Project Two – Get a Grip:

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

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 05

Team Tues-28

Julian Cecchini (cecchinj)

Luke West (westl5)

Luigi Quattrociocchi (quattrl)

Hetash Rattu (rattuh)

Submitted: December 10, 2020

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Academic Integrity Statement

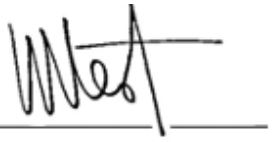
The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

X 

Julian Cecchini 400319506

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.

Luke West 400310803

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.

Luigi Quattrociocchi 400318027

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.

Hetash Rattu 400324698

Executive Summary

People in rural areas of Canada typically have less access to healthcare and must travel long distances to receive sterile surgery [1]. This issue gave rise to the main goal of the project: design a system to securely hold and transfer a surgical tool to be sterilized in an autoclave. Such a system would assist in the transfer and distribution of sterile equipment, increasing the accessibility of quality surgery for rural Canadians.

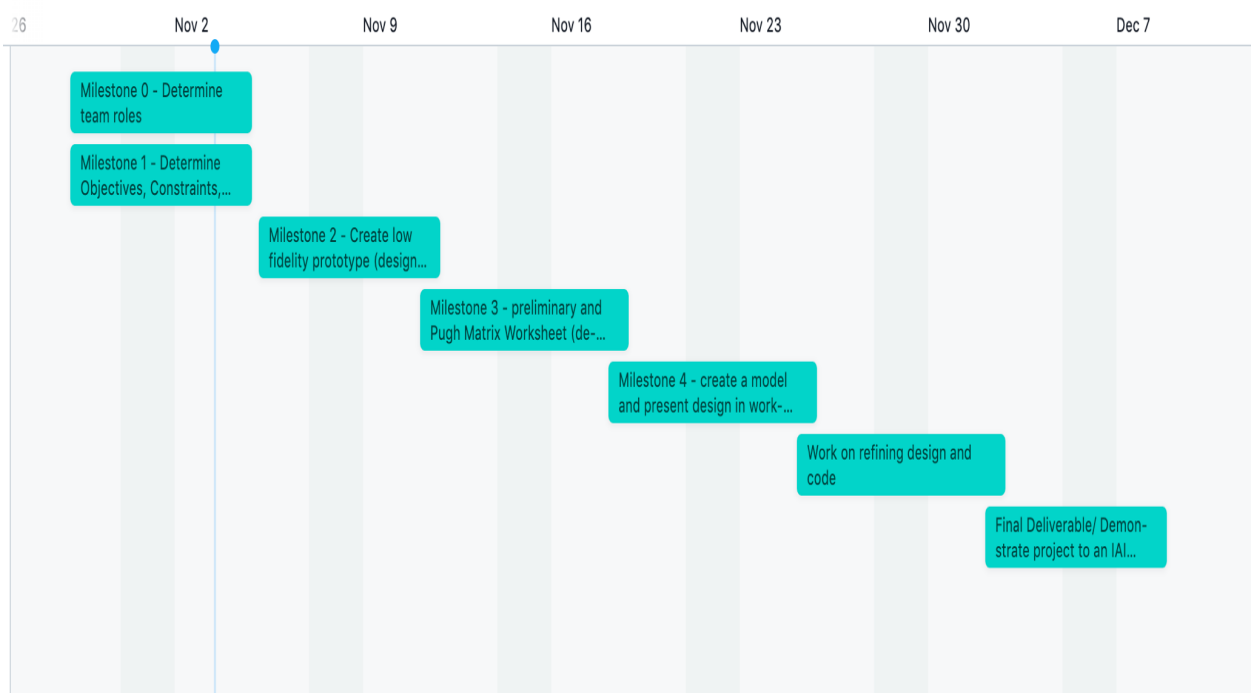
The project had two main segments: designing a container to hold the tool and implementing code to command a robotic arm to move that container. The design segment was a success. The container's constraints were all met as the final design weighed less than 350 grams, every feature exceeded 4 mm, and it was capable of fitting with the assigned footprint [1]. No structural faults prevent the container from meeting the objective of rigidity, nor does its mass fail the lightweight objective. The primary function was to allow for sterilization of a surgical tool, and our design maintained it by incorporating a cylindrical shape with rectangular slots that steam could enter. The friction-fit system through which the retractor enters the open end, hooks onto the bar at the other side, and falls in place onto the protrusion by its entrance allows for security, placement, and extraction of the tool. Lastly, the endpieces create stability, so the container does not roll during transfer, while their extended tops offer more surface area for the robot grip. The container's proposed design is promising and may be usable in the future for the transfer of sterile surgical tools.

The computing segment involved developing a workflow that encompassed five main tasks. The tasks were: identify the correct autoclave bin, open/close the gripper, move the robotic arm end-effector to a specified location, open/close an autoclave bin drawer, and continue/terminate the program based on an inventory of container objects given [1]. A combination of EMG muscle sensor input (one sensor for each arm) satisfies these tasks through the implementation of our program. For example, flexing the left arm while extending the right would change the angle of the robot effector gripper. Execution of the workflow’s python implementation in the virtual environment under supervision found each task was successfully performed, demonstrating that the proposed workflow was correct. Our successful virtual trials prove that robots can have a practical application for the healthcare issue within Canada in transferring containers.

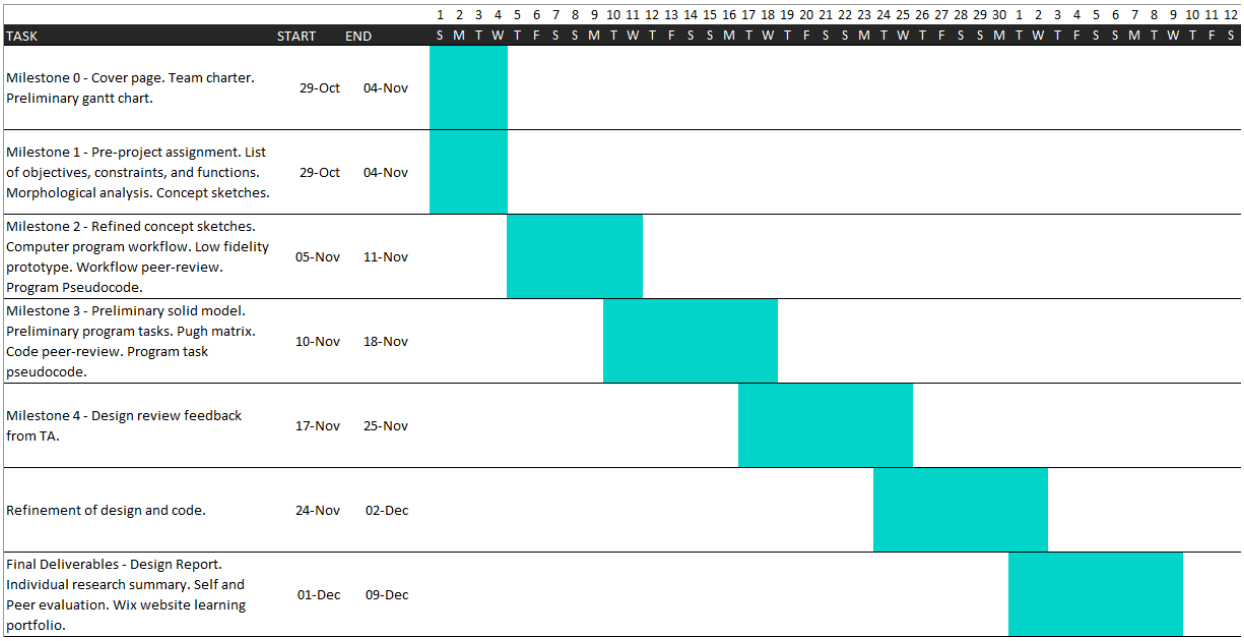
Through the completion of the container and code to the satisfaction of both the problem requirements and supervisor expectations (interview), it is clear the format for the second project allowed for a cohesive and productive team. Further experience in real-world problem-solving was provided through helpful design studio sessions and instruction given. The only issue was ambiguity initially found within the requirements for the design and code, but through communication among teammates as well as project staff, these were overcome. The result was a container and program that deserve further research to change the lives of real people.

Project Schedule

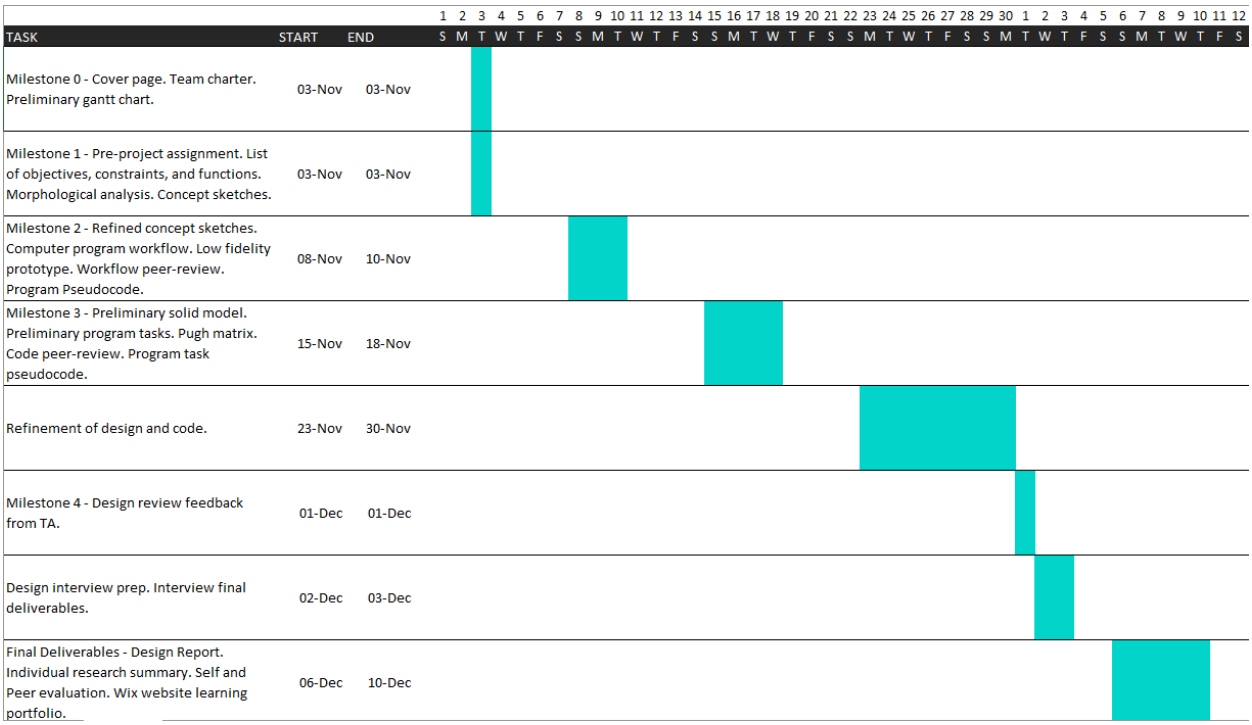
Preliminary Gantt Chart



Revised with new software, asana membership expired.



Final Gantt Charts



Logbook of Additional Meetings and Discussions

Note: * represents meetings outside of allotted time pertaining to project 2

Date:	Title & Purpose:	Time & Duration
Nov 3, 2020	**Milestone 0 and 1** Members were introduced to each other, took a group picture, and discussed their favorite video games. Proceeded to throw ideas back and forth for functions, constraints, objectives, and how the project is going to shape up.	12:30 p.m. - 3 hours, 43 minut
Nov 4, 2020	**Computations 4** Talked to Kevin Gilmore (TA) about program for breaking down lists of products and assessing which ones meet the specified standards.	11:30 a.m. - 2 hours, 15 minute

Nov 5, 2020	**Graphics 4** Learned how to complete engineering drawings within inventor off a base template McMaster provided.	2:30 p.m. - 1 hour, 19 minutes
Nov 8th, 2020	***Design sub-team** Luke and Julian met up to talk about refined sketch ideas and plans to execute prior to milestone 2.	11:30 pm - 1 hour
Nov 10th, 2020	**TA progress meeting:** -discussed progress on workflow for computer sub-team and refined sketches for design sub-team -filled in agenda	1:00 p.m. 10 minutes
	Milestone 2: Design sub-team meeting: formed prototypes in communication with each other. Attempted to inhibit biases from reaching each other.	1:05 p.m. 2 hours, 40 minutes
	Milestone 2: Computations sub-team: compared flow-charts and made pseudocode.	1:05p.m. 2 hours, 40 minutes
Nov 11th, 2020	**Lab B Q-labs started** Worked for a prolonged period in Q-labs. Learned to have the robot act autonomously eventually after trial and error.	12:15 p.m. 3 hours
Nov 12th, 2020	**Graphics Lab 5** - Assembling glasses	2:30 p.m. 2 hours, 10 minutes

	- Discussed methods of constraining parts such as insertion or mating.	
Nov 17th, 2020	**Milestone 3: Design Sub-team:** Critiqued each other's prototype models through matrix and discussed improvements for the future.	1:00 p.m. 2 hours, 28 minutes
	Milestone3: **Computations Sub-Team** Compared pseudocode and discussed issues found in attempting to abstract the coding process according to information given.	1:00 p.m. 2 hours
	Week 9 Project TA Meeting started Met with our TA Michelle Pham and discussed our progress from previous milestone.	1:10 p.m. 20 minutes
Nov 18th, 2020	**Materials Lab – Flexor Sensors** Discussed material quiz and methodically went over answers.	2:00 p.m. 1 hour
Nov 19th, 2020	**Computations 5** Went over I/O methods in python along with methods to extrapolate info from files. Ended up creating our own .txt files.	3:00 p.m. 3 hours

Nov 24th, 2020	**TA Progress Meeting** -discussed adjustments made to pseudocode as per Dami's instructions -talked about improvements made to models as was discussed the week before -planned to have code finalized along with choosing the good copy model design.	1:15 p.m. 10 minutes
	***Design Sub-team prep for M4:** -discussed pros and cons of each design -tested print times in 3D software and found barrel design to be much more accommodating of time constraint (1 hour without support) -Ryan Isaac discussed with us about design press fitting for barrel design, gave some tips about what to research and place fourth as a consideration for our final deliverable (press-fit)	1:00 p.m. 2 hours, 40 minutes

	***Computations Sub-team prep for M4:** -experimented around with positions in Q-labs and adjusted the code to grab the container -had to be within precision of 0.1 degrees to ensure gripper fingers did not phase through floor -left some position adjustments within the code to be finished for upcoming week	1:00 p.m. 2 hours, 30 minutes
Nov 25th,2020	**Hip Implant Materials Lab** -Used Granta to conduct material selection which would be ideal for a hip implant (reference week 10 lab B) Conclusion: Tensile strength, Shear modulus, CO2 footprint, Fatigue strength, Mechanical loss coefficient Final choices: Titanium, Stainless steel, Cobalt-chromium alloys	1:00 p.m. 50 minutes
	***Determining Project Interview** Discussed when it would be optimal to book interview.	9:35 p.m. 20 minutes
Nov 28th, 2020	***Final Design Consultation** Design sub-team completed some final edits for the g-code file of their container	3:00 p.m. 2 hours

	after designing a better system for securing the tool. All constraints were thought to be met but further discussion will be done with the TA before submitting G-code	
Nov 30th, 2020	***G-code consultation for interview submission w/ IAI (Dami Oriole)** Discussed final concerns of container involving its fillets and possible combination into a one file instead of a press-fit which may have not coincided with constraints. It was found the fillets (2.5 mm) were unsafe to do with the size of our parts and it was necessary to either create a gap between the storage barrel and outer rectangular prisms for a press-fit (assembly) or to lengthen the rectangular prisms all around to ensure 4mm constraint was met with edge of storage barrel (single part). The fillets were discarded, and it was elected to go with the press-fit for submission. It was also found the object needed to be dissected into a cross section to be printed with minimal support.	12:30 p.m. 3 hours

	***Team Meeting for deliberations of submissions** Team was pulled together to discuss what needed to be handed in before the design studio that was a day ahead. Roles were also assigned for research of biomedical devices.	4:30 p.m. 1 hour
Dec 1st, 2020	**Design Review w/ TA** No issues listed with either sub-team except for inconsistency with box placement within the simulation via the computations sub-team. Tweaking will be attempted.	12:45 p.m. 30 minutes
	***Post TA interview discussion/M4** Discussed interview, what was necessary to hand-in, plans for FD, and what each team member should look at finishing.	1:15 p.m. 2 hours
Dec 2nd, 2020	**Research breakout room 1** Attempted an executive summary and power point corresponding to the topic of gallium.	1:00 p.m. 2 hours

	Ga LED recycling PowerPoint Finished the latter part of the previous assignment with decorative designs and due deliberation.	5:30 p.m. 1 hour, 30 minutes
	***Design sub-team** Finished constraining tool and set up assembly file via pack-n-go for submission to M4 and sterilization container drop-boxes.	7:00 p.m. 2 hours
	***Computing sub-team** Finalized code for computer program drop-box by adding in comments and testing consistency of runs. Ultimately, handed it in and reconvened with design team to discuss preparation for the interview on the following day.	8:00 p.m. 2 hours
Dec 3rd, 2020	***Design sub-team interview prep** Went through possible questions about designing the model or different parts.	2:00 p.m. 30 minutes
	***Computations sub-team interview prep** Went back over code and recorded runs for evidence when discussing consistency of Q-lab runs.	2:00 p.m. 30 minutes

	***Post interview** Discussed how the interview went for each sub-team, congratulated each other on results, and planned to meet for final deliverable.	3:00 p.m. 30 minutes
Dec 6th, 2020	***Final Deliverable Meeting** Discussed breakdown of responsibilities for final deliverable template, what to do complete before the 9th, and onion soup.	8:00 p.m. 4 hours

Scheduled Weekly Meetings

ENGINEER 1P13
MEETING WITH TEAM TUES-28 - TUESDAY, NOV. 10, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Luke West**	**westl5**	**Yes**
Administrator	**Luigi Quattrociocchi**	**quattrl**	**Yes**
Coordinator	**Julian Cecchini**	**cecchinj**	**Yes**
Subject Matter Expert	**Hetash Rattu**	**rattuh**	**Yes**
Guest	**Ryan McIsaac**	**N/A**	**Yes**

AGENDA ITEMS

1. Catching up with the computing sub-team (workflow diagrams)
2. Catching up with modelling sub-team (preliminary refined sketches)

MEETING MINUTES

1. Attendance & Updates
    a. Everyone is present.
    b. Team is somewhat stressed. Midterms have returned and members are preparing.
    c. Discussed meetings or lack thereof members underwent with respective sub-teams before design studio
    d. Expressed origination of ideas (referenced project module for workflow of coding sub-team)
2. Issues from past week
    a. None
3. Discuss changes from last week's model/code
    a. Added more detail to sketches from milestone 1 while ensuring they held true to objectives
4. Action Items for next meeting
    a. Preliminary Solid Model Worksheet and Program Tasks Worksheet (individual)
5. Final Notes
    a. Discussed relation between logbook and agenda
    b. Team members offered help to anyone struggling in their studies

POST-MEETING ACTION ITEMS

1. *Finish Low-Fidelity Prototypes and record observations [Modelling]*
2. *Find out which surgical tool will be used [Modelling]*
3. *Understand how muscle sensors will eventually factor into code [Computations]*

ENGINEER 1P13
MEETING WITH TEAM 1 - TUESDAY, Nov 17th, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Luke West**	**westl5**	**Yes**
Administrator	**Luigi Quattrociocchi**	**quattrl**	**Yes**
Coordinator	**Julian Cecchini**	**Cecchini**	**Yes**
Subject Matter Expert	**Hetash Rattu**	**rattuh**	**Yes**
Guest	**Michelle Pham**	**N/A**	**Yes**

AGENDA ITEMS

1. Attendance, updates on how everyone is doing
2. Discuss last design studio: What did each sub-team accomplish? Any Issues/Problems?
3. Discuss what was done between design studios (i.e., preliminary cad models, Initial code)
4. Discuss what is to be done for today's design studio, and deliverables
5. Final notes, extra significant points

MEETING MINUTES

1) Attendance & Updates
    a) Everyone is present.
    b) Team is a little less stressed. Midterms are almost over.
    c) All work was done (individual worksheets were done in isolation so members were not influenced by each other's ideas)
2) Issues from past week
    a) Coding team had issues with ambiguity of code guidelines
        i) Dami gave clarification
3) Discuss changes from last week's model/code
    a) Specific models were chosen to be further scrutinized for final design
    b) Bare bones of code were conceptualized through workflow
4) Action Items for next meeting
    a) Modelling sub-team: design creation in inventor and generate G-code
    b) Computations sub-team: Translate part of workflow into a python program.
5) Final Notes
    a) Members have been encouraged to meet outside of design studio time to refine model and code.

ENGINEER 1P13
MEETING WITH TEAM 1 - TUESDAY, Nov 17th, 2020

POST-MEETING ACTION ITEMS

1. *Finish comparing and critiquing models via Pugh matrix [Modelling]*
2. *Discuss improvements to make upon workflow/pseudocode before implementing it within Python [Computations]*

ENGINEER 1P13
MEETING WITH TEAM 1 - TUESDAY, Nov 24th, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Luke**	**westl5**	**Yes**
Administrator	**Luigi Quattrociocchi**	**quattrl**	**Yes**
Coordinator	**Julian Cecchini**	**cecchinj**	**Yes**
Subject Matter Expert	**Hetash Rattu**	**rattuh**	**Yes**
Guest	**None**	**-**	**-**

AGENDA ITEMS

1. Attendance & Updates
2. What has been accomplished since last studio (i.e., improvements in code/ CAD design), both teams
3. What needs to be done this studio (i.e., finishing code/choosing and refining final CAD design), both teams
4. Discuss any issues

MEETING MINUTES

1) Attendance & Updates
    a) Everyone is present.
    b) Team is generally happy; exams are in view, but midterms are over.
    c) Designs were successfully modelled, and code was partially implemented.
    d) It was found modelling sub-team met in a call outside of arranged time to discuss design improvements while coding sub-team simply texted each other.
    e) Cylinder container was chosen for final interview
2) Issues from past week
    a) Modelling team was unsure about whether certain parts of their designs met length constraints or not.
        i) Dami was consulted along with TA. It was found everything was relatively good, but fillets were risky.
3) Discuss changes from last week's model/code
    a) Models were improved upon criticism via Pugh matrix from previous week and code was further refined to meet specifications of project as defined by Dami.
    b) With the code now implemented in python, team was able to work within the simulated environment.

ENGINEER 1P13
MEETING WITH TEAM 1 - TUESDAY, Nov 24th, 2020

4) Action Items for next meeting
    a) Gather all necessary items for upcoming review session in M4 and start constructing questions for future interview.
5) Final Notes
    a) Teammates are pleased with each other, and it seems all aspects of the project are more than adequate.
    b) No milestone was handed in, week of December 1st will involve M4.

POST-MEETING ACTION ITEMS

1. *Consult IAI/TA for specifics about container pertaining to new fillets after modification and supports used for printing [Modelling]*
2. *Discuss with IAI/TA some confusion about the implementation of muscle emulators within code [Computations]*

ENGINEER 1P13
MEETING WITH TEAM 1 - TUESDAY, Dec 1st, 2020

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Luke**	**westl5**	**Yes**
Administrator	**Luigi Quattrociocchi**	**quattrl**	**Yes**
Coordinator	**Julian Cecchini**	**cecchinj**	**Yes**
Subject Matter Expert	**Hetash Rattu**	**rattuh**	**Yes**
Guest	-	-	-

AGENDA ITEMS

1. Attendance & Updates
2. What did the computing team accomplish in the last week? (show off/explain finalized code)
3. What did the modelling team accomplish in the last week? (show off/ explain finalized design)
4. Explain issues or hurdles from the last week
5. Final Remarks/additions/prepare for upcoming design review

MEETING MINUTES

1. Attendance & Updates
    a. Everyone is present.
    b. Team is well prepared; each component has been prepared for the interview
    c. No major issues were found by TA, all parts of the project were given the greenlight for submission.
    d. Minor hiccup with consistency of box placements discussed further in M4 worksheet
2. Issues from past week
    a. Modelling sub-team had to consult an IAI or TA about how to cut figure for g-code
        i. Bassem aided members and instructed them on how to cut it for the print
3. Discuss changes from last week's model/code
    a. Implemented a friction-fit system for securing the tool in chosen design.
    b. Code is commented fully along with slight changes to the implemented coordinates of the boxes. Also, muscle emulator is fully functional.
4. Action Items for next meeting

   a. No further planned meetings but objectives lie mainly in completing the finalized Gantt chart and doing independent research summaries for tools
   b. Prepare all resources for final deliverable
5. Final Notes
   a. It was a fun project and members enjoyed the synergy gained between them.

POST-MEETING ACTION ITEMS

1. *Transfer ipt files for administrator to upload*
2. *Prepare interview questions for Thursday, December 3rd*

Design Studio Worksheets

Milestone 0

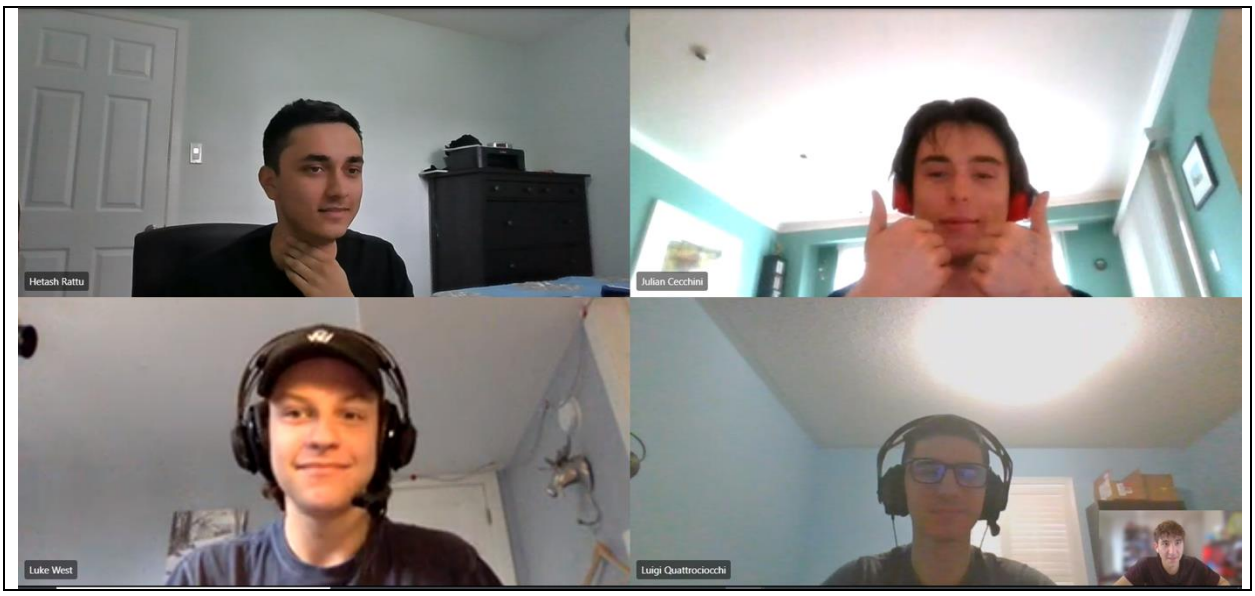
PROJECT TWO: MILESTONE 0 – COVER PAGE

Team Number:	Tues-28

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

Full Name:	MacID:
Julian Cecchini	cecchinj
Luke West	westl5
Luigi Quattrociocchi	quattrl
Hetash Rattu	rattuh

Insert your Team Portrait in the dialog box below



MILESTONE 0 – TEAM CHARTER

Team Number:	Tues-28

Incoming Personnel Administrative Portfolio:

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

	Team Member Name:	**Project Leads**
1.	Julian Cecchini	☒M ☐A ☐C ☐S
2.	Luke West	☐M ☐A ☒C ☐S
3.	Luigi Quattrociocchi	☐M ☐A ☐C ☒S
4.	Hetash Rattu	☐M ☒A ☐C ☐S
		☐M ☐A ☐C ☐S

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

Project Leads:

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

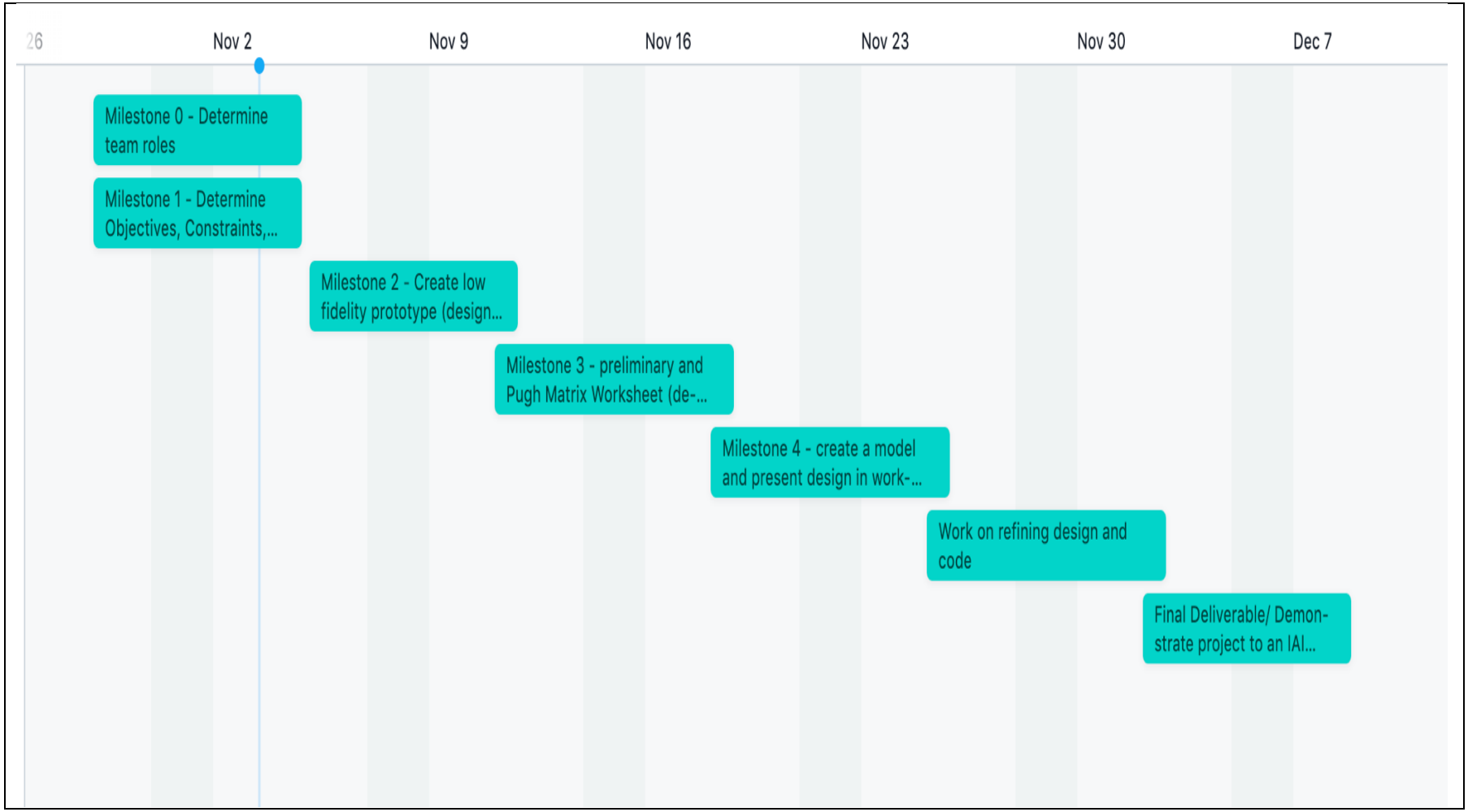
Role:	**Team Member Name:**	**MacID**
Manager	Luke West	westl5
Administrator	Luigi Quattrociocchi	quattrl
Coordinator	Julian Cecchini	cecchinj
Subject Matter Expert	Hetash Rattu	rattuh

MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team Number: Tues-28

Full Name of Team Manager:	MacID:
Luke West	westl5

Preliminary Gantt chart


26
Nov 2
Nov 9
Nov 16
Nov 23
Nov 30
Dec 7
Milestone 0 - Determine team roles
Milestone 1 - Determine Objectives, Constraints,...
Milestone 2 - Create low fidelity prototype (design...
Milestone 3 - preliminary and Pugh Matrix Worksheet (de-...
Milestone 4 - create a model and present design in work-...
Work on refining design and code
Final Deliverable/ Demonstrate project to an IAI...

MILESTONE 1 (STAGE 1) – PRE-PROJECT ASSIGNMENT

Team Number:	Tues-28

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:	Tues-28

Name: Julian Cecchini	MacID: cecchinj

Objectives:

- Identifiable by colour and size
- High durability, does not deform easily
- Heat resistant for possible steam sterilization
- Tool's weight is balanced well around grip

Constraints:

- Thicker than 4mm
- Minimum of 80mm in width
- Maximum of 170mm in width
- Scaled down design does not exceed 350g in mass
- No excessively complex parts which would cause print replication time to exceed 2 hours; simple

Function:

- Can contain surgical tools
- Allows surgical tools to be sterilized
- Can be held by effector grip
- Secures tools during travel

Team Number:	Tues-28

Name: Luke West	MacID: westl5

Objectives

- Container should be lightweight, to be able to be held by the robot
- Container should be rigid, to be able to hold its shape
- Container should be temperature resistant, to withstand steam
- Container: unreactive with cleaning chemicals

Constraints

- Container: base must fit within the autoclave
- Container: All features must be greater than 4mm in size
- Container must fit securely in between the gripper of the robot (not too big or too small)
- Container: Mass cannot exceed 350 grams

Functions

- Container must hold tools securely
- Container must allow sterilization of tools through use of steam
- Container must be able to be held by the robotic arm

Team Number:	Tues-28

Name: Luigi Quattrociocchi	MacID: quattrl

Objectives

- Should be resistant to high temperatures
- Should be lightweight
- Should be chemically inert

Constraints

- Must not exceed 350 grams
- Must have all features exceeding 4mm
- Must fit in autoclave

Functions

- Be able to securely house tools
- Be able to be picked up by arm
- Be able to allow sterilization of contents

Team Number:	Tues-28

Name: Hetash Rattu	MacID: rattuh

Objectives (should be…)

- Hold medical Instruments
- Allows fluid to be stored
- Allows fluid to leave

Constraints

- 4mm is the smallest dimension
- Must be bigger than the instruments
- Must have opening so arm can add the medical instruments

Functions (What is does)

- House fluids
- Accepting equipment
- Transfer Equipment

*If you are in a team of 5, please copy and paste the above on a new page

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

Team Number:	Tues-28

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
Should be resistant to high temperatures	All features must be greater than 4mm	Tools should be able to be placed and extracted from the container
Should have a distinct colour	Scaled down weight does not exceed 350 g	Be able to securely house tools
Should be chemically inert	Complexity of parts if minimum; print time of replication cannot exceed 2 hours	Be able to able to be picked up by the robot arm
Should be lightweight	Max 170 mm min 80 mm	Must allow sterilization of tools by steam
Should be rigid and hold its shape	Base must fit within the autoclave	Base must be able to remain inside its respective autoclave
	Caters towards effector grip	

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

Must allow sterilization of tools by steam

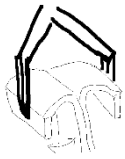
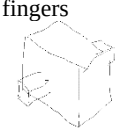
3. What are the secondary functions?

Tools should be able to be placed and extracted from the container
Be able to securely house tools
Be able to able to be picked up by the robot arm

MILESTONE 1 (STAGE 3) – MORPHOLOGICAL ANALYSIS

Team Number:	Tues-28

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	Grooves on side	Lip around upper edge	Fork-lift style holes for fingers	Squeezable part 	Rough surface	Rectangular prisms sticking out for effector fingers 
House tools	Snap in component for tool	Tools loose in container	Magnets	Adhesive of sorts (like a tape)	Padding on inside	Flaps
Place/Extract	Hinged lid	Removable lid	Angled tube where it could be grabbed	Spring mechanism (think AAA batteries)	Suction cups within	Sliding out drawer

MILESTONE 1 (STAGE 4) – CONCEPT SKETCHES

Team Number:	Tues-28

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

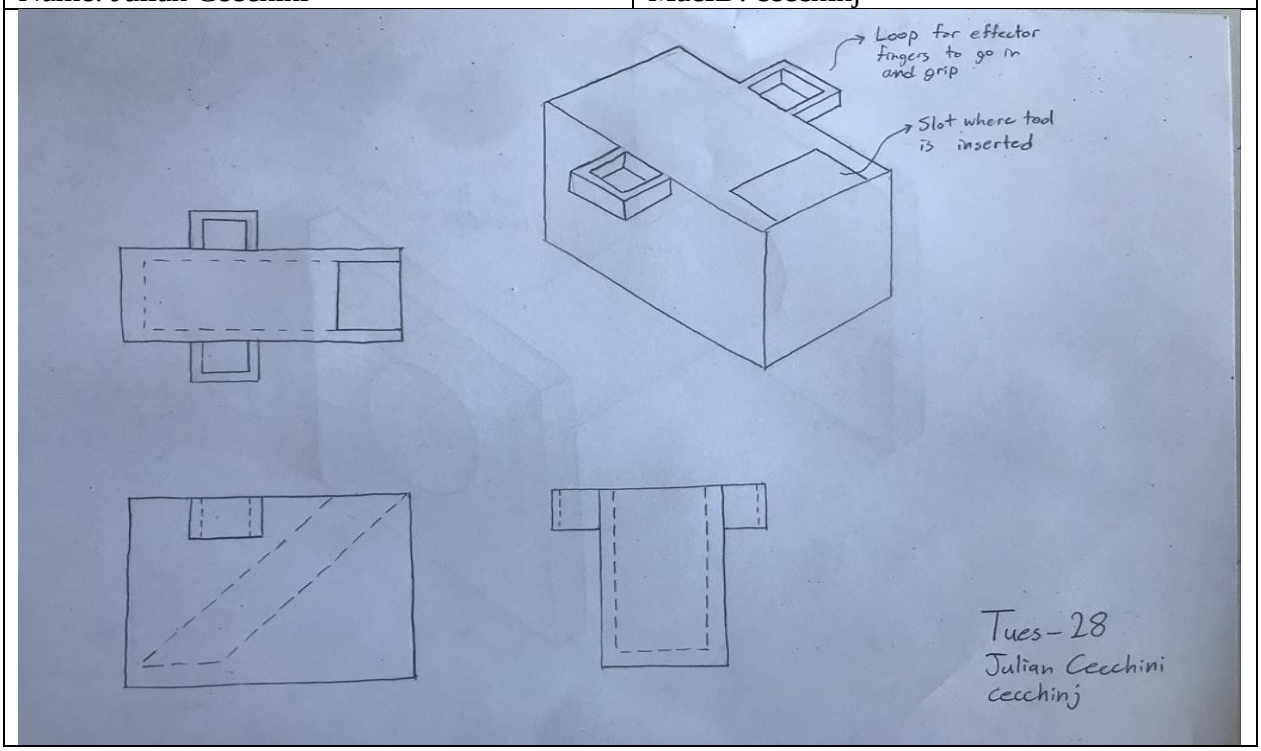
1. Each team member should copy-and-paste the photo of their individual concept sketches in the space indicated on the following pages
   → The photo's should be the same one your included in the **Milestone One Individual Worksheets** document
   → Be sure to include your **Team Number** on each page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

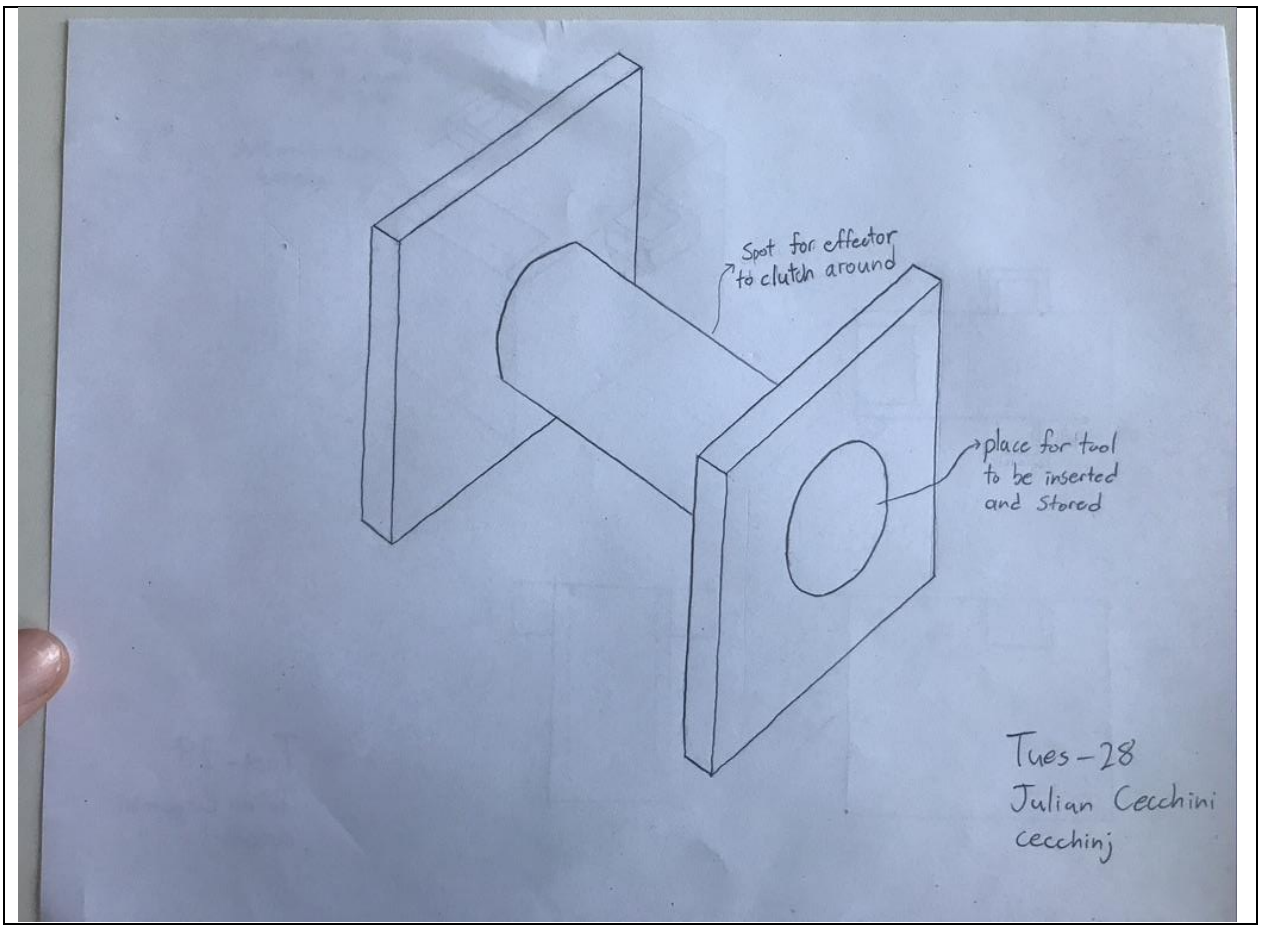
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- 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:	Tues-28

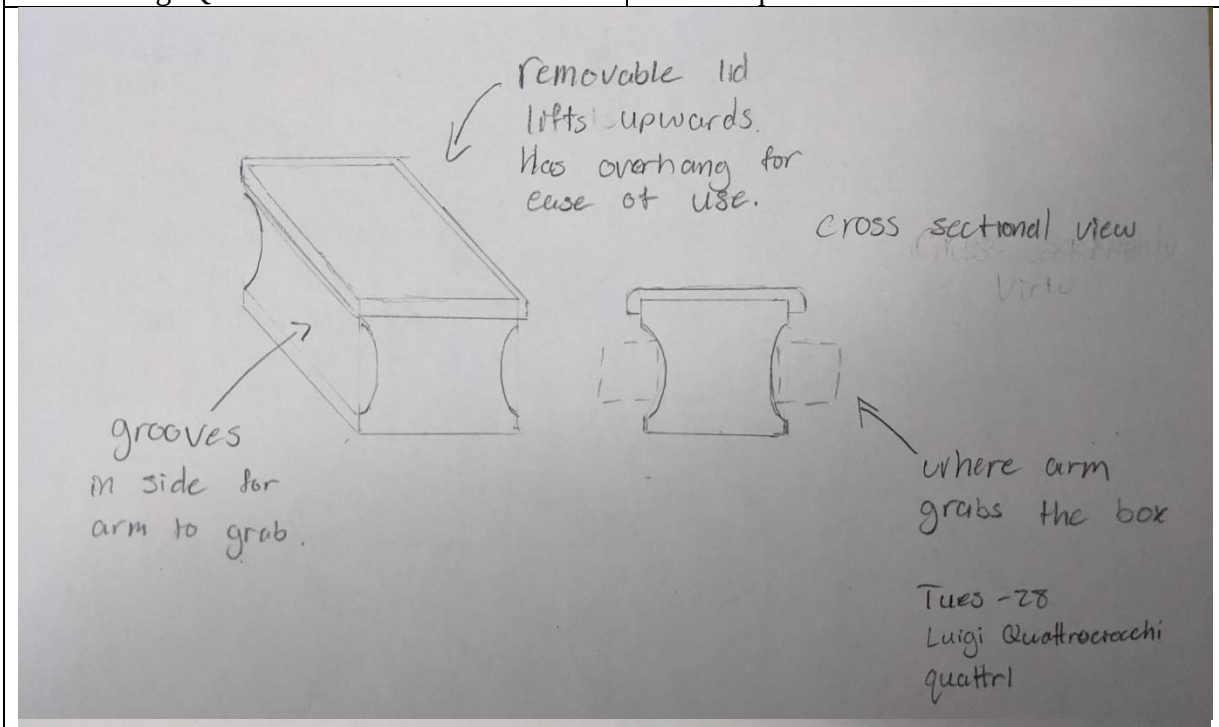
Name: Julian Cecchini	MacID: cecchinj

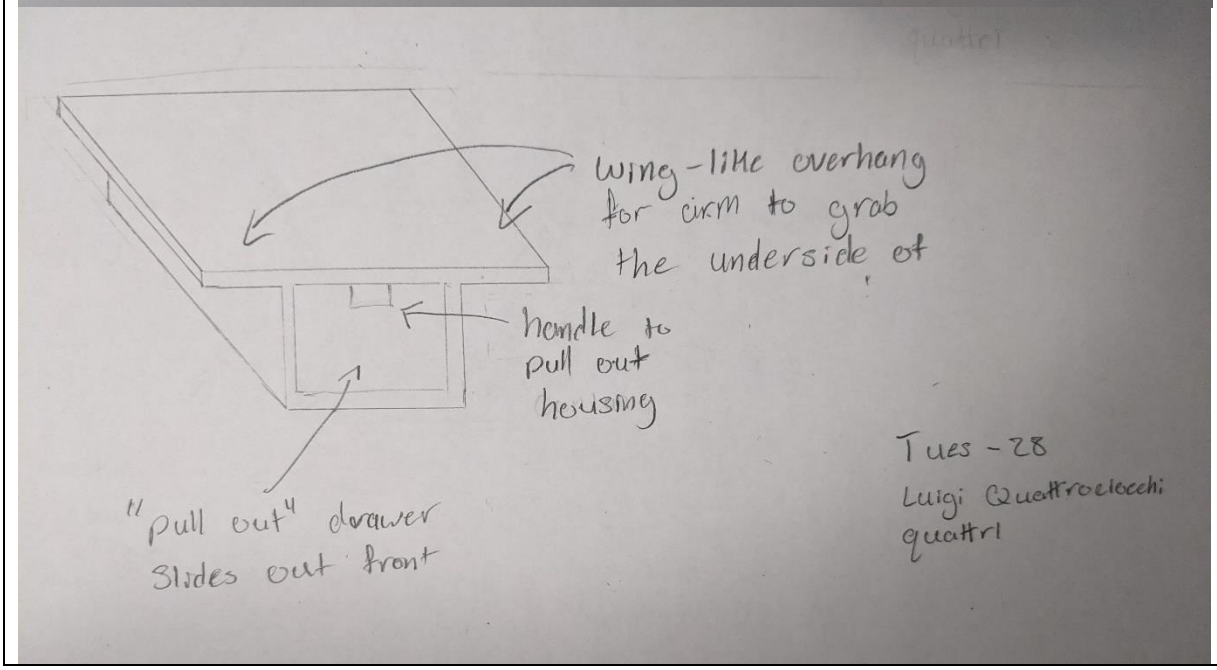



Spot for effector to clutch around
place for tool to be inserted and stored
Tues-28
Julian Cecchini
cecchinj

Team Number:	Tues-28

Name: Luigi Quattrociocchi	MacID: quattrl

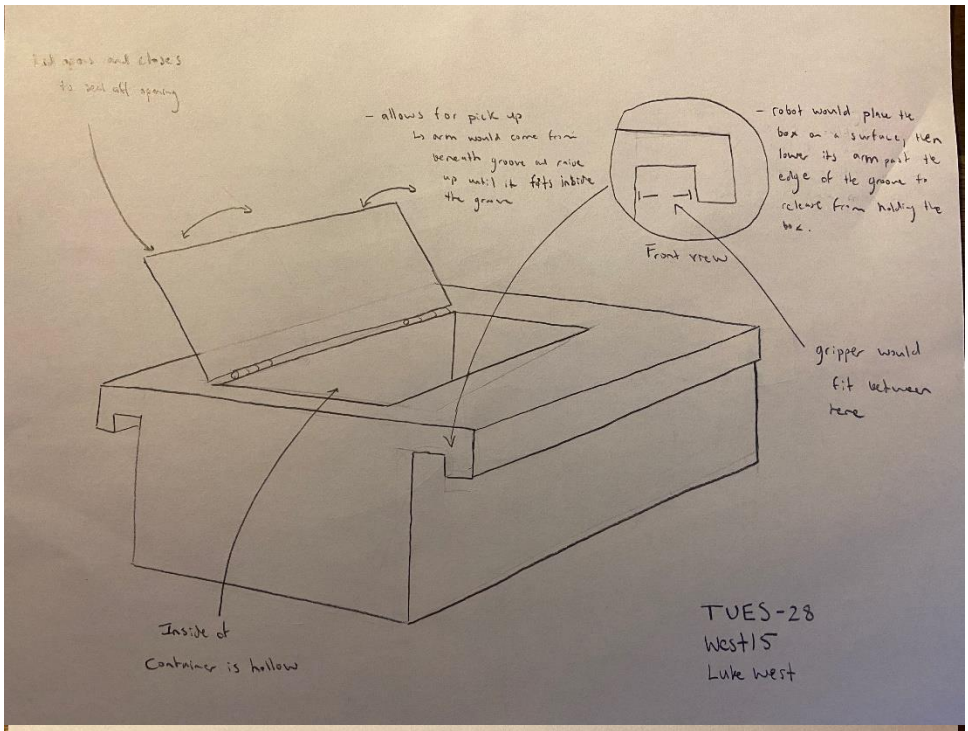


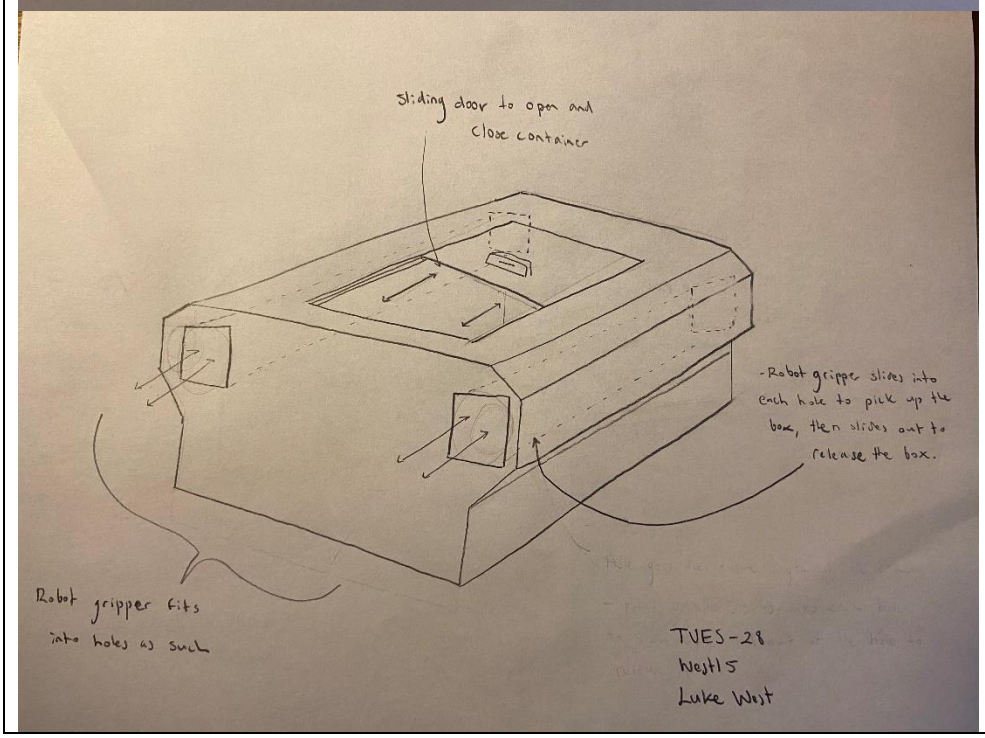


Team Number:	Tues-28

Name: Luke West	MacID: Westl5

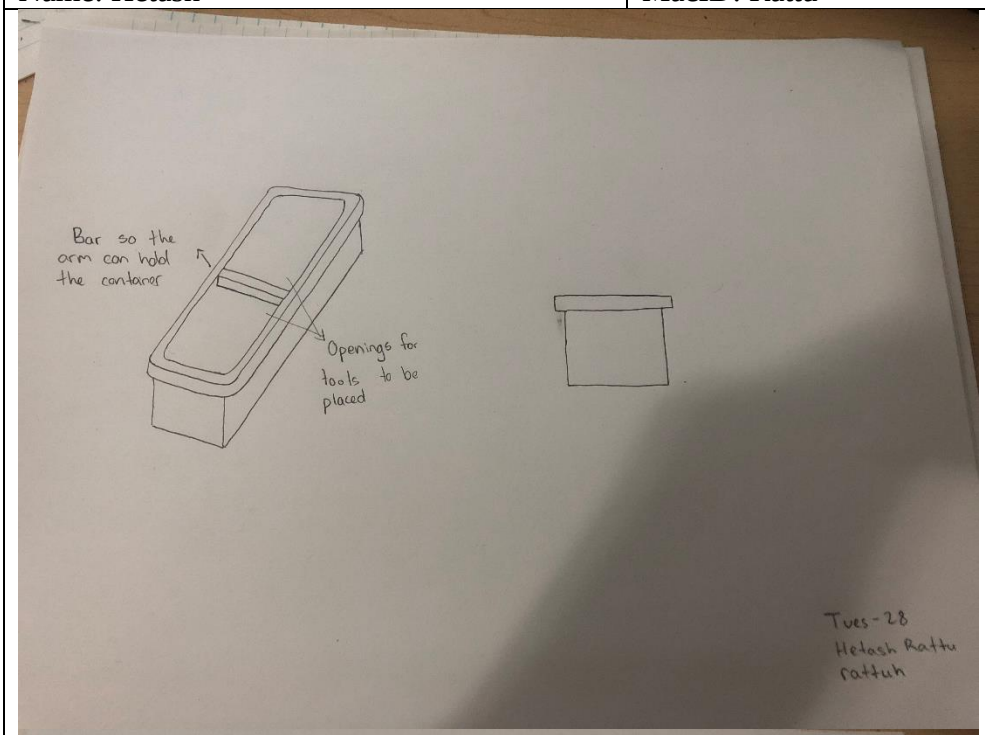
Insert screenshot(s) of your concept sketches below

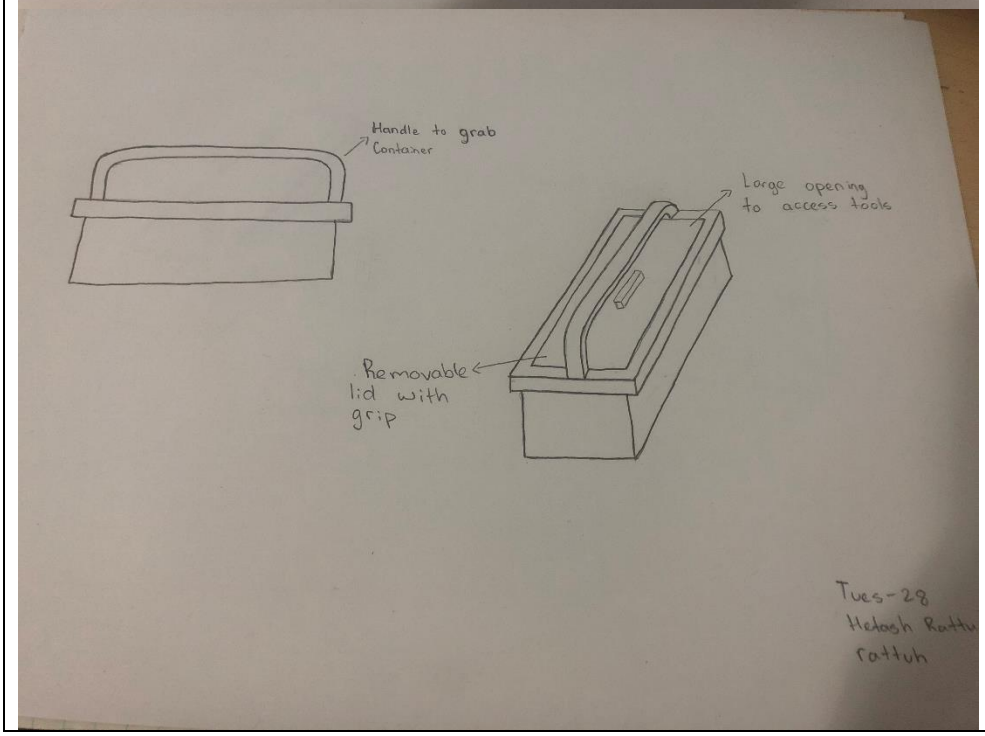




Team Number:	Tues-28

Name: Hetash	MacID: Rattu





Milestone 2

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

Team Number:	Tues-28

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

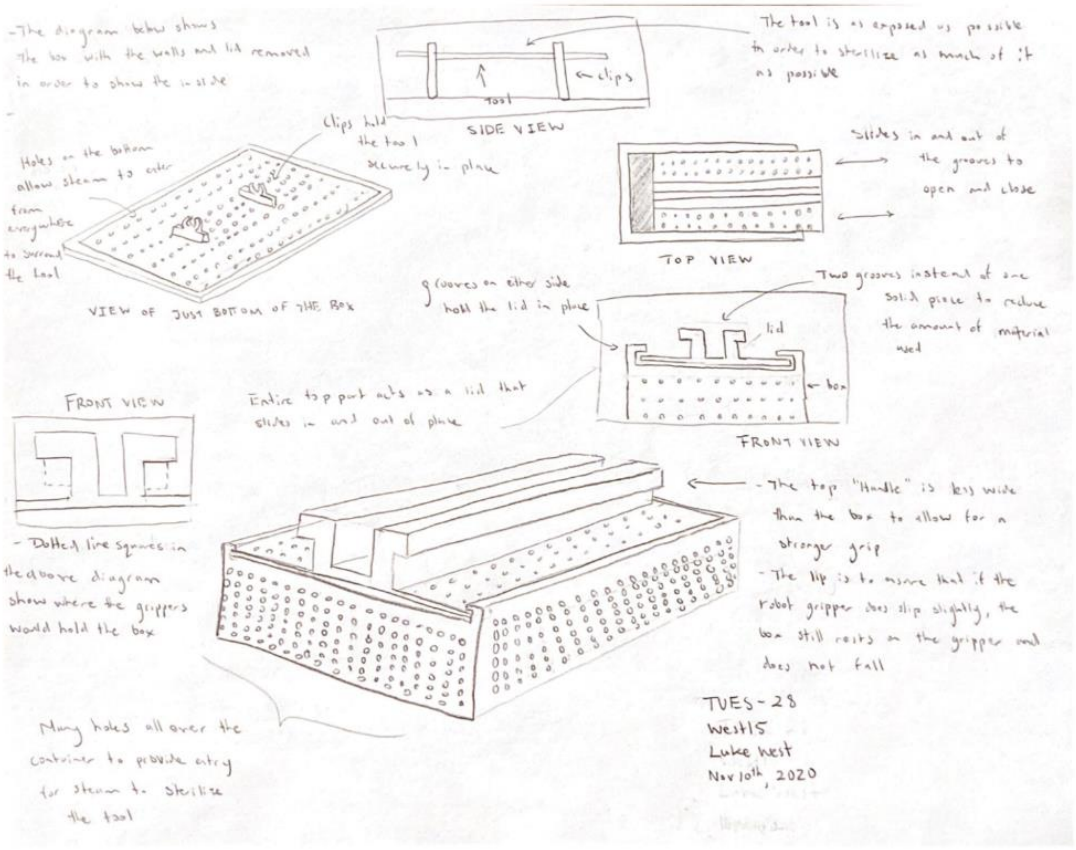
1. Copy-and-paste each sub-team member's refined sketch on the following pages (1 sketch per page)
   → Be sure to indicate each team member's Name and MacID

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

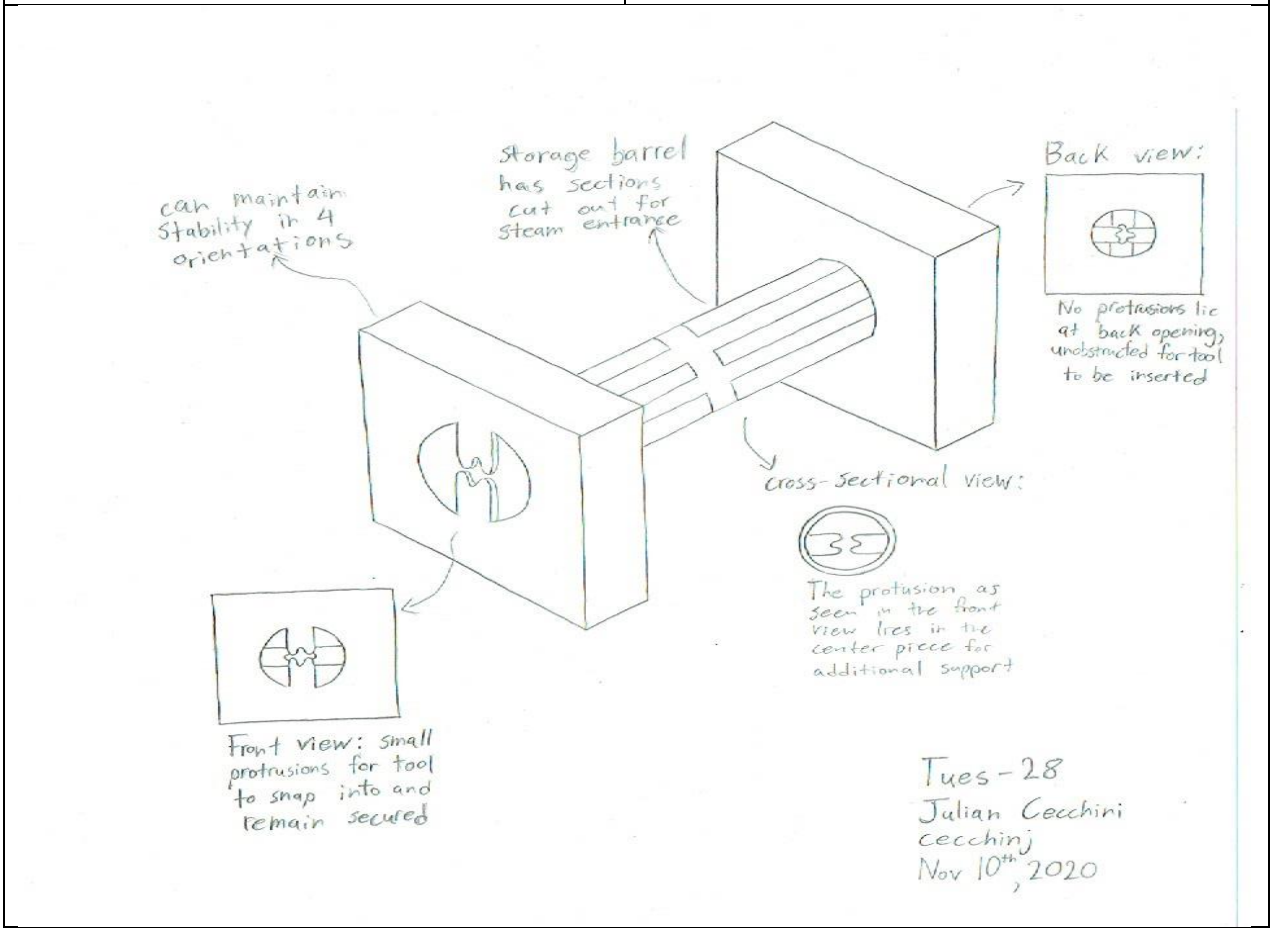
Team Number:	Tues-28

Name: Luke West	MacID: westl5



Team Number:	Tues-28

Name: Julian Cecchini	MacID: cecchinj



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

Team Number:	Tues-28

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

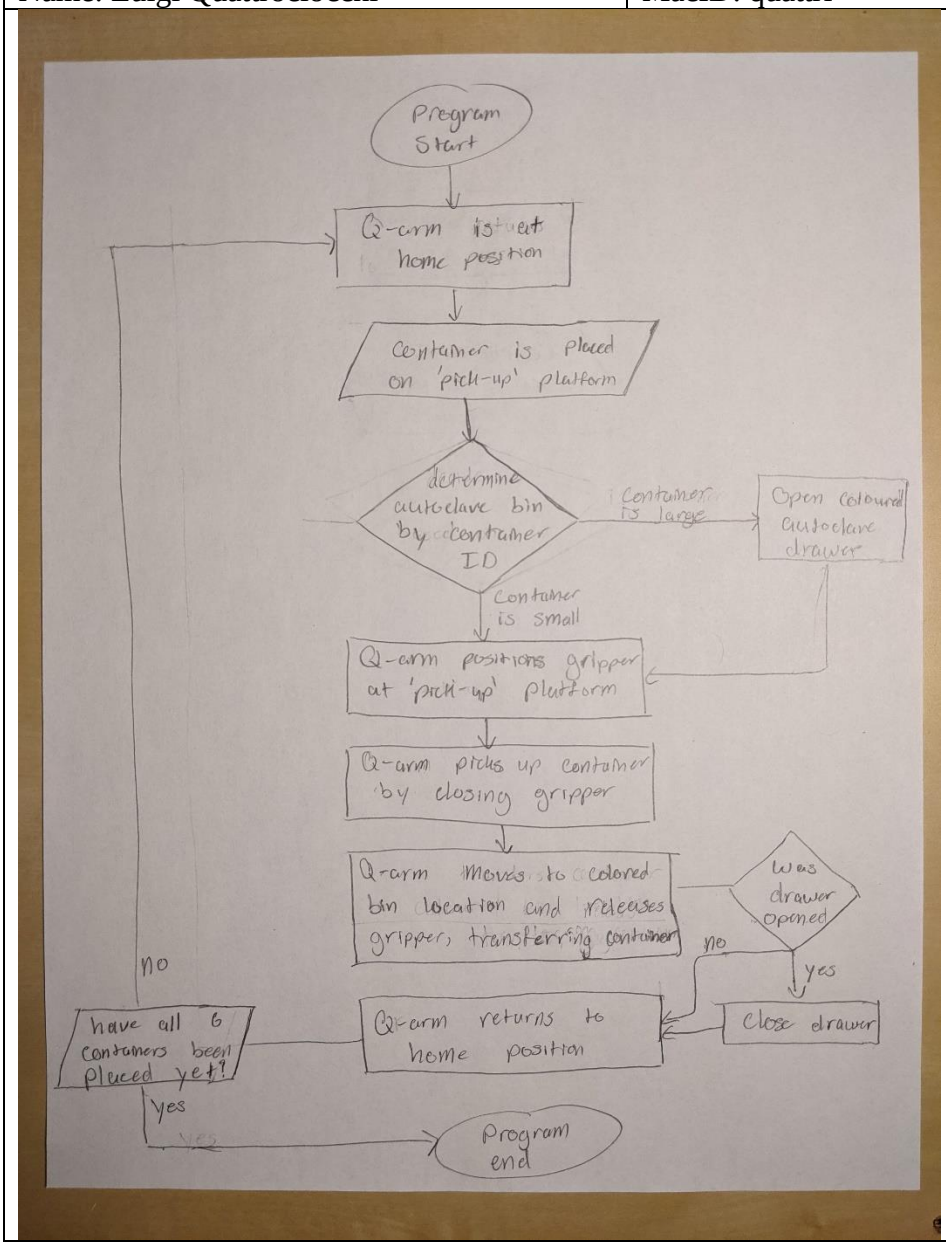
1. Copy-and-paste each team member's storyboard or flowchart sketches on the following pages (1 team member per page)
   → Be sure to indicate each team member's Name and MacID

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

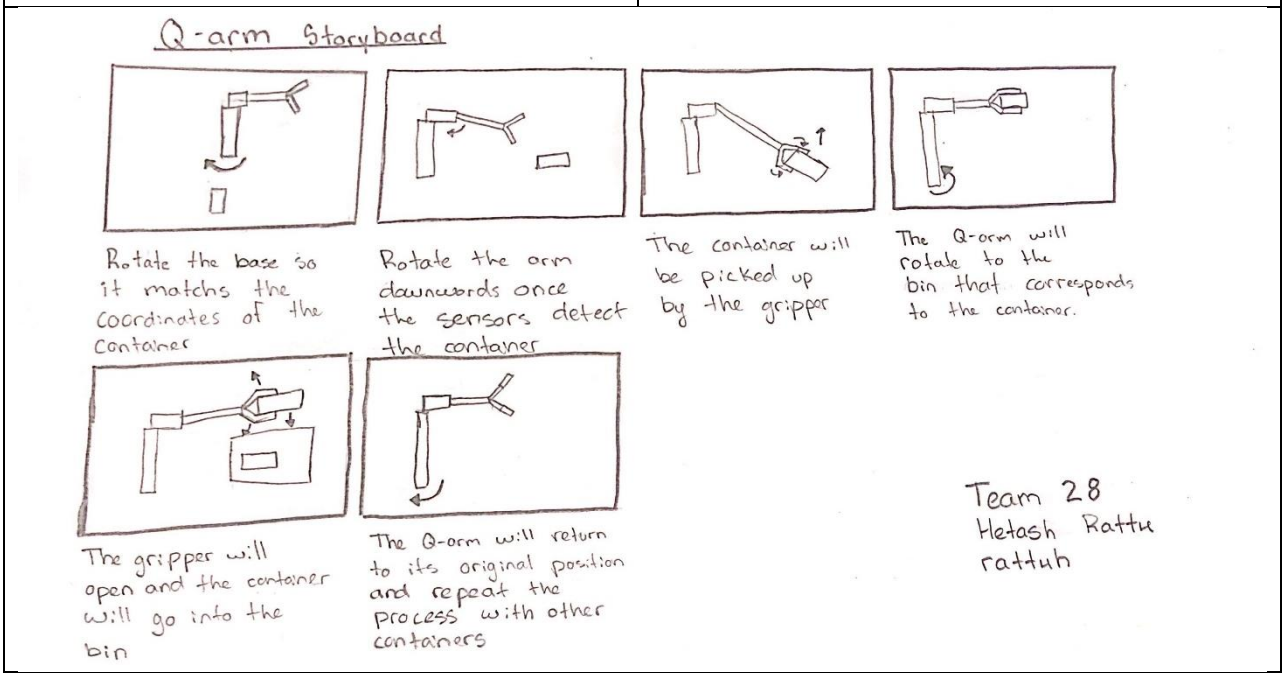
Team Number:	Tues-28

Name: Luigi Quattrociocchi	MacID: quattrl



Team Number:	Tues-28

Name: Hetash Rattu	MacID: rattuh



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

Team Number:	Tues-28

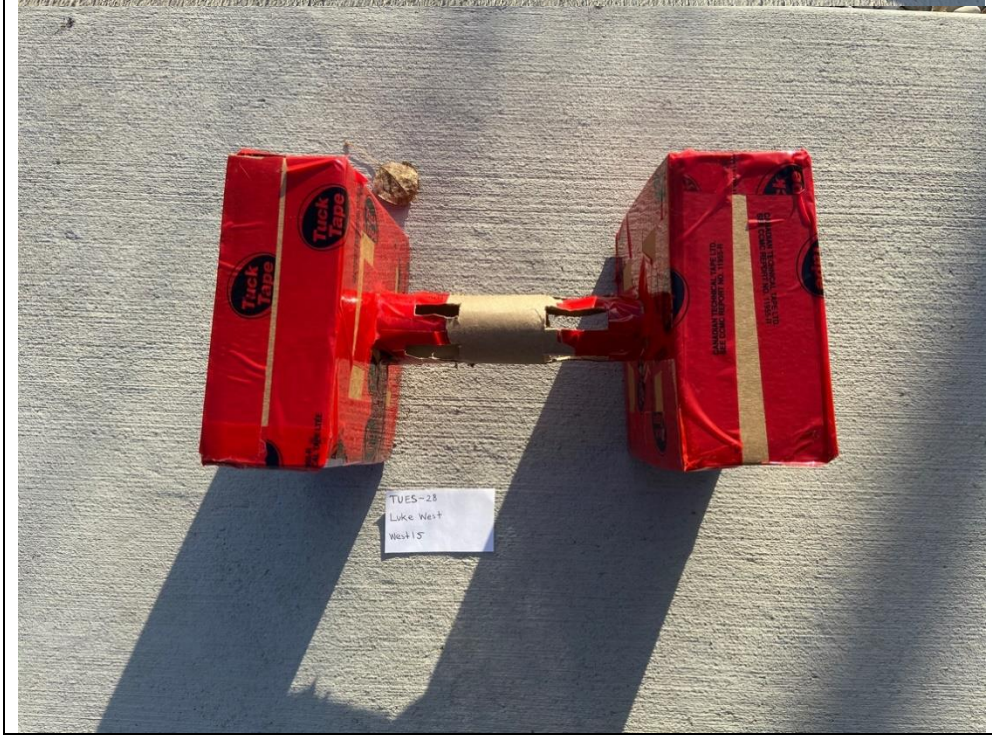
Complete this worksheet during design studio 8 after creating the low-fidelity prototypes.

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:	Tues-28

Name: Luke West	MacID: westl5

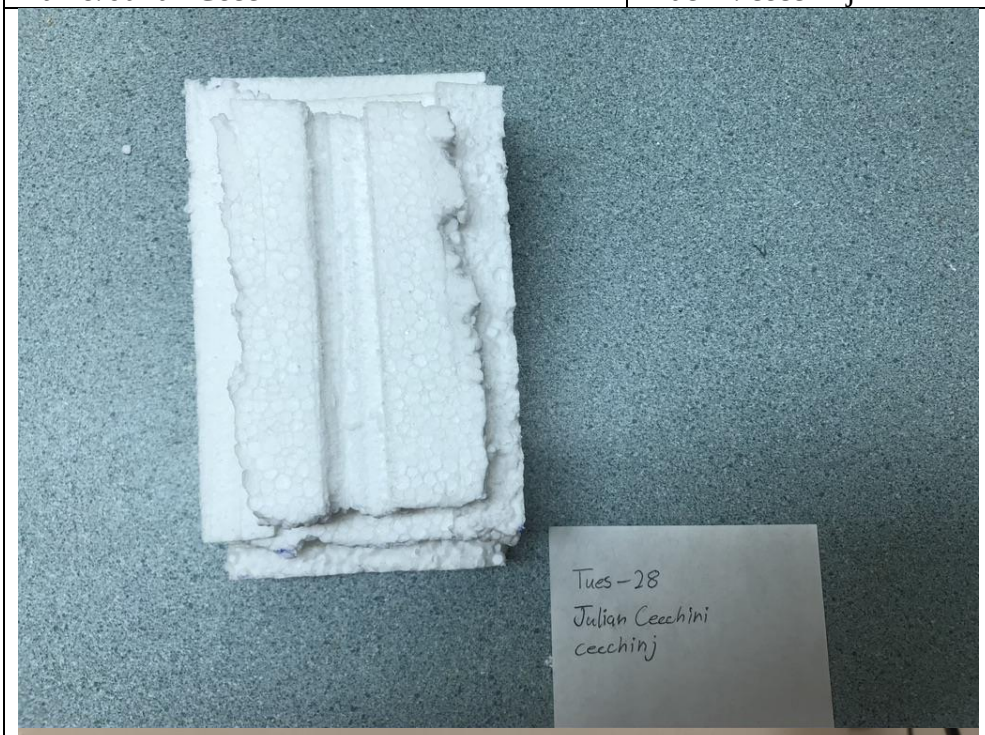


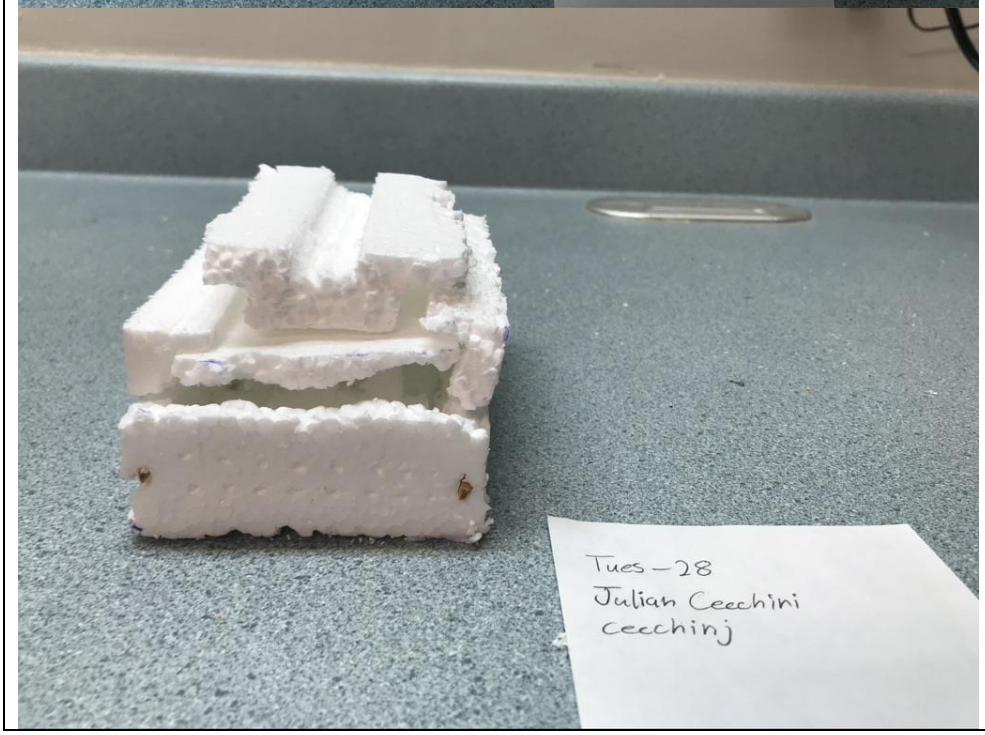

TUES-28
Luke West
West15

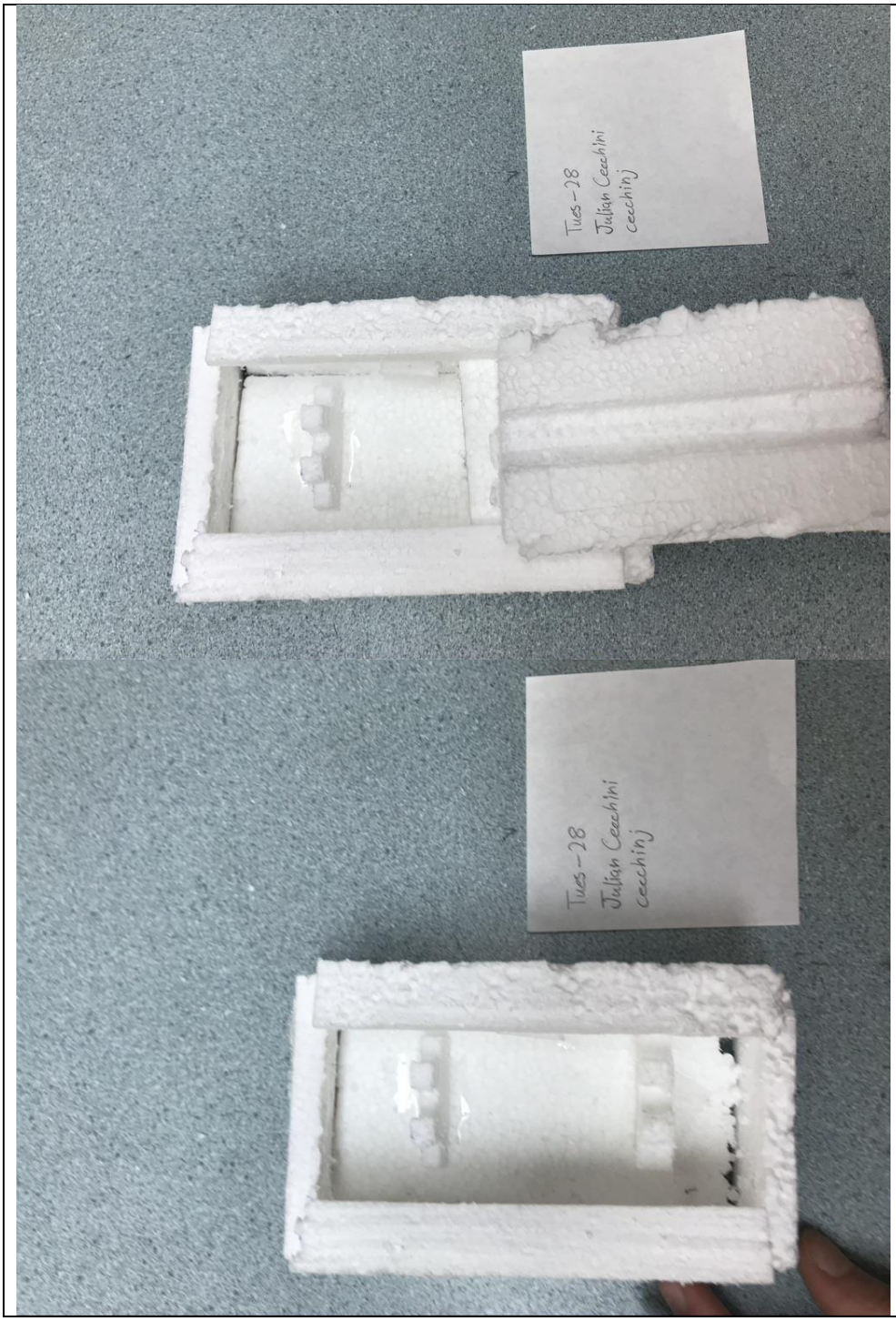

TECHNICAL TAPE LTD.
REPORT NO. 11955-R
Tuck Tape
TUES-28
Luke West
West15

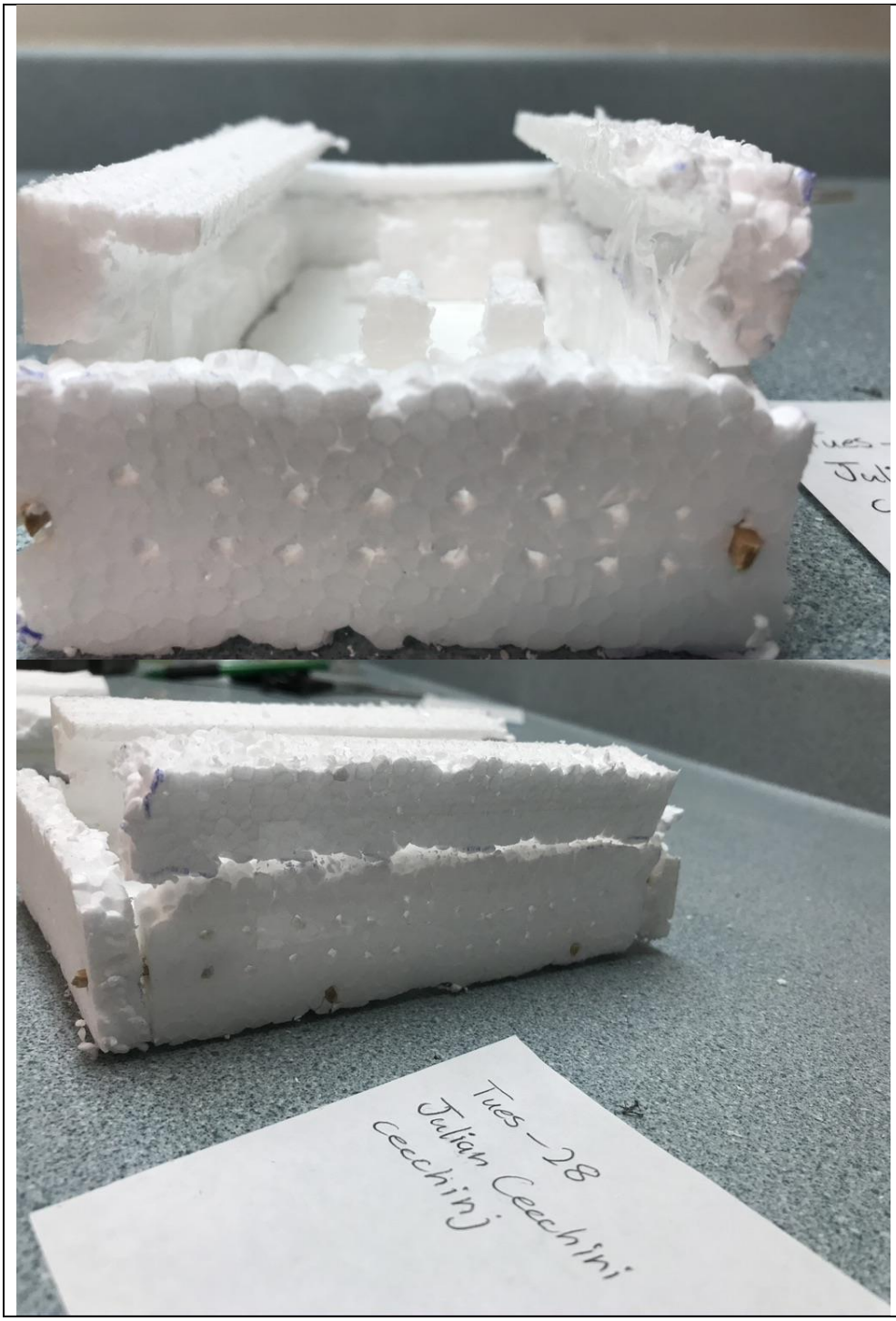
Team Number:	Tues-28

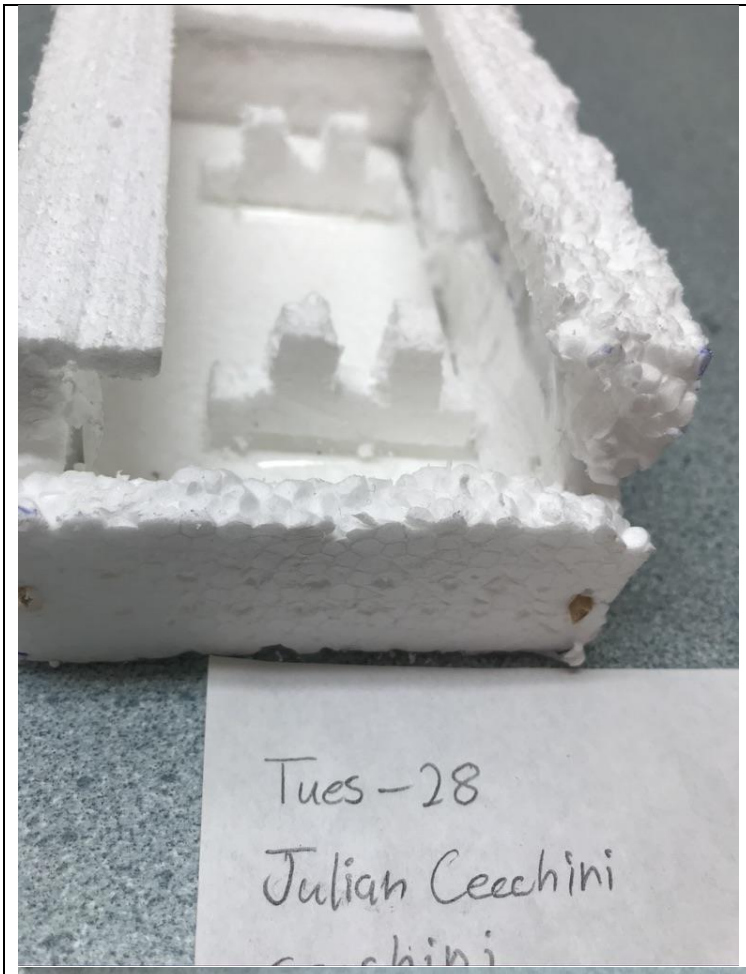
Name: Julian Cecchini	MacID: cecchinj

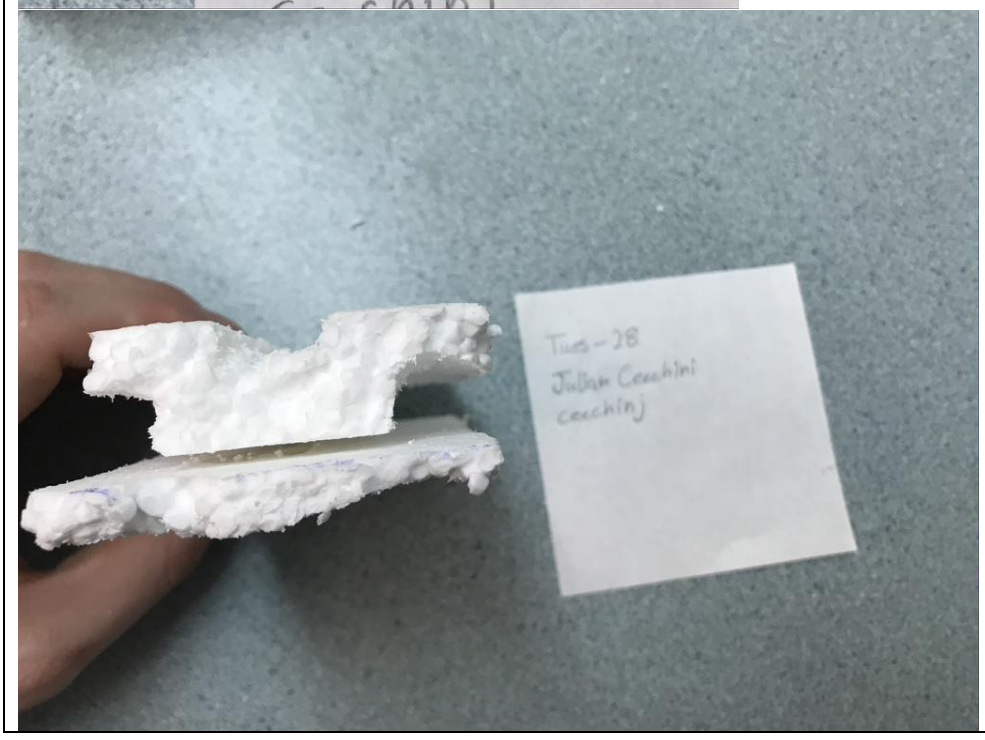





Tues-28
Julian Cecchini
cecchinj
Tues-28
Julian Cecchini
cecchinj


Tues -28
Julian Ceechini
Ceechinj


Tues-28
Julian Ceechini


Tues-28
Julian Ceechini
ceechinj

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

Team Number:	Tues-28

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 – Julian Cecchini/cecchinj's design prototyped by Luke West/westl5 (displayed first)

- *Advantage: can be picked up or dropped off in different orientations (once tool is inside cylinder, it can take on each orientation the rectangular-prism blocks provide)*
- *Advantage: Overall design has design low complexity (I.e., no sliding parts & small number of components)*
- *Disadvantage: original design has a lot of thinned out parts that may need to be reconsidered for the minimum thickness of 5 mm in the 3D printing process.*
- *Disadvantage: The area where the robot grips the container is circular, while gripper is square, therefore, the robot may have trouble gripping the container. Thus depending on the size of the tool that it must contain, it may be less reliable for pick up via the robot arm.*
- *Is reliable for securing the surgical tool via internal protrusions.*
- *Of our objectives, it fulfills being rigid and should be lightweight as there's no excessively large component. Constraint-wise: it possibly fails complexity goal, but further analysis is needed to determine this. Lastly, it fulfills the functions of securing the tool, being sterilizable by steam, and being picked up by the robotic arm. The rest are indeterminable as the dimensions and material are still unknown.*
- *Unique in concept, untypical to find containers which stray so far from a rectangular prism.*
- *Since cardboard toilet paper was used for cylinder, holes in central tube resulted in loss of structural integrity – therefore, a stiff material must be used.*

- *As mentioned, allows for a high level of sterilization through cut out spots along central cylinder (steam can enter and exit with relative ease).*

Prototype – Luke West/westl5 's design prototyped by Julian Cecchini/cecchinj (displayed second)

- *Advantage: spacious, allows for any range of tools (versatile).*
- *Disadvantage: hole size/number may need to be modified in order to accommodate for 3D printing.*
- *Advantage: Easily gripped by robot, stable/secure holding of tool.*
- *Disadvantage/modification: The grooves that the robot grips are a potentially excessive use of filament. May need to shorten as needed.*
- *Since there are holes everywhere, very reliable for sterilization.*
- *Can be easily modified (sized up or down) to accommodate different sizes*
- *Objectives: Fulfills rigidity, fulfills the constraints and functions in the same way as mentioned for the first model.*
- *Sliding mechanism is both aesthetic and useful. Adds some flair to the design.*
- *Unlike first prototype, resizing won't affect the robot's ability to grip it*

(From previous milestone, table of objectives constraints, and functions)

Objectives	Constraints	Functions
Should be resistant to high temperatures	All features must be greater than 4mm	Tools should be able to be placed and extracted from the container
Should have a distinct colour	Scaled down weight does not exceed 350 g	Be able to securely house tools
Should be chemically inert	Complexity of parts if minimum; print time of replication cannot exceed 2 hours	Be able to able to be picked up by the robot arm
Should be lightweight	Max 170 mm min 80 mm	Must allow sterilization of tools by steam
Should be rigid and hold its shape	Base must fit within the autoclave	Base must be able to remain inside its respective autoclave
	Caters towards effector grip	

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

Team Number:	Tues-28

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

Differences:

- One workflow was in the form of a flowchart while the other was a storyboard
  - Flowchart was chosen for more organized workflow
  - Storyboard was chosen for visual representation of workflow
  - Both methods are valid for this workflow
- Moving to home position was described differently: storyboard was more specific
  - Flowchart assumed the home process would be premade and consistent
  - Storyboard manually rotated to the zero position
  - Flowchart is recommended as there is an existing arm.home() method
- Flowchart had decision processes while storyboard was vaguer about deciding which autoclave bin each container would go to
  - Flowchart decides which location to move to based on ID (colour and size)
  - Storyboard didn't take into account that there would be differences in ID
- Flowchart had decision process to open and close drawer while storyboard did not
  - Flowchart realized drawer only needs to be opened if container is large
- Storyboard detailed movements and rotations of arm, while flowchart did not
  - Storyboard was specific about each movement of the Q-arm

Similarities:

- Both workflows described the moving of container to the proper autoclave bin
- Both described action of picking up and container by gripping the container
- Both described moving container to its correct autoclave bin
- Both had a looping structure that would iterate for every container

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

Team Number:	Tues-28

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

```
Start

Arm moves to home position

Place container on pick-up platform

Determine which color the container is based on ID

Position arm at pick up platform

Close gripper

Position arm over corresponding colored autoclave bin location

If container ID is large size

        Open corresponding colored autoclave drawer

Open gripper

If container ID is large size

        Close corresponding colored autoclave drawer

Arm moves to home position

Repeat for all containers

Stop
```

Milestone 3

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

Team Number:	Tues-28

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

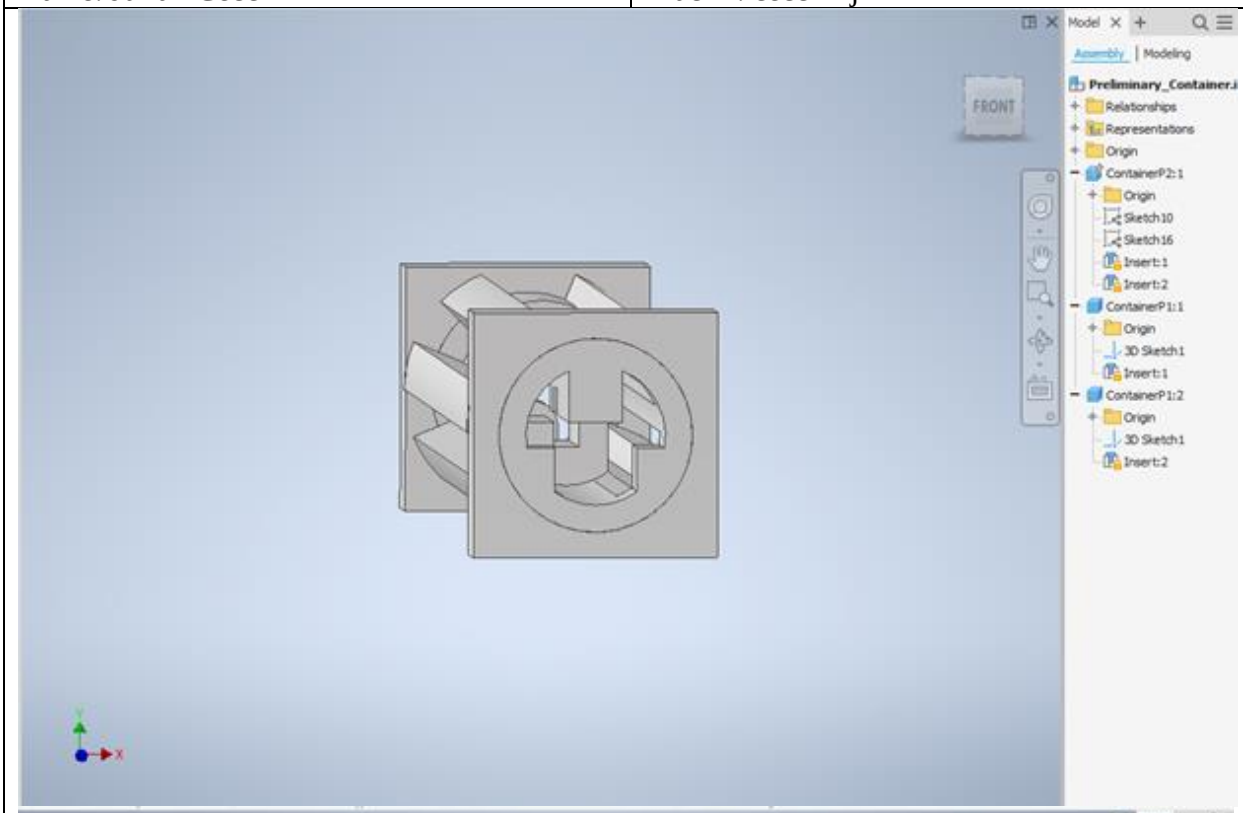
1. Copy-and-paste each team member's screenshots of their preliminary solid model on the following pages (1 team member per page)
   → Be sure to clearly indicate who each model belongs to

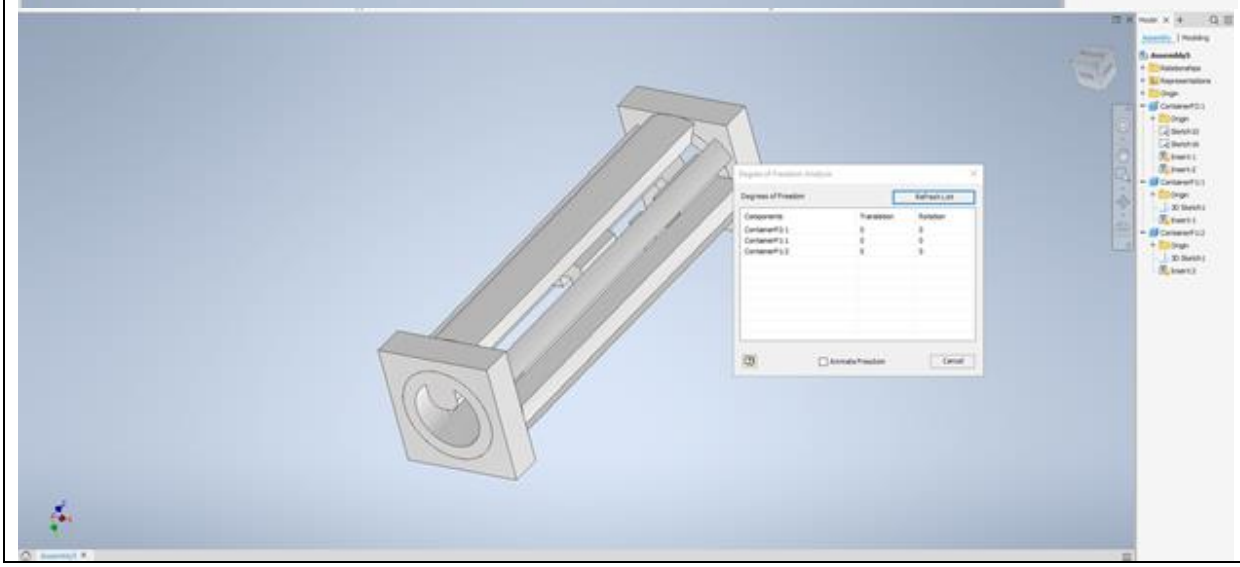
We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

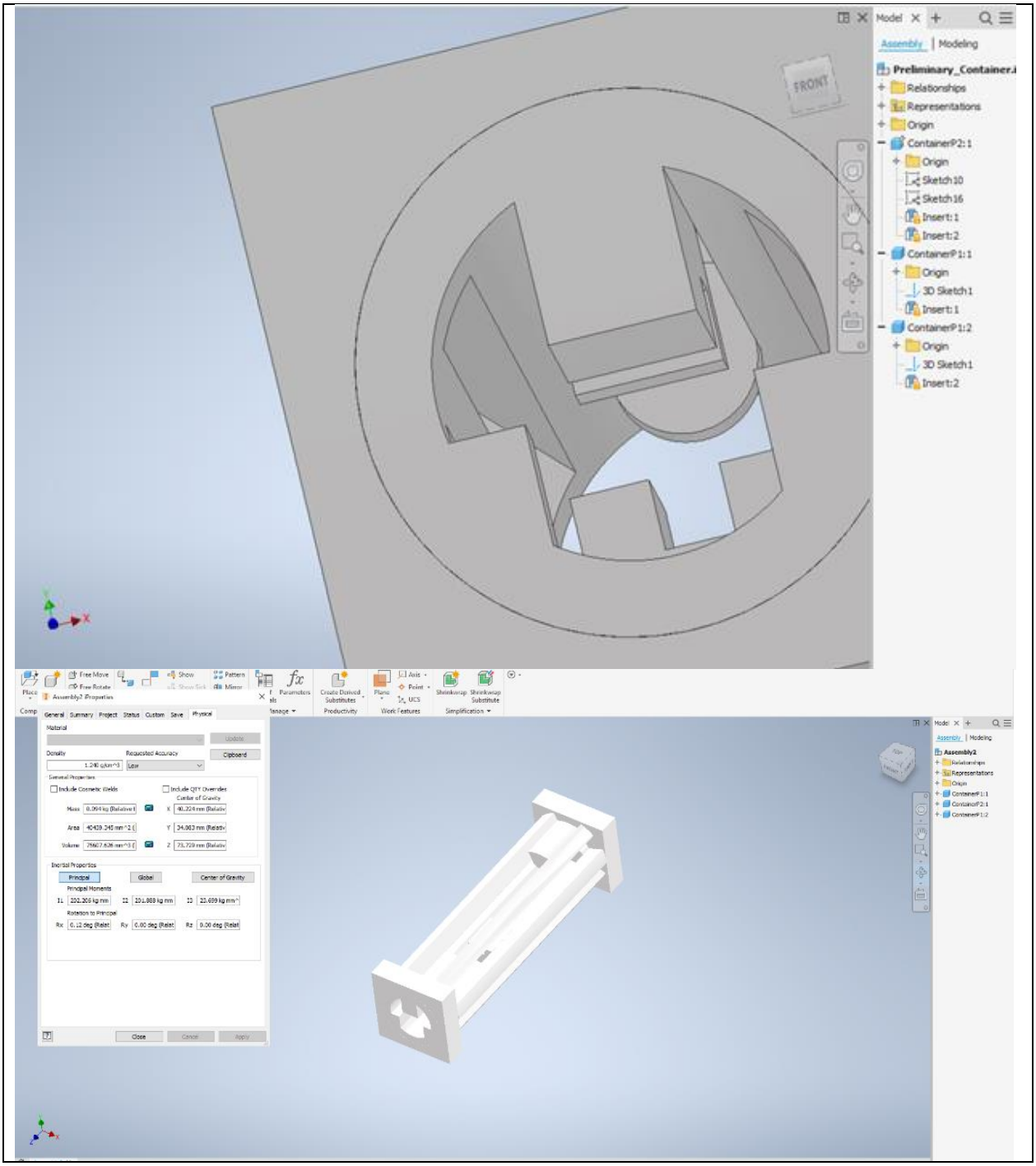
- Each team member needs to submit their solid model screenshots with the **Milestone Three Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone Three Team Worksheets** document allows you to readily access your team member's work
  -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

Team Number:	Tues-28

Name: Julian Cecchini	MacID: cecchinj

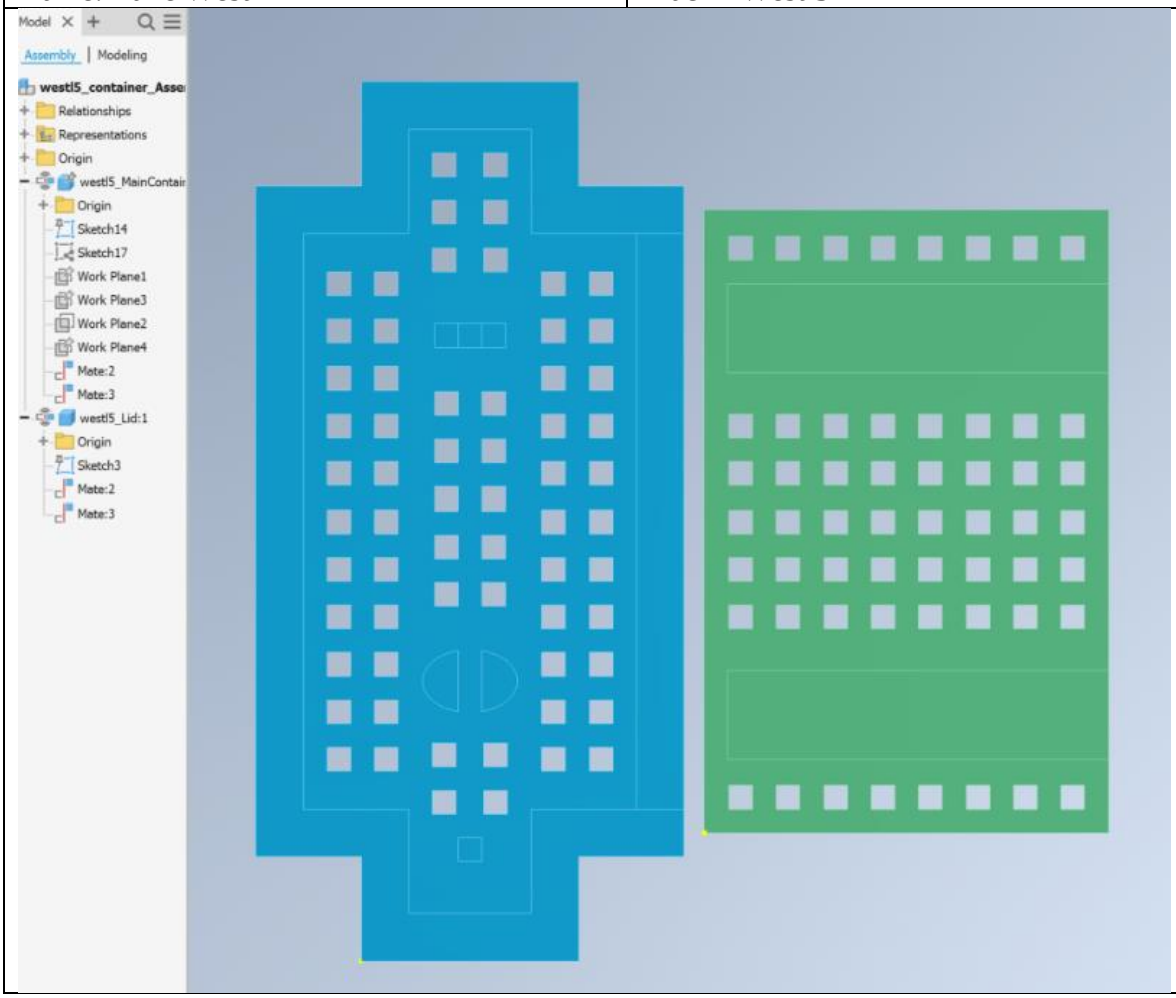


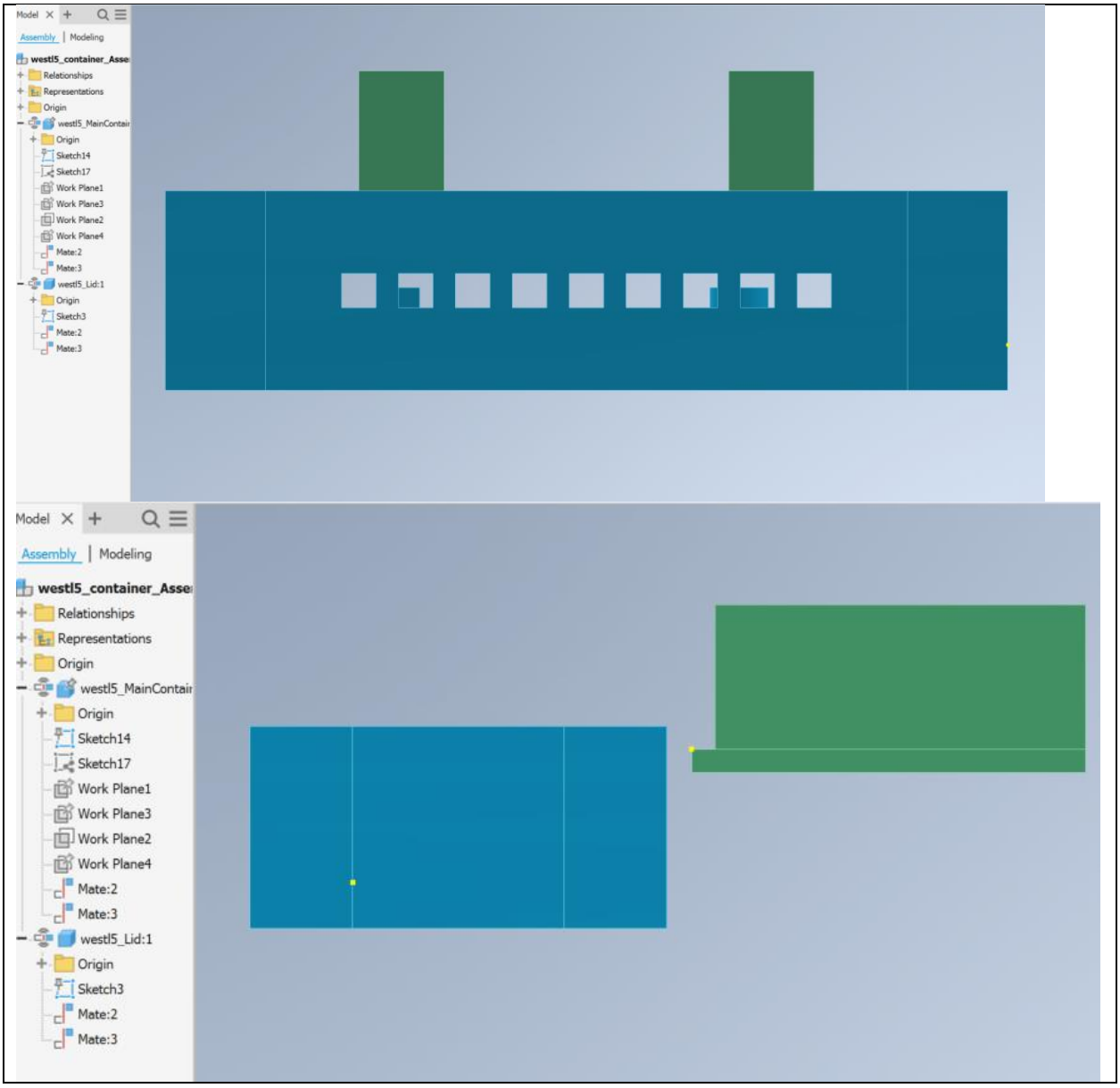


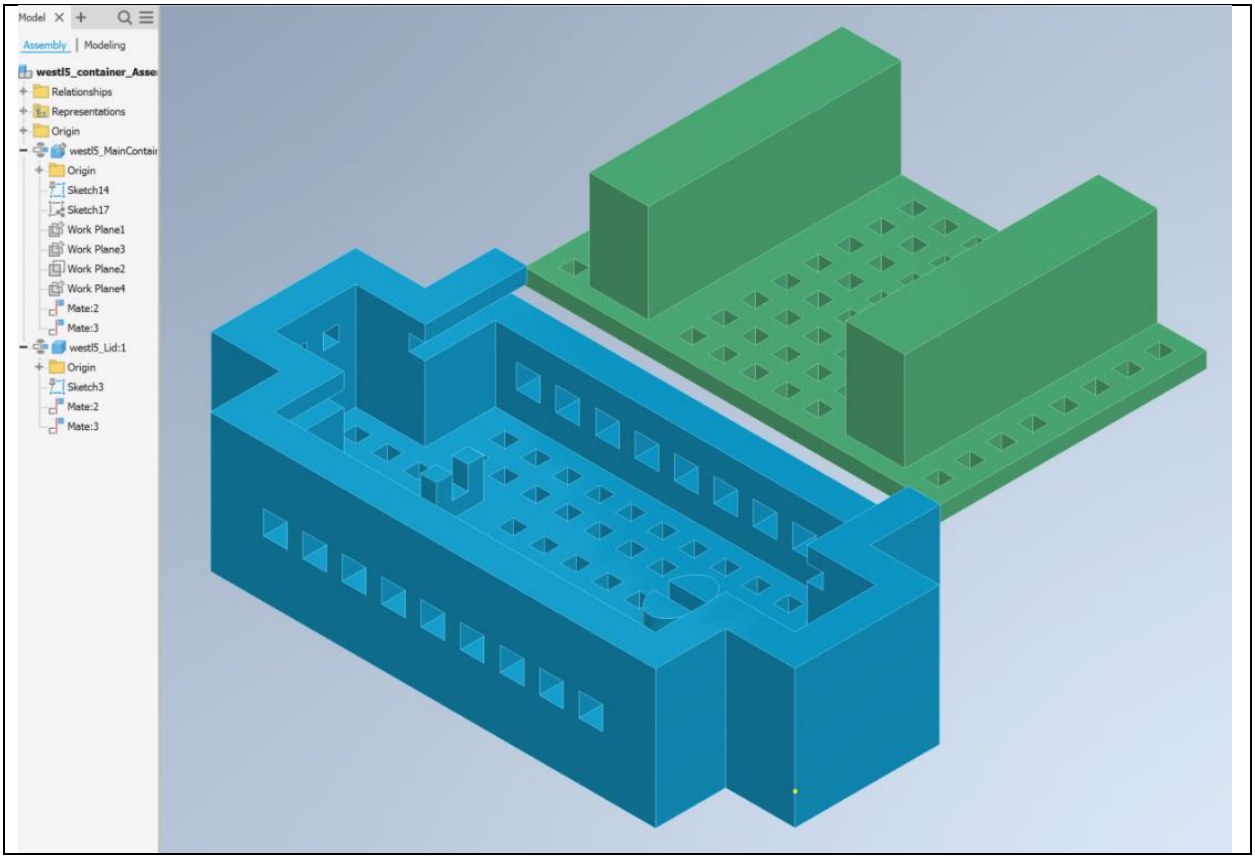

FRONT
Model
Assembly
Modeling
Preliminary_Container
Relationships
Representations
Origin
ContainerP2:1
Origin
Sketch10
Sketch16
Insert:1
Insert:2
ContainerP1:1
Origin
3D Sketch1
Insert:1
ContainerP1:2
Origin
3D Sketch1
Insert:2
Material
Density
Requested Accuracy
Clipboard
Include Cosmetic Welds
Include QTY Overrides
Center of Gravity
Mass
Area
Volume
Inertial Properties
Principal
Global
Center of Gravity
Principal Moments
Rotation to Principal
Close
Cancel
Apply

Team Number:	Tues-28

Name: Luke West	MacID Westl5




Model
Assembly | Modeling
westl5_container_Asse
Relationships
Representations
Origin
westl5_MainContair
Origin
Sketch14
Sketch17
Work Plane1
Work Plane3
Work Plane2
Work Plane4
Mate:2
Mate:3
westl5_Lid:1
Origin
Sketch3
Mate:2
Mate:3



*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:	Tues-28

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:	Tues-28

Name: Luigi Quattrociocchi	MacID: quattrl

```
def identify_autoclave_bin_location(container_id):
    '''
    Returns a list with 3 elements describing x, y, z coordinates of the
    location of an autoclave bin that corresponds to the given container id

    >>> identify_autoclave_bin_location(1)
    [-0.6099, 0.2464, 0.3784]
    >>> identify_autoclave_bin_location(0)
    [0.4064, 0.0, 0.4826]
    '''

    if container_id == 1: # small red
        return [-0.6099, 0.2464, 0.3784]
    if container_id == 2: # small green
        return [0.0, -0.6578, 0.3784]
    if container_id == 3: # small blue
        return [0.0, 0.6578, 0.3784]
    if container_id == 4: # large red
        return [-0.394, 0.1592, 0.2374]
    if container_id == 5: # large green
        return [0.0, -0.4249, 0.2374]
    if container_id == 6: # large blue
        return [0.0, 0.4249, 0.2374]

    # base case home position
    return [0.4064, 0.0, 0.4826]
```

Team Number:	Tues-28

Name: Hetash Rattu	MacID rattuh

In [ ]:
```
def moveeffector ():
    if arm>= thres
    arm.move_arm(0,0,0) #starting position
    time.sleep(2)
    arm.move() #move to the given position
    time.sleep(2)
```

*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: Tues-28

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 - Standard Box	**Sliding Lid Design**	**Barrel Design**
Sterilization	S	S	S
Stabilization	S	S	-
Rigidity	S	-	S
Mass	S	S	S
Complexity/ Printability	S	-	-
Ability to grip	S	+	S
Total +	0	1	2
Total –	0	2	0
Total Score	0	-1	-2

*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

Julian: barrel design

- Adjust design for securing the tool to ensure it will not fall out after excessive shaking
- Reduce complexity of internal parts by reducing overhangs and/or total number of parts for the sake of the 3D printer process.
- Make container easier for effector to latch onto (original intention was barrel but upon examination it may be too small, therefore, the rectangular prisms will likely be given that purpose instead)
- Possibly adjust dimensions so it is more spacious in autoclave

Luke: sliding lid design

- Add thickness to lid for strength/structural integrity
- Make more room so that the sliding mechanism fits less snug within the groove and leaves more room for printer error.
- Reinforce part where robot grips the lid/container in order to keep it rigid under the force of the gripper
- Possibly resize so it completely fits in autoclave without protruding upward

Note: Decide final design concept before wk-10.

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

Team Number:	Tues-28

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**: Luigi Quattrociocchi
There were no error found in the code. Code worked in the Q-labs environment There are comments that relate the bin number to the colour and size If statements could be replaced with elif statements Locations may not be exactly correct and may need to be modified	
Move End-Effector Task	**Team Member Name**: Hetash Rattu
• Code would not compile: o Missing colon after if statement o Missing indentation after if statement o arm does not have a move() method o thres is not defined	

- function should take parameters for x, y, z coordinates
- arm should move to specified location
- arm >= thres is not a valid comparison (object to number)
- should use arm.emg_left() or arm.emg_right() methods
- 0, 0, 0 is not the exact home position
- a few short comments

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

Team Number:	Tues-28

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

Control Gripper

```
Define threshold value
Define Control Gripper function with open or close flag passed in
Begin indefinite loop
    Check muscle sensor values
    Wait until right arm is flexed (above threshold) and the left arm is fully extended
        Fully open or close the fingers of the gripper (based on flag)
        Break out of indefinite loop
```

Open Autoclave Bin Drawer

Define threshold value

Define Open Autoclave Bin Drawer function with open or close flag and container id

If container is large

Begin indefinite loop

Wait until both arms are flexed

Decide which drawer to open based on container color (red, green, or blue respectively)

Open or close the corresponding colored autoclave drawer based on the flag

Break out of indefinite loop

Continue or Terminate

Track all containers which have not been placed yet using a list

Loop while all containers have not been successfully placed in their correct autoclave bins yet (list is not empty)

Choose a random container to place next

Pick up and place the next container in its correct autoclave bin

Remove placed container from “containers that have not been placed” list

Once loop is finished, terminate the program

Milestone 4

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

Team Number:	Tues-28

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

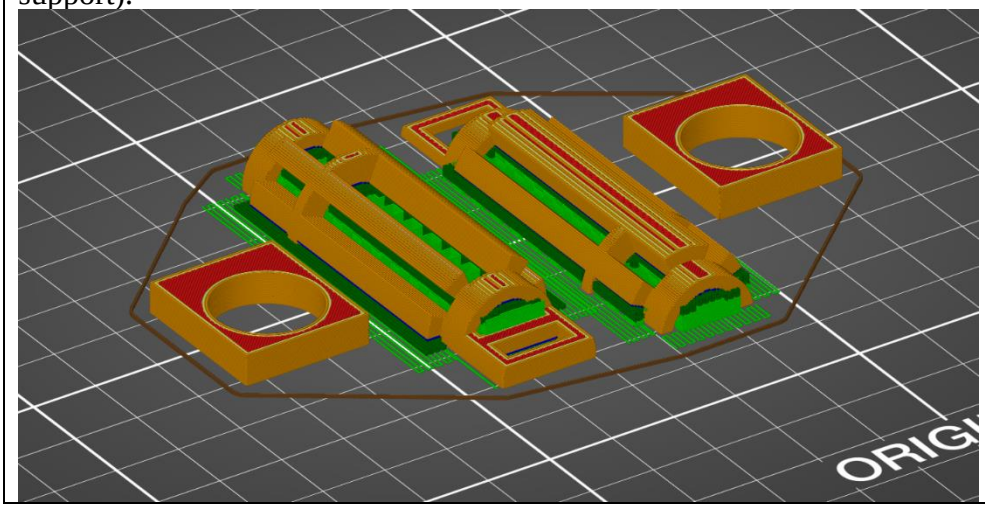
Inventor File comments:
-none
G-code comments:
-none
Constraints Met:

- Mass of 350 g or less
- Length of 4mm or greater for all features
- Print time under 2 hours
- Sterilization
- Tool Security

Go without warning

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

Based on the feedback, our design does not require improvements. However, prior to the design review many crucial improvements were made, such as redesigning the securing method of the tool, splitting our design into 4 pieces rather than 3 by cutting the tube into cross-sections to allow for easier 3D printing (i.e., supports can more easily be removed but still allows for the printing of the cylindrical shape that would be impossible without proper support).

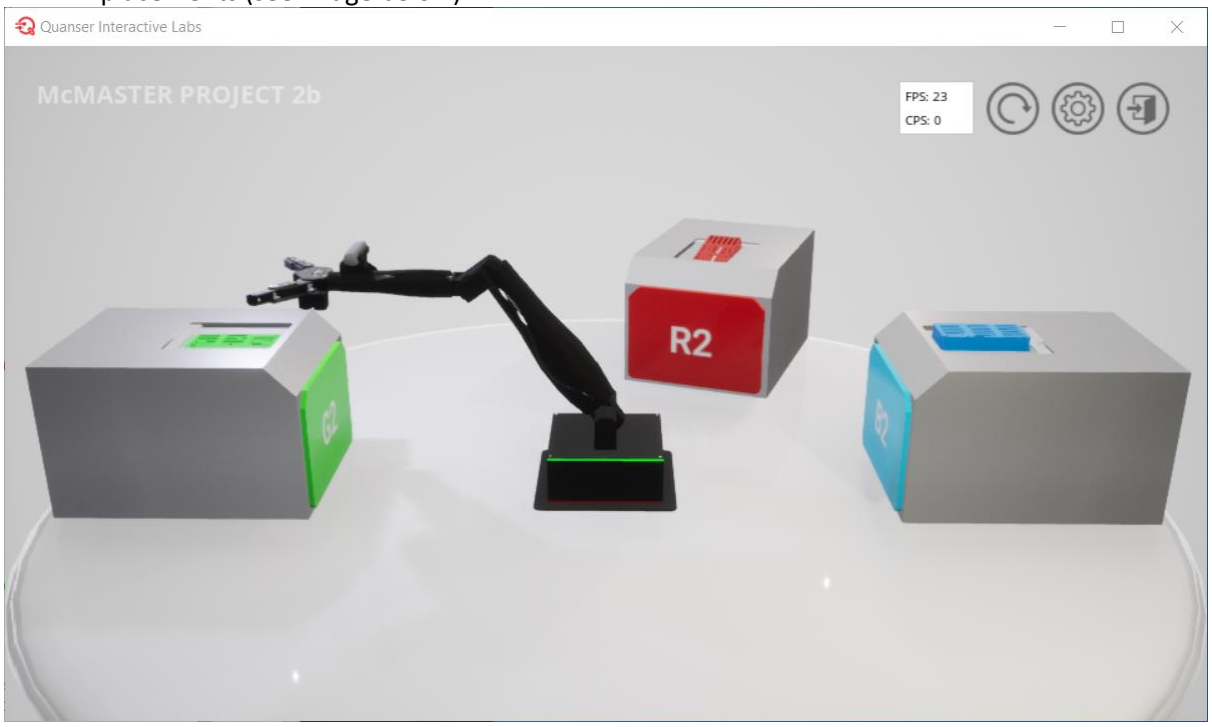


MILESTONE 4 (STAGE 3) – DESIGN REVIEW FEEDBACK (COMPUTATION SUB-TEAM)

Team Number:	Tues-28

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

- No feedback on any function definitions or logic
- No feedback on commenting or code neatness
- No feedback on single cycle pick up or transfer
- Feedback on drop off: Tweak small container drop off locations for more consistent placements (see image below)



Go without warning

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

Adjust pick up and drop off locations so that container placement is more consistent. In the image above each of the small containers is placed with a different degree of success, despite all being based on the same series of joint rotations.

NOTE: Even though all the small container drop-off locations have the same exact arm rotation amounts (except the base rotation), different behavior is observed for each of them (see image above). See the code snippet included below.

```
if container_id == 1: # small red
    return [-0.5771, 0.229, 0.4218]
if container_id == 2: # small green
    return [0.0, -0.6153, 0.4218]
if container_id == 3: # small blue
    return [0.0, 0.6153, 0.4218]
```

List of Sources

[1] "Project 2: *Get a Grip,*" class notes for 1P13, McMaster University, Fall, 2020

[2] "Lecture 15a Concept Evaluation and Selection," class notes for 1P13, McMaster University, Fall, 2020

[3] "Lecture 15b Design Configuration and Communication," class notes for 1P13, McMaster University, Fall, 2020

[4] "Functions I" class notes for 1P13, McMaster University, Fall, 2020

[5] "Functions II" class notes for 1P13, McMaster University, Fall, 2020

[6] "Sequences, Lists, Repetition I" class notes for 1P13, McMaster University, Fall, 2020

[7] "Sequences, Lists, Repetition II" class notes for 1P13, McMaster University, Fall, 2020

[8] "Conditionals" class notes for 1P13, McMaster University, Fall, 2020

[9] 2020. *Autodesk Inventor Professional 2021*. Autodesk.

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[14] "Isometric Views," class notes for 1P13, McMaster University, Fall 2020

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[17] "Engineering Drawing," class notes for 1P13, McMaster University, Fall 2020

[18] "Assembly Modelling I," class notes for 1P13, McMaster University, Fall 2020

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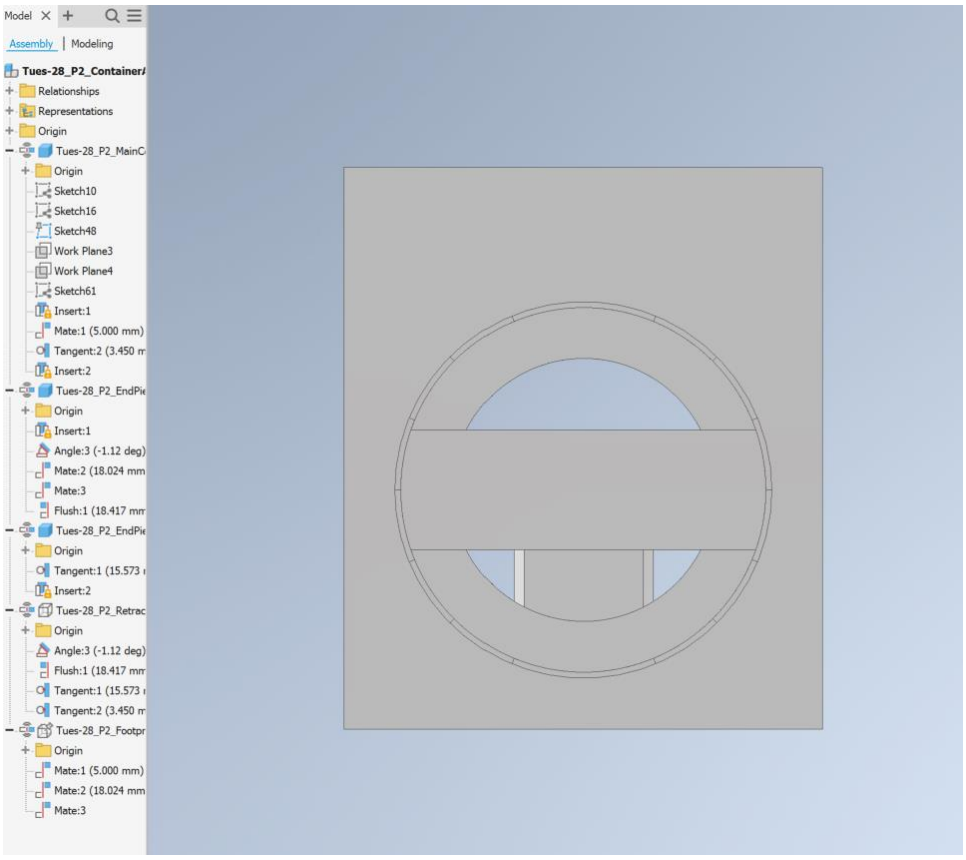
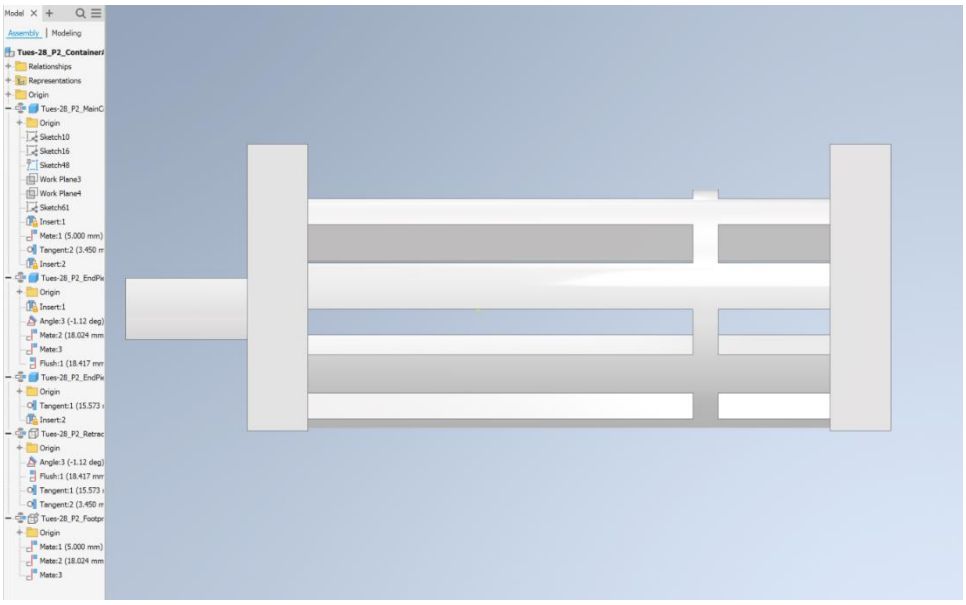
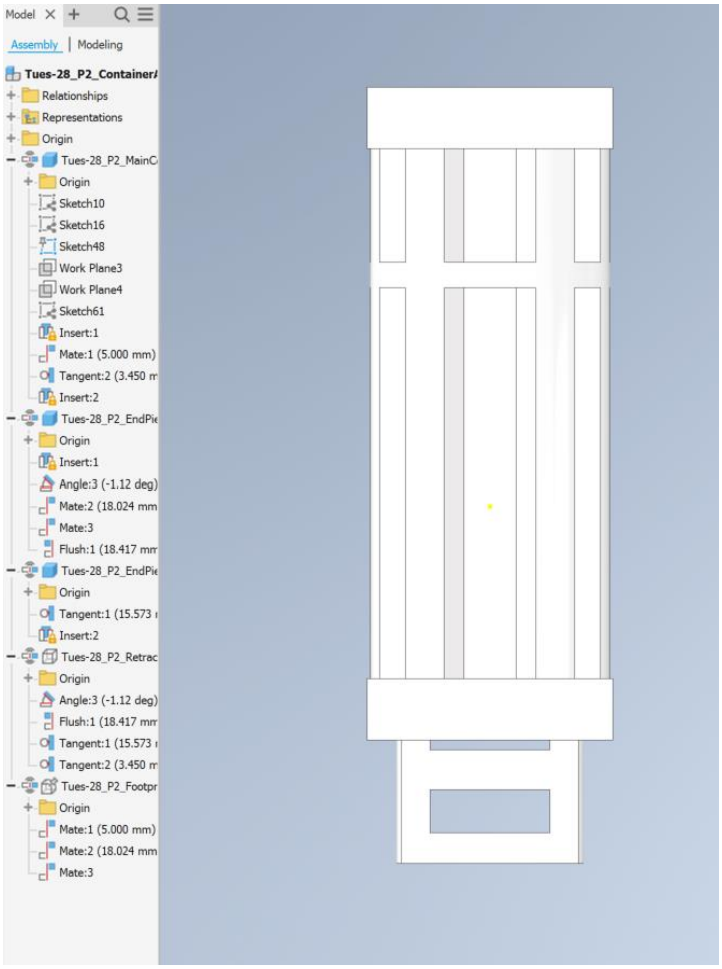
Appendix A – Screenshots of Solid Model:






Model
Assembly | Modeling
Tues-28_P2_Container
Relationships
Representations
Origin
Tues-28_P2_MainC
Origin
Sketch10
Sketch16
Sketch48
Work Plane3
Work Plane4
Sketch61
Insert:1
Mate:1 (5.000 mm)
Tangent:2 (3.450 m
Insert:2
Tues-28_P2_EndPie
Origin
Insert:1
Angle:3 (-1.12 deg)
Mate:2 (18.024 mm
Mate:3
Flush:1 (18.417 mm
Tues-28_P2_EndPie
Origin
Tangent:1 (15.573
Insert:2
Tues-28_P2_Retrac
Origin
Angle:3 (-1.12 deg)
Flush:1 (18.417 mm
Tangent:1 (15.573
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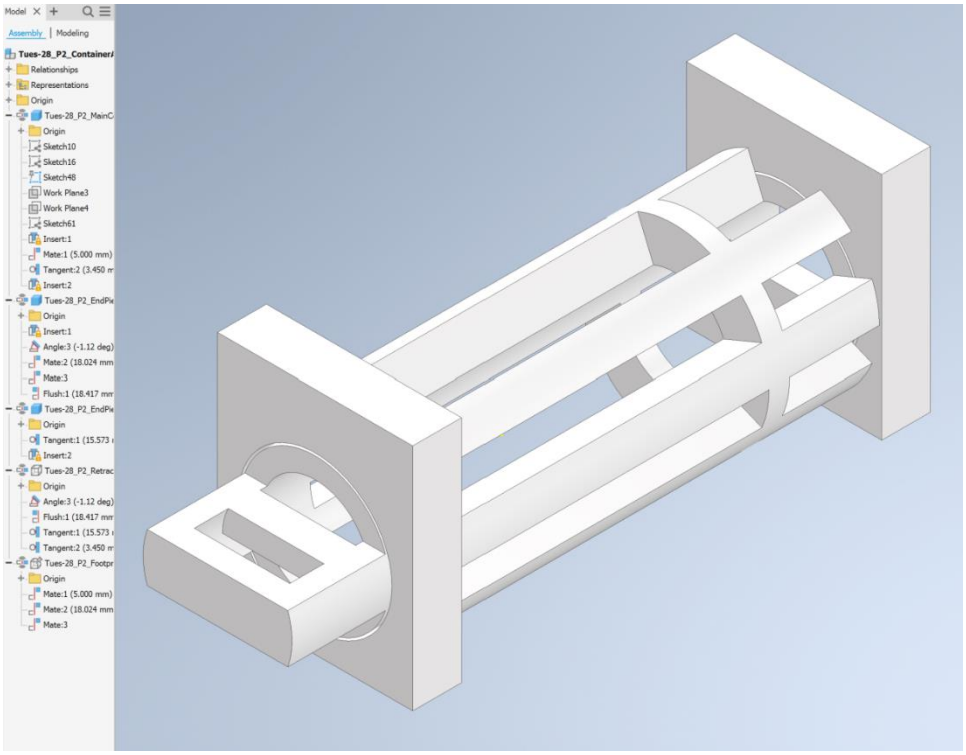
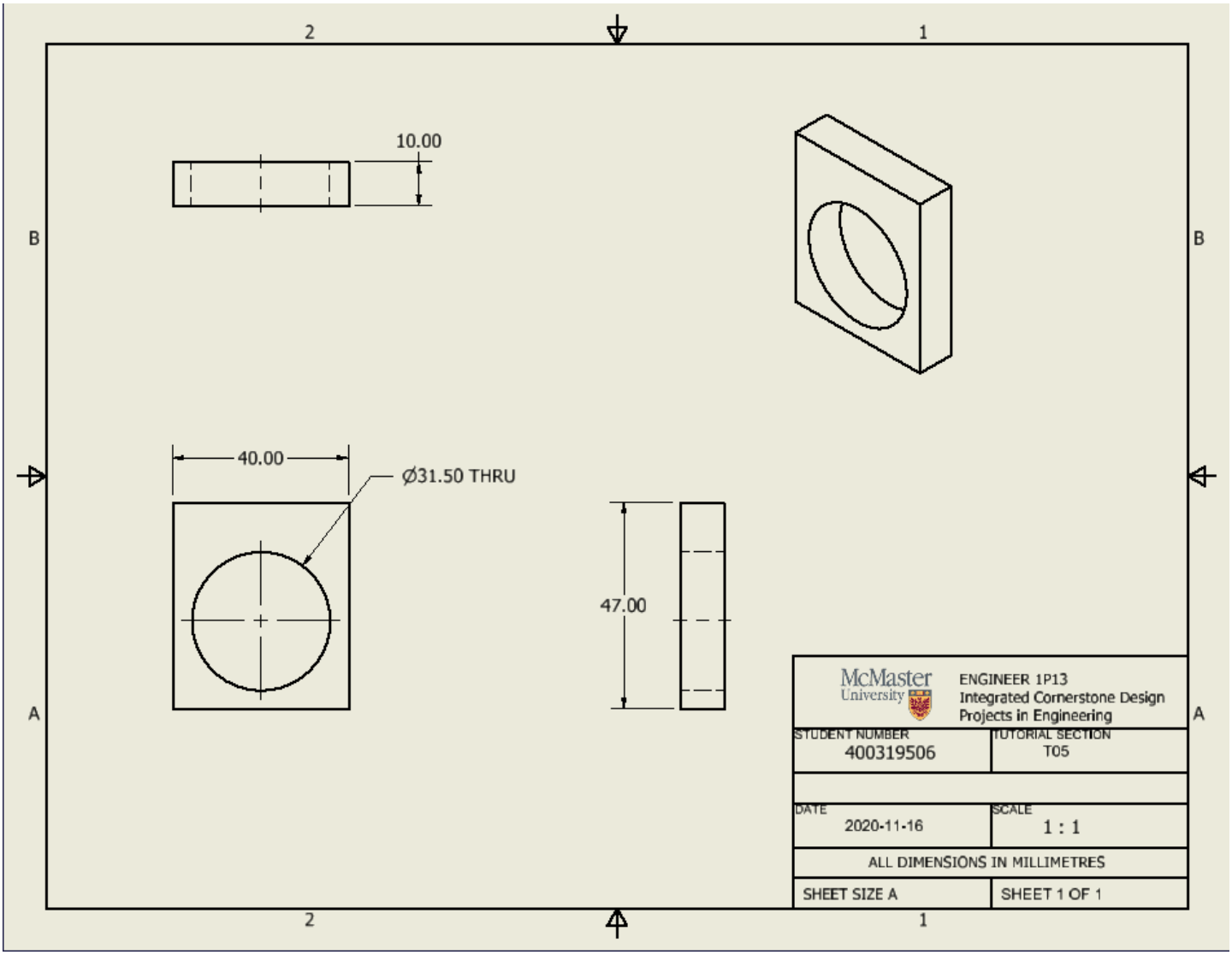
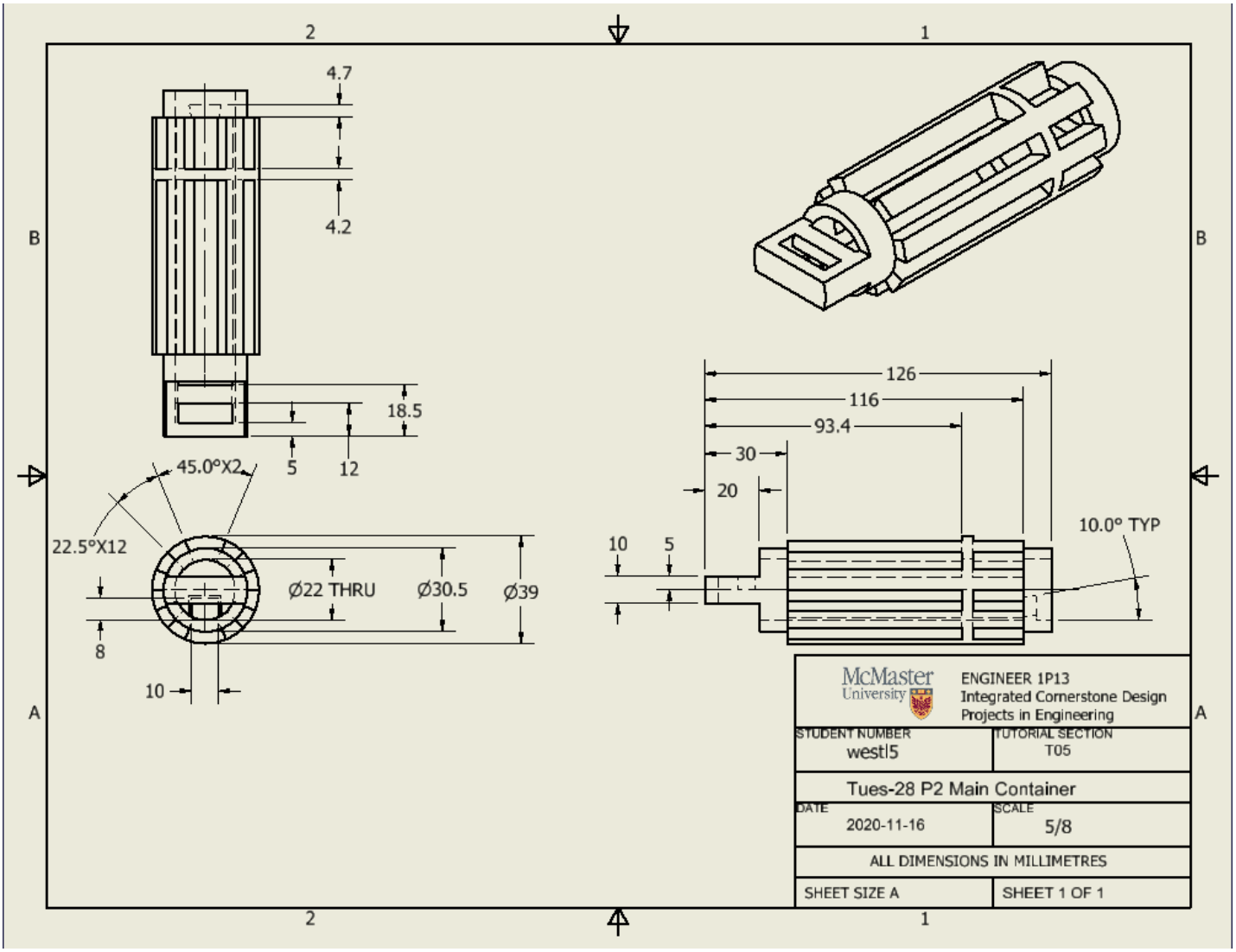
Tues-28_P2_Footpr
Origin
Mate:1 (5.000 mm)
Mate:2 (18.024 mm
Mate:3



Appendix B – Engineering Drawings of Sterilization Container Design:




4.7
4.2
18.5
5
12
45.0°X2
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Ø22 THRU
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8
10
126
116
93.4
30
20
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10.0° TYP
McMaster University
ENGINEER 1P13
Integrated Cornerstone Design
Projects in Engineering
STUDENT NUMBER
westl5
TUTORIAL SECTION
T05
Tues-28 P2 Main Container
DATE
2020-11-16
SCALE
5/8
ALL DIMENSIONS IN MILLIMETRES
SHEET SIZE A
SHEET 1 OF 1

Appendix C – Screenshots of Computer Program:

```
## ------------------------------------------------------------------------------------------------------------
## TEMPLATE
## Please DO NOT change the naming convention within this template. Some changes may
## lead to your program not functioning as intended.

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

from Common_Libraries.p2_lib import *

import os
from Common_Libraries.repeating_timer_lib import repeating_timer

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

arm = qarm()

update_thread = repeating_timer(2, update_sim)


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

'''
1P13 Project 2
Dec 2nd, 2020
Tues-28 Computing subteam:
    Luigi Quattrociocchi (quattrl)
    Hetash Rattu (rattuh)
'''
```

```
'''NECESSARY CONSTANT VARIABLES'''

EMG_THRESHOLD = 0.4                         # 0-1 muscle sensor value
DELAY = 3.0                                 # number of seconds between commands
SMALL_GRIP = 28.4                           # angle for containers 1-3
LARGE_GRIP = 23.3                           # angle for containers 4-6

HOME_LOCATION = [0.4064, 0.0, 0.4826]       # effector position at arm.home()
PICK_UP_LOCATION = [0.4989, 0.003, 0.0408]  # effector position of container



'''BEGIN FUNCTION DEFINITIONS'''

def identify_autoclave_bin_location(container_id):
    '''
    Returns a list with 3 elements describing x, y, z coordinates of the
    location of an autoclave bin that corresponds to the given container id

    Parameters:
        container_id (int): the id of the desired container (1-6)

    Returns:
        a list of floats of length 3 containing location coordinates
    '''

    if container_id == 1: # small red
        return [-0.5711, 0.229, 0.4218]
    if container_id == 2: # small green
        return [0.0, -0.6253, 0.4072]
    if container_id == 3: # small blue
        return [0.0, 0.6253, 0.4072]

    if container_id == 4: # large red
        return [-0.3481, 0.1442, 0.3303]
    if container_id == 5: # large green
        return [0.0, -0.3886, 0.3638]
    if container_id == 6: # large blue
        return [0.0, 0.3886, 0.3638]

    # base case home location
    return HOME_LOCATION

def move_end_effector(x, y, z):
    '''
    Waits for the correct configuration of emg sensor values (left arm
    flexed above the threshold and right arm fully extended), then moves
    the arm to the specified x, y, z coordinate location.

    Parameters:
        x (float): x coordinate location of the end effector
        y (float): y coordinate location of the end effector
        z (float): z coordinate location of the end effector

    Returns: None
    '''

    # remind the user
    print("MOVE: FLEX LEFT ONLY")

    # wait for left flexed and right extended
    while True:
        left_value =  arm.emg_left()
        right_value = arm.emg_right()

        if left_value > EMG_THRESHOLD and \
           right_value == 0:

            # move arm to specified location
            arm.move_arm(x, y, z)

            # terminate the function
            break
```

```
def control_gripper(to_open, container_id):
    '''
    Waits for the correct configuration of emg sensor values (right arm
    flexed above the threshold and left arm fully extended), then opens
    or closes the gripper based on the given to_open boolean flag by an
    amount that is determined by the container size.

    Parameters:
        to_open (bool): should gripper be opened (True) or closed (False)
        container_id (int): the id of the desired container (1-6)

    Returns: None
    '''

    # determine what grip angle to use based on container size
    is_small = 1 <= container_id <= 3
    grip_amount = SMALL_GRIP if is_small else LARGE_GRIP

    # determine if gripper should be opened or closed
    grip_amount = -grip_amount if to_open else grip_amount

    # remind the user
    print("GRAB: FLEX RIGHT ONLY")

    # wait for right flexed and left extended
    while True:
        left_value =  arm.emg_left()
        right_value = arm.emg_right()

        if right_value > EMG_THRESHOLD and \
           left_value == 0:

            # change gripper angle by predetermined grip amount
            arm.control_gripper(grip_amount)

            # terminate the function
            break

def open_autoclave_drawer_bin(to_open, container_id):
    '''
    Waits for the correct configuration of emg sensor values (both left
    and right arms flexed above the threshold). After waiting it will
    check if the container is a large size and should continue (id 4-6).
    Then based on the to_open boolean flag will open or close the drawer
    which corresponds to the color of the container.

    Parameters:
        to_open (bool): should drawer be opened (True) or closed (False)
        container_id (int): the id of the desired container (1-6)

    Returns: None
    '''

    # determine container size based on container id
    is_large = 4 <= container_id <= 6

    # terminate the function immediately if container is small
    if not is_large:
        return

    # remind the user
    print("OPEN: FLEX BOTH ARMS")

    # wait for left and right both flexed
    while True:
        left_value =  arm.emg_left()
        right_value = arm.emg_right()

        if left_value > EMG_THRESHOLD and \
            right_value > EMG_THRESHOLD:

            # open or close drawer based on color
            if container_id == 4: # large red
                arm.open_red_autoclave(to_open)
            if container_id == 5: # large green
                arm.open_green_autoclave(to_open)
            if container_id == 6: # large blue
                arm.open_blue_autoclave(to_open)

            # terminate the function
            break
```

```
def main():
    '''
    The main logic and execution of task. This function will choose the
    ids of containers 1 to 6 in a random order and perform a full cycle
    of spawn, pick up, transfer, drop off, and home operations for each
    of them. There are no parameters or return values.
    '''

    # return to home before beginning
    # assume environment has been reset
    arm.home()
    time.sleep(DELAY)


    # initializes a list of containers from 1 to 6 inclusive
    containers = list(range(1, 7))
    # randomly shuffles the list of ids.
    random.shuffle(containers)

    # iterates over shuffled list of container ids
    for container in containers:
        '''
        a single cycle will do the following:
            spawn container
            pick up container
            transfer container
            drop off container
            return to home

        some delay is added between each command
        '''


        # spawn
        arm.spawn_cage(container)
        time.sleep(DELAY)

        # pick up
        move_end_effector(*PICK_UP_LOCATION)
        time.sleep(DELAY)
        control_gripper(False, container)
        time.sleep(DELAY)
        move_end_effector(*HOME_LOCATION)
        time.sleep(DELAY)

        # transfer
        open_autoclave_drawer_bin(True, container)
        time.sleep(DELAY)
        move_end_effector(*identify_autoclave_bin_location(container))
        time.sleep(DELAY)

        # drop off
        control_gripper(True, container)
        time.sleep(DELAY)

        # return home
        move_end_effector(*HOME_LOCATION)
        time.sleep(DELAY)
        open_autoclave_drawer_bin(False, container)
        time.sleep(DELAY)


    # program is finished
    print("DONE")



'''MAIN EXECUTION'''

if __name__ == '__main__':
    main()
```