
Project Two – Get a Grip

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

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial T07

Team 12

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Submitted: December 10th, 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.

Couper Smith 400324905



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.

Eric Hitsman 400255996



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.

Yuvraj Sandhu 400319134



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.

Chengyao Liu 400234569

Click or tap here to enter text.

A handwritten signature in black ink, appearing to read "S. P. S. A.", is positioned in the top left corner of the page.

Executive Summary

In remote parts of Canada, it can be very difficult to gain access to appropriate health care [1]. One of the solutions to increase accessibility to globalized health care is remote surgery so doctors can perform operations without traveling, from anywhere around the world [2]. For remote surgery to be implemented on a large scale, sterilization is integral with the tools having to be sterilized through autoclaves. Therefore, the problem presented to us is that we need to develop a system that allows for the remote sterilization of the surgical tools. This is a two-step process that involves the design of an appropriate autoclave container to allow the sterilization of tools, as well as a computer program capable of remote controlling a Q-Arm to transport the bin to the proper sterilization location.

The main purpose of the container is to securely hold the surgical tool in place during transport and help facilitate sterilization in the autoclave. On top of these main functions, it is stated that the container also must adhere to multiple design constraints including fitting within the assigned footprint, having all features larger or equal to 4mm, having a mass not exceeding 350g, and having a print time fewer than 2 hours. To achieve these functions while ensuring that all the constraints were met, we are implementing numerous design features. Firstly, we are adding handles to the sides of the container that help the end-effector have a better grip on the container and reduce the likelihood of slipping. We also are adding extrusions to the inside of the container with areas carved out to help secure the tool during transport. A lid is also being created to provide a backup in case the container was to be dropped so that the tool would not fall out and get damaged. Finally, long rectangular holes were added to the top and bottom of the design to allow for the pressurized steam to penetrate the container and sterilize the tool. The bottom holes also allow for the condensation to exit afterward.

The computer program that moves the container requires input from two muscle sensor emulators. The muscle emulators can be hooked up to a person remotely allowing for the robotic arm to transport the containers almost fully automatically. The program can scan the container to determine its size and colour, and identify which autoclave bin the container needs to be placed in. The remote arm then picks up the container and moves to the corresponding drop off, opening and closing the autoclave doors if necessary. After dropping the container off for sterilization, it then returns to its default position and repeats the process until there are no more containers to transport.

The efficient design of the container paired alongside the high accuracy and consistency of the computer program provides a solution that allows remote surgeries to be achievable in the modern era.

Project Schedule

Preliminary Gantt Chart

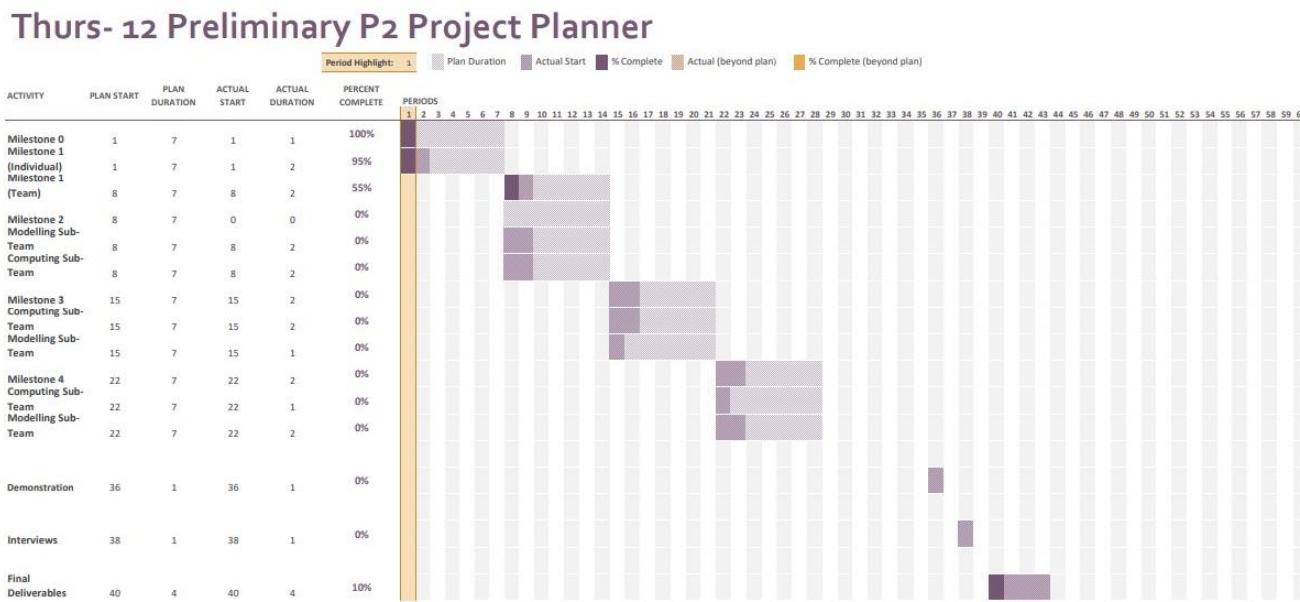


Chart 1: Preliminary Gantt Chart

Final Gantt Chart

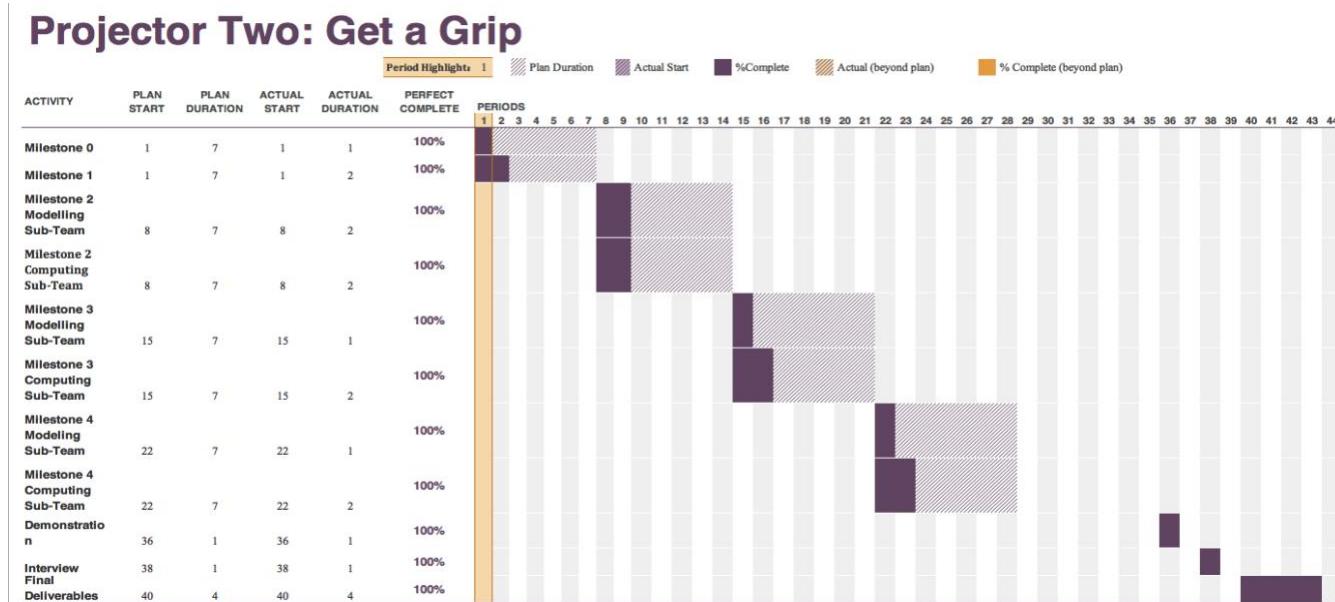
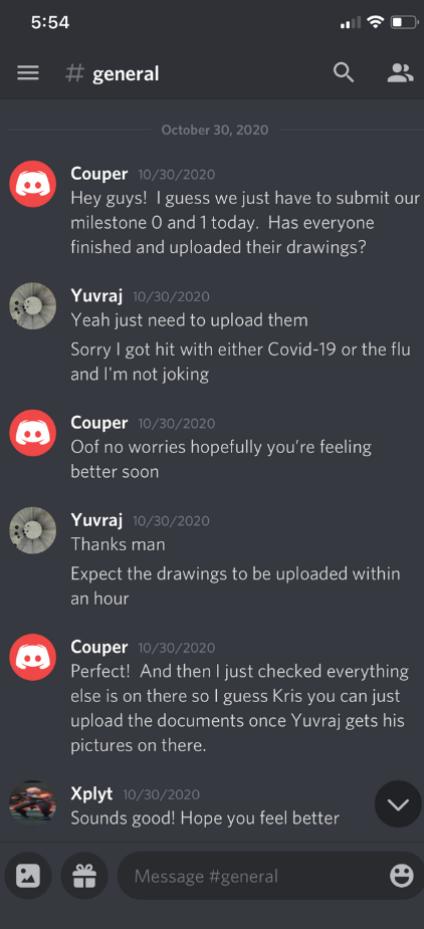
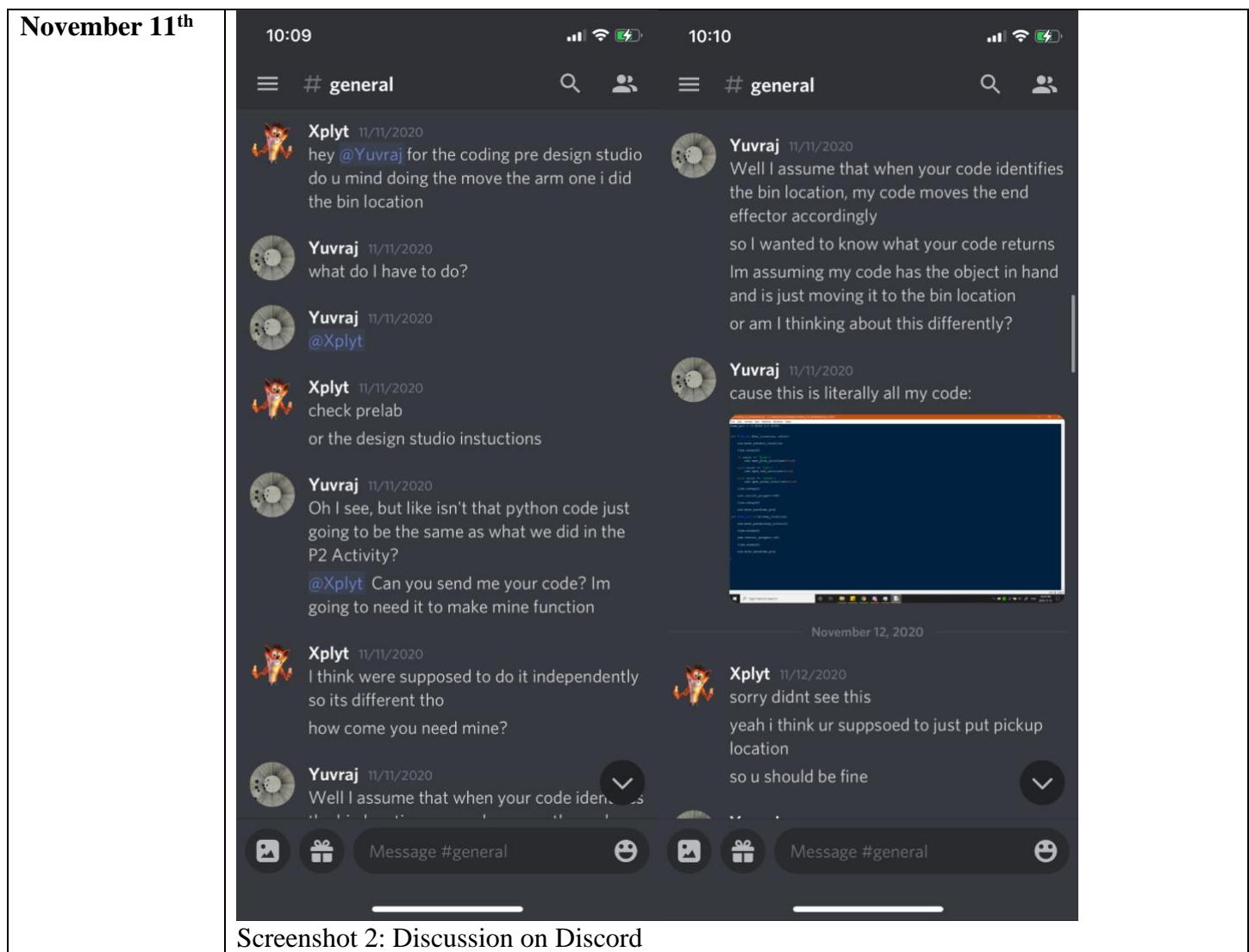


Chart 2: Final Gantt Chart

Logbook of Additional Meetings and Discussions

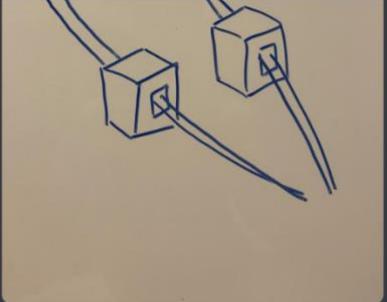
Date	Logbook of Additional Meetings and Discussions
October 30 th	<p>Note: Xplyt is Eric</p>  <p>Couper 10/30/2020 Hey guys! I guess we just have to submit our milestone 0 and 1 today. Has everyone finished and uploaded their drawings?</p> <p>Yuvraj 10/30/2020 Yeah just need to upload them Sorry I got hit with either Covid-19 or the flu and I'm not joking</p> <p>Couper 10/30/2020 Oof no worries hopefully you're feeling better soon</p> <p>Yuvraj 10/30/2020 Thanks man Expect the drawings to be uploaded within an hour</p> <p>Couper 10/30/2020 Perfect! And then I just checked everything else is on there so I guess Kris you can just upload the documents once Yuvraj gets his pictures on there.</p> <p>Xplyt 10/30/2020 Sounds good! Hope you feel better</p>

Screenshot 1: Discussion on discord



November 12th

8:33 @ Kris Liu



smitc25 Today at 8:26 PM
Also I just wrote out what you said and then wrote out the ideas we had written down in full sentences. Do you think there is anything else we can improve on?

Kris Liu Today at 8:30 PM
Ok yeah that's good! The other idea that I was thinking of is we could also make the clips more like slots that the tweezers fit into. It's hard to describe what I mean so I'll just send a sketch.

So in this idea, Is there no clip at the other end of the tweezers?
btw, I don't have other ideas right now

8:17 @ Kris Liu

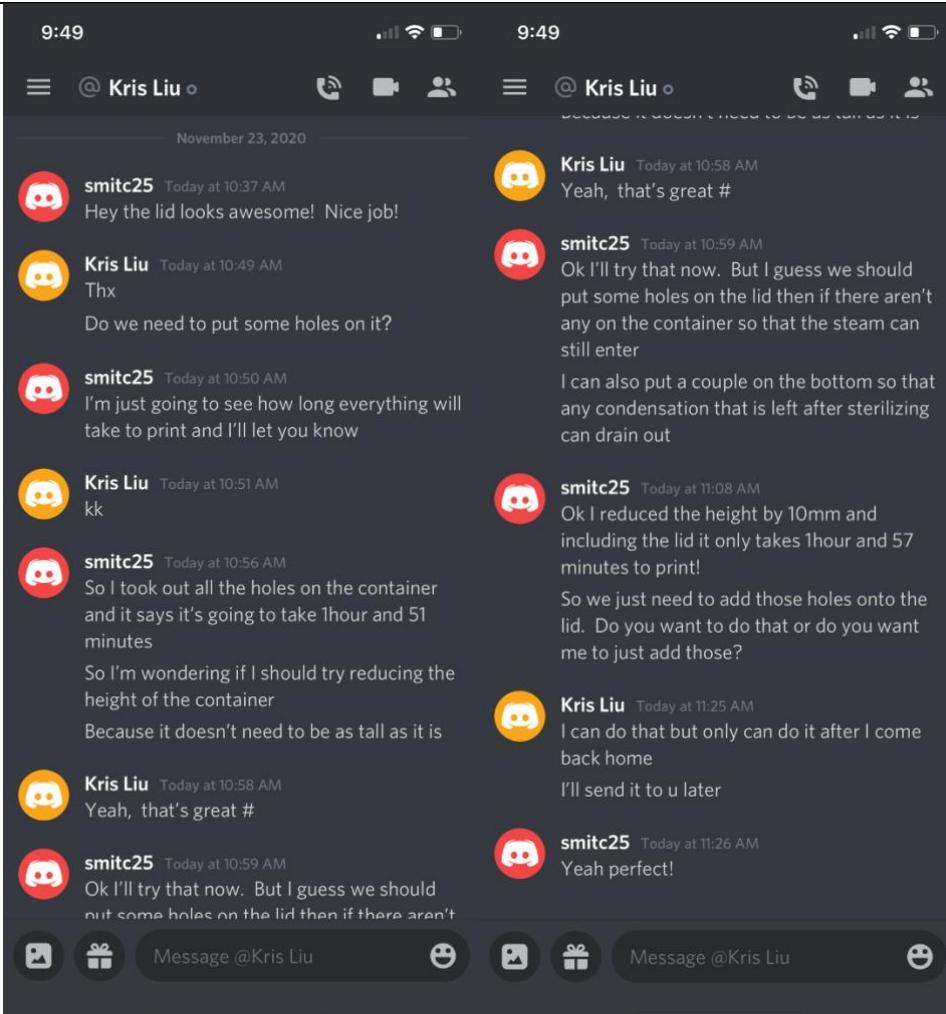
November 12, 2020

Kris Liu Today at 11:35 AM
About the clips, what bout tilting the sides of the clips inward? Furthermore making a groove inside the each clip which can make the tool just stuck there ?
If we want to talk about the details bout making grooves, I think we should consider the characteristics of the material. If the toughness is too low, the tool may be stuck in and can't be taken out.
but I don't think it's necessary to think about it now. I mean no need to consider too far, just realize what we want.

smitc25 Today at 8:16 PM
Ok yeah that's good! The other idea that I was thinking of is we could also make the clips more like slots that the tweezers fit into. It's hard to describe what I mean so I'll just send a sketch.



Screenshot 3: Discussion on Discord

November 23rd	
December 4th	<ul style="list-style-type: none"> - Met on MS Teams to discuss the Final Deliverable and assigned the tasks that each of us had to complete - Also agreed to meet the next day at 3:00 to finish the executive summary
December 5th	<ul style="list-style-type: none"> - Met to Finalize the executive summary and upload our individual assignments
December 8th	<ul style="list-style-type: none"> - Went over the layout and made sure everything was correct - Finalized everything and confirmed the document could be submitted

Scheduled Weekly Meetings

Weekly Design Studio Agendas and Meeting Minutes

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MEETING 1 (TEAM 12) – THURSDAY, OCTOBER 29

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Yuvraj Sandhu	sandhuy	Yes
Administrator	Chengyao Liu	liuc169	Yes
Coordinator	Couper Smith	hitsmane	Yes
Subject Matter Expert	Eric Hitsman	smitc25	Yes
Guest	-	-	-

AGENDA ITEMS

1. Introductions & Attendance
2. Team Portrait
3. Team Charter Document (Milestone 0)
4. Milestone 1
5. Create Subteams
6. Assign Responsibilities for the Week/Final Notes

MEETING MINUTES

1. Introductions & Attendance
 - a. Everyone introduced themselves and told the group some fun facts about themselves
2. Team Portrait
 - a. Got Monica (TA) to take our team portrait
3. Team Charter Document (Milestone 0)
 - a. Assigned the roles of each member
 - i. Yuvraj – Manager
 - ii. Chengyao – Administrator
 - iii. Couper – Coordinator
 - iv. Eric – Subject Matter Expert
4. Milestone 1
 - a. Shared our lists of objectives, constraints, and functions completed prior to the design studio
 - b. Collaborated and combined everyone's ideas into one finalized list
 - c. Identified the main and secondary functions of the entire system
 - d. Completed a morphological analysis
 - e. Individually created two sketches for the container
5. Create Subteams
 - a. Split into two subteams
 - i. Modelling – Couper and Chengyao
 - ii. Computing – Eric and Yuvraj

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MEETING 1 (TEAM 12) – THURSDAY, OCTOBER 29

6. Assign Responsibilities for the Week/Final Notes
 - a. All of us did not finish our sketches and agreed to have them done by 6:00pm tomorrow
 - b. Reminded everyone of their responsibilities for the week to complete either their refined concept sketch or their flowchart

POST-MEETING ACTION ITEMS

1. *Each member complete their tasks for the TEAM document [Everyone]*
2. *Each member submit their individual worksheet and update their online portfolio [Everyone]*
3. *Complete one refined concept sketch [Couper and Chengyao]*
4. *Complete flowchart [Yuvraj and Eric]*

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MEETING 2 (TEAM 12) – THURSDAY, NOVEMBER 5

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Yuvraj Sandhu	sandhuy	Yes
Administrator	Chengyao Liu	liuc169	No
Coordinator	Couper Smith	hitsmane	Yes
Subject Matter Expert	Eric Hitsman	smitc25	Yes
Guest	-	-	-

AGENDA ITEMS

1. Attendance & Updates
2. Issues/Concerns
3. Share Refined Concept Sketches and Flowcharts
4. Create Prototypes and Pseudocode
5. Meeting with TA
6. Assign Responsibilities for the Week/Final Notes

MEETING MINUTES

1. Attendance & Updates
 - a. All present except Chengyao
 - i. Couper will reach out and relay missed notes/responsibilities
 - b. Talked about the Physics midterm happening tonight
2. Issues/Concerns
 - a. Chengyao's refined concept sketch not here
 - i. Couper talked to TAs and IAs and was told to prototype his own sketches
3. Share Refined Concept Sketches and Flowcharts
 - a. Everyone's work completed to a high degree
4. Create Prototypes and Pseudocode
 - a. Split off into two teams to complete our subteam tasks
5. Meeting with TA
 - a. Shared our ideas with Monica and updated her on our progress
 - b. She thought everything was coming along great and that we were on the right track
6. Assign Responsibilities for the Week/Final Notes
 - a. Did not finish everything and therefore agreed to have our individual tasks done by the next day at 6:00
 - b. Ensured that everyone knew what they had to bring to next week's design studio (ie preliminary solid model for modelling subteam and preliminary program tasks worksheet for computing subteam)

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MEETING 2 (TEAM 12) – THURSDAY, NOVEMBER 5

POST-MEETING ACTION ITEMS

1. *Each member complete their tasks for the TEAM document [Everyone]*
2. *Each member submit their individual worksheet and update their online portfolio [Everyone]*
3. *Complete preliminary solid model [Couper and Chenyao]*
4. *Complete Program task worksheet [Yuvraj and Eric]*

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MEETING 3 (TEAM 12) – THURSDAY, NOVEMBER 12

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Yuvraj Sandhu	sandhuy	Yes
Administrator	Chengyao Liu	liuc169	Yes
Coordinator	Couper Smith	hitsmane	Yes
Subject Matter Expert	Eric Hitsman	smitc25	Yes
Guest	-	-	-

AGENDA ITEMS

1. Attendance
2. Midterms
3. Issues/Concerns/Updates
4. Share Preliminary Solid Models and Program Tasks
5. Meeting with TA
6. Milestone 3 Deliverables
7. Assign Responsibilities for the Week/Final Notes

MEETING MINUTES

1. Attendance
 - a. All present
2. Midterms
 - a. Talked about how the Physics midterm went and whether everyone was ready for the Chemistry and Math midterms coming up
3. Issues/Concerns/Updates
 - a. None
4. Share Preliminary Solid Models and Program Tasks
 - a. Computing team shared their pseudocode
 - b. Modelling team shared their solid models
5. Meeting with TA
 - a. Updated Monica on our progress and received feedback
 - i. Modelling team
 1. Ensure that all measurements are greater than 4mm
 2. Looking very good so far
 - ii. Computing team
 1. Clarified a few misconceptions about the functions
 2. Ensure to comment the code
 3. Very good so far

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MEETING 3 (TEAM 12) – THURSDAY, NOVEMBER 12

6. Milestone 3 Deliverables
 - a. Split off into subteams to complete milestone 3 deliverables (Pugh matrix and code review)
7. Assign Responsibilities for the Week/Final Notes
 - a. Did not finish everything and therefore agreed to have our individual tasks done by the next day at 6:00
 - b. Ensured that everyone knew what they had to bring to next week's design studio (ie finish the final solid model and generate g-code, and write part of the computer program in python)

POST-MEETING ACTION ITEMS

1. *Each member complete their tasks for the TEAM document [Everyone]*
2. *Each member submit their individual worksheet and update their online portfolio [Everyone]*
3. *Complete Solid Model and Generate G-code [Couper and Chenyao]*
4. *Complete Part of Computer Program [Yuvraj and Eric]*

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MEETING 4 (TEAM 12) – THURSDAY, NOVEMBER 19

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Yuvraj Sandhu	sandhuy	Yes
Administrator	Chengyao Liu	liuc169	No
Coordinator	Couper Smith	hitsmane	Yes
Subject Matter Expert	Eric Hitsman	smitc25	Yes
Guest	-	-	-

AGENDA ITEMS

1. Attendance
2. Catchup
3. Issues/Concerns/Updates
4. Meeting with TA
5. Independent Work

MEETING MINUTES

1. Attendance
 - a. All present except for Chengyao
2. Catchup
 - a. Talked about chem and math midterms
 - b. Talked about getting ready for exams
 - c. Talked about what next semester is going to be like
3. Issues/Concerns/Updates
 - a. None
4. Meeting with TA
 - a. Updated Monica on our progress and received feedback
 - i. Modelling team
 1. Ensure that the container fits in the footprint
 2. Asked clarification questions
 - a. What is the width of the end effector?
 - b. How do we generate the G-code?
 3. Looks very good and does not need any modifications
 - ii. Computing team
 1. Check to see that muscle sensor is included in the code
 2. Very good so far just need to compile it together into one file
 5. Independent Work
 - a. By next week each team needs to have completed their assigned tasks

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MEETING 4 (TEAM 12) – THURSDAY, NOVEMBER 19

- i. Modelling
 - 1. Finish the solid model
 - 2. Generate the G-code
- ii. Computing
 - 1. Compile it all into one file
 - 2. Make sure it works and that the code can pick up one container at least and drop it off in the right bin

POST-MEETING ACTION ITEMS

- 1. Complete Solid Model and Generate G-code [Couper and Chenyao]
- 2. Complete Part of Computer Program [Yuvraj and Eric]

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MEETING 5 (TEAM 12) – THURSDAY, NOVEMBER 26

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Yuvraj Sandhu	sandhuy	Yes
Administrator	Chengyao Liu	liuc169	Yes
Coordinator	Couper Smith	hitsmane	Yes
Subject Matter Expert	Eric Hitsman	smitc25	Yes
Guest	-	-	-

AGENDA ITEMS

1. Attendance
2. Catchup
3. Issues/Concerns/Updates
4. Plan Final Deliverable
5. Sign up for Interview
6. Design Review with TA
7. Assign Responsibilities for the Week/Final Notes

MEETING MINUTES

1. Attendance
 - a. All present
2. Catchup
 - a. Talked about school and how everyone is doing
3. Issues/Concerns/Updates
 - a. None
4. Plan Final Deliverable
 - a. Went through final deliverable expectations and assigned tasks
 - b. Decided to individually complete all these tasks and meet on Friday, December 4th @ 3:00
 - c. On the Friday we will finalize everything and complete the executive summary together
5. Sign up for Interview
 - a. Discussed everyone's availability and signed up for our interview on Friday, December 4th @ 2:30pm
6. Design Review with TA
 - a. Presented to the TA showing our container design, g-code, and python program and received feedback
 - i. Modelling
 1. Everything looked great
 2. Put some more holes on the container to allow for steam to enter more

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MEETING 5 (TEAM 12) – THURSDAY, NOVEMBER 26

3. To overcome the printing time, make the holes square (these are faster to print)
- ii. Computing
 1. Everything looks good
7. Assign Responsibilities for the Week/Final Notes
 - a. Subteams must finish their part of the project and have it ready for Friday
 - b. Everyone must have their parts of the final deliverable done by Friday as well
 - c. After lecture on Wednesday explaining the interview we will determine a time to meet to plan the interview out

POST-MEETING ACTION ITEMS

1. Complete Solid Model, Generate G-code, Make Assembly, Create Engineering Drawing [Couper and Chenyao]
2. Complete Computer Program [Yuvraj and Eric]

Design Studio Worksheets**Milestone 0/1 – October 29th, 2020****PROJECT TWO: MILESTONE 0 – COVER PAGE****Team Number:** Thurs-12

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

Full Name:	MacID:
Couper Smith	smitc25
Eric Hitsman	hitsmane
Yuvraj Sandhu	Sandhuy
Chengyao Liu	liuc169

Insert your Team Portrait in the dialog box below



MILESTONE 0 – TEAM CHARTER

Team Number: Thurs-12

Incoming Personnel Administrative Portfolio:

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

	Team Member Name:	Project Leads
1.	Couper Smith	<input checked="" type="checkbox"/> M <input type="checkbox"/> A <input type="checkbox"/> C <input type="checkbox"/> S
2.	Eric Hitsman	<input type="checkbox"/> M <input type="checkbox"/> A <input checked="" type="checkbox"/> C <input type="checkbox"/> S
3.	Yuvraj Sandhu	<input type="checkbox"/> M <input checked="" type="checkbox"/> A <input type="checkbox"/> C <input type="checkbox"/> S
4.	Chengyao Liu	<input type="checkbox"/> M <input type="checkbox"/> A <input type="checkbox"/> C <input checked="" type="checkbox"/> 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.

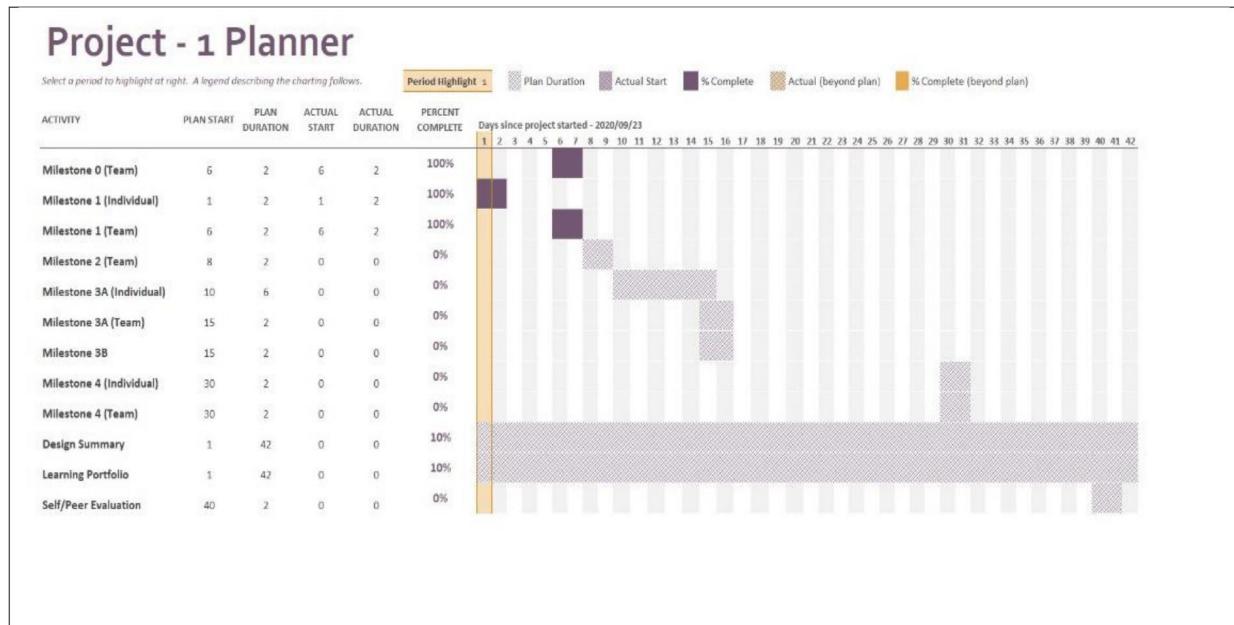
Role:	Team Member Name:	MacID
Manager	Yuvraj Sandhu	Sandhuy
Administrator	Chengyao Liu	liuc169
Coordinator	Couper Smith	smitc25
Subject Matter Expert	Eric Hitsman	hitsmane

MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team Number: Thurs-12

Full Name of Team Manager:	MacID:
Yuvraj Sandhu	Sandhuy

Preliminary Gantt chart



PROJECT TWO: MILESTONE 1 – COVER PAGE

Team Number: THURS-12

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

Full Name:	MacID:
Yuvraj Sandhu	Sandhuy
Eric Hitsman	hitsmane
Chengyao Liu	liuc169
Couper Smith	smitc25

MILESTONE 1 (STAGE 1) – PRE-PROJECT ASSIGNMENT

Team Number: Thurs-12

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: Thurs-12

Name:Eric Hitsman	MacID:hitsmane
<i>Objectives</i>	
<ul style="list-style-type: none"> • Easy for machine to access • Holds tools securely • Tools return to same spot every time 	
<i>Constraints</i>	
<ul style="list-style-type: none"> • Must be secure • Must not exceed 350g • Container must be smaller than grabber 	
<i>Functions</i>	
<ul style="list-style-type: none"> • Hold surgical tools • Sort containers 	

Team Number: Thurs-12

Name: Chengyao	MacID: liuc169
<i>Objectives</i>	
<ul style="list-style-type: none"> Easy to be picked up by the robotic arm. Able to hold the surgical tools securely. 	
<i>Constraints</i>	
$M \leq 350g$	
<i>Functions</i>	
<ul style="list-style-type: none"> Able to securely hold surgical instrument. Held by robotic arm stably. Classify the surgical tools by colors. 	

Team Number: Thurs-12

Name: Yuvraj Sandhu	MacID: Sandhuy
<i>Objectives</i>	
<ul style="list-style-type: none">• Easily be able to carry• Fits within the claw's dimensions	
<i>Constraints</i>	
<ul style="list-style-type: none">• Safe to utilize• Must be able to carry up to 1 kilogram• Cannot weigh larger than 350g• Holds surgical tool in place without moving	
<i>Functions</i>	
<ul style="list-style-type: none">• Firmly holds objects mid-air• Can store solids and liquids without any leakage• Transports objects to correct• Allows steam to sanitize surgical tools	

Team Number: Thurs-12

Name: Couper Smith	MacID: smitc25
<p>Containers:</p> <p><i>Objectives</i></p> <ul style="list-style-type: none"> • Made of material with high coefficient of friction (to prevent slipping) • Sturdy design (can survive drops and not spill contents) <p><i>Constraints</i></p> <ul style="list-style-type: none"> • Must NOT have a length or width greater than 150mm (proximal end limits of end-effector) • Size of the container must fit inside the autoclave (different dimensions depending on assigned scenario) • All features must be greater than 4mm (minimum dimension to be properly fabricated) • Must not exceed 350g <p><i>Functions</i></p> <ul style="list-style-type: none"> • Able to securely hold the surgical tool in place during transfer • Must allow sterilization to occur (ie steam must be able to penetrate the container) 	<p>Robotic Arm/Autoclave Bins:</p> <p><i>Objectives</i></p> <ul style="list-style-type: none"> • Reliable (ie is able to ID the container and put it in the right location each time) • Require minimal human intervention Must allow sterilization to occur (ie steam must be able to penetrate the container) <p><i>Constraints</i></p> <ul style="list-style-type: none"> • Must provide enough force to move the container but not enough force to break the container <p><i>Functions</i></p> <ul style="list-style-type: none"> • Able to identify the type of container placed on the pick-up platform • Able to pick up the containers and securely move them to the correct container

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

Team Number: Thurs-12

- 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
Made of material with high coefficient of friction (to prevent slipping)	Must not exceed 350g	Must allow sterilization to occur (ie steam must be able to penetrate the container)
Sturdy design (can survive drops and not spill contents)	Must NOT have a length or width greater than 150mm (proximal end limits of end-effector)	Securely hold the surgical tool in place during transfer
Easily able to be carried	All features must be greater than 4mm (minimum dimension to be properly fabricated)	Classify the surgical tools by colors and size
Holds tools securely	Size of the container must fit inside the autoclave (different dimensions depending on assigned scenario)	

- What is the primary function of the entire system?

Allow Transport of Surgical Tools

- What are the secondary functions?

Sterilizes Tools
Correctly Identifies Container and End Location
Securely hold the surgical devices in place

MILESTONE 1 (STAGE 3) – MORPHOLOGICAL ANALYSIS

Team Number: Thurs-12

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	Grasp (from the sides)	Lift from bottom	Hoop on container	Suction Cups	Magnetic	Handle
Securely holds devices	Container	Indent in Container	High Friction Claw Material	Magnetic	Clips	Velcro
Correctly identifies end location	Camera	Coordinates system	Colour sensor	Depth sensor	Pre-Planned Code	

MILESTONE 1 (STAGE 4) – CONCEPT SKETCHES

Team Number: **Thurs-12**

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 you 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: **Thurs-12**

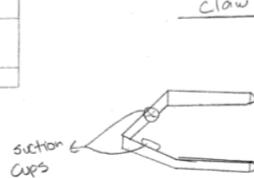
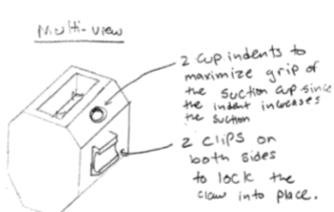
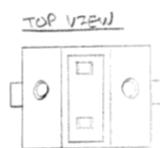
Name: Yuvraj Sandhu

MacID: Sandhuy

Yuvraj Sandhu
Sandhuy
THURS-12

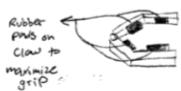
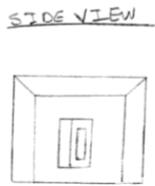
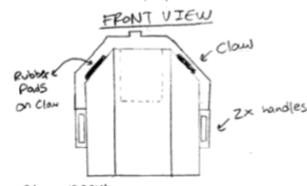
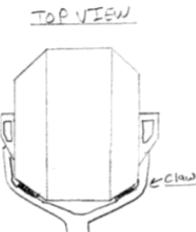
Design Features:

- 2 Clips for security
- Suction cups to firmly grasp the indented cups on the container



Yuvraj Sandhu
Sandhuy
THURS-12

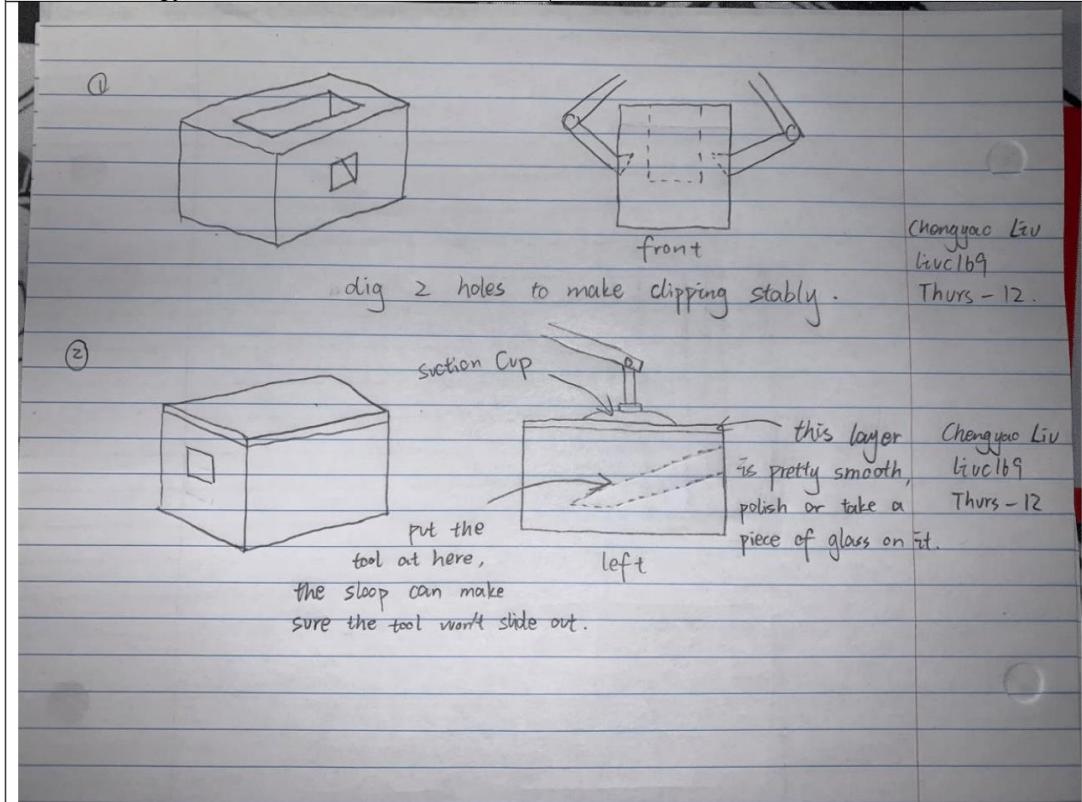
- Design Features:
- 2 Gripping handles for gripping in multiple angles.
 - Indents for better gripage of the claw.
 - 3 secure positions for transportation. Rubber claw pads to increase grip on container.



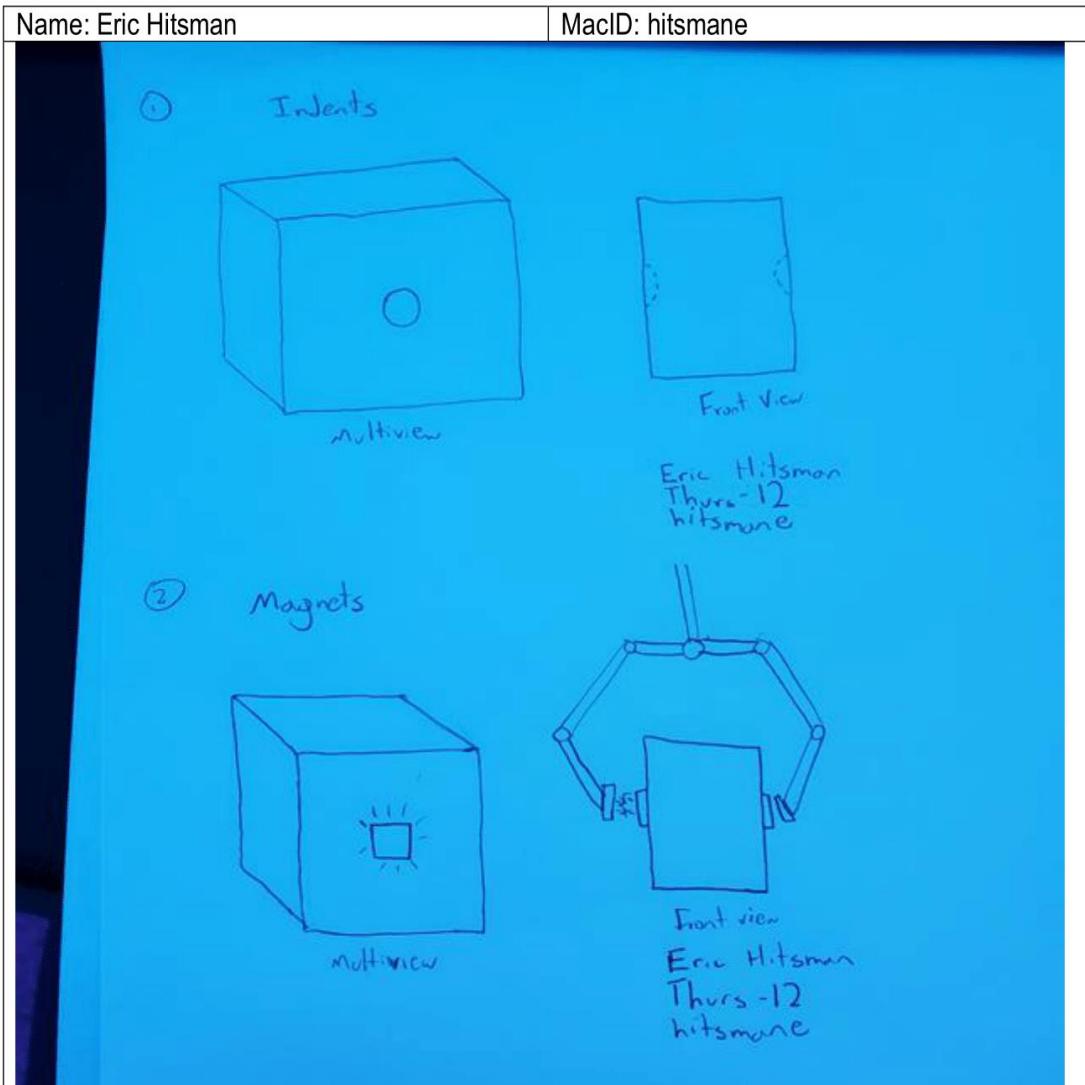
Team Number: Thurs-12

Name: Chengyao Liu

MacID: liuc169



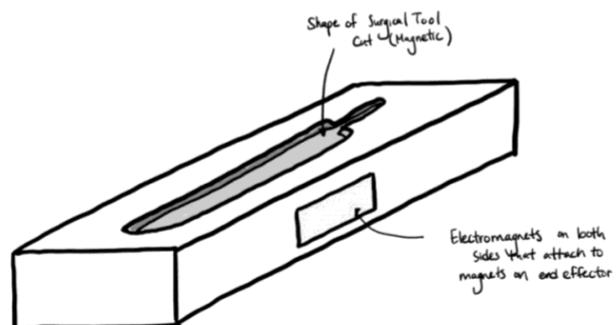
Team Number: Thurs-12



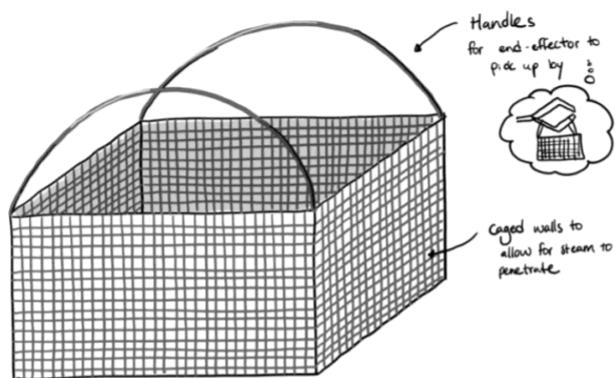
Team Number: Thurs-12

Name: Couper Smith

MacID: smitc25



Thurs-12
Couper Smith
Smitc25



Thurs-12
Couper Smith
Smitc25

Milestone 2 – November 5th, 2020

PROJECT TWO: MILESTONE 2 – COVER PAGE

Team Number: **Thurs-12**Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Couper Smith	smitc25
Eric Hitsman	hitsmane
Yuvraj Sandhu	sandhuy
Chengyao Liu	liuc169

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

Team Number: Thurs-12

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

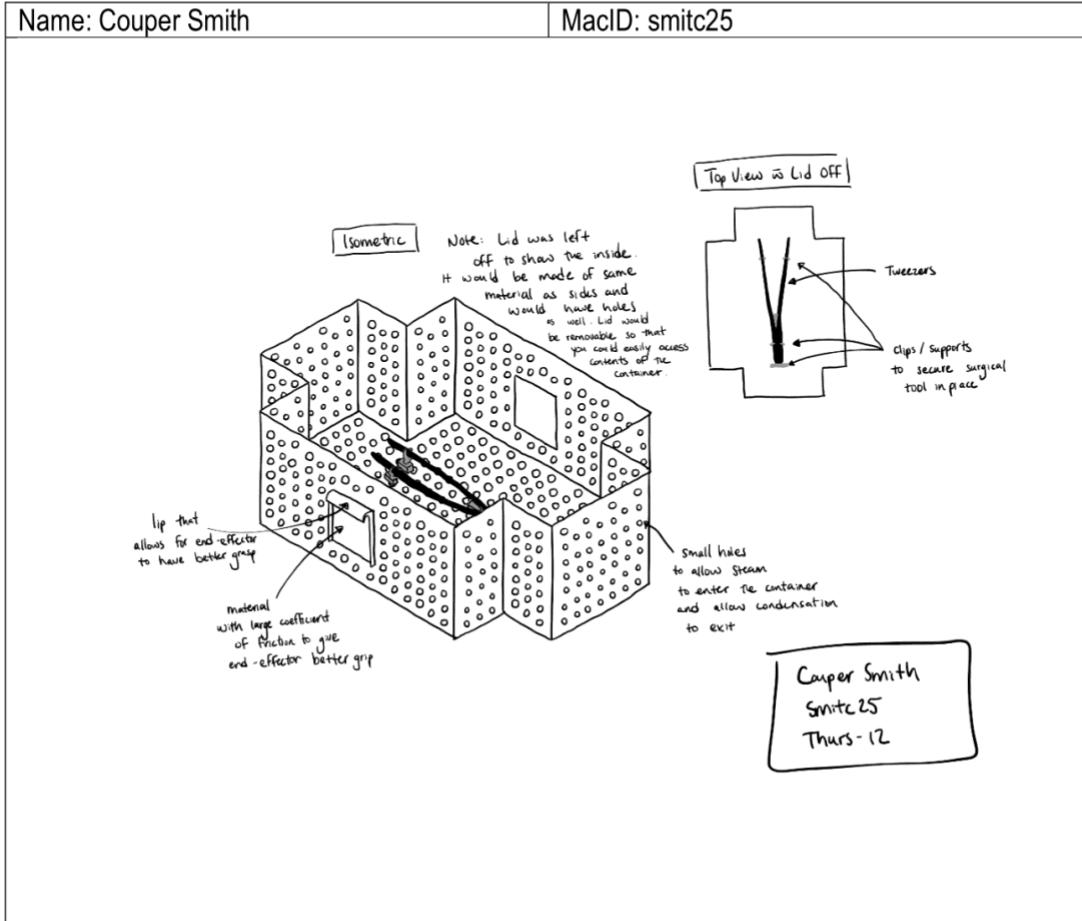
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- 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: Thurs-12

Name: Couper Smith

MacID: smitc25

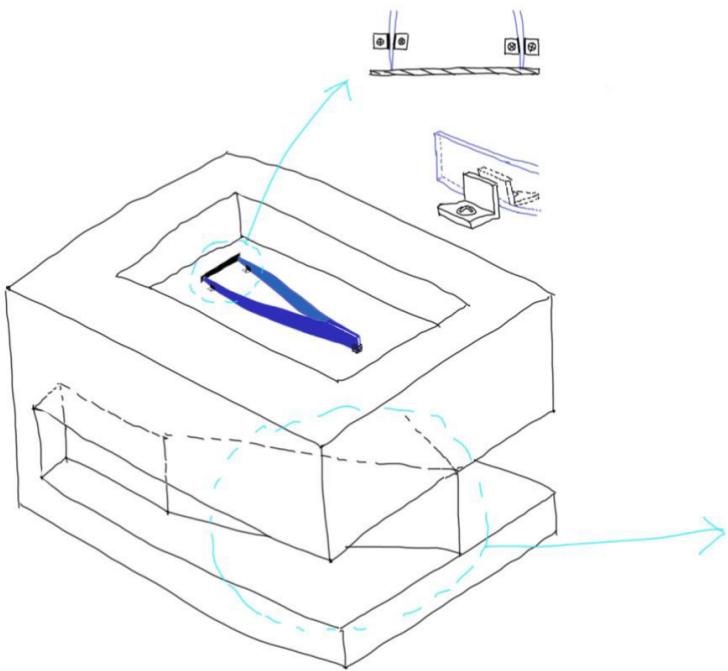


Team Number: Thurs-12

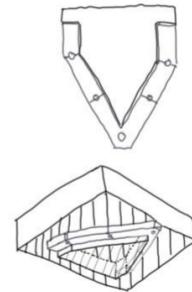
Name: Chengyao Liu

MacID: liuc169

Chengyao Liu
liuc169
Thurs -12



The shape of this part is able to fit the shape of the clip, and at the same time there is a flat surface on it, which enables the shelf to hold the container, thus making a double-stable effect.



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

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

Team Number: **Thurs-12**

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

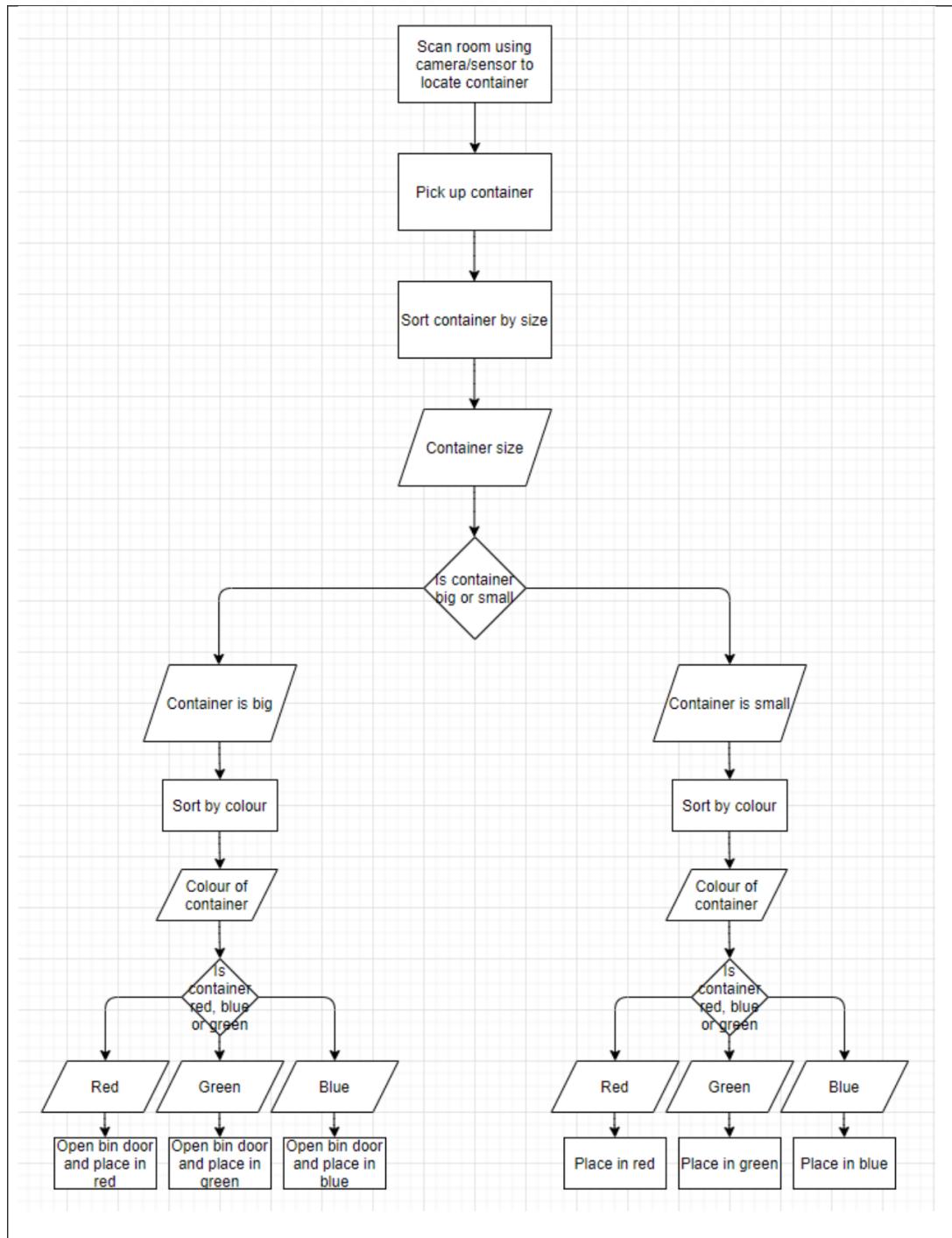
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- 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

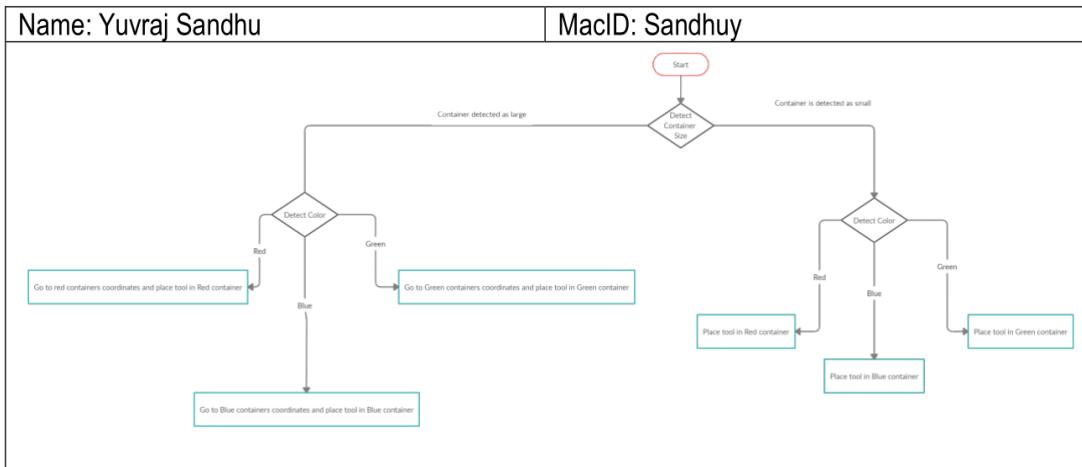
Team Number: **Thurs-12**

Name: Eric Hitsman

MacID:hitsmane



Team Number: Thurs-12



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

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

Team Number: Thurs-12

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**

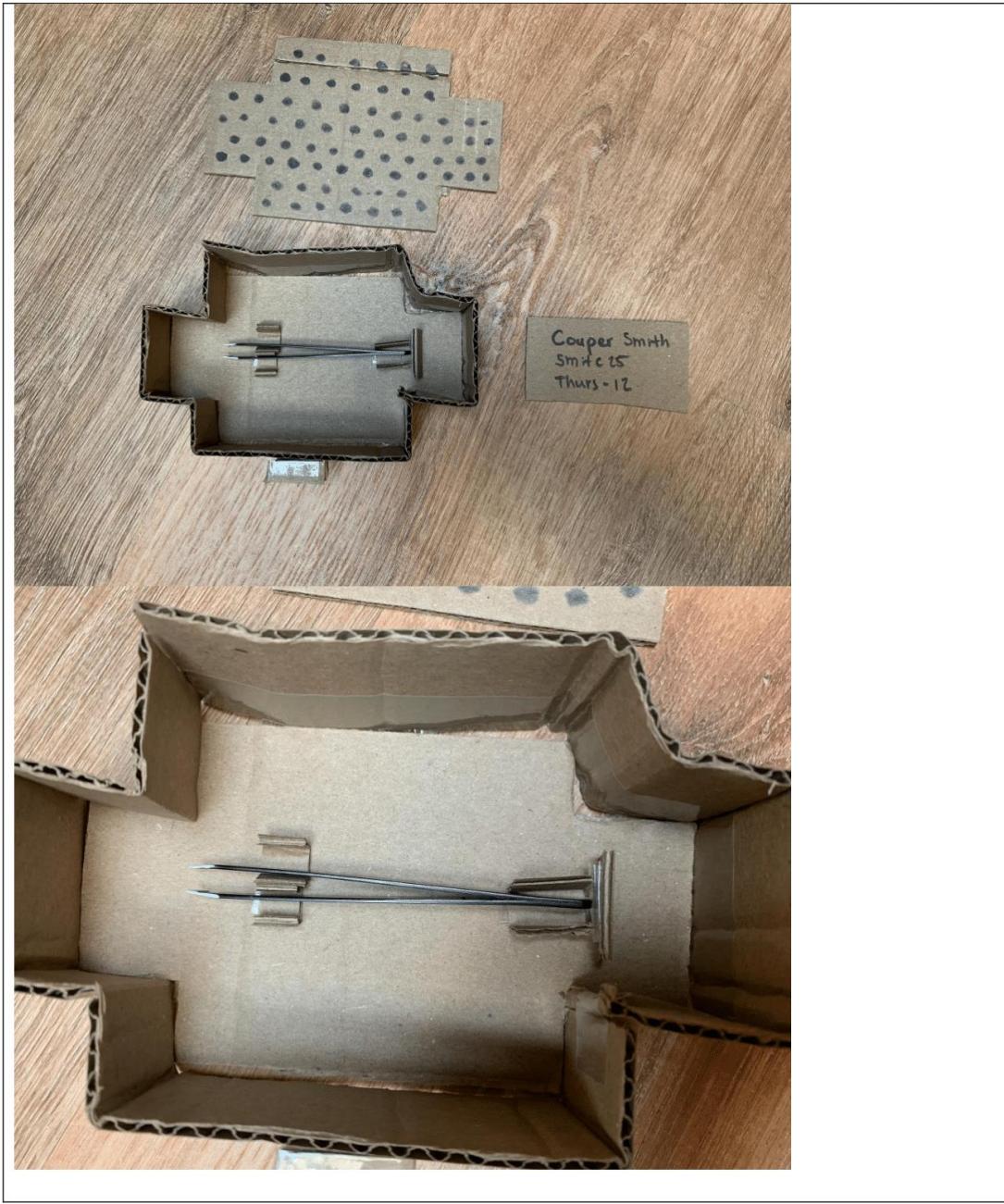
Make sure to include photos of each team member's prototype

Team Number: Thurs-12

Name: Couper Smith	MacID: smitc25
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Note: Chengyao's wifi was down on the day of the design studio and therefore was not able to pass along his sketches. I talked to a TA and the IAI and they gave us permission to model our own sketches instead of each other's.





Team Number: Thurs-12

Name: Chengyao Liu

MacID: liuc169





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

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

Team Number: Thurs-12

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 (Couper Smith, smtc25)	
Advantages:	<ul style="list-style-type: none"> • Use of handles allows for a more secure hold on the container during transport • Holes allow for effective sterilization (ie steam is easily able to penetrate the container and reach the surgical tool) • Clips inside the container keep the surgical tool in place • Lid can be removed to provide easy access • Lid acts as a backup so that if the tool does come loose during transport, it will not fall out of the container entirely
Disadvantages:	<ul style="list-style-type: none"> • Holes will weaken the frame making the overall design less durable • If the tool did come loose during transport, there is a lot of space for it to move around in and get damaged
Objectives:	<ul style="list-style-type: none"> • Easy to carry <ul style="list-style-type: none"> ○ Handles ○ Made of material with high coefficient of friction • Hold tools <ul style="list-style-type: none"> ○ Clips ○ Lid • Sturdy design <ul style="list-style-type: none"> ○ Made of durable material that can survive drops

	<ul style="list-style-type: none"> Potentially weak because of the holes (ie need to ensure that the holes are not having significant impacts on the overall sturdiness)
Constraints:	<ul style="list-style-type: none"> Length and width are less than 150mm All features (including the holes) are larger than 4mm Container meets the required footprint specifications
Functions:	<ul style="list-style-type: none"> Allows sterilization to occur through the use of holes in the sides, top, and bottom Clips securely hold the tool in place during transport
Reliability:	<ul style="list-style-type: none"> Believe that the design should be reliable as it appears to meet all the objectives, constraints and functions, but will require more testing to ensure this is true (ie test to ensure that the container can consistently be picked up and transported, do some drop tests to see if container breaks or if the surgical tool comes loose, etc.) If something becomes apparent after testing this, then the proper changes would be made to those areas
Sterilization:	<ul style="list-style-type: none"> Holes in the container should allow for the steam to enter and sterilize the tool Again, we should test to see how much steam is able to enter the container (if not enough is entering, this may mean adding more holes to the walls and lid is necessary)
Areas to Improve:	<ul style="list-style-type: none"> Could make more efficient use of space and have multiple tools inside the container at once (this would make the sterilization process more efficient by saving time and energy) Consider reducing the height of the container to reduce cost of materials and make the tools more secure (ie less space to bounce around in if the tools did get loose)
Other Notes:	<ul style="list-style-type: none"> Check to see if the handles get in the way of the container fitting inside the autoclave (if this does happen consider making the handles more like indents in the container)
Prototype 2 (Chengyao Liu, liuc169)	
Advantages:	<ul style="list-style-type: none"> End-effector fits inside the container giving it a very solid grip (very unlikely to slip out) Clips inside the container keep the surgical tool in place Container is solid (ie no holes) and thus has a more solid frame Surgical tool placed in a well that adds a backup in case it gets loose from the clips (ie won't just fall off)
Disadvantages:	<ul style="list-style-type: none"> Doesn't have a lid which if the container were to fall could result in the tool falling out of the container

	<ul style="list-style-type: none"> • End-effector must be very precise when picking up the container (ie won't have a solid grasp on the container if it is off by even a little)
Objectives:	<ul style="list-style-type: none"> • <i>Easy to carry</i> <ul style="list-style-type: none"> ◦ <i>End-effector fits into the container</i> • <i>Hold tools</i> <ul style="list-style-type: none"> ◦ <i>Clips</i> ◦ <i>Well that surgical tool sits in</i> • <i>Sturdy design</i> <ul style="list-style-type: none"> ◦ <i>Made of durable material that can survive drops</i>
Constraints:	<ul style="list-style-type: none"> • <i>Length and width are less than 150mm</i> • <i>All features are larger than 4mm</i> • <i>Container does not meet the required footprint specifications (this could easily be modified to make this work)</i>
Functions:	<ul style="list-style-type: none"> • <i>Allows sterilization to occur as the design is open concept (steam will be able to reach the tool easily)</i> • <i>Clips securely hold the tool in place during transport</i>
Reliability:	<ul style="list-style-type: none"> • End-effector fitting directly into the container makes the design very reliable (ie very unlikely to fall off) • Clips hold the tool securely in place and thus is unlikely to move around during transport • The shape of the bottom fits the shape of the clip very well, which makes it very reliable during the clamping process.
Sterilization:	<ul style="list-style-type: none"> • Open concept design allows for sterilization to occur • Very little room for error and you can't have a more direct access to the steam
Areas to Improve:	<ul style="list-style-type: none"> • Consider adding a lid to add another layer of protection • Add high friction material to the parts of the container that are in direct contact with the gripper to make it even more secure • Change the base so that it follows the footprint
Other Notes:	<ul style="list-style-type: none"> • Check to see that the base is big enough that when setting down the container it doesn't fall over • The container seems to be held up, and the clip is clamped under the container during installation. It may hinder in the installation process.

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

Team Number: **Thurs-12**

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

Both flowcharts have:

- Sort container by size
- Sort container by colour
- Pick up container
- Place container in corresponding bin

Differences

- Place tool in container
- Movement directions
- Opening of doors

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

Team Number: **Thurs-12**

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

Start

Initialize Claw motors

Scan room for container and autoclave bin locations

While there is a container on the pick-up platform

 Go to Container XYZ coordinates

 Identify container size and colour

 If the color equals red, green, or blue go to the corresponding bin

 If the container is large open the corresponding bin door

 Start Pick up function

 Move to corresponding autoclave bin that was determined in the identify size and colour step

 Place the container in the autoclave bin

 If the container is large, then it will be placed in the door and the door will be closed

 If the container is small, it will be placed in the top slot

 Start Go to Home function

 Scan for new containers

End

Milestone 3 – November 12th, 2020**PROJECT TWO: MILESTONE 3 – COVER PAGE****Team Number:** Thurs-12

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

Full Name:	MacID:
Couper Smith	smitc25
Yuvraj Sandhu	Sandhuy
Eric Hitsman	hitsmane
Chegnyao Liu	liuc169

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

Team Number: **Thurs-12**

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

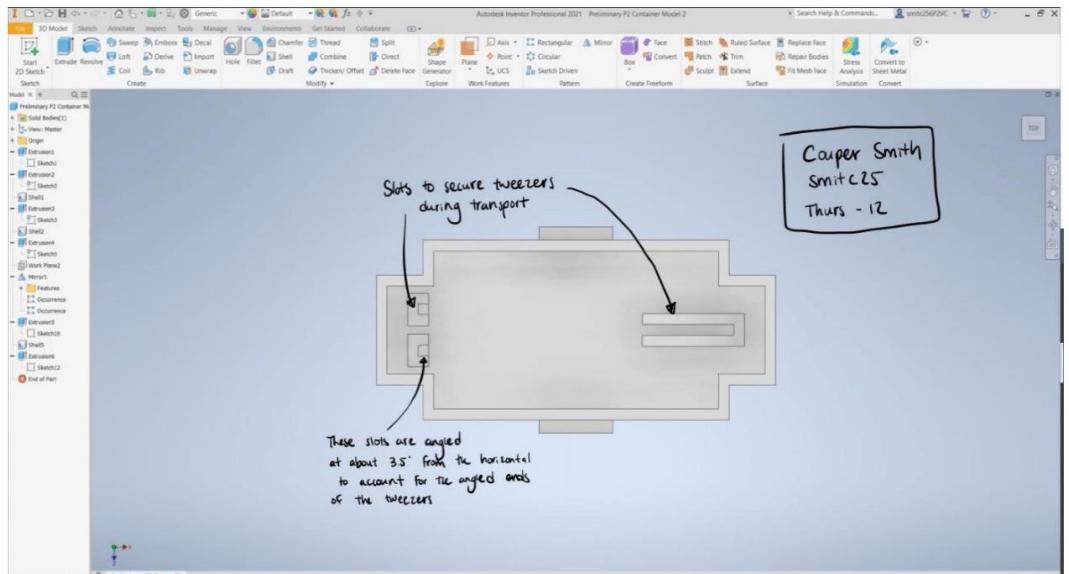
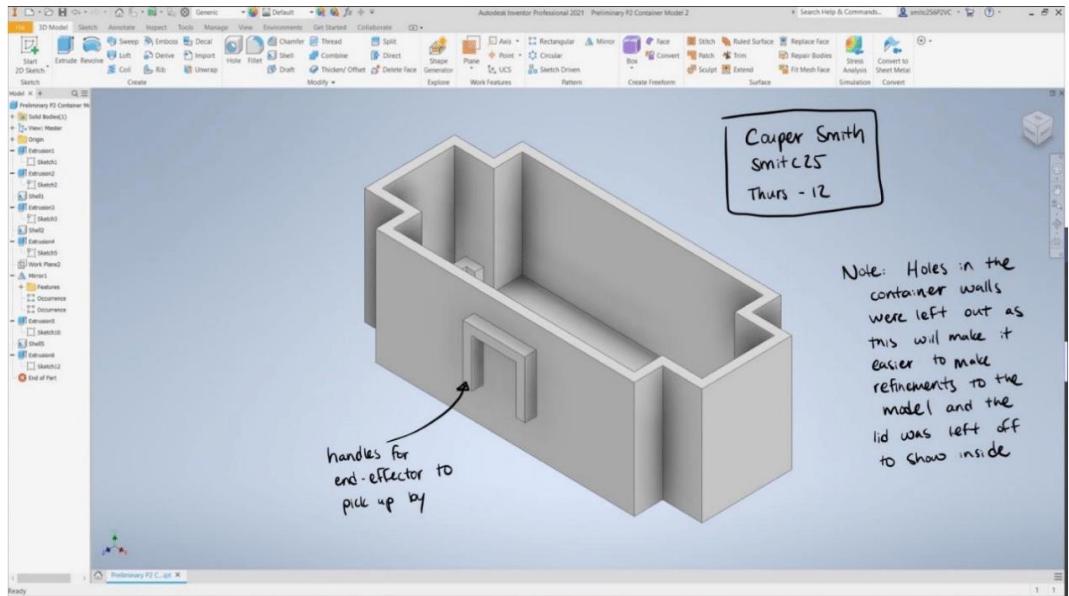
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

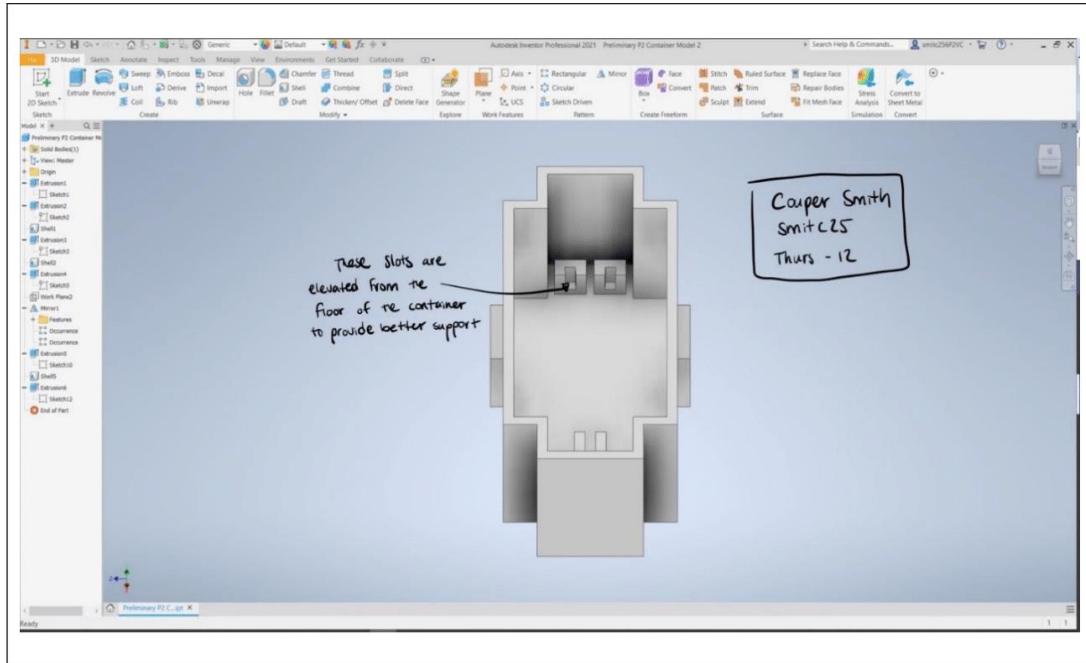
- Each team member needs to submit their solid model screenshots with the **Milestone Three Individual Worksheets** document so that it can be **graded**
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
 - This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

Team Number: Thurs-12

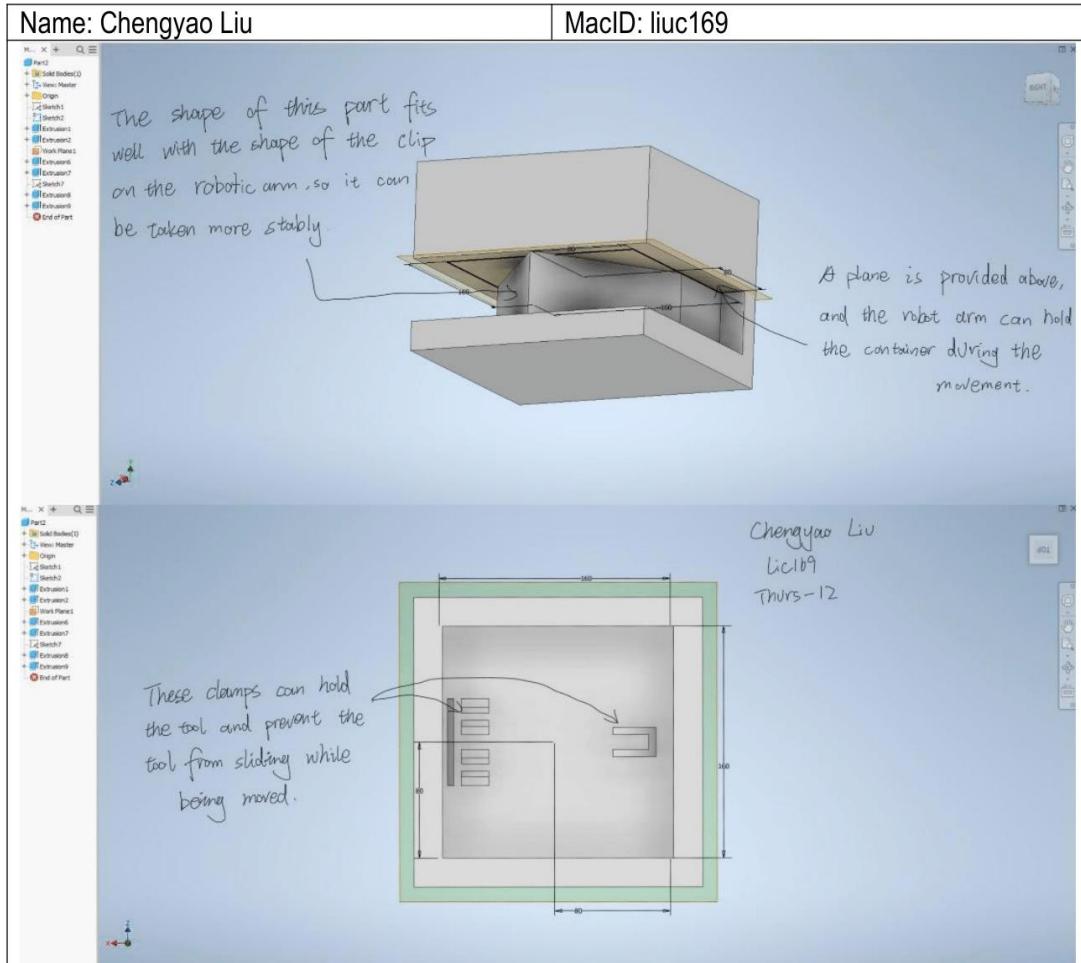
Name: Couper Smith

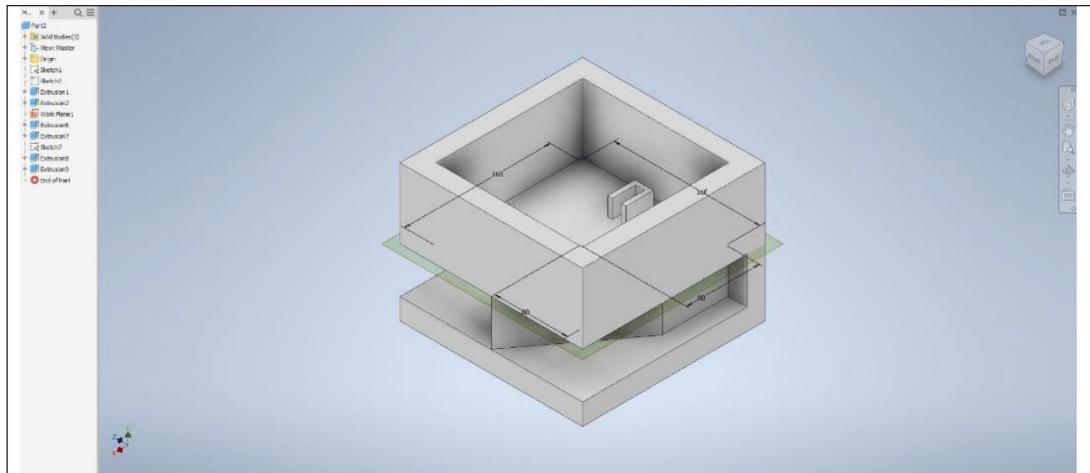
MacID: smitc25





Team Number: Thurs-12





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

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

Team Number: **Thurs-12**

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: Thurs-12

Name: Yuvraj Sandhu	MacID: Sandhuy
<pre># Sandhuy # Yuvraj Sandhu # 400319134 # Task: Move End-Effector home_pos = [0.4064,0,0.4826] def Move_bin(bin_location, color): arm.move_arm(bin_location) time.sleep(2) if color == 'blue': arm.open_blue_autoclave(True) elif color == 'red': arm.open_red_autoclave(True) elif color == 'green': arm.open_green_autoclave(True) time.sleep(2) arm.control_gripper(-45) time.sleep(2) arm.move_arm(home_pos) def Move_pickup(pickup_location): arm.move_arm(pickup_location) time.sleep(2) arm.control_gripper(-45) time.sleep(2) arm.move_arm(home_pos)</pre>	

Team Number: **Thurs-12**

Name:Eric Hitsman

MacID: hitsmane

```
def get_bin_locations():
    x = int(input ("Which dropoff would you like: small green = 1, small red = 2, small blue = 3, large green = 4, large red
if x == 1:
    y = (0.0, -0.6726, 0.4261)
    return y
elif x == 2:
    y = (-0.6096, 0.2843, 0.4261)
    return y
elif x == 3:
    y = (0.0, 0.6726, 0.4261)
    return y
elif x == 4:
    y = (0.0, -0.4064, 0.4826)
    return y
elif x == 5:
    y = (-0.3683, 0.1718, 0.4826)
    return y
elif x == 6:
    y = (0.0, 0.4064, 0.4826)
    return y
else:
    print ("That is not a valid dropoff id")
```

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

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

Team Number: Thurs-12

- 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

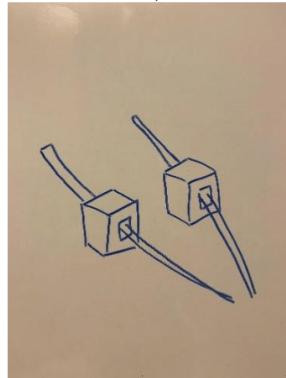
	Datum	Couper's Design (smitec25)	Chengyao's Design (liuc169)
Facilitate Sterilization of Surgical Tool	S	S	S
Securely Hold Tools During Transport	S	-	-
Easy to Move/Carry	S	+	+
Sturdy Design	S	S	S
Design Fits within the Assigned Footprint	S	+	S
Features are all Minimum of 4mm	S	+	+
Total +	0	3	2
Total -	0	1	1
Total Score	0	2	1

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

- Propose one or more suggested design refinements moving forward

As next steps or areas in need of improvement, we concluded that both had similar weaknesses. For starters, both designs we concluded didn't do as well securely holding the surgical tools in place as the datum did. This is because our designs just have the tool resting in a groove. To improve this, we need to further minimize the likelihood of the tool slipping out. Some ideas we had included tilting the sides of the clips inwards to make it more difficult for the tweezers fall out or by making the clips encircle the tweezers but move them more to the centre of the container

(see sketch below for visual). Another design refinement that we think both prototypes could benefit from is increasing the thickness of the walls. Right now the walls are only 4mm thick which could become a problem as this will make the design less sturdy. If dropped or if the end-effector grasps the container with too much force, this could cause the container to break.



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

Team Number: Thurs-12

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: Eric Hitsman
Observations: <ul style="list-style-type: none"> • Does not have comments to explain code • Showcases full coordinates instead of variables that contain the coordinates • Asks for user inputted values to direct the claw to the bin location 	
Errors: <ul style="list-style-type: none"> • A better way of troubleshooting the code would be adding print statements at the end of each if/elif statement to make sure the right coordinates are outputted • Input Question is not very spaced out and gets messy • Needs to be commented for better understanding and for peer-review editing 	
Move End-Effector Task	Team Member Name: Yuvraj Sandhu
Observations: Requires input for pickup location, bin location, and colour Controls gripper by itself Opens autoclave door by itself Errors: Needs to have threshold assigned for muscle sensor Needs to be commented for easy understanding Splits the function in 2	

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

Team Number: **Thurs-12**

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

Control Gripper

If L reading is bigger than or equal to threshold

 Pinch gripper by 45 degrees

Elif L reading is smaller than threshold

 Release gripper by 45 degrees

Open Autoclave Bin Drawer

If L and R are both > threshold

 If color is equal to blue

 Command to open blue drawer

 If color is equal to red

 Command to open red drawer

 If color is equal to green

 Command to open green drawer

Continue or Terminate

Each loop z has 1 added to it

If z = 6

 terminate the program

Else

 continue

Milestone 4 – November 26th, 2020

PROJECT TWO: MILESTONE 4 – COVER PAGE

Team Number: Thurs-12Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Couper Smith	smitc25
Chengyao Liu	liuc169
Yuvraj Sandhu	Sandhuy
Eric Hitsman	hitsmane

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

Team Number: **Thurs-12**

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

- Make the holes square to reduce the print time
- Increase the number of holes

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

- We are going to increase the number of holes and make them square

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

Team Number: **Thurs-12**

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

- On track
- Everything is good

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

- N/A

List of Sources

References

- [1] Newfoundland and Labrador Medical Association, “Rural Health Care”. [Online]. Available: <https://nlma.nl.ca/News-And-Events/Media/Fact-Sheets>. [Accessed Dec. 8, 2020].
- [2] Dotto L. “Long-distance surgery” [Internet]. The Globe and Mail Canada; 2004 Oct 2. Available from: <https://www.theglobeandmail.com/technology/science/long-distancesurgery/article4220774/>. [Accessed Aug 31, 2020].

Source Materials Database

- [1] Newfoundland and Labrador Medical Association, “Rural Health Care”. [Online]. Available: <https://nlma.nl.ca/News-And-Events/Media/Fact-Sheets>. [Accessed Dec. 8, 2020].
- [2] Dotto L. “Long-distance surgery” [Internet]. The Globe and Mail Canada; 2004 Oct 2. Available from: <https://www.theglobeandmail.com/technology/science/long-distancesurgery/article4220774/>. [Accessed Aug 31, 2020].
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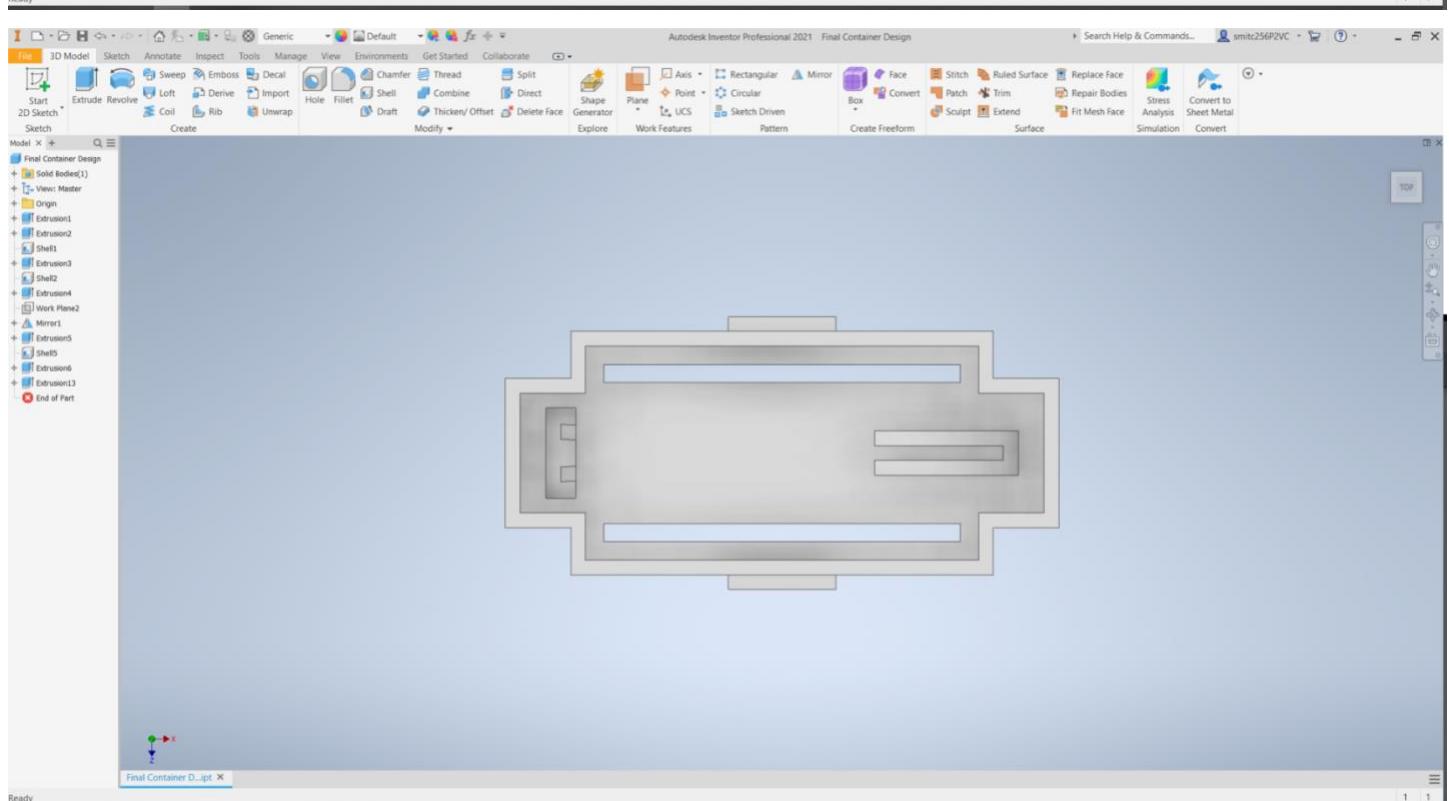
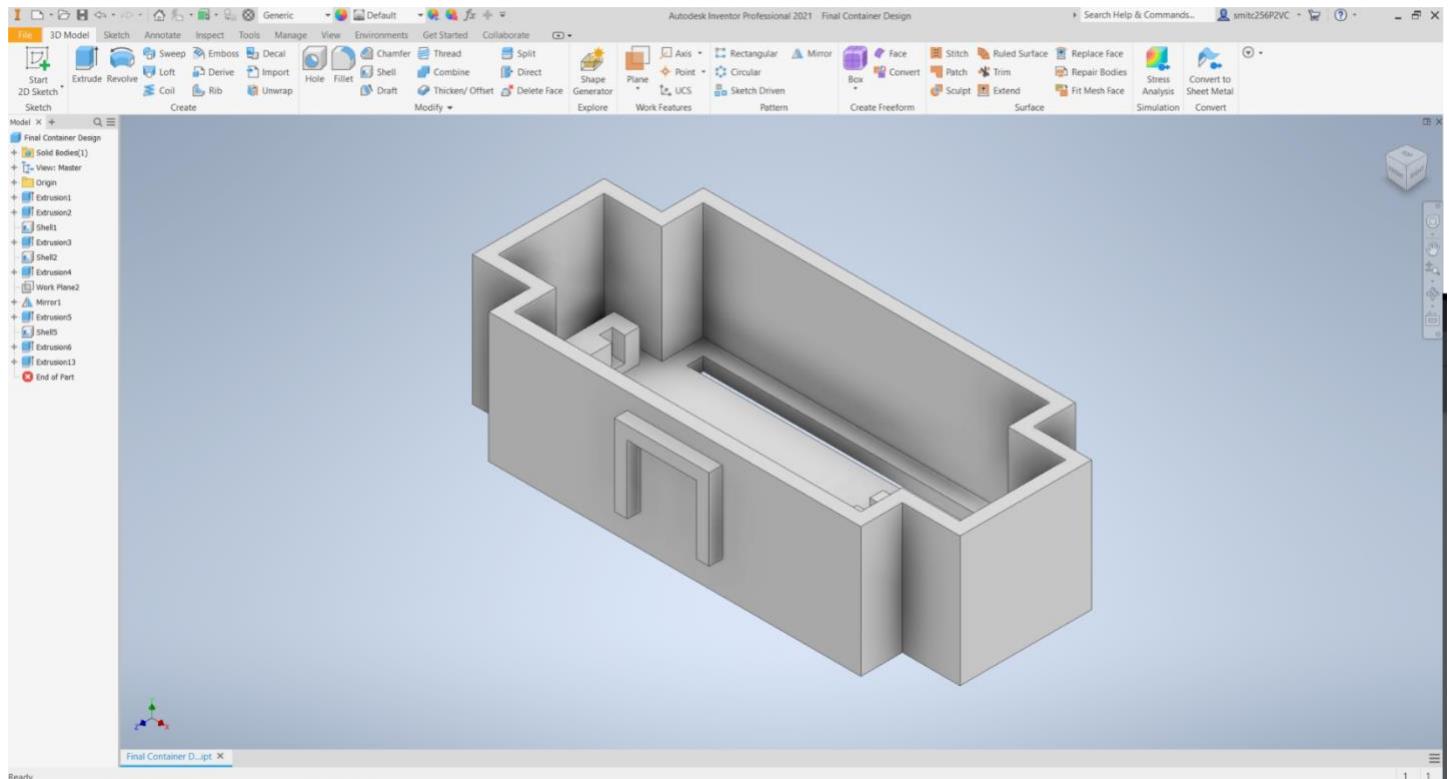
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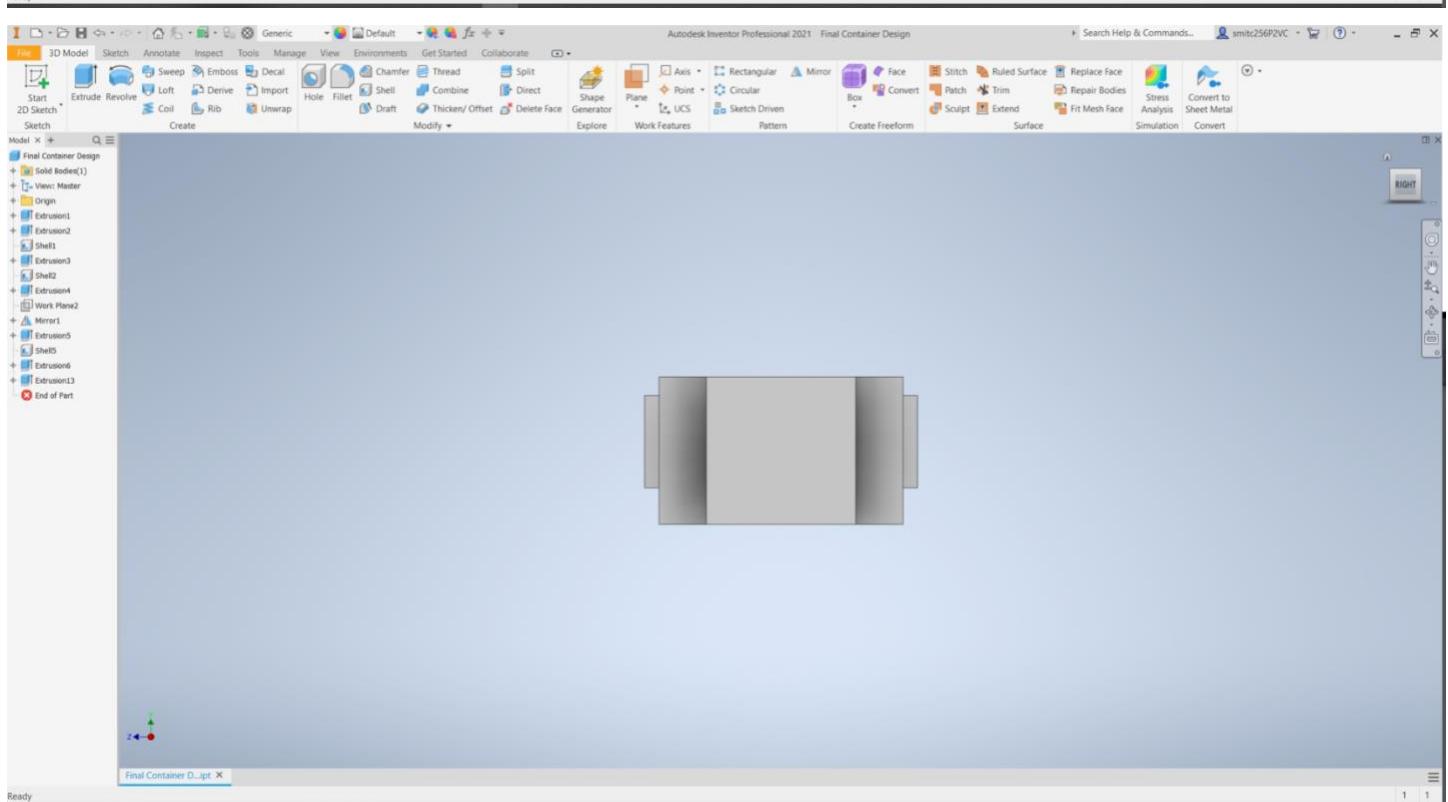
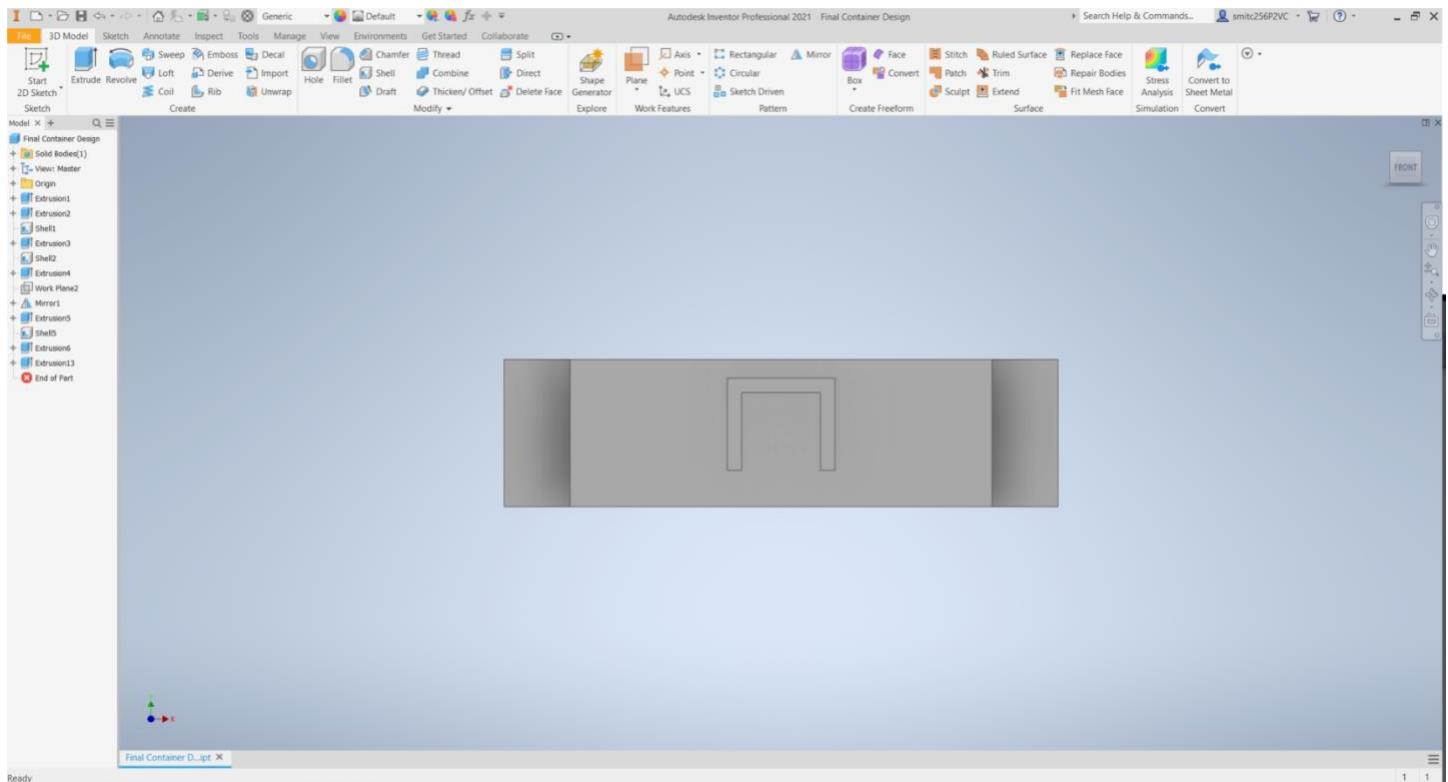
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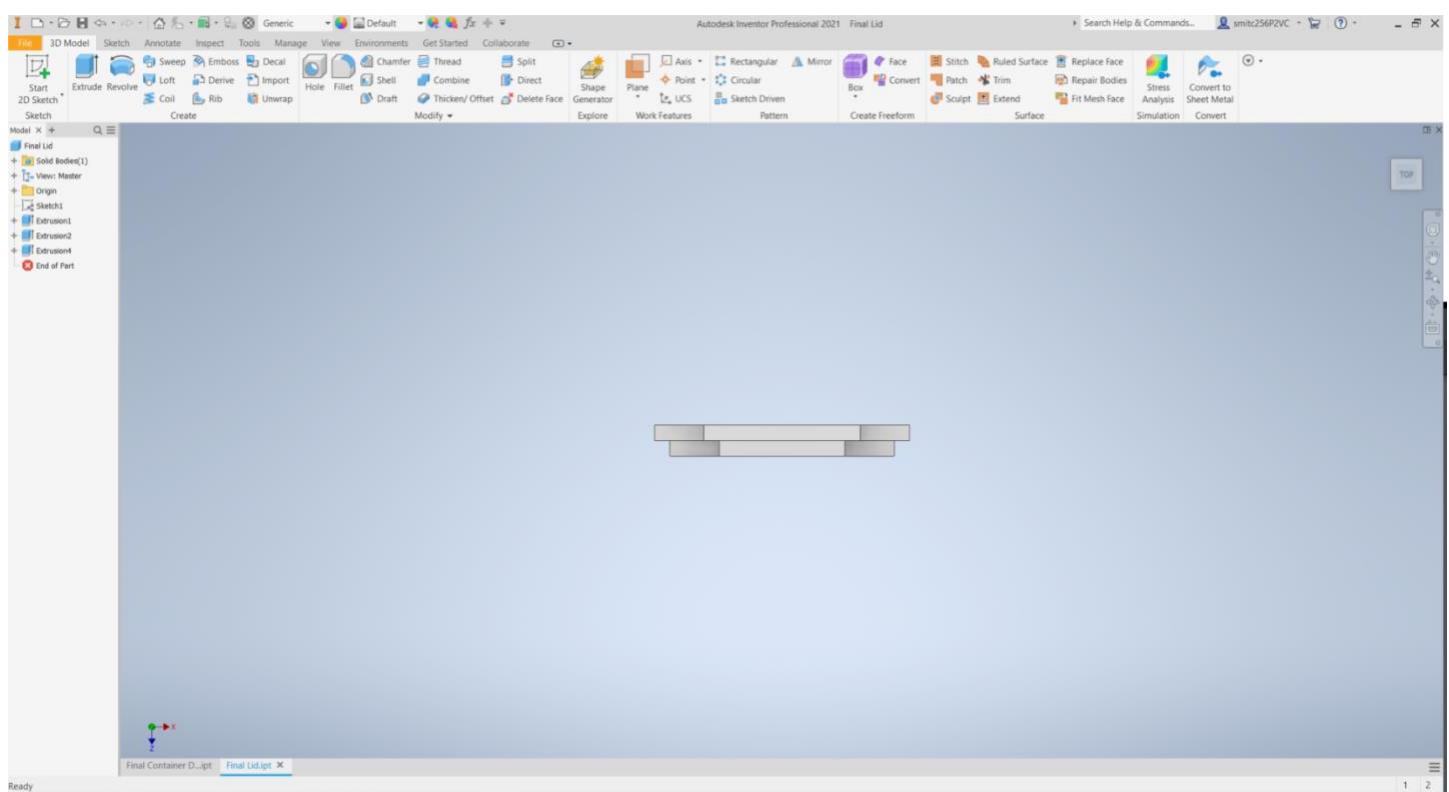
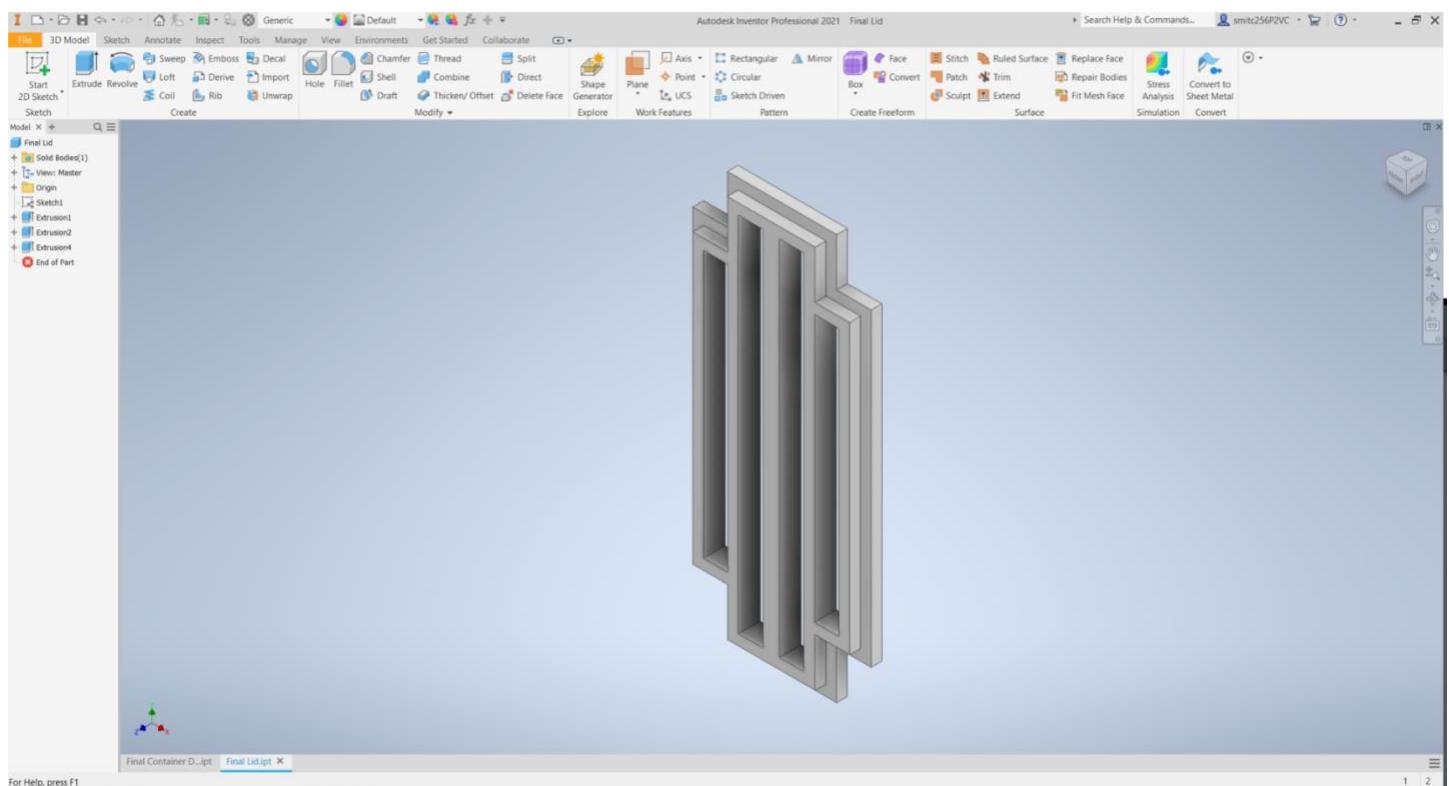
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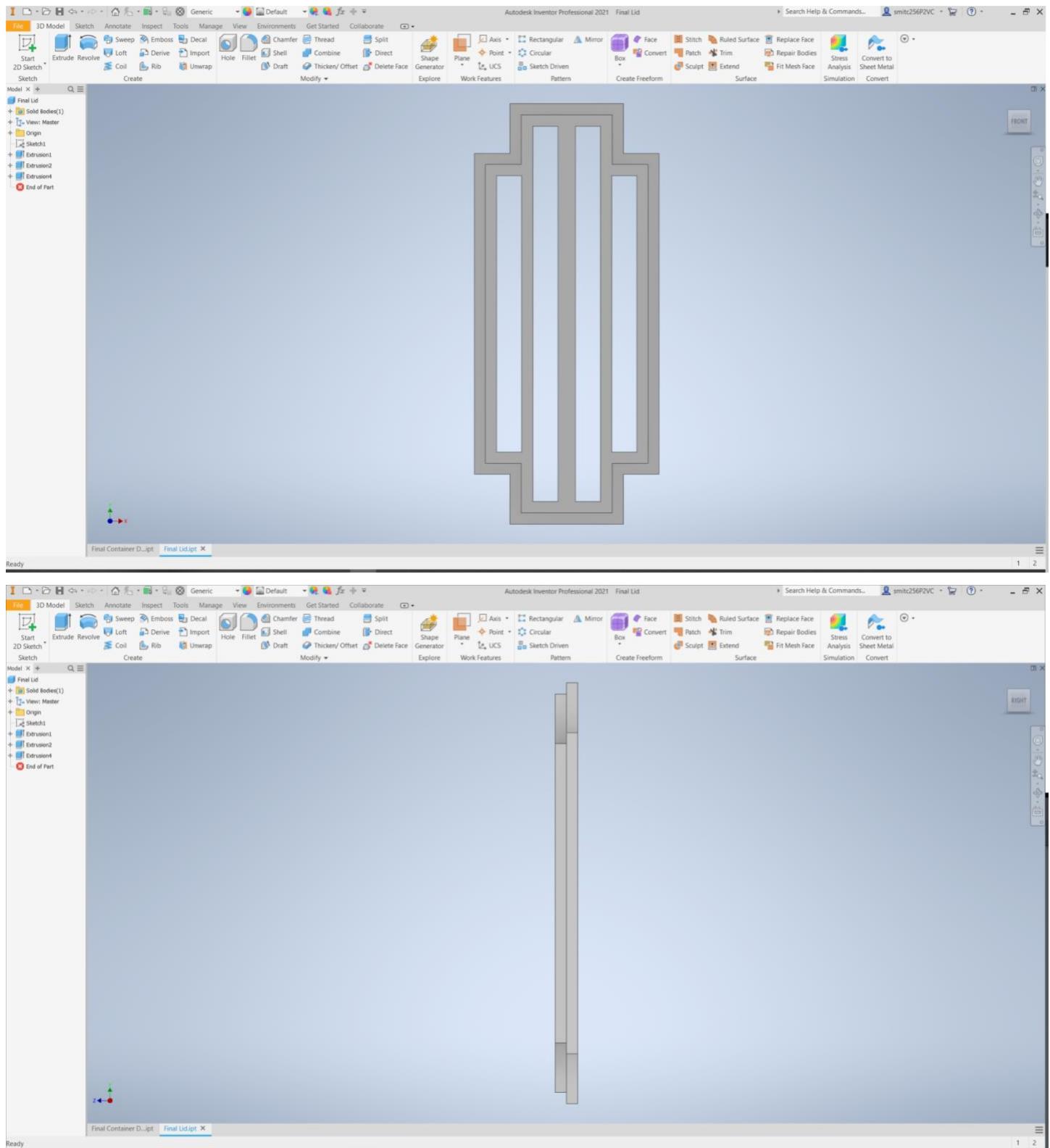
Appendices

Appendix A: Solid Model









Figures 1-8: Screenshots of design shown in Autodesk Inventor

Appendix B: Engineering Drawings

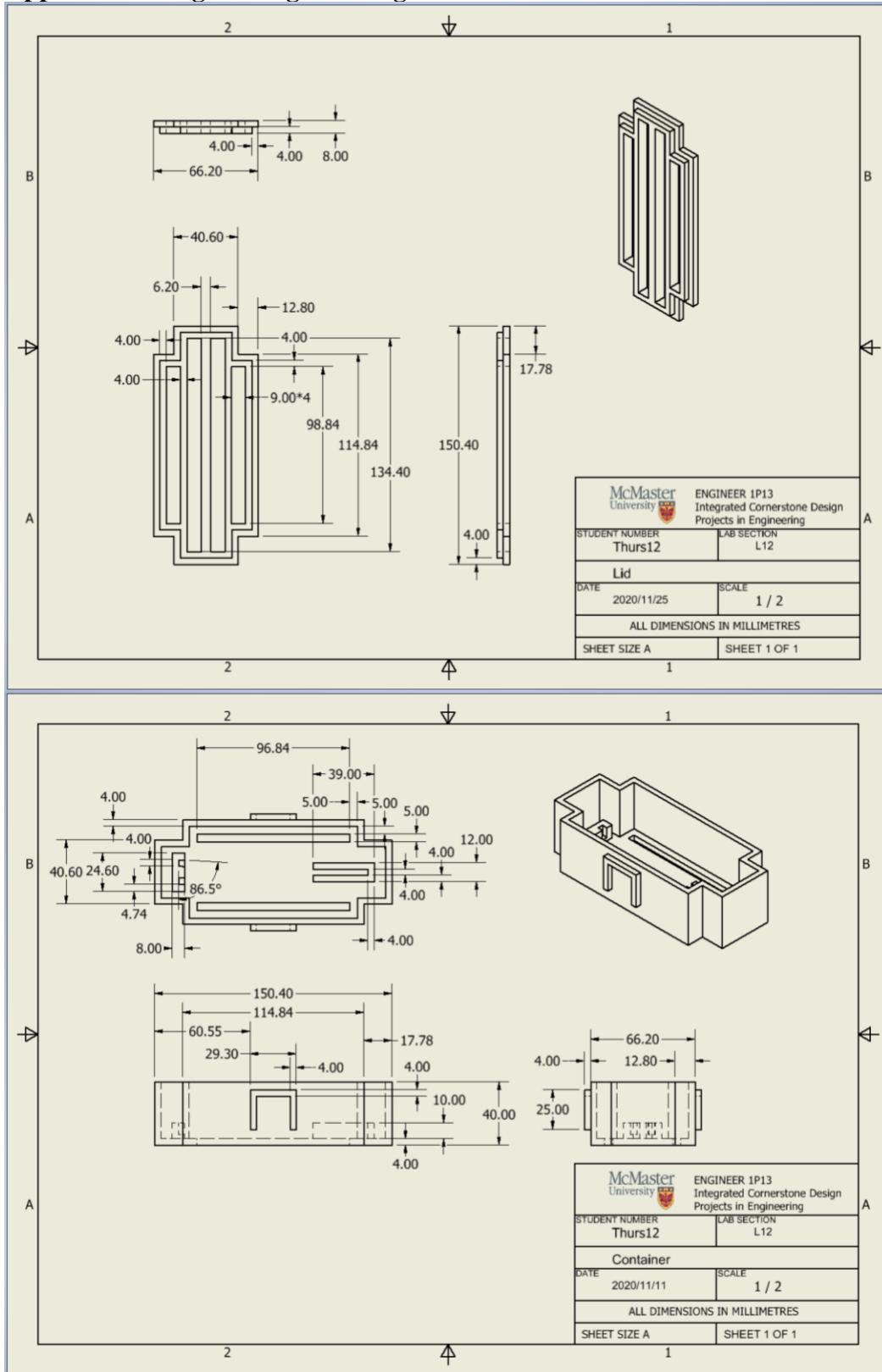


Figure 9-10: Fully dimensioned engineering drawings of the container and lid

Appendix C: Computer Program

```

#Global Variables of Autoclave bin locations, Home locations, Pickup Locations, Assigning autoclave values as well as randomizing their order, and Threshold.
home = (0.4064, 0.0, 0.4826)
pickup = (0.517, 0.0, 0.031)
small_red_cage = (-0.613, 0.245, 0.385)
small_green_cage = (0.0, -0.6666, 0.39)
small_blue_cage = (0.0, 0.6666, 0.385)
large_red_cage = (-0.39, 0.14, 0.29)
large_green_cage = (0.0, -0.41, 0.29)
large_blue_cage = (0.0, 0.41, 0.29)
autoclaves = [1,2,3,4,5,6]
random_autoclaves = random.shuffle(autoclaves)
thres = 0.6

#Yuvraj Sandhu
def move_end_effector(location):#Functions moves to any location
    if arm.emg_left() == 1.00 and arm.emg_right() == 1.00:
        print("Moving arm")
        arm.move_arm(location[0],location[1],location[2])
        time.sleep(2)
        print("Moved arm")
    return

def scanner(container): #Scanner function attaches a cage to the dropoff position that matches the autoclave.
    print("Scanner Activated")
    if container == 1:
        dropoff_position = small_red_cage
    elif container == 2 :
        dropoff_position = small_green_cage
    elif container == 3 :
        dropoff_position = small_blue_cage
    elif container == 4 :
        dropoff_position = large_red_cage
    elif container == 5 :
        dropoff_position = large_green_cage
    elif container == 6 :
        dropoff_position = large_blue_cage
    return dropoff_position

def gripper(control):#When the muscle sensor is in the right position AND the gripper has an open state then the gripper will open,
    #If the gripper is in the close state then it will close the gripper and set the "control" variable to closed
    if arm.emg_left() > thres and arm.emg_right() == 0: #Checks the muscle sensor reading and only runs if the conditons are met
        if control == "open":
            print("Opened Gripper")
            arm.control_gripper(-45)
            control = "open"
            return control
        elif control == "close":
            print("Closed Gripper")
            arm.control_gripper(45)
            control = "close"
            return control

def control_autoclave_drawer(num,autoclave_state):#Autoclave drawers will open only for the large autoclaves if the criteria is met.Then sets the state of the autoclave to true so it won't be called again.
    if arm.emg_left() == 0 and arm.emg_right() > thres:
        if num == 4 and autoclave_state == True:
            arm.open_red_autoclave(False)
            autoclave_state = False
            return autoclave_state
        elif num == 4:
            arm.open_red_autoclave(True)
            autoclave_state = True
            return autoclave_state
        elif num == 5 and autoclave_state == True:
            arm.open_green_autoclave(False)
            autoclave_state = False
            return autoclave_state
        elif num == 5:
            arm.open_green_autoclave(True)
            autoclave_state = True
            return autoclave_state
        elif num == 6 and autoclave_state == True:
            arm.open_blue_autoclave(False)
            autoclave_state = False
            return autoclave_state
        elif num == 6:
            arm.open_blue_autoclave(True)
            autoclave_state = True
            return autoclave_state

```

```

#Eric Hitsman
for i in autoclaves:
    #The variable i is utilized so since we're not looking for a value but for when i isn't a value anymore I.E when there aren't anymore autoclaves in the list, this for loop will break
    arm.spawn_cage(i) #Will spawn a random arrangement of autoclaves

    #Initially setting variables to their preferred states so that it can be changed accordingly in the code
    x = True
    check = False
    autoclave_state = False
    gripper_state = True
    dropoff = scanner(i)
    time.sleep(2)
    control = "open"

    while x == True: #While loops setup a straight-forward path for the arm to follow for each autoclave. This while loop checks if the arm at pickup.
        if arm.effector_position() == pickup:
            break
        else:
            move_end_effector(pickup)

    while x == True: #While loop sets the gripper to close itself when at the pickup location
        if control == "close":
            break
        else:
            control = gripper("close")

    while x == True: #While loop will move to the dropoff location and if it is not there then it will move to the drop off location and open the door (if the autoclave is large)
        if arm.effector_position() == dropoff:
            break
        else:
            time.sleep(1.5)
            move_end_effector(home)
            time.sleep(1.5)
            move_end_effector(dropoff)

    if i == 4 or i == 5 or i == 6: #While loop opens the door in the scenario when a large autoclave is being dropped-off
        while x == True:
            if autoclave_state == True:
                break
            else:
                autoclave_state = control_autoclave_drawer(i,autoclave_state)

    while x == True: #While loop will drop the autoclave into the opened drawer
        if control == "open":
            break
        else:
            control = gripper("open")

    if i == 4 or i == 5 or i == 6: #While loop closes the door in the scenario when a large autoclave is being dropped-off
        while x == True:
            if autoclave_state == False:
                break
            else:
                autoclave_state = control_autoclave_drawer(i,autoclave_state)

    while x == True: #Returns home to restart the loop for another autoclave
        if arm.effector_position() == home:
            break
        else:
            move_end_effector(home)

```

Figures 11-13: Screenshots of computing team's code