Control the robotic arm |
| Find the position of the container/autoclave |
| Grasp/release container |
| Hold the surgical tool in place (container) |
| Allow for sterilization (container) |

# MILESTONE 1 (STAGE 3) – MORPHOLOGICAL ANALYSIS

Team Number: Mon-01

1. Identify multiple means to perform the secondary functions that your team came up with during Stage 1 of this milestone. One sub-function (pick up) is already listed for you. The other two sub-functions are for your team to choose.
    - Make sure that every mean for the "pick up" sub-function assumes that the end effector of the robot arm is a gripper. The means for your other sub-functions do not need to follow this assumption.

| **Function** | **Means** | | | | | |
|---|---|---|---|---|---|---|
| Pick up | Slots in container | Hole and grabbable hook | Rough surface(increase friction) | adhesive | Suction cup on grabber | Electro-magnet |
| Transfer | Pulley system | wormhole | projectile | belt | Vacuum transfer | Mechanical arm |
| Release | Unsnap from slots | Open grabber | Wind tunnel | Deactivate adhesive | Peel off suction cup | Turn off Electro-magnet |

# MILESTONE 1 (STAGE 4) – CONCEPT SKETCHES

Team Number: Mon-01

Complete this worksheet *after* having completed stage 3 as a team ***and*** after having ***individually*** created your concept sketches.

1. Each team member should copy-and-paste the photo of their individual concept sketches in the space indicated on the following pages
    - The photo's should be the same one your included in the **Milestone One Individual Worksheets** document
    - Be sure to include your **Team Number** on each page
    - Be sure each team member's **Name** and **MacID** are included with each sketch

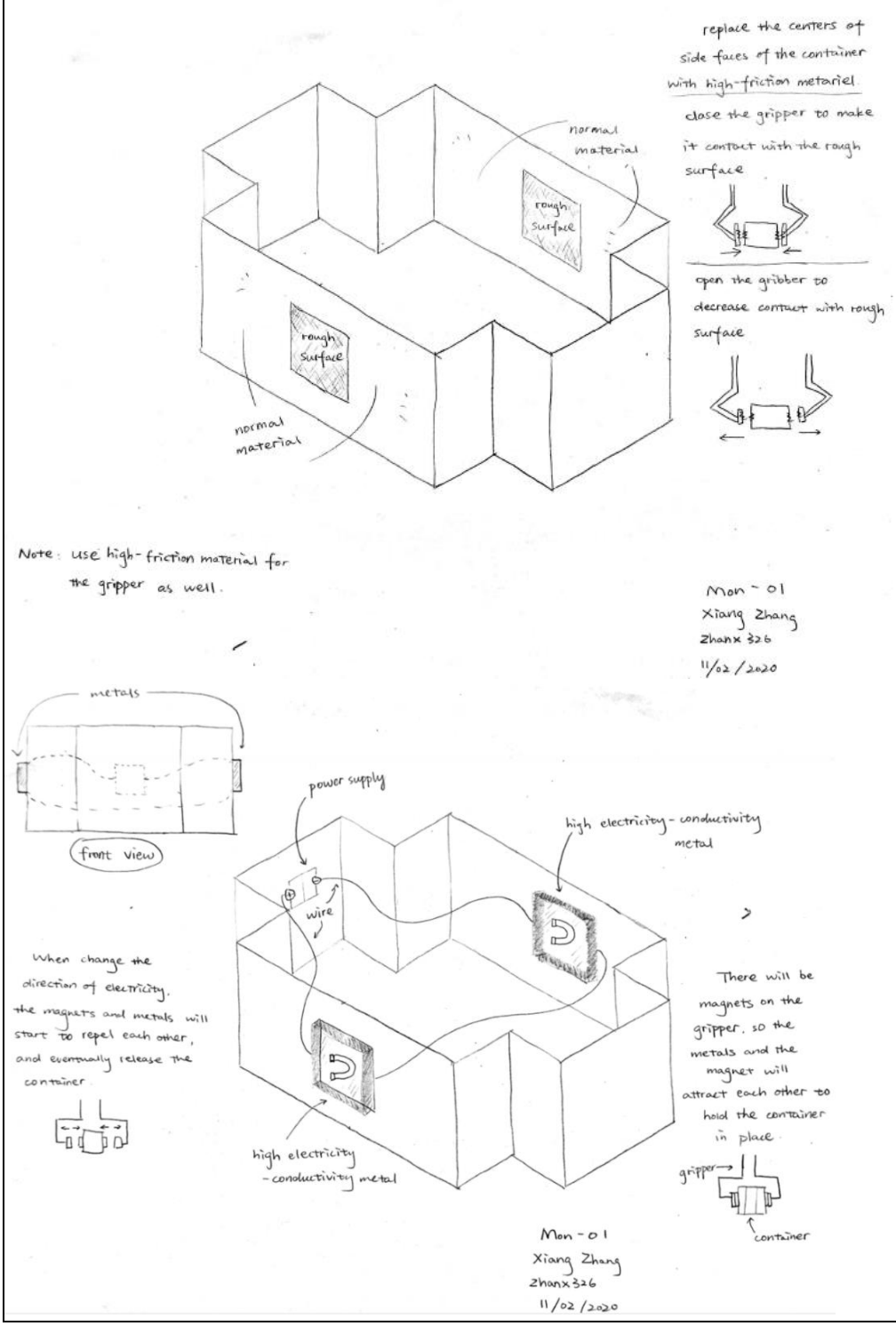
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their sketch with the **Milestone One Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone One Team Worksheets** document allows you to readily access your team member's work

Team Number: Mon-01

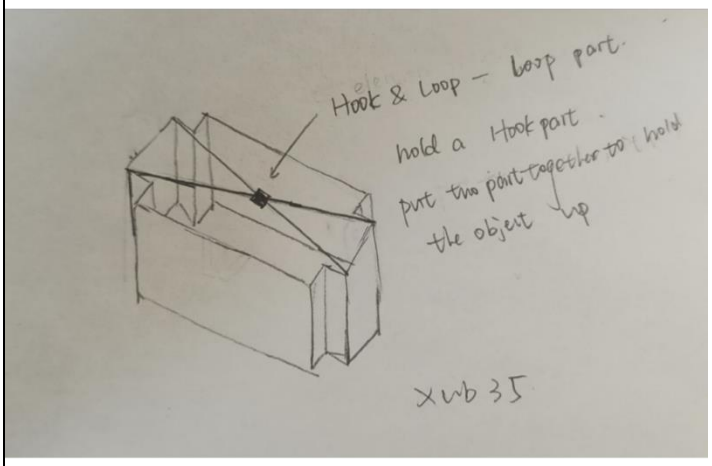
| Name: Xiang Zhang | MacID: zhanx326 |
|---|---|

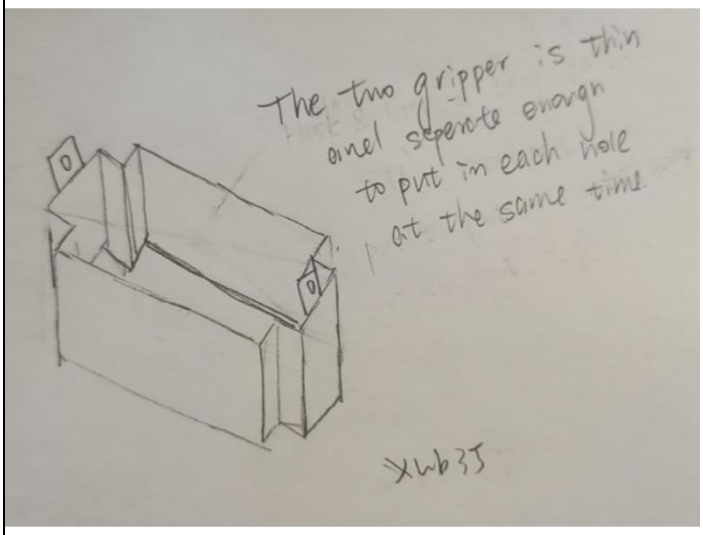
*Insert screenshot(s) of your concept sketches below*



Team Number: Mon-01

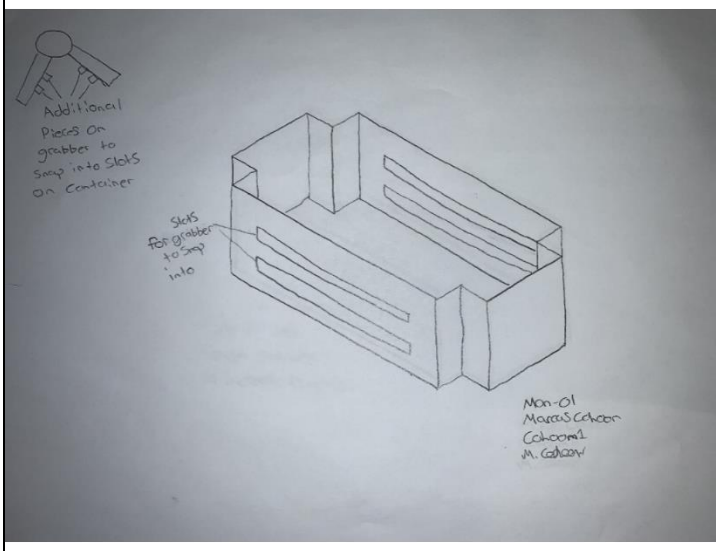
| Name: Boshi Xu | MacID: xub35 |
|---|---|

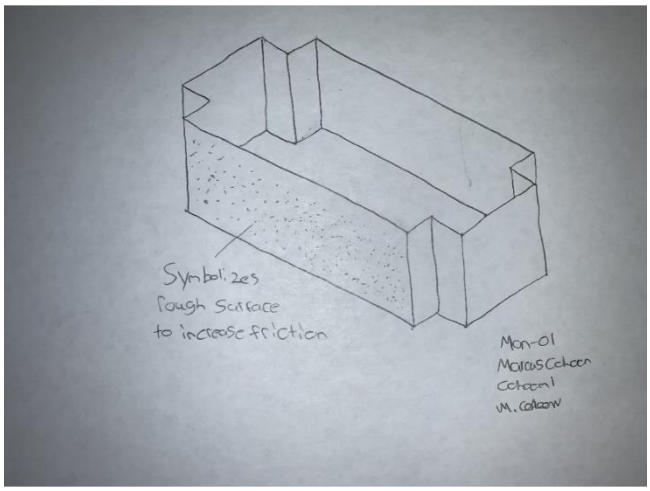


Team Number: Mon-01

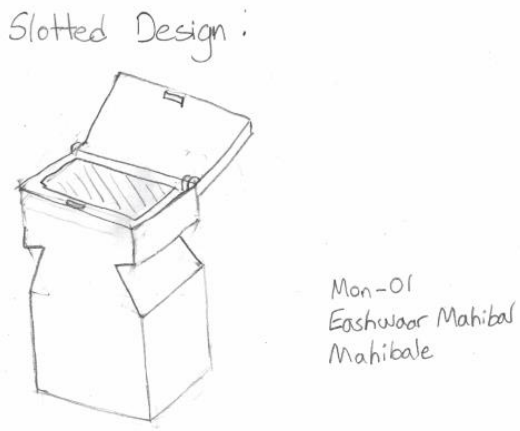
| Name: marcus cohoon | MacID: cohoom1 |
|---|---|

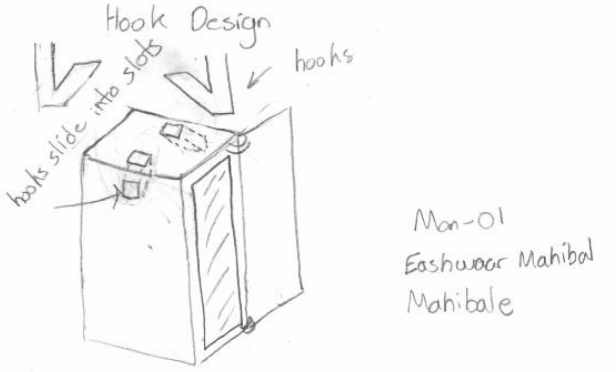


Team Number: Mon-01

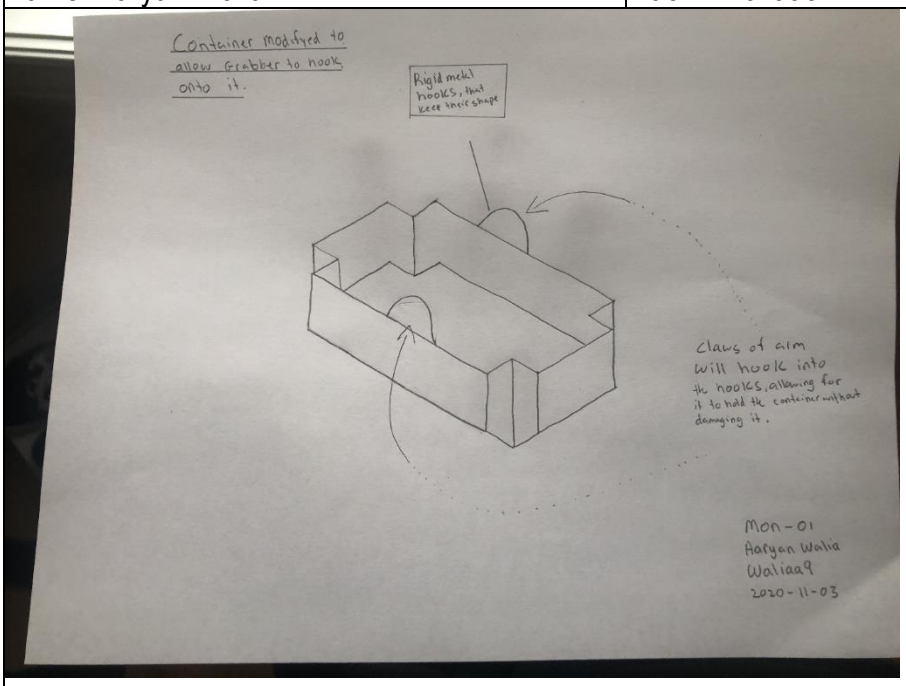
| Name:Eashwaar Mahibal | MacID: mahibale |
|---|---|

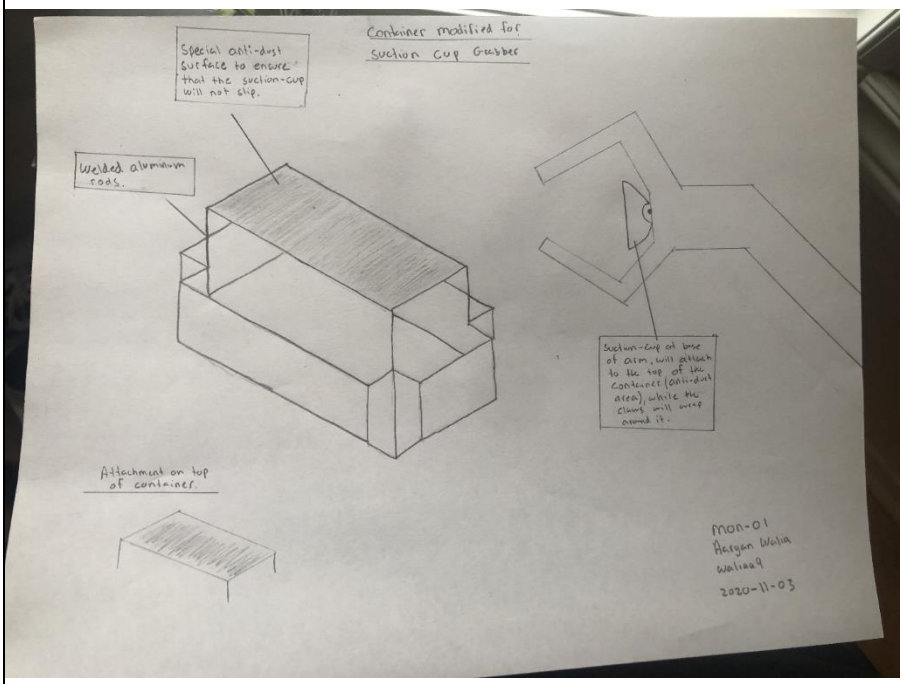


# Team Number: Mon-01

| Name: Aaryan Walia | MacID: waliaa9 |
|---|---|



# Milestone 2

## MILESTONE 2 (STAGE 1) – REFINED CONCEPT SKETCHES (MODELLING SUB-TEAM)

Team Number: Mon-01

You should have already completed this task individually prior to Design Studio 8.

1. Copy-and-paste each sub-team member's refined sketch on the following pages (1 sketch per page)
    - Be sure to indicate each team member's Name and MacID

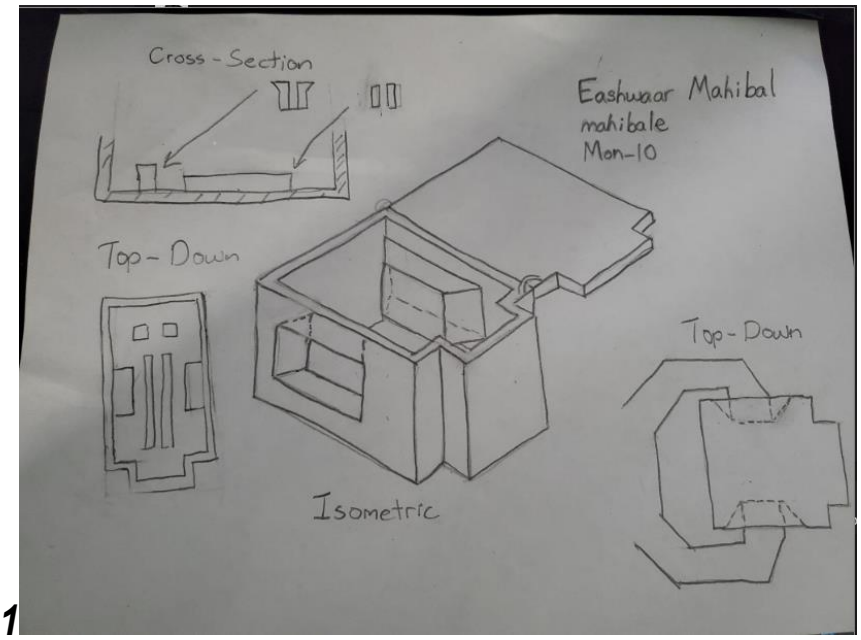
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their refined concept sketches with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
    - This will be especially helpful when completing ***Stage 3*** of the milestone

Team Number: Mon-01

| Name: Eashwaar Mahibal | MacID: mahibale |
|---|---|

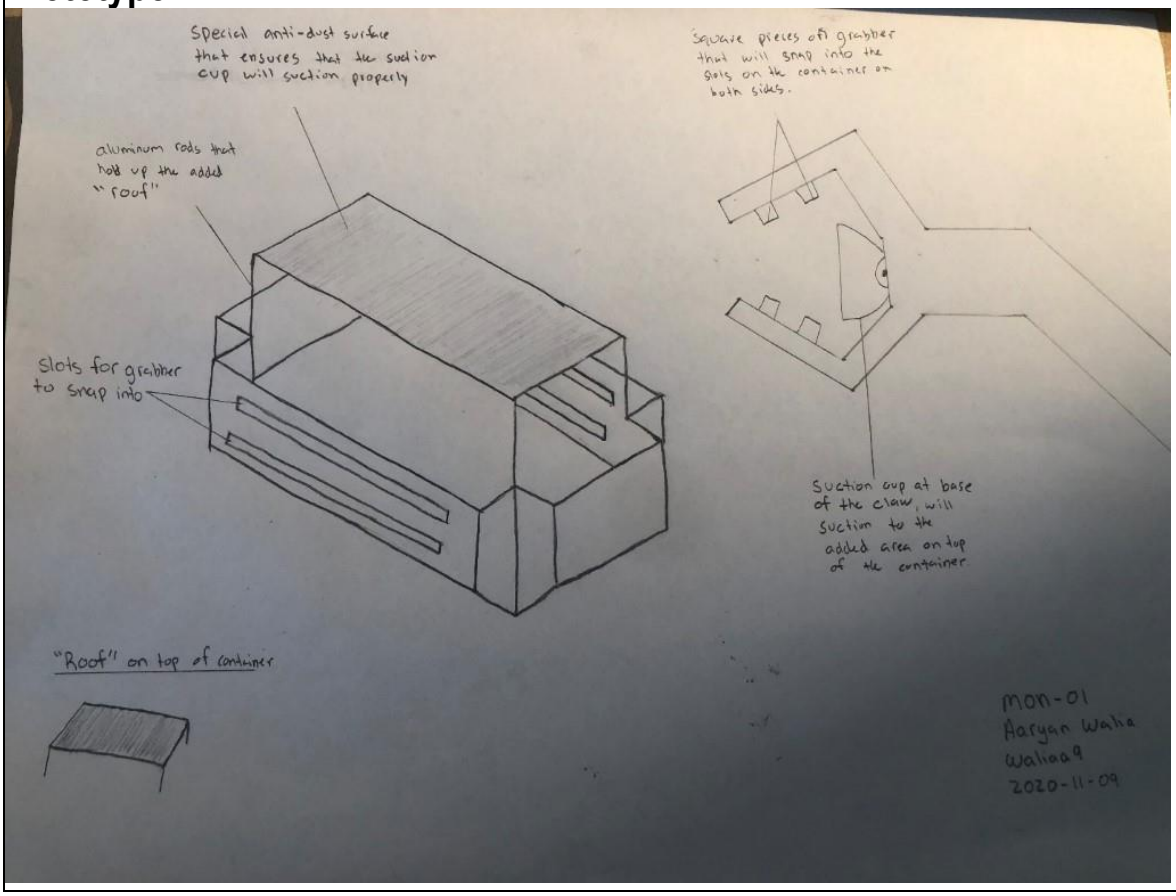
***Prototype 1***



Team Number: Mon-01

| Name: Aaryan Walia | MacID: waliaa9 |
|---|---|

## Prototype 2



# MILESTONE 2 (STAGE 2) – COMPUTER PROGRAM WORKFLOW (COMPUTATION SUB-TEAM)

Team Number: Mon-01

You should have already completed this task individually prior to Design Studio 8.

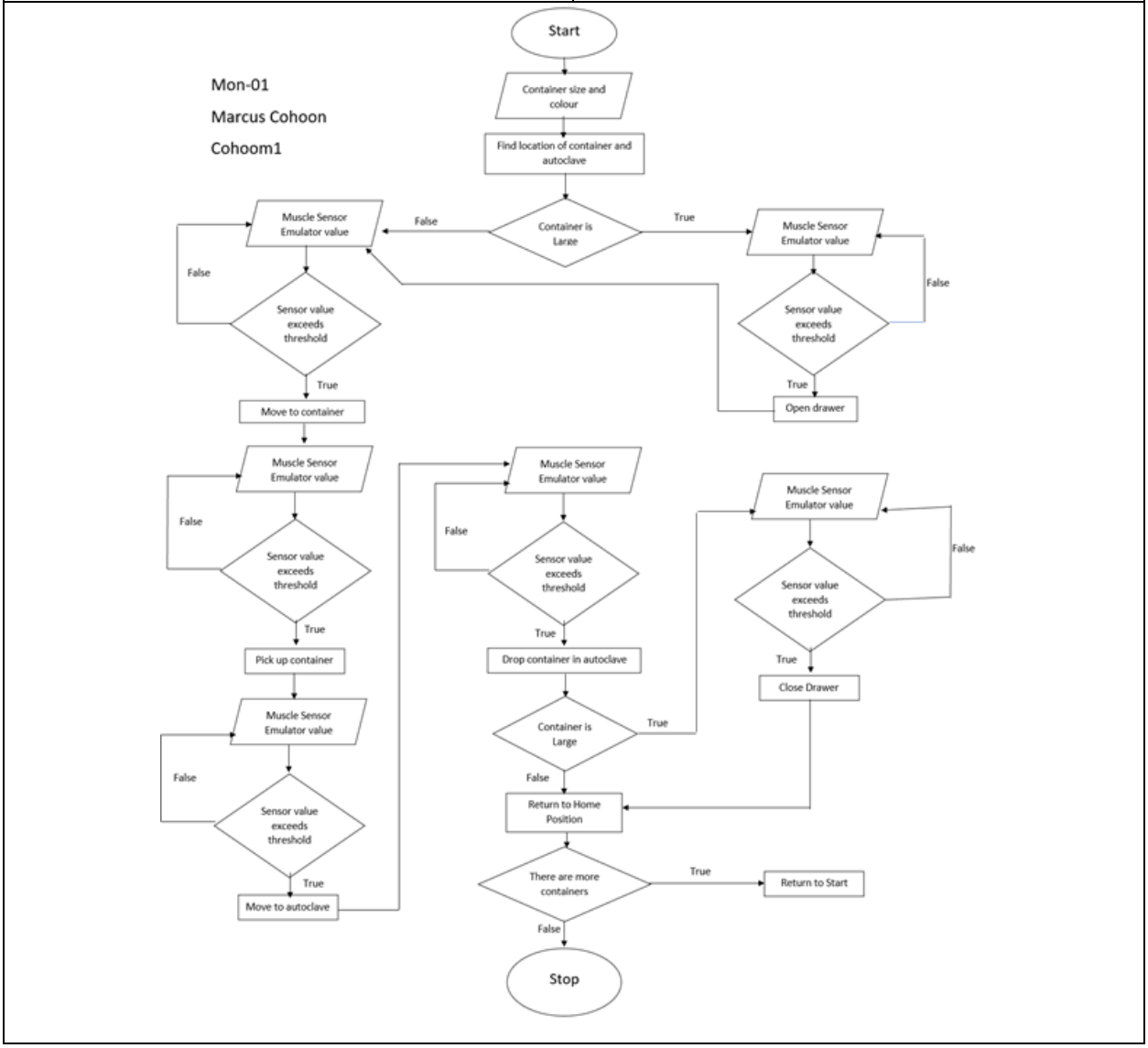
1. Copy-and-paste each team member's storyboard or flowchart sketches on the following pages (1 team member per page)
    - Be sure to indicate each team member's Name and MacID

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their storyboard/flowchart with the **Milestone Two Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Two Team Worksheets** document allows you to readily access your team member's work
    - This will be especially helpful when completing ***Stage 4*** of the milestone

Team Number: Mon-01

| Name: Marcus Cohoon | MacID: cohoom1 |
|---|---|



Team Number: Mon-01

| Name: Xiang Zhang | MacID: zhanx326 |
|---|---|

*Insert screenshot(s) of your concept workflow below*

Input: data from muscle sensor emulators

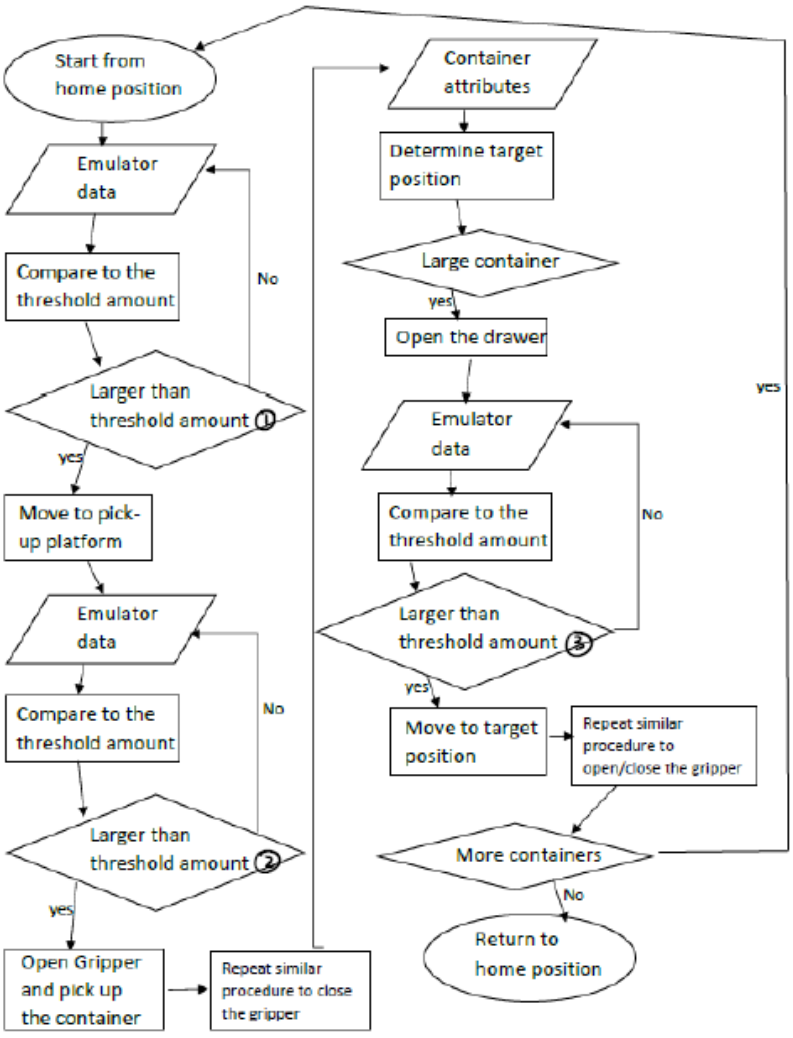
Size and color of the container

Output: q-arm movement (wrist, elbow, shoulder)

open/close gripper

for large containers, open /close drawers

Need to define the threshold amount for the emulator



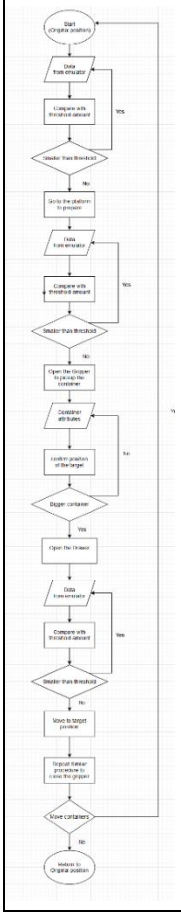

Note that threshold amount ①, ②, ③ are different

*If you are in a sub-team of 3, please copy and paste the above on a new page

Team Number: Mon-01

| Name: Boshi Xu | MacID: xub35 |
|---|---|

*Insert screenshot(s) of your concept workflow below*



Page Break

# MILESTONE 2 (STAGE 3A) – LOW-FIDELITY PROTOTYPE (MODELLING SUB-TEAM)

Team Number: Mon-01

Complete this worksheet during design studio 8 after creating the low-fidelity prototypes.

1. Take multiple photos of your low-fidelity prototypes
    - Include an index card (or similar) next to the prototype, clearly indicating your Team Number, Name and MacID on *each* sketch
2. Insert your photo(s) as a Picture (Insert > Picture > This Device)
3. **Do not include more than *two* prototype photo's per page**

Make sure to include photos of each team member's prototype

Team Number: Mon-01

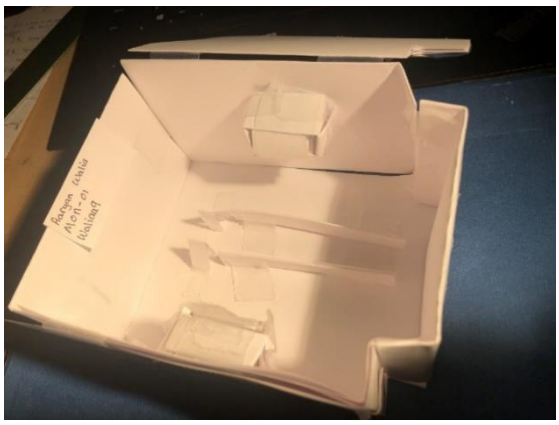
| Name: Eashwaar Mahibal | MacID: mahibale |
|---|---|

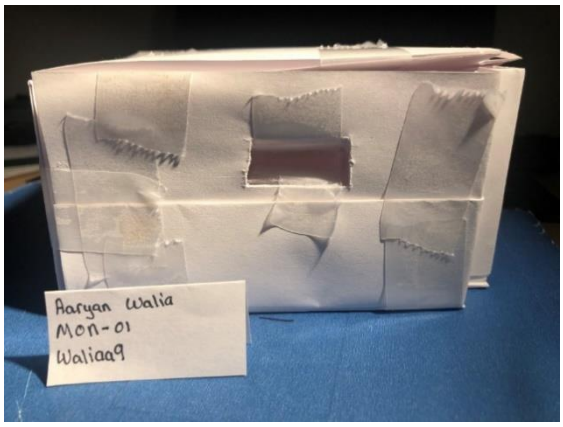
# *Prototype 2 Model*

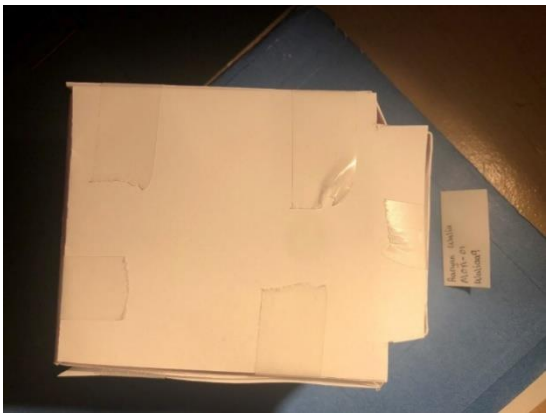
Team Number: Mon-01

| Name: Aaryan Walia | MacID: waliaa9 |
|---|---|

# *Prototype 1 model*



# MILESTONE 2 (STAGE 3B) – LOW-FIDELITY PROTOTYPE OBSERVATIONS (MODELLING SUB-TEAM)

Team Number: Mon-01

As a team, document your observations for each low-fidelity prototype. Make sure to label your observations to indicate which prototype it belongs to. As a starting, consider the following: (note, this does not fully encompass all discussion points)

- Advantages and disadvantages of each prototype
- Extent to which each concept aligns (or does not align) with the List of Objectives, Constraints, and Functions you came up with for Milestone 1
- Reliability of the design in picking up the surgical tool
- Reliability of the design in securing the surgical tool
- Extent to which it allows for tool sterilization

**Prototype 1:**

Objective:

- Container has a simple design that allows for easy transfer of surgical tools by robotic arm to be placed into an autoclave for sterilization, meeting the objective.

Restrictions:

- Design can be implemented within the 4mm feature and 350g weight restriction meeting the requirement.

Functions:

- Container is designed with a slotted design to allow for easy pick up while also securing the grip to the container
- Slots on the bottom of the container allow the tool to be clicked into place and prevent the tool from moving around during transfer

Advantages:

- Slants on sides of slots allow for arm to fit into the slots easier and securely grab onto container even if accuracy of arm is not perfect.
- Container can be easily opened and closed
- Multiple tools can be placed into and secured in container at once

Disadvantages:

- While slants make it easier for arm to grab onto the container, if the slot is not deep enough or the slant is too steep or the strength of the arm is too little, the grabber may lose grip of the container. This can be overcome by adjusting slot depth accordingly
- Removing the tool from the container once it is placed in the autoclave would be difficult and requires some adjustments. One possible change that be made is designing the slots to allow the tool to easily fall out of the container when the container is flipped over.

Reliability in picking up the surgical tool:

- Accuracy required to pick up tool is very forgiving as slants on sides of container will guide the grip into the slot
- Slots will keep grip from sliding off while in movement and require less strength from the grip

Reliability in securing the surgical tool:

- The two shorter slots on the bottom of the container allow the tool to be clicked into place. The longer guide slots keep the container in place. The tool should not move while in transfer

Tool Sterilization:

- Once placed in autoclave the container would have to be opened by flipping the container upside-down and the tool must be pulled off or shaken to be removed from the container.
- Container can be easily reused once sterilized

## Prototype 2:

Advantages- Has an extremely secure hold due to the suction cup and the clip-in slots. Also securely holds the surgical tool with a clip in slot customized for each tool.

Disadvantages- Due to the suction cup and clip-in slots it will be more complicated to release the container from the gripper. Another design flaw is that the “roof” of the container is not detachable and therefore it would be hard to put in the surgical tools.

This design meets the objectives of the container being secure/stable while having a simple design. However, it may not meet the objectives for the container to be easy to use, since the suction cup creates some complexities when trying to release the container. Exact dimensions for the prototypes have not been determined yet therefore it is unknown whether it will fit the constraints. This prototype does fit some functions for a container because it can securely hold the tool in place but may not allow for easy sterilization since the “roof” does not swing open therefore it will be hard to move things in and out of the container. This a design flaw that must be tweaked.

# MILESTONE 2 (STAGE 4A) – WORKFLOW PEER-REVIEW (COMPUTATION SUB-TEAM)

Team Number: Mon-01

As a team, document your observations, specifically any similarities and differences between each team member's visual storyboard or flowchart in the table below.
*Document your observations for each visual storyboard / flowchart in the space below.*

*Similarity:*

- *Consistently checking emulator data and comparing it to the threshold values*
- *Used similar functions*
- *Keep checking emulator data if it doesn't exceed threshold amount*

*Difference:*

- *Checked for attributes (size and colour) at different times in the program. Needs to be done after the end effector moves but before controlling gripper.*
- *Shawn identified where different threshold values would be used since Python uses different variable names to store values*
- *Consider returning to original position as an end / as a procedure. Should be a conditional statement*

# MILESTONE 2 (STAGE 4B) – PROGRAM PSEUDOCODE (COMPUTATION SUB-TEAM)

Team Number: Mon-01

As a team, write out a pseudocode outlining the high-level workflow of your computer program in the space below.

```
Main function
    While true
        Get emulator data
        Call control gripper
        Call find autoclave location
        Call move end effector
        Call open autoclave bin drawer
        If container is dropped in auto calve
            Return
    Return to home position
    Call function to determine continue/terminate the program

Create function to find location of autoclave bin
    To be determined via Trial and Error

Create a function to control the gripper
    Get data from emulator
    If greater than threshold value
        If open
            Close gripper
        else
            Open gripper
    Else
        return

Create a function to control the end-effector
    Get data from emulator
    If greater than threshold value
        Move to pre-set position
    Else
        return

Create function to control autoclave bin drawer
    Get data from emulator
    If greater than threshold value
        If open
            Close drawer
        else
            Open drawer
    Else
        return

Create function to determine continue/terminate the program
    If there is more container
        Call main
    Else
End the program
```

**Milestone 3:**

# MILESTONE 3 (STAGE 1) – PRELIMINARY SOLID MODEL (MODELLING SUB-TEAM)

TEAM NUMBER: MON-01

You should have already completed this task individually prior to Design Studio 9.

1. Copy-and-paste each team member's screenshots of their preliminary solid model on the following pages (1 team member per page)

Be sure to clearly indicate who each model belongs to

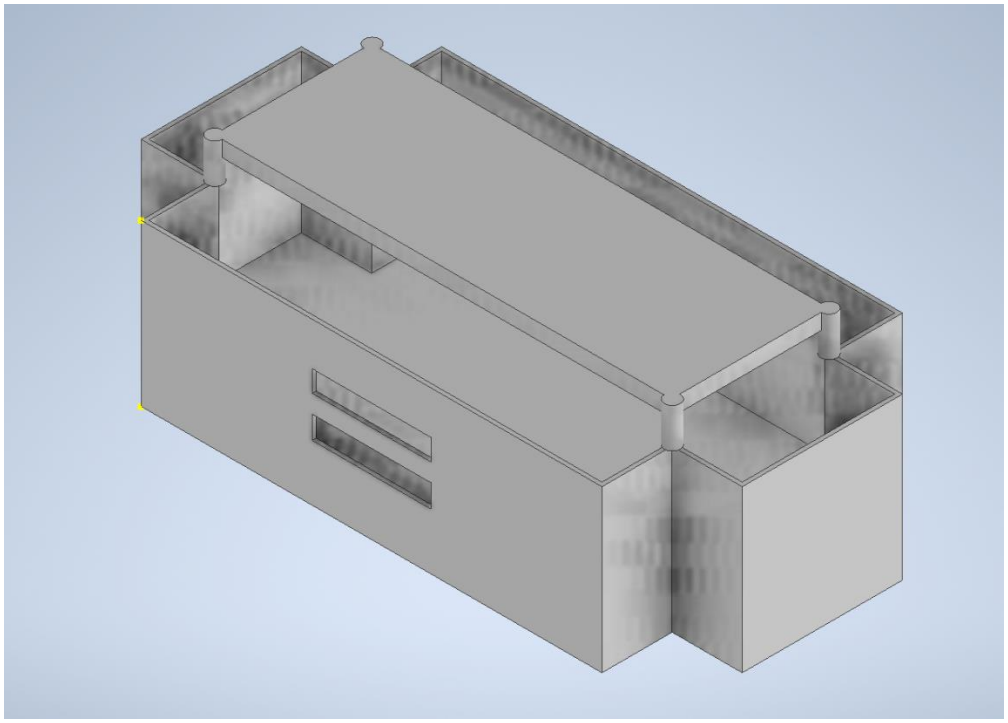
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

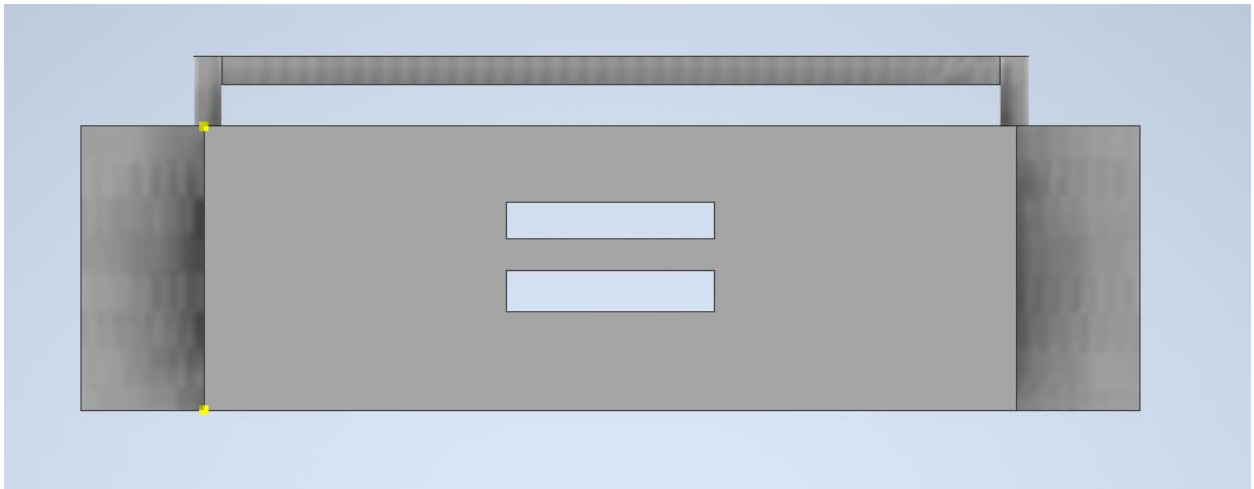
- Each team member needs to submit their solid model screenshots with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
    - This will be especially helpful when completing ***Stage 3*** of the milestone

TEAM NUMBER: MON-01

| NAME: AARYAN WALIA | MACID WALIAA9 |
|---|---|

# PROTOTYPE 2

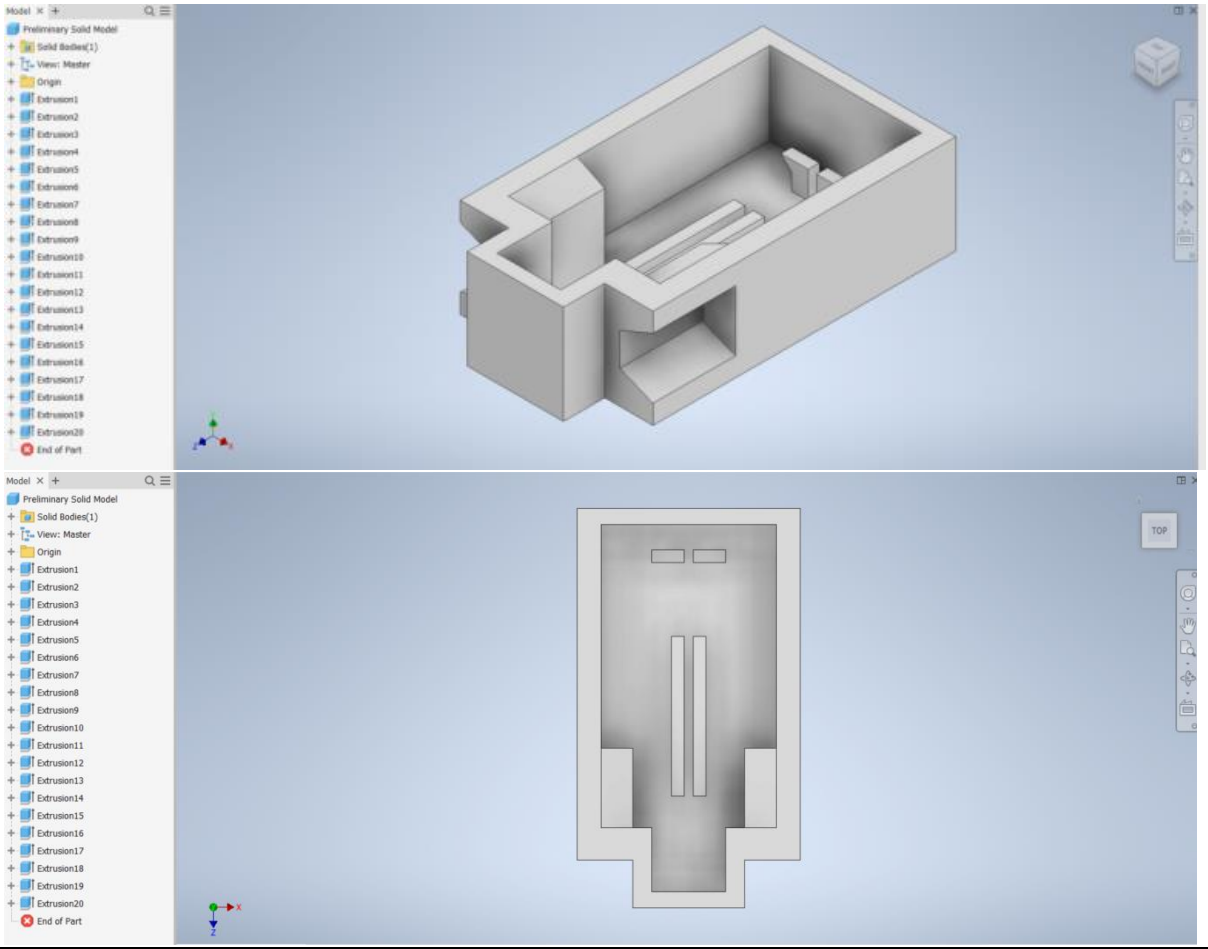




| TEAM NUMBER: | MON-01 |
|---|---|

| NAME: EASHWAAR MAHIBAL | MACID: MAHIBALE |
|---|---|

**PROTOTYPE 1:**



# MILESTONE 3 (STAGE 2) – PRELIMINARY PROGRAM TASKS (COMPUTATION SUB-TEAM)

| TEAM NUMBER: | MON-01 |
|---|---|

You should have already completed this task individually prior to Design Studio 9.

1. Copy-and-paste each team member's code screenshots on the following pages (1 team member per page)
   → Be sure to clearly indicate who each code belongs to

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their code screenshots with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 4*** of the milestone

| TEAM NUMBER: | MON-01 |
|---|---|

| NAME: XIANG ZHANG | MACID: ZHANX326 |
|---|---|

*p2_template.py - /home/pi/QLabs ...ject 2 Files/p2_template.py (3.7.3)*

File Edit Format Run Options Window Help

```
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)


## STUDENT CODE BEGINS
## ---------------------------------------------------------------------------
## Example to rotate the base: arm.rotateBase(90)


def move_end_effector(left_arm_data, final_location):

    threshold = 0.3
    if left_arm_data >= threshold:      # move the robotic arm if the left arm i
                                        # stretch beyond the threshold amount
        time.sleep(2)
        arm.move_arm(final_location[0],final_location[1],final_location[2])
        time.sleep(2)



while True:
    left_data = arm.emg_left()          # get data from left arm and check it by
                                        # calling the function

    move_end_effector(left_data, [-0.6167, 0.2245, 0.343])
```

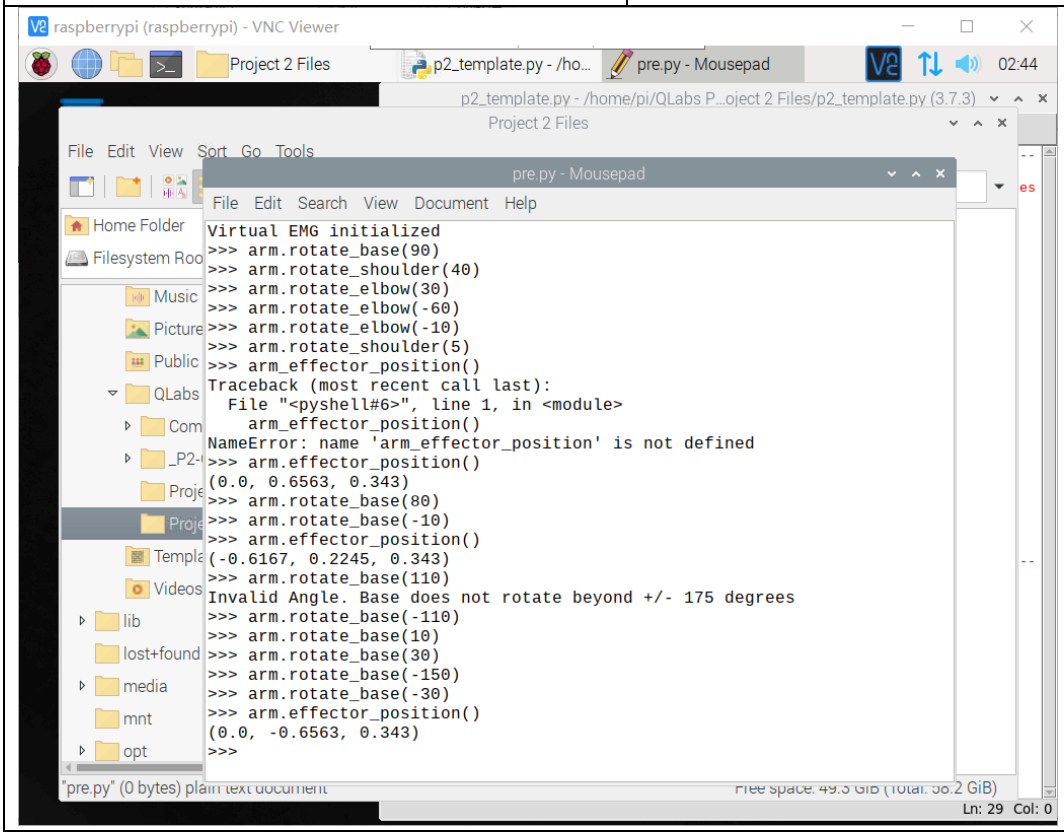
| TEAM NUMBER: | MON-01 |
|---|---|

| NAME: MARCUS COHOON | MACID: COHOOM1 |
|---|---|

```
def autoclave_bin_location(colour, large):
    if large == True:
        location = [[-0.3992, 0.1617, 0.322],[0.0, -0.42, 0.3],[0.0, 0.42, 0.3]]
    else:
        location = [[-0.6052, 0.2452, 0.3998],[0.0, -0.6573, 0.3998],[0.0, 0.6573, 0.3998]]

    if colour == 1: ##red
        return location[0]
    elif colour==2: ##green
        return location[1]
    elif colour==3: ##blue
        return location[2]
    else:
        print("Error: This colour is unknown.")
        return [0.4064, 0.0, 0.4826]
##pick up position:(0.5244, 0.0, -0.0019)
##blue top:(0.0, 0.6573, 0.3998) bottom: (0.0, 0.42, 0.3)
##green top:(0.0, -0.6573, 0.3998) bottom: (0.0, -0.42, 0.3)
##red top:(-0.6052, 0.2452, 0.3998) bottom: (-0.3992, 0.1617, 0.322)
```

| NAME: BOSHI XU | MACID: XUB35 |
|---|---|



# MILESTONE 3 (STAGE 3) – PUGH MATRIX (MODELLING SUB-TEAM)

| TEAM NUMBER: | MON-01 |
|---|---|

1. As a team, evaluate your designs for the sterilization container in the table below
   → List your Criteria in the first column
      - You should include a minimum of 5 criteria
   → Fill out the table below, comparing your designs against the given baseline
      - Replace "Design A" and "Design B" with more descriptive labels (e.g., a distinguishing feature or the name of the student author)
      - Assign the datum as the baseline for comparison
      - Indicate a "+" if a concept is better than the baseline, a "–" if a concept is worse, or a "S" if a concept is the same

| | **Datum** | **Prototype 1** | **Prototype 2** |
|---|---|---|---|
| Easy to Pick Up | S | + | + |
| Easily released from gripper | S | S | - |
| Secures Surgical Tool | S | S | S |
| Allows Sterilization | S | - | - |
| Secure when being transferred | S | + | + |
| Total + | 0 | 2 | 2 |
| Total – | 0 | 1 | 2 |
| Total Score | 0 | 1 | 0 |

*For a team of 3, click the top-right corner of the table to "Add a New Column"

2. Propose one or more suggested design refinements moving forward

The design we will be choosing is Prototype 1. Since Prototype 2 was meant to be used with a suction cup gripper which is in this scenario is impractical and unnecessary. Prototype 1 meets most criteria but can use some improvements in its sterilization and pick up design. The improvements we want to implement into the design of the container are a closed mesh top that can open and close. To allow the container to be sterilized without being opened. Another adjustment is moving slots at the front of the container towards the middle for better balance. We may also modify the slots to be vertical instead of horizontal. After speaking with the computation sub team, we learned about the limitations of the mobility of the robot arm and gripper. Modifications to the slots will be made to account for these limitations.

# MILESTONE 3 (STAGE 4A) – CODE PEER-REVIEW (COMPUTATION SUB-TEAM)

| TEAM NUMBER: | MON-01 |
|---|---|

Document any errors and/or observations for each team member's preliminary Python program in the space below

| **Identify Autoclave Bin Location Task** | **Team Member Name**: Marcus Cohoon Boshi Xu |
|---|---|
| 1. In final else statement which will execute if the colour is not an integer 1, 2, or 3 it prints an error but does not return anything so functions relying on it may fail. It should be edited to return the home position.<br>2. The function written works well to return the positions in proper format to be used by other functions later.<br>3. All positions with the exception of R2 are accurate. R2 needs slight adjustment as cage does not perfectly fit into autoclave cut out. | |

| **Move End-Effector Task** | **Team Member Name**: Xiang Zhang |
|---|---|
| 1. If the arm is flexed accidently over the threshold amount, the arm will still move. One way to resolve this is to write a function that determines whether the emulator's status stays unchanged for over 5 seconds, if it does, the q-arm will then move.<br>2. Need to check for the right arm data as well. Otherwise, some other functions may be called, and the q-arm will have multiple tasks at the same time.<br>3. The q-arm can start from random positions in the environment, and it always moves to the desire positions once the emulator data exceeds the threshold value. | |

# MILESTONE 3 (STAGE 4B) – PROGRAM TASK PSEUDOCODE (COMPUTATION SUB-TEAM)

| TEAM NUMBER: | MON-01 |
|---|---|

As a team, write out the pseudocode for each of the *remaining* tasks in your computer program in the space below.

**Control Gripper**

```
Create a function to control the gripper with arguments right arm emulator data and Boolean
that is true if gripper is open
        If greater than right arm threshold value
                If open
                        Close gripper
                else
                        Open gripper
        Else
                return
```

### Open Autoclave Bin Drawer

```
Create function to control autoclave bin drawer with arguments both arm's emulator data,
colour, and size
    If both arms greater than threshold value
        If large
            If blue
                If open
                    Close blue drawer
                Else
                    Open blue drawer
            If red
                If open
                    Close red drawer
                Else
                    Open red drawer
            if green
                if open
                    close green drawer
                else
                    open green drawer
```

### Continue or Terminate

```
Create function to determine continue/terminate the program with argument list of
containers
    If list of containers is not empty
        Call main
    Else
        End the program
```

## Milestone 4

# MILESTONE 4 (STAGE 3) – DESIGN REVIEW FEEDBACK (MODELLING SUB-TEAM)

Team Number: Mon-01

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

-looks alright

-Only concern is supports

-should be alright

-print time is good

-container fitted the constraints

-mass was 18.13g which meets the constraints for mass

(Go with warning?)

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

No design refinements based on feedback

## MILESTONE 4 (STAGE 3) – DESIGN REVIEW FEEDBACK (COMPUTATION SUB-TEAM)

Team Number: Mon-01

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

- Executes process properly
- Needs additional comments
- The arm needs to go to home position before going to autoclave

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

- Add comments on top of each function's
- Comment variables with names that are not obvious
- Comment complex situations inside function as well
- Add additional step to go to home position before autoclave

## *List of Sources*

[1] “FACT SHEET-Rural Health Care.” Accessed: Dec. 03, 2020. [Online].

[2] C. R. Wilson, J. Rourke, I. F. Oandasan, and C. Bosco, “Progress made on access to rural health care in Canada,” *Canadian Family Physician*, vol. 66, no. 1, 2020, Accessed: Dec. 03, 2020. [Online].

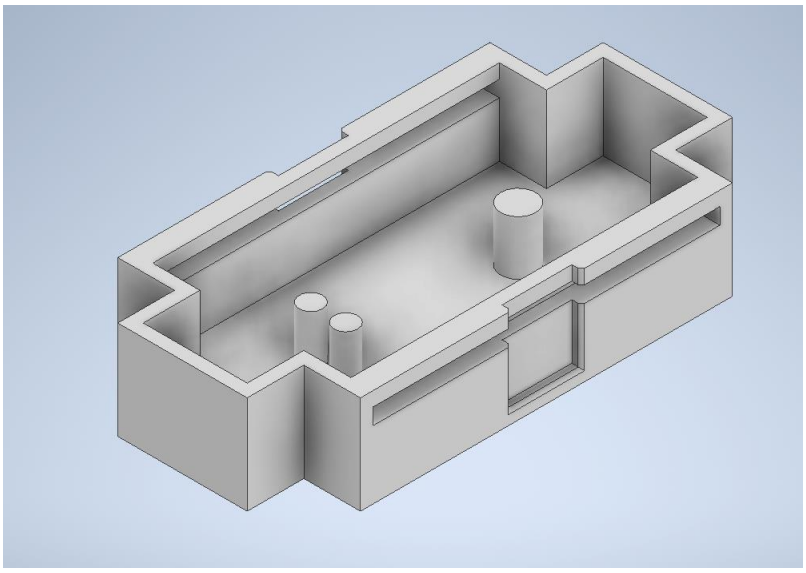
[3] “Improve Health Outcomes for Those in Rural and Remote Areas - The Way Forward.” https://www.gov.nl.ca/thewayforward/action/improve-health-outcomes-for-those-in-rural-and-remote-areas/ (accessed Dec. 03, 2020).

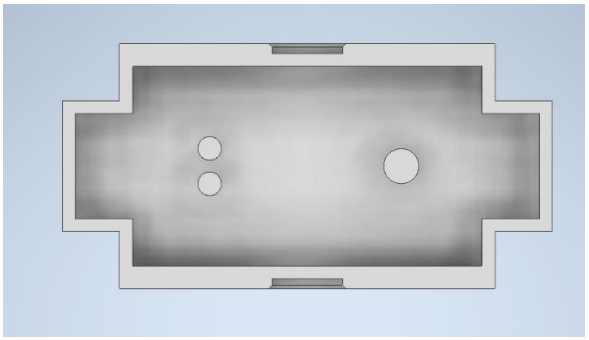
[4] “Long-distance surgery - The Globe and Mail.” https://www.theglobeandmail.com/technology/science/long-distance-surgery/article4220774/ (accessed Dec. 03, 2020).

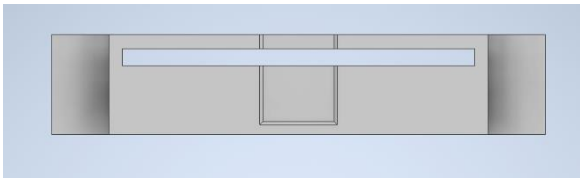
[5] “Steam Sterilization | Disinfection & Sterilization Guidelines | Guidelines Library | Infection Control | CDC.” https://www.cdc.gov/infectioncontrol/guidelines/disinfection/sterilization/steam.html (accessed Dec. 03, 2020).

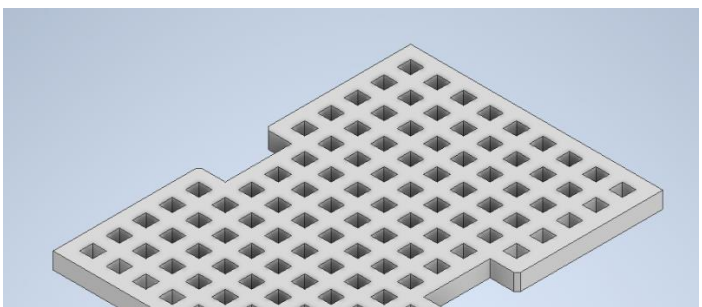
## *Appendices*

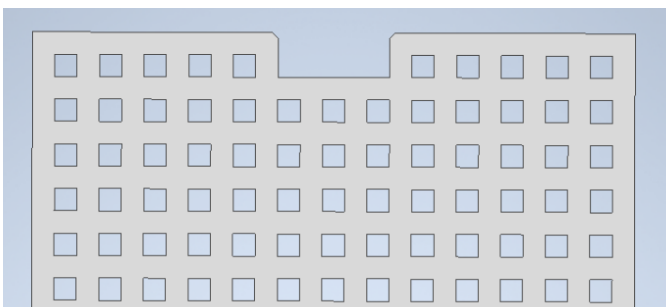
### Appendix A – Container Design

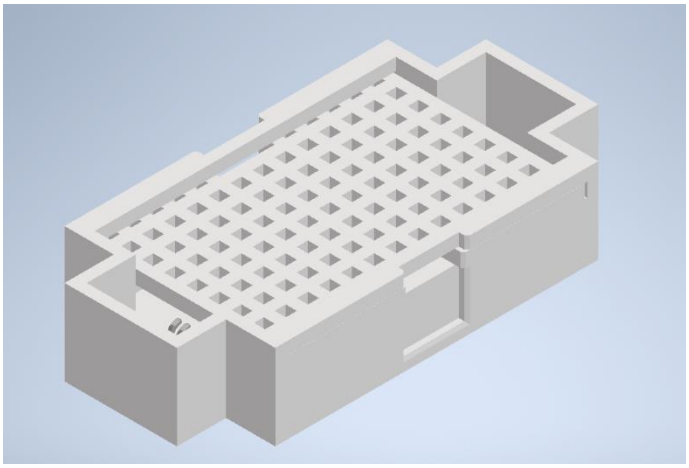


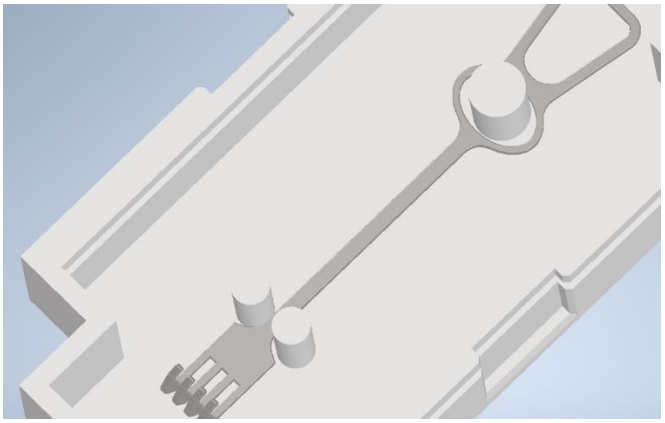




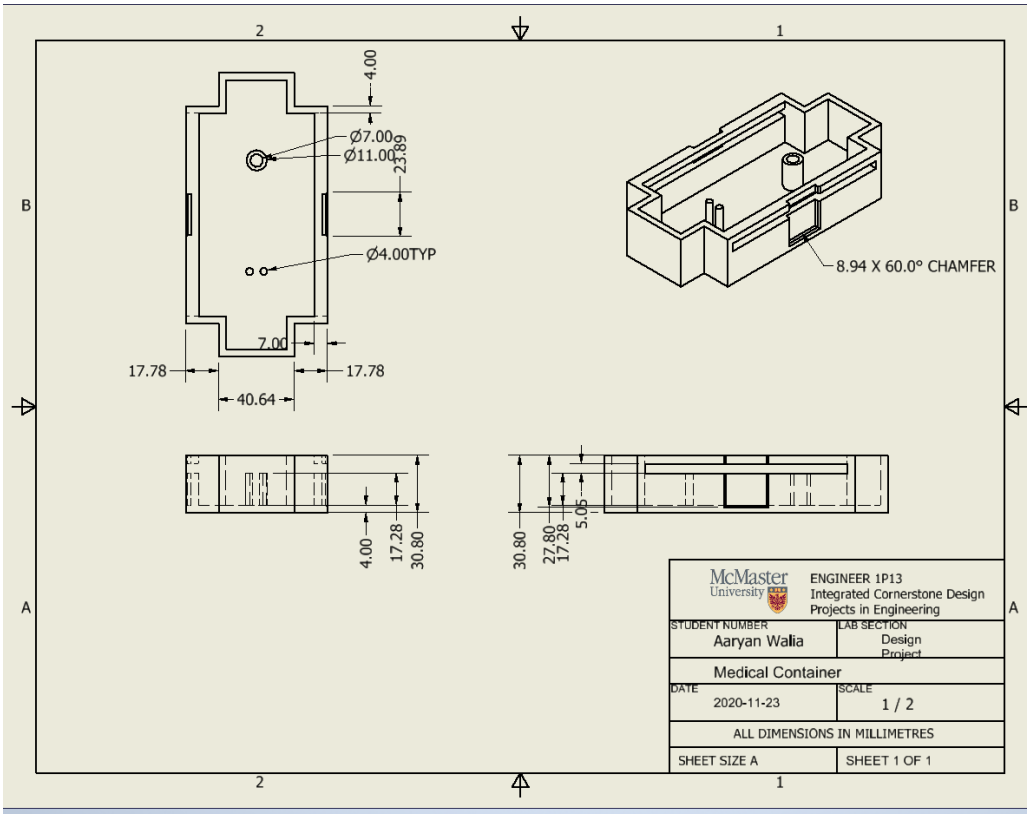


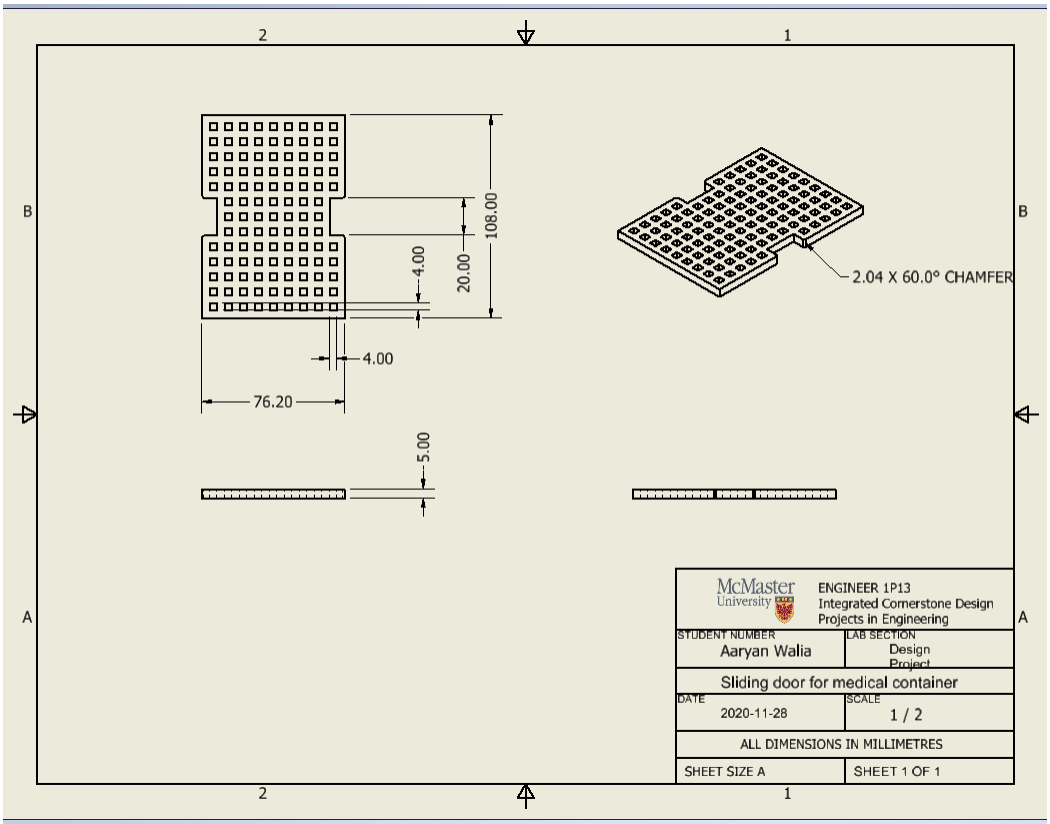






## Appendix B – Fully Constrained Engineering Drawings



## Appendix C – Computer Program

*Mon01_P2_Python_Program.py - /home/pi/P2_Activity_Given_Files/Mon01_P2_Python_Program.py (3.7.3)*

File Edit Format Run Options Window Help

```
import random

import time

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)


#Initializing global variables

gripper_open = True
drawer_status = [False, False, False]


def main():
    '''
    Function: main()
    Purpose: Execute workflow for each randomly generated container based on step
             varible that ensures it is executed in correct order
    Author: Xiang Zhang & Marcus Cohoon
    Last Updatated: Novemeber 30, 2020
    '''
    #Author: Marcus Cohoon
    #Create a list of container ID's in random order
    containers = []
    while len(containers) < 6:
        x = random.randint(1,6)
        if x not in containers:
            containers.append(x)
    print ("")
    print ("Order of containers:", containers)

    #Author: Xiang Zhang
    for i in containers:
        step  = 0
        while True:
            #Obtain data from muscle sensor emulator
            left_data = arm.emg_left()
            right_data = arm.emg_right()

            #Check which step of the workflow the simulation is on and executes the current task accordingly
            if step == 0:
                print ("New container coming! Cotainer ID:", i)
                #Spawns cage from the generated random list
                arm.spawn_cage(i)
                print ("Move on to step 1 - move end effector")
                step += 1

            elif step == 1:
                #The variable completed holds a boolean value that is used to
                #check if the function called executes correctly
                completed = move_end_effector(left_data, right_data, [0.528,0.0,-0.0019])
                if completed:
                    step += 1
                    print ("Move on to step 2 - control gripper")
                    completed = False
```

```
            elif step == 2:
                #Grab the container by closing gripper
                completed = open_and_close_gripper(right_data,left_data)
                if completed:
                    time.sleep(2)
                    arm.move_arm(0.4064,0.0,0.4826)
                    step += 1
                    print ("Move on to step 3 - move end effector")
                    completed = False


            elif step == 3:
                #Determine the colour of the container
                colour = i % 3
                if colour == 0:
                    colour = 3
                completed = move_end_effector(left_data, right_data, autoclave_bin_location(colour,i>3))
                if completed:
                    step += 1
                    print ("Move on to step 4 - control gripper(small) / control drawer(larger)")
                    completed = False

            elif step == 4:
                #If the contianer is small(i<=3) release container
                #If it is large open the bin drawer
                if i <= 3:
                    completed = open_and_close_gripper(right_data,left_data)
                    if completed:
                        step += 1
                        print ("Move on to step 5 - move to home position")
                        completed = False
                else:
                    completed = open_close_drawer(left_data, right_data, i)
                    if completed:
                        step += 1
                        print ("Move on to step 5 - control gripper")
                        completed = False

            elif step == 5:
                #If the container is small move to home position and break out of while loop
                #if it is large release container
                if i <= 3:
                    completed = move_end_effector(0.5, 0, [0.4064,0.0,0.4826])
                    if completed:
                        print ("Move on to step 0 - a new container")
                        print ("")
                        completed = False
                        break
                else:
                    completed = open_and_close_gripper(right_data,left_data)
                    if completed:
                        step += 1
                        print ("Move on to step 6 - control drawer")
                        completed = False

            elif step == 6:
                #if container is large close the bin drawer
                completed = open_close_drawer(left_data, right_data, i)
                if completed:
                    step += 1
                    print ("Move on to step 7 - move to home position")
                    completed = False

            elif step == 7:
                #If the container is large return to home position
                completed = move_end_effector(0.5, 0, [0.4064,0.0,0.4826])
                if completed:
                    print ("Move on to step 0 - a new container")
                    print ("")
                    completed = False
                    #Break out of while loop after the workflow for a container is finished
                    break

    print ("Finished.")



def move_end_effector(left_arm_data, right_arm_data, final_location):
```

```
    '''
    Function: move_end_effector()
    Purpose: This function takes in data from left arm and right arm,and decide
             whether to move the arm to intended position
    Input: left_arm_data and right_arm_data - data from emulator
           final_location - the intended position for q-arm
    Output: a boolean value that shows whether the arm is moved
    Author: Xiang Zhang
    Last Update: November 30, 2020
    '''
    # move the q-arm to intended location if left arm data exceed threshold value
    # and right arm data is less than the variable, max_value
    threshold = 0.4
    max_value = 0.05
    if left_arm_data >= threshold and right_arm_data < max_value:
        time.sleep(2)
        arm.move_arm(final_location[0],final_location[1],final_location[2])
        time.sleep(2)
        return True
    else:
        return False

def autoclave_bin_location(colour, large):
    """
    Function: autoclave_bin_location()
    Purpose: Returns the location of autoclave bin based on size of the spawned container and colour of container
    Input: colour - represented by a number between 1-3
           large - a boolean representing size of caontainer
    Output: Location of autoclave in form of a list
    Authour: Marcus Cohoon
    Last Updated: November 30, 2020

    """
    if large == True:
        location = [[-0.3992,0.1617,0.322],[0.0,-0.42,0.3],[0.0,0.42,0.3]]
    else:
        location = [[-0.6052,0.2452,0.3998],[0.0,-0.6573,0.3998],[0.0,0.6573,0.3998]]

    if colour == 1:  # red
        return location[0]
    elif colour == 2:   # green
        return location[1]
    elif colour == 3:   # blue
        return location[2]
    else:
        print ("Error: This colour is unknown.")
        return [0.4064,0.0,0.4826]


def open_close_drawer(left_arm_data, right_arm_data, container_ID):
    '''
    Function: open_close_drawer()
    Purpose: This function takes in data from left arm and right arm, and
             the container ID that is currently being processed. It then
             determine whether or not to open the corresponding drawer.
    Input: left_arm_data and right_arm_data - data from emulator
           container_ID - a number from 1 to 6 that indicates the
                          container now being processes
    Output: a boolean value that determines if the task was completed
    Author: Xiang Zhang
    Last Update: November 30, 2020
    '''
    global drawer_status
    # open or close the drawer if both left and right hand data exceed threshold
    threshold = 0.4
    if left_arm_data >= threshold and right_arm_data >= threshold:
        if container_ID == 4:
            if drawer_status[0]:
                time.sleep(2)
                arm.open_red_autoclave(False)
                time.sleep(2)
                # changing boolean in drawer_status to False representing a closed drawer
                drawer_status[0] = False
                return True
            else:
                time.sleep(2)
                arm.open_red_autoclave(True)
                time.sleep(2)
                # changing boolean in drawer_status to True representing a open drawer
                drawer_status[0] = True
```

```
            return True
        elif container_ID == 5:
            if drawer_status[1]:
                time.sleep(2)
                arm.open_green_autoclave(False)
                time.sleep(2)
                # changing boolean in drawer_status to False representing a closed drawer
                drawer_status[1] = False
                return True
            else:
                time.sleep(2)
                arm.open_green_autoclave(True)
                time.sleep(2)
                # changing boolean in drawer_status to True representing a open drawer
                drawer_status[1] = True
                return True
        elif container_ID == 6:
            if drawer_status[2]:
                time.sleep(2)
                arm.open_blue_autoclave(False)
                time.sleep(2)
                # changing boolean in drawer_status to False representing a closed drawer
                drawer_status[2] = False
                return True
            else:
                time.sleep(2)
                arm.open_blue_autoclave(True)
                time.sleep(2)
                # changing boolean in drawer_status to True representing a open drawer
                drawer_status[2] = True
                return True
        else:
            print ("Error: Invalid container ID")
            return False

def open_and_close_gripper(right_arm_data,left_arm_data):
    '''
    Function: open_and_close_gripper()
    Purpose: Opens or closes the Q-Arm gripper if the right arm exceeds the threhold while left arm is less than a small nur
    Input: Right_arm_data - right arm data from emulator
           Left_arm_data - left arm data from emulator
    Output: a boolean varible that determines if the task was completed
    Author: Boshi Xu
    Last Updated: November 30, 2020
    '''
    global gripper_open
    # close or open the gripper if right arm data exceed threshold value
    # and left arm data is less than the variable, max_value
    threshold = 0.4
    max_value = 0.05
    if right_arm_data >= threshold and left_arm_data < max_value:
        if gripper_open == True:
            time.sleep(2)
            arm.control_gripper(55)
            time.sleep(2)
            gripper_open = False
            return True
        else:
            time.sleep(2)
            arm.control_gripper(-55)
            gripper_open = True
            return True
    else:
        return False

#Call main function to execute the workflow
main()
```