McMaster University

Project Two: *Get a Grip*

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

TABLE OF CONTENTS

Project Summary

In Project Two, students will work in teams to design a system for securely transferring a surgical instrument to an autoclave for sterilization. This project will introduce you to principles of rapid prototyping (i.e., 3D printing) and physical computing. As a team, you will design a computer program for controlling movement of a robotic arm to pick up and transfer a container for sterilization. You will also design and prototype the container such that it can securely hold a surgical instrument in place during transfer. Throughout the project, you will explore the conceptual design and preliminary design phases of the Engineering Design Process, and you will demonstrate functionality of your design to your Instructional Assistant Interns during a project interview.

TIMELINE

WEEK	DATE	DESIGN STUDIO AGENDA
7	Thurs Oct 28 – Wed Nov 3	Milestone 0 and Milestone 1
8	Nov 4 – 10	Milestone 2
9	Nov 11 – 17	Milestone 3
10	Nov 18 – 24	Milestone 4
11	Nov 25 – Dec 1	Dedicated Project Time (No Milestone)
12	Dec 2 – 8	Project Interview

TEAM FORMATION

Assigned teams of 4 students

SUMMARY OF PROJECT OBJECTIVES

Working in a team of 4 students, you will be required to:

1. Identify means of picking up and transferring a container to an autoclave for sterilization

Working in 2 groups of 2 students, each group will complete *one* of the following:

2. *Design* a container that securely holds a surgical tool for sterilization
3. *Design* a computer program for operating a robotic arm

Once again in a team of 4 students, you will be required to:

4. *Demonstrate* functionality and correctness of your design

SUMMARY OF PROJECT DELIVERABLES

At the end of the project, you will be required to submit:

1. A *solid model* of your proposed sterilization container design modelled in Autodesk Inventor and a *3D-printed prototype* (Modelling Sub-Team)
2. A *computer program* written in Python (Computation Sub-Team)
3. A *design project report* that documents your work throughout the project

This project will also require you to: 1) complete a set of assigned administrative tasks inherent to the project, 2) complete and submit a series of milestones throughout the project, 3) write an *independent research summary*, 4) update your learning portfolio to reflect your progress and development, and 5) complete a self- / peer-evaluation at the end of the project.

SUMMARY OF PROJECT GRADING BREAKDOWN

Project 2 is worth **10% of your overall ENGINEER 1P13 grade (i.e., 10 marks out of 100**). Each team of students will be divided into sub-teams, each having their own set of deliverables throughout the project. Each deliverable is associated with 1 of 3 course modules (C – Computation, M – Materials, D – Design and Professionalism). Table 1 outlines the breakdown of Project 2 marks by course module. Table 2 lists each deliverable, the number of marks available for that deliverable, and the module associated with that deliverable.

Table 1. Breakdown of Project 2 marks by course module

COURSE MODULE	MODELLING SUB-TEAM	COMPUTATION SUB-TEAM
Computation (C)	-	6
Design and Professionalism (D)	8	2
Materials (M)	2	2

Table 2. List of deliverables

Deliverable	Deadline	Modelling Sub-Team		Computation Sub-Team	
		Marks	Module	Marks	Module
Admin Responsibilities	–	P/F	D	P/F	D
Milestone 0	End of DS-7 (Wk-7)	P/F	D	P/F	D
Milestone 1	End of DS-7 (Wk-7)	0.5	D	0.5	D
Milestone 2	End of DS-8 (Wk-8)	1.0	D	1.0	C
Milestone 3	End of DS-9 (Wk-9)	P/F	D	P/F	C
Milestone 4	End of DS-10 (Wk-10)	P/F	D	P/F	C
Sterilization Container Design	Prior to DS-12 (Wk-12)	5.0	D	-	-
Computer Program	Prior to DS-12 (Wk-12)	-	-	5.0	C
Research Summary	Sun November 28th	2	M	2	M
Design Project Report	Wed December 8th	1.5	D	1.5	D
Learning Portfolio	Thurs December 9th	P/F	D	P/F	D
Self- and Peer-Evaluation	Thurs December 9th	P/F	D	P/F	D

Introduction

Aerosmith is an American rock band that has been around longer than you, and quite possibly your parents! Formed in 1970, this band proved that screaming like a banshee is a great way to make a buck, and that fashion is truly in the eye of the beholder. In 1993, Aerosmith released their eleventh studio album, *Get a Grip*. This album became the band's best-selling studio album, 23 years into their career, as it sold more than 20 million copies worldwide. Whether it was due to the fact some of their biggest hits can be found on the album, including "*Livin' on the Edge*", "*Cryin'*" and "*Crazy*", or the result of an album cover that featured a pierced cow's udder, nobody knows! Now that we have dropped that little bit of pop culture knowledge upon you, it is time to *get a grip* on something else, remote sensing and actuation of surgical robots in healthcare applications.

People living in rural and remote areas of Canada generally have poorer health and shorter life expectancies than those living in urban centres [1]. It is often difficult for rural and northern communities to access basic healthcare as most of these areas have few or no healthcare providers that can provide basic needs, let alone specialized services [1]. This means that Canadians living in remote areas either must travel long distances for proper medical services or get no care at all [1].

In Canada, this issue disproportionately affects the Aboriginal population as approximately 50% live in rural and remote locations [2]. It is important for individuals living in these areas to have access to treatment options in their own community.

The use of remote surgery or remote mentoring of physicians could be a potential solution to this problem. With research, this technology may allow specialists to direct a general physician, nurse, or even someone with no medical background to perform procedures themselves [3].

To operate and control the instruments, a variety of sensors such as haptic, position, force, and many more are embedded into the robotic surgical system. These sensors translate the movement of a specialist into tasks performed by the robotic system elsewhere [4].

One of the important tasks in surgery includes sterilization of the equipment used in order to remove microbes, spores, and viruses. Sterilization is commonly performed by autoclaves; a process in which instruments are placed in a container that allows exposure to pressurized steam [5].

Robot-assisted surgery set-up; surgeon is at the control console directing the instruments remotely (left) while nurses are at patient bedside making sure instruments are operating appropriately (right).

List of Sources

[1] Newfoundland and Labrador Medical Association, "Rural Health Care". [Online]. Available: https://nlma.nl.ca/News-And-Events/Media/Fact-Sheets. [Accessed Aug 31, 2020].

[2] Social Determinants of Health, "Social Determinants of Health, "Access to Health Services as a Determinant of First Nations, Inuit and Metis Health". [Online]. Available: . [Accessed Aug 31, 2020].https://www.nccih.ca/docs/determinants/FS-AccessHealthServicesSDOH-2019-EN.pdf. [Accessed Aug 31, 2020].

[3] Dotto L. "Long-distance surgery" [Internet]. *The Globe and Mail Canada*; 2004 Oct 2. Available from: . [Accessed Aug 31, 2020].https://www.theglobeandmail.com/technology/science/long-distance-surgery/article4220774/. [Accessed Aug 31, 2020].

[4] J.M. Gomez-de-Gabriel and W. Harwin, "Evaluation of Sensor Configurations for Robotic Surgical InstrumentsJ.M. Gomez-de-Gabriel and W. Harwin, "Evaluation of Sensor Configurations for Robotic Surgical Instruments", *Sensors (Basel)*, vol. 15, no. 10, Oct, 2015. doi: 10.3390/s151027341.

[5] Centres for Disease Control and Preventation, "Guideline for Disinfection and Sterilization in Healthcare Facilities (2008)". [Online]. Available: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/sterilization/steam.html. [Accessed Aug 31, 2020].

Project Two Objectives

Your team has been approached with an opportunity to design a system for securely transferring surgical tools to an autoclave for sterilization. This challenge will require your team to:

1. Identify a means of picking up and transferring a container (i.e., sterilization cage) to an autoclave
2. Design the container such that it can securely hold a surgical tool in place, be picked up by a robotic arm for transfer, and facilitate sterilization
3. Design a computer program for operating the robotic arm using two muscle sensor emulators
4. Verify that your design is functionally correct

To meet these objectives, your team has been **provided** with the following:

1. A solid model (*.IPT file) of a surgical tool (Figure 1)
2. A dimension drawing (*.DWG) of a footprint (Figure 2)
3. A virtualized environment that includes a robotic arm and autoclave (Figure 3)

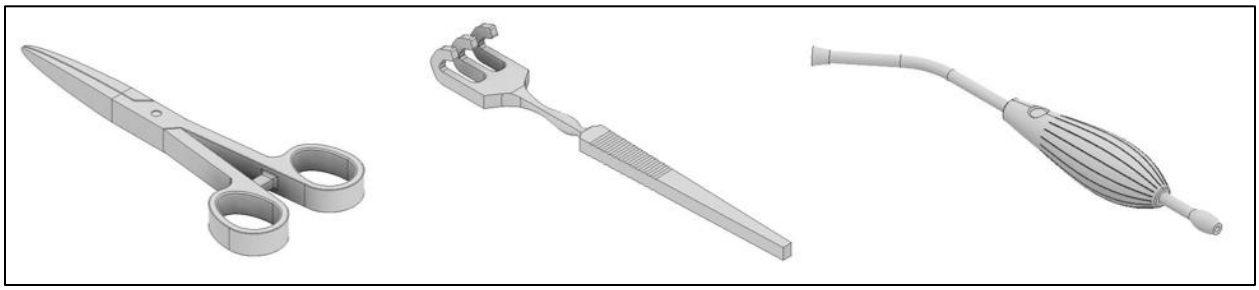

Figure 1. Each team will be required to design a container that *securely* holds in place one of the above surgical tools.

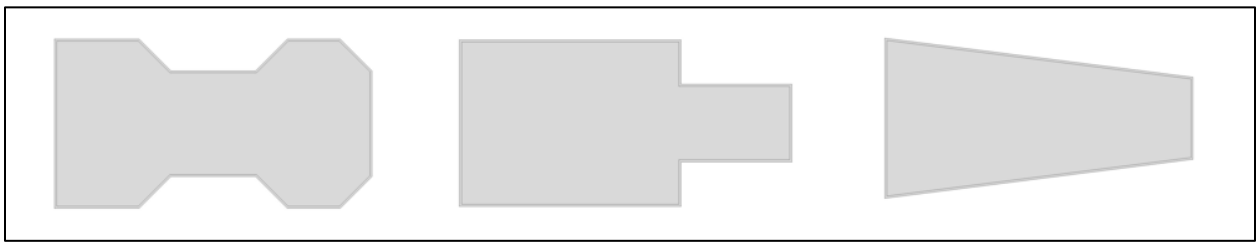

Figure 2. Each team will also be assigned one of the above footprints. The designed container must fit inside the footprint, as well as satisfy additional design criteria.

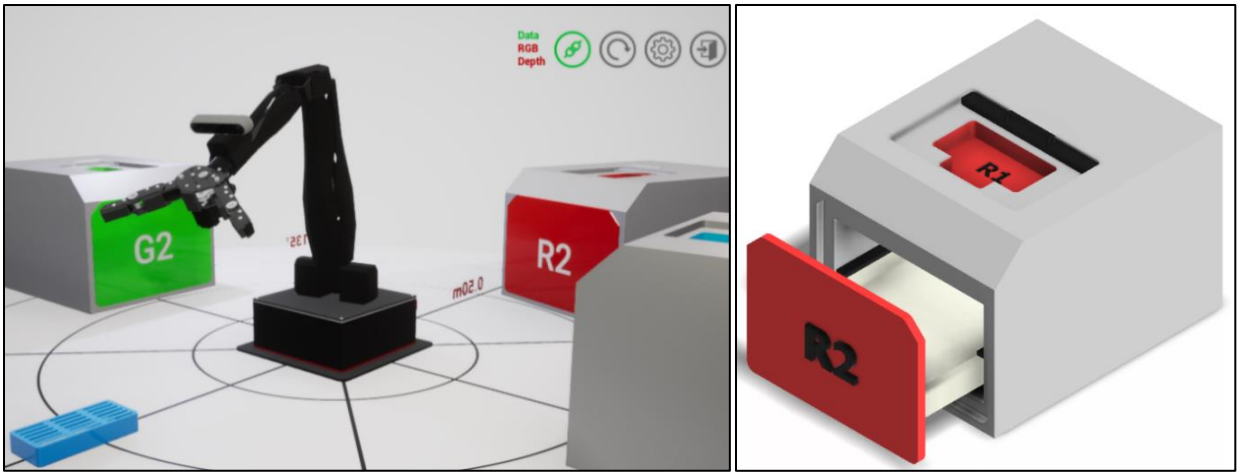

Figure 3. A virtualized environment will allow you to interface with a robotic arm in order to pick up the surgical tool and transfer it to the appropriate autoclave bin. The image on the right is an autoclave meant for red containers. Large containers are placed in the sliding drawer whereas small containers are placed on top.

This project requires that your team complete and submit several assigned deliverables by the appropriate deadline(s) and present your proposed design at the end of the Fall term during a scheduled Project Interview. Listed below are the Project Objectives outlined in greater detail.

PROJECT OBJECTIVE #1:

IDENTIFY MEANS OF PICKING UP AND TRANSFERRING A CONTAINER TO AN AUTOCLAVE FOR STERILIZATION

Your team has been presented with a well-defined design challenge related to the sterilization of surgical tools. Your team will complete a set of design exercises meant to conceptualize the means by which your container will be picked up and transferred to the autoclave. It is required that your team **identify:** the **attributes and behaviours** that a design solution should have or exhibit (i.e., the *objectives*), the **restrictions** on the design solutions behaviours or attributes (i.e., the *constraints*) and the **actions** that the overall system is expected to perform (i.e., the *functions*). Focusing specifically on the functions of your design challenge, your team is required to propose **multiple means** for accomplishing these functions.

PROJECT OBJECTIVE #2:

DESIGN A CONTAINER THAT SECURELY HOLDS A SURGICAL TOOL FOR STERILIZATION (MODELLING SUB-TEAM ONLY)

The Modelling Sub-Team is required to **design, model, and fabricate** a container for transferring and sterilizing a surgical tool. Your team will be provided with a solid model (*.IPT file) of the surgical tool, specifications related to the robot arm's end effector, and the footprint (i.e., the amount of occupied space) in the autoclave where the container is to be placed. Refer to the "Detailed Description of Project Objective 2" section for additional details.

PROJECT OBJECTIVE #3:

DESIGN A COMPUTER PROGRAM FOR OPERATING A ROBOTIC ARM (COMPUTATION SUB-TEAM ONLY)

The Computation Sub-Team is required to **design a computer program** that allows for transfer of a sterilization container. The computer program interfaces with the Quanser Interactive Labs (Q-Labs) environment using two muscle sensor emulators. Your team will be provided with a general workflow that the computer program is recommended to follow, as well as a list of tasks that the computer program must be able to accomplish. Refer to the "Detailed Description of Project Objective 3" section for additional details.

PROJECT OBJECTIVE #4:

DEMONSTRATE FUNCTIONALITY AND CORRECTNESS OF YOUR DESIGN

The final stage of this project is to present your design during a scheduled Project Interview. During this interview, it is required that you **explain your design** and **justify design decisions** by answering questions asked individually and as a team. It is required that your team **verify that your design meets the required objectives**. For the Modelling Sub-Team, this includes verifying that the 3D fabrication of your container design can securely hold the surgical tool in place. For the Computation Sub-Team, this includes verifying all 6 container objects are able to be identified, picked up and successfully placed in the corresponding autoclave bin location.

Detailed Description of Sub-Team Objectives

Detailed Description of Project Objective 2

DESIGN A CONTAINER THAT SECURELY HOLDS A SURGICAL TOOL FOR STERILIZATION (MODELLING SUB-TEAM ONLY)

The Modelling Sub-Team is required to design, model, and fabricate a container for transferring and sterilizing a surgical tool. Your team will be provided with a solid model (*.IPT file) of the surgical tool, specifications related to the robot arm's end effector, and the footprint (i.e., the amount of occupied space) in the autoclave where the container is to be placed.

Design

The Modelling Sub-Team is required to **design a container** for transferring into an autoclave and sterilizing a surgical tool. Three surgical tools have been provided (tool-1, tool-2, tool-3). Three autoclave footprints have been provided (footprint-1, footprint-2, footprint-3) to represent the shapes of the autoclave bases. Each team's assigned surgical tool and assigned autoclave footprint is listed in the Team List document that you can view on Avenue. The container must fit within the assigned autoclave and must be designed such that **the base (i.e., largest cross section) of the container lays parallel to the assigned autoclave floor** upon placement.

The container should be designed such that **it can be picked up by the robot arm's end effector**. The robot arm end effector is a 2-fingered multi-articulated gripper. Each finger has 2 locations ideal for gripping objects, indicated by the rectangular pads in Figure 4. Gripping at the proximal (i.e., situated towards the body) end limits the size of objects to a maximum width of ~80mm, but allows for the entire end effector to grasp the object (making for a more secure grip). By comparison, gripping at the distal (i.e., situated away from the body) end allows for larger objects to be grasped (up to a width of ~150mm), but less securely.

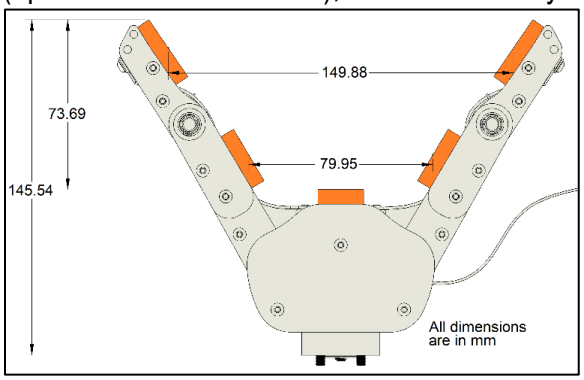

Figure 4. Two-dimensional view of robot arm end-effector.

The container should **securely hold the surgical tool** in place such that its movement is restricted during transfer (i.e., it does not slide around inside the container). Finally, the design of the container is required to **facilitate sterilization**, allowing steam to penetrate the surfaces of the surgical tool and inactivate any bacteria, viruses, fungi, etc.

Model

The Modelling Sub-Team is required to **create a solid model of your sterilization container** in Autodesk Inventor. Your solid model is expected to be based off the design you came up with as a team, although some refinements and deviations are both acceptable and to be expected. If your design includes multiple components, it is required that you **create a solid model for each component**. An **assembly model with proper constraints** must be made, showing that the **designed sterilization container can correctly hold the surgical tool**. It is expected that your solid model be created using correct and efficient modelling practices, and without any errors or warnings in your model. To ensure your design can be fabricated (see below), it is required that **all features be greater than 2mm** in size. Students must use their own discretion when including small features (2mm – 4mm) to ensure that the design is not compromised by these elements. Examples of features include the diameter of a hole or the length of an edge of a surface (Figure 5). Finally, it is required that you **create fully-dimensioned engineering drawings of all components** for the purpose of documenting your design, being sure to adhere to appropriate international standards.

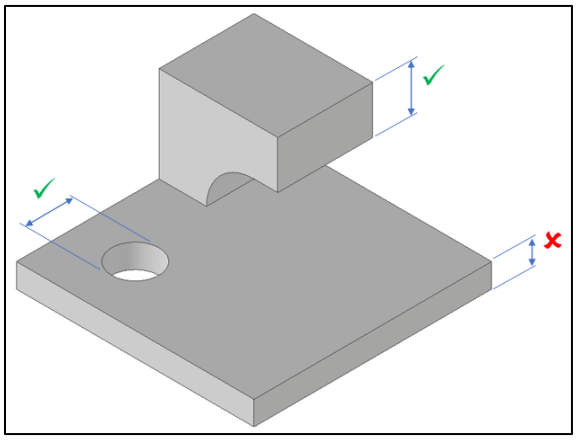

Figure 5. Examples of feature sizes for a sample part. The two features indicated by a green checkmark are 2mm in size (i.e., the hole has a diameter of 2mm), whereas the feature indicated by a red 'x' is only 1mm, and thus too small.

Fabricate

The Modelling Sub-Team is required to prepare a **G-code file** of the sterilization container for fabrication on a 3D printer. 3D printing will be facilitated by your IAIs. It is required that all components be appropriately positioned on the print bed such that print times are minimized and all features print with minimal material use. To minimize print time, it is required that you **scale down your design by 50% (1:2)** prior to creating your G-code. Designs with total print times that **exceed 2 hours** after scaling down (for all components, ***not*** each component) will **not** be accepted. Keep in mind that components that are unnecessarily complicated may result in excessively long print times and possibly unexpected print failure. If multiple components are to be 3D printed, the assembly of any components should **not impede functionality of the container**. Your container will be printed using PLA (polylactic acid) filament, which has a diameter of 1.75-mm and a density of 1.24-g/cm^3. Students must use their own discretion when including small features (2mm – 4mm) in their design and ensure that these elements do not introduce errors upon printing. **The mass of your design prior to scaling down for fabrication cannot exceed 350 grams.**

Detailed Description of Project Objective 3

DESIGN A COMPUTER PROGRAM FOR TRANSFERRING SURGICAL TOOLS TO THE CORRECT AUTOCLAVE BIN (COMPUTATION SUB-TEAM ONLY)

The Computation Sub-Team is required to design a computer program that interfaces with the Quanser Interactive Labs (Q-Labs) using two muscle sensor emulators.

The Q-Labs environment for Project 2 includes a robotic arm and an autoclave. The robotic arm (Q-arm) consists of 4 joints (base, shoulder, wrist, and elbow) and a 2-fingered gripper that serves as the end-effector (Figure 6). The autoclave consists of 6 bins, with each bin meant to receive a different sterilization container (3 colors x 2 sizes, Figure 7). Bins meant for large sterilization containers are required to open and close as needed to receive the container.

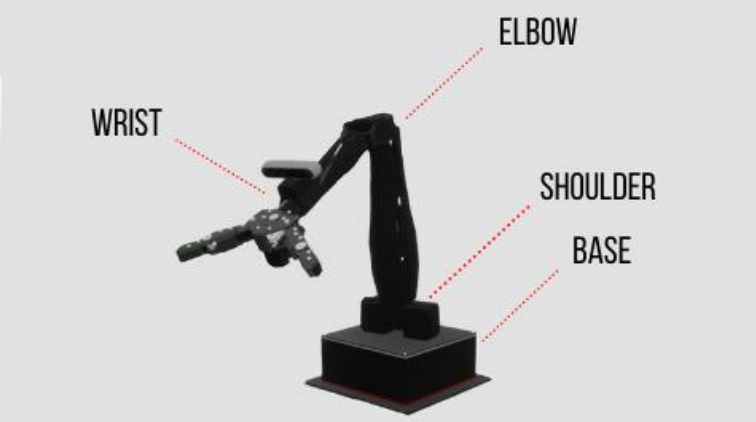

Figure 6. The 4 joints of the Q-arm (base, shoulder, elbow, wrist).

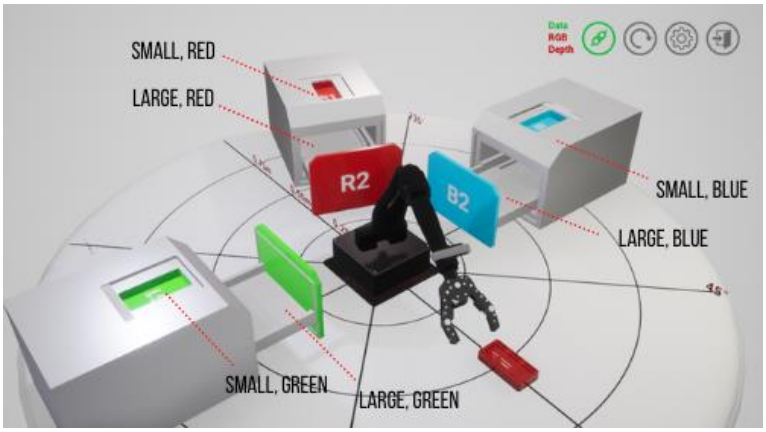

Figure 7. The 6 autoclave bin locations are shown. For each color (R – red, G – green, B – blue), large containers are placed in sliding drawer and small containers are placed on top.

Within your computer program, you will interface with the Q-Labs environment in three ways:

- Open/close the 2-fingered gripper
- Move the robotic arm end-effector to a specified XYZ location
- Open/close an autoclave bin

Each of the above actions can be controlled using 2 muscle sensor emulators (**L** and **R**). You can interface with each muscle sensor by clicking on a GUI with your cursor (Figure 8). Muscle sensor **L** corresponds to the left arm and muscle sensor **R** corresponds to the right arm. Each muscle sensor returns a value corresponding to the position of the respective arm, with full extension returning a value of 0 and full flexion returning a value of 1. To align with the above actions, you can interface with the muscle sensor emulators in three ways:

- Flex/extend muscle sensor **L** *only*, keeping muscle sensor **R** fully extended (i.e., 0)
- Flex/extend muscle sensor **R** *only*, keeping muscle sensor **L** fully extended (i.e., 0)
- Flex/extend both muscle sensor **L** *and* **R** together

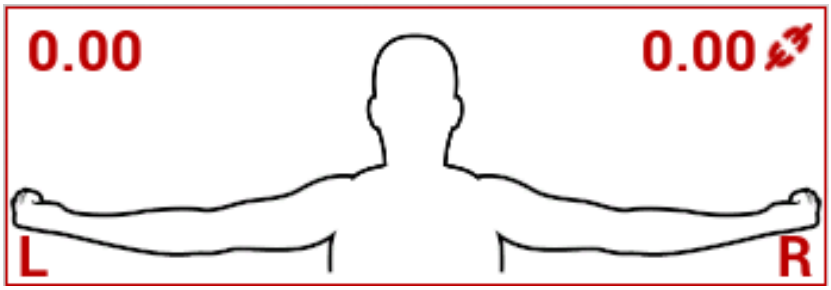

Figure 8. The muscle sensor emulator allows for flexion/extension of the left arm (L) only, the right arm (R) only, or both arms together.

Before designing your computer program:

→ **Determine the XYZ location** of the container pick-up platform
→ **Determine the XYZ location** of all autoclave drop-off bins
→ **Determine threshold** for muscle sensor emulator

The following is a general workflow for your computer program:

→ The **Q-arm begins at the Home position**, this corresponds to the base, shoulder, and elbow joints at 0° rotation and the gripper being fully open
→ **One container is placed on the 'pick-up' platform** for pick-up by the Q-arm
  - The container ID is randomly selected from a list of 6 unique (size and colour) containers and then the container is spawned to the pick-up platform
  - Each container can only be spawned once (container must be different each time)
→ The **Q-arm moves**, positioning the gripper end-effector at the 'pick-up' platform *
  - The predetermined XYZ location of the pick-up platform is to be used
→ The **Q-arm closes the gripper**, grabbing the container *
→ The drop-off location position is determined from the container ID
  - Each container ID is associated with a unique autoclave drop-off bin location
  - The predetermined XYZ location of the drop-off bin is to be used
→ The **Q-arm moves**, transferring one container object from the pickup platform location to the correct autoclave drop-off bin location *
→ For large containers *only*, the correct **autoclave drawer is opened** *

→ The **Q-arm opens the gripper**, releasing the container object into the drop-off bin *
→ For large containers *only*, the correct **autoclave drawer is closed** *
→ The **Q-arm moves**, returning to the *Home* position
→ The above steps are **repeated until all 6 container objects have been successfully placed** in the correct autoclave drop-off bins, at which point the program terminates

Steps indicated with an asterisk (*) indicate that the movement of the Q-arm/gripper/drawer is dependent on the use of muscle sensor emulator. In the in-person environment, a muscle sensor replaces the emulator input.

You will need to write a set of functions to accomplish the following tasks:

1. Identify the correct autoclave bin based on the size and colour of the container object
2. Open and close the 2-fingered gripper for picking up and releasing the container object
3. Move the robotic arm end-effector to a specified XYZ location
4. Open and close an autoclave bin drawer for container object placement (large containers only)
5. Continue or terminate the program based on an inventory of container objects that have been placed in the correct autoclave bin location

There is also a built-in library you have been provided that includes pre-defined functions for controlling various aspects of the virtual environment (the library has already been imported in the template file you have been provided). These built-in functions are described in the "**P2 Python Library Documentation**" PDF posted to the Avenue course page.

Some basic requirements of your computer program are as follows:

1. Your program is required to be written in Python
2. Unless otherwise specified, each of the tasks described below must be written as a function

Identify Autoclave Bin Location

Each container object placed on the 'pick-up' platform has a set of *known* attributes – specifically the size and colour of the container (Table 1). An additional attribute corresponding to the target location in the autoclave bin is unknown and needs to be determined. Within the Computation Sub-Team's computer program, **a function should be written for assigning a target location within the autoclave (in XYZ Cartesian coordinates) based on the container object's *known* attributes**. Target locations can be determined through trial-and-error by exploring the Q-Labs environment using the built-in library, rotating the joints a specified amount, and calculating the corresponding XYZ location. Each target location assigned to the container object should be a list of 3 items, representing the XYZ Cartesian coordinates of the corresponding autoclave bin.

Table 1. List of container attributes (size and colour)

Container ID	Container Size	Container Colour	Target *XYZ* Location in Autoclave
01	Small	Red	*Unknown*
02	Small	Green	*Unknown*
03	Small	Blue	*Unknown*
04	Large	Red	*Unknown*
05	Large	Green	*Unknown*
06	Large	Blue	*Unknown*

Control Gripper

The Q-arm is required to *pick up* the container object at the 'pick-up' platform and *drop it off* into the correct autoclave bin. This pick-up/drop-off task is achieved by calling the appropriate functions in the built-in library in order to rotate the gripper joint to a specified location on a continuum between fully open and fully closed (Figure 9). Within the Computation Sub-Team's computer program**, a function should be written for controlling movement of the gripper joint (i.e., open or closed) in response to input data from one or both muscle sensor emulators**. The value of the muscle sensor emulator(s) should be evaluated within the **control gripper** function, with the gripper either opening or closing based on the emulator value(s) exceeding some threshold (defined by you).

Figure 9. The Q-arm gripper in the fully-open (left) and fully-closed (right) positions.

Move End-Effector

The Q-arm is required to move the end-effector to a desired location (e.g., the *Pick-Up platform* and *each autoclave bin*) such that it can pick up and drop off containers (Figure 10). This task is achieved by calling the appropriate functions in the built-in library and specifying the target Cartesian (XYZ) coordinate location of the end-effector. Within the Computation Sub-Team's computer program**, a function should be written for controlling movement of Q-arm in response to input data from one or both muscle sensor emulators**. The value of the muscle sensor emulator(s) should be evaluated within the **move end-effector** function, with the Q-arm moving to the specified XYZ location based on the emulator value(s) exceeding some threshold (defined by you).

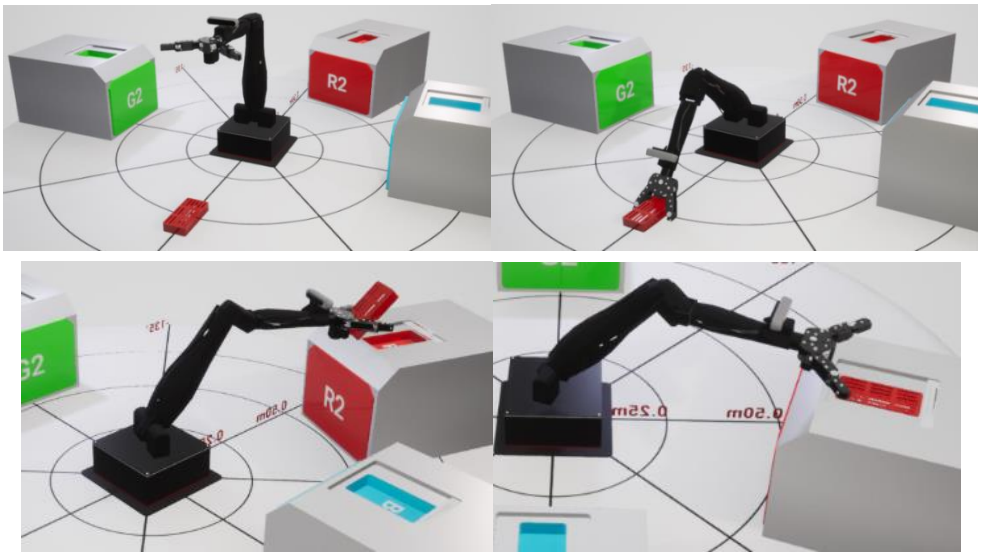

Figure 10. The Q-arm is required to move between the Home position, the Pick-Up platform and one of 6 autoclave bin locations.

Open Autoclave Bin Drawer

When placing container objects in the respective autoclave bins, the three larger container objectives must be placed in a bin that can only be accessed by first opening a drawer (Figure 11). This task (opening the drawer) must be done prior to *dropping off* the container object (i.e., *after* **move end-effector**, but *before* **control gripper**). This open drawer task is achieved by calling the appropriate functions in the built-in library, one function for each autoclave drawer. Within the Computation Sub-Team's program, **a function should be written for opening the correct autoclave bin drawer in response to input data from one or both muscle sensor emulators**. The value of the muscle sensor emulator(s) should be evaluated within the **open autoclave bin drawer** function, with the correct drawer opening or closing based on the emulator value(s) exceeding some threshold (defined by you).

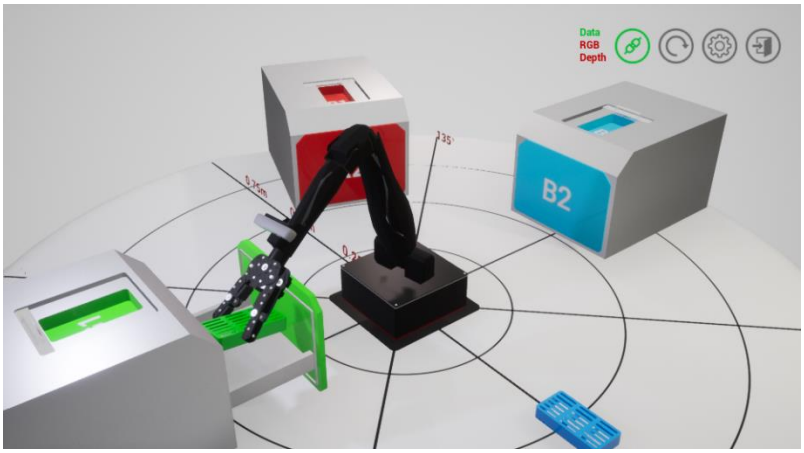

Figure 11. Large container objects must be placed in the correct autoclave bin drawer, which can be controlled using one of the muscle sensor emulators.

Continue or Terminate

An inventory of container objects that are successfully placed in the correct autoclave bin is required to be kept and updated as the program is run. The status of this inventory can inform decisions on whether to continue the program (i.e., move the Q-arm to the 'pick-up' platform to retrieve the next object) or terminate the program. Within the Computation Sub-Team's computer program, **code should be written for continuing or terminating the program based on the number of container objects successfully placed in the autoclave**. Unlike the previous tasks, it is not explicitly required that this task be written as a function. Your sub-team may choose whatever approach you think is appropriate.

It is up to your sub-team to decide which muscle sensor emulator to use (**L**, **R**, or both **L and R**) for the **control gripper**, **move end-effector**, and **open autoclave bin drawer** functions. Keep in mind that **you must select a different scenario for each function.** For each scenario, your program must evaluate the following:

- For **muscle sensor emulator L *only***, an action should be taken when **L exceeds some threshold** (defined by you) ***and* R is 0** (i.e., fully extended)
- For **muscle sensor emulator R *only***, an action should be taken when **R exceeds some threshold** (defined by you) ***and* L is 0** (i.e., fully extended)
- For ***both* emulators L and R**, an action should be taken when ***both* L and R are equal to each other *and* exceed some threshold** (defined by you)

We have outlined for you the 6 possible combinations to use these scenarios in Table 2. Your sub-team is required to pick **only one** of these combinations.

Table 2: Six possible combos given the three different scenarios

	Combo 1	**Combo 2**	**Combo 3**	**Combo 4**	**Combo 5**	**Combo 6**
L > threshold and R = 0	Control Gripper	Move End-Effector	Open Autoclave Bin Drawer	Control Gripper	Move End-Effector	Open Autoclave Bin Drawer
R > threshold and L = 0	Move End-Effector	Open Autoclave Bin Drawer	Move End-Effector	Open Autoclave Bin Drawer	Control Gripper	Control Gripper
L > threshold and R > threshold	Open Autoclave Bin Drawer	Control Gripper	Control Gripper	Move End-Effector	Open Autoclave Bin Drawer	Move End-Effector

Project Two Schedule of Activities

Week #	Date	Activity	Complete **BEFORE** Design Studio	Complete **DURING** Design Studio
Wk-7	Thurs Oct 28 – Wed Nov 3	**Milestone 0** • Determine and document administrative responsibilities for each team member	Review the Administrative Responsibilities section of the P2 Project Module	***Team***: Complete Sub-Team Charter and Team Charter worksheets
		Milestone 1 • Complete a series of design exercises to frame the given problem and begin proposing concept solutions	***Individually***: Complete Pre-Project Assignment worksheet	***Team***: Complete List of Objectives, Constraints and Functions worksheet
				Team: Complete Morphological Analysis worksheet
				Individually: Complete Concept Sketches worksheet
Wk-8	Thurs Nov 4 – Wed Nov 10	**Milestone 2** • Conceptualize both the sterilization container and operation of the robotic arm	***Team***: N/A	***Team***: Update your TA on team progress (Manager chairs meeting and Coordinator takes minutes)
			Modelling Sub-Team: Refined Concept Sketches worksheet (Individually)	***Modelling Sub-Team***: Low-Fidelity Prototype Observations worksheet (Sub-Team)
			Computation Sub-Team: Computer Program Workflow worksheet (Individually)	***Computation Sub-Team***: Program Pseudocode worksheet (Sub-Team)
Wk-9	Thurs Nov 11 – Wed Nov 17	**Milestone 3** • Create preliminary models of design in Autodesk Inventor and Python • Evaluate and propose refinements/corrections	***Team***: N/A	***Team***: Show preliminary sub-team designs to your TA and whole team. (Manager chairs meeting and Coordinator records feedback)
			Modelling Sub-Team: Preliminary Solid Model worksheet (Individually)	***Modelling Sub-Team***: Pugh Matrix worksheet (Sub-Team)
			Computation Sub-Team: Preliminary Program Tasks worksheet (Individually)	***Computation Sub-Team***: Code Peer-Review worksheet and Program Task Pseudocode worksheet (Sub-Team)

Project Two Schedule of Activities

Week #	Date	Activity	Complete **BEFORE** Design Studio	Complete **DURING** Design Studio
Wk-10	Thurs Nov 18 – Wed Nov 24	**Milestone 4** • Submit a portion of your design for TA feedback	***Team***: N/A	***Team***: update your TA on team progress (Manager chairs meeting and Coordinator takes minutes)
			Modelling Sub-Team: Model your design in Autodesk Inventor and generate G-code for 3D printing	***Modelling Sub-Team***: Present proposed design, document feedback, and list "Action Items" on worksheet
			Computation Sub-Team: Write part of your Computer Program in Python	***Computation Sub-Team***: Present proposed design, document feedback, and list "Action Items" on worksheet
Wk-11	Thurs Nov 25 – Wed Dec 1	**Dedicated Project Time** • Student teams work towards finalizing their design	N/A	***Team***: update your TA on team progress and revisit M4 checklist as required (Manager chairs meeting and Coordinator takes minutes)
				There are no deliverables for this week
Wk-12	Thurs Dec 2 – Wed Dec 8	**Project Demonstration and Interview** • Student teams demonstrate their design to an IAI. • Students are expected to individually answer questions of their design in an individual interview	***Modelling Sub-Team***: Upload Autodesk Inventor files (in a ZIPPED folder) to Avenue *** G-code must be submitted **at least** 72-hrs prior to your scheduled interview to ensure adequate time for printing ***	***Modelling Sub-Team***: Explain design to IAI. Individually, students answer questions related to both the design and modelling practices
			Computation Sub-Team: Upload Python code (in a ZIPPED folder) to Avenue	***Computation Sub-Team***: Explain and demonstrate design to IAI. Individually, students answer questions related to both the design and computing practices

Project Two Deliverables

MILESTONE ZERO: TEAM DEVELOPMENT AND PROJECT PLANNING

Assessment Type: Team
Time Allotted: Week 7 Design Studio (DS-7)
Submission Deadline: End of DS-7

Objectives and Requirements

For Milestone Zero, your team is required to formally document your team's personnel and the administrative roles and responsibilities each member will take on for the duration of the project. This formal documentation process is in the form of a **Team Charter**. Complete your charter on the **Team Charter worksheet**. Your worksheet must include the following:

1. **Team Personnel**: Record each team member's name (preferred name) and MacID in the Team Personnel table on the **Milestone 0 Cover Page worksheet**.
2. **Team Portrait**: Take a selfie of your team, (or if virtual, a screenshot of your team during a virtual meeting). Be creative! Include your photo on the **Cover Page worksheet**.
3. **Incoming Personnel Administrative Portfolio**: Record each team's administrative contributions on all projects up to this point, identifying their Project Lead roles
4. **Sub-Team Choice**: As a *team,* come to an agreement on who will be on the Modelling or Computing sub-team. Keep in mind that you will be on the opposite sub-team for Project 3. Refer to the **P2P3 Overview** document on Avenue for a summary on each of the sub-team expectations. Record each sub-team member's name on the **Sub-Team Charter worksheet**, located in the *Wk-7 (Fall) - P2 Milestone 0 Worksheets TEAM.docx* document.
5. **Project Leads**: *As a team*, come to an agreement on who will take the **Lead** for each administrative task (**M**anager, **A**dministrator1, **A**dministrator2, **C**oordinator). The administrators must be on different sub-teams, due to their required administrative duties.
   → Record each team members name next to their assigned role in the *Project Leads* table on the **Team Charter worksheet**
      - For a team of 5 students, there will be **two (2) Coordinators**
      - Otherwise, there can only be one team member for each role
   → Give consideration to each team member's administrative portfolio to ensure team members have the opportunity to take on different roles across projects
   → Each team member must sign next to their name, indicating their acceptance of the expectations and responsibilities specific to their assigned role
      - Refer to the *Administrative Roles and Responsibilities* section

Submission Details

1. **Project Administrator 2 ONLY**: save your Milestone 0 **Cover Page** and **Team Charter worksheets** (both pages) as a single PDF, and submit it to the *Avenue Dropbox* titled **P2 Milestone 0 (Team) – Day**
   → Use the following naming convention: **DSDay-##_P2_Milestone0.pdf**
   → This is a *team* submission that is the responsibility of the Project *Administrator 2*
   → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Zero

Milestone Zero is graded on a **Pass/Fail** basis. Failure to submit all worksheets will result in a **10% deduction to your Project 2 grade**.

MILESTONE ONE: PROBLEM FRAMING

Assessment Type: Individual (Stages 1 and 4) + Team (Stages 2 and 3)
Time Allotted: Week 7 Design Studio (DS-7)
Submission Deadline: End of DS-7

Objectives and Requirements

For Milestone One, your team is required to conceptualize how the design of your container will facilitate it being picked up, transferred, and placed into an autoclave bin for sterilization. The design activities described below are meant to inform design decisions for your container, with the outcome of this Milestone being a set of preliminary concept sketches. This is a 4-stage Milestone with details outlined below.

1. **Stage 1 (Prior DS-7)** *Each team member* is required to identify a set of objectives, constraints, and functions for your design solution. This list will serve as a scaffold for your design solution as it will guide your team both in terms of design attributes as well as the limits it must adhere to. Complete your list on the **Pre-Project Assignment worksheet** located in the *Wk-7 (Fall) - P2 Milestone 1 Worksheets INDIVIDUAL.docx* document.
   → **Objectives**: attributes and/or behaviours that a design solution should have or exhibit (e.g., should *be* easy to use)
   → **Constraints**: limits or restrictions to be adhered to (e.g., *must* be lighter than 10kg)
   → **Functions**: physical functionality of the design (e.g., *able* to store liquid)
2. **Stage 2** (During DS-7) *As a team*, have each member share their **Pre-Project Assignment Worksheet** list and discuss them. Together, create a final list and document it on the **List of Objectives, Constraints, and Functions worksheet**, located in the *Wk-7 (Fall) - P2 Milestone 1 Worksheets TEAM.docx* document. The exact number you should have depends on what information you have gathered from the Project Pack. Next, identify the primary and secondary functions of your system and document them on the **List of Objectives, Constraints, and Functions worksheet** as well. A comprehensive list will help inform the remaining of the activities for this design studio and subsequent ones.
3. **Stage 3 (During DS-7)**: *As a team*, complete a morphological chart for your design, identifying multiple means for accomplishing sub-functions of your design. One subfunction (pick up) is already outlined for you. The other two subfunctions are for your team to decide on. Make sure that every mean listed under the "pick up" subfunction assumes that the end effector of the robot arm is a gripper. Complete your chart on the **Morphological Analysis worksheet**, located in the *Wk-7 (Fall) - P2 Milestone 1 Worksheets TEAM.docx* document.
4. **Stage 4 (During DS-7)**: *Each team member* is required to generate two (2) concept sketches for the container. Complete your sketches on a separate sheet of paper, take a photo, and Insert as a Picture each sketch on the **Concept Sketches worksheet**, located in the *Wk-7 (Fall) - P2 Milestone 1 Worksheets TEAM.docx* document.

Submission Details

1. **Each Team Member**:
    - Upload a ***.PDF** copy of *Wk-7 (Fall) - P2 Milestone 1 Worksheets INDIVIDUAL* document to the *Avenue Dropbox* titled **P2 Milestone 1 (Individual)**
        → Use the following naming convention: **macID_P2_Milestone1.pdf**
        → The Project Administrator must submit a copy as well
2. **Project Administrator 2 ONLY**:
    - Upload a ***.PDF** copy of *Wk-7 (Fall) – P2 Milestone 1 Worksheets TEAM* document to the *Avenue Dropbox* titled **P2 Milestone 1 (Team) – *Day***
        → Use the following naming convention: **DSDay-##_P2_Milestone1.pdf**
        → This is a *team* submission that is the responsibility of the Project *Administrator 2*
        → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone One

Milestone One is worth **0.5/10 marks of your total Project-2 grade (5%)**. Each team member will receive their own grade for Stages 1 and 4 of the Milestone. All team members will receive the same grade for Stages 2 and 3 of the Milestone.

MILESTONE TWO: CONCEPTUAL DESIGN

Assessment Type: Individual + Team
Time Allotted: ***Prior to*** and ***During*** Week 8 Design Studio (DS-8)
Submission Deadline: End of DS-8

Objectives and Requirements

For Milestone Two, you are required to: 1) **conceptualize how the container will securely hold a surgical tool** in place during pick-up, transfer, and sterilization (Modelling Sub-Team), and 2) **conceptualize the operation of the robotic arm** for transferring picking up, transferring, and dropping off containers (Computation Sub-Team).

1. **Refined Design Sketches (Prior to DS-8, Modelling Sub-Team ONLY)**: *Each team member* of the *Modelling Sub-Team* is required to create one refined concept sketch of the container, building off one or more of your preliminary concept sketches from Milestone One, while incorporating one or more features that facilitate securing a surgical tool in place. Complete your sketches on a separate sheet of paper *prior to your scheduled Design Studio*, take a photo, and insert the sketch as a picture on the **Refined Concept Sketches worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets INDIVIDUAL.docx* document.
2. **Computer Program Workflow (Prior to DS-8, Computation Sub-Team ONLY)**: *Each team member* of the *Computation Sub-Team* is required to describe the workflow of the entire system (outlined in Project Objective #3) through a visual storyboard OR a flowchart. Complete your program workflow on a separate sheet of paper *prior to your scheduled Design Studio*, take a photo, and insert as a picture on the **Computer Program Workflow worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets INDIVIDUAL.docx* document.
3. **Low-Fidelity Prototype of Container (During DS-8, Modelling Sub-Team ONLY)**: The *Modelling Sub-Team* is required to exchange their refined concept sketches with each other. Individually, *each team member* is required to build a low-fidelity prototype of their team member's proposed concept. Finally, the *Modelling Sub-Team* is required to document observations of each low-fidelity prototype.
   → Take multiple photos of each prototype and insert each image file as a Picture on the **Low-Fidelity Prototype worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM.docx* document
   → Document observations on the **Low-Fidelity Prototype Observations worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM.docx* document
4. **Computer Program Pseudocode (During DS-8, Computation Sub-Team ONLY)**: The *Computation Sub-Team* members are required to exchange their storyboards or flowcharts for peer-review, documenting similarities and differences between them. Together, members

of the *Computation Sub-Team* are required to consolidate their ideas and translate them into pseudocode, outlining the high-level workflow of the computer program. At this stage, the focus should be on how the program achieves the high-level objective rather than how each of the various tasks are executed (i.e., the pseudocode should simply list the functions and not describe the processes involved in executing the functions). Furthermore, the *Computation Sub-Team* should decide which muscle sensor emulator scenario to use for the *control gripper*, *move end-effector*, and *open autoclave bin drawer* functions. Please refer to Table 2 on page 18 of the project module at this stage.

→ Document similarities and differences between ideas (as a sub-team) on the **Workflow Peer-Review worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM.docx* document

→ Write out your computer program's pseudocode on the **Program Pseudocode worksheet** located in the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM.docx* document

Submission Details

1. **Each Team Member (Modelling Sub-Team ONLY)**:
   - Upload a ***.PDF** copy of the *Wk-8 (Fall) - P2 Milestone 2 Worksheets INDIVIDUAL* document to *Avenue Dropbox* titled **P2 Milestone 2 (Individual - Modelling)**
     → Use the following naming convention: **macID_P2_Milestone2.pdf**
     → The Project Administrator must submit a copy as well, if applicable
2. **Each Team Member (Computation Sub-Team ONLY)**:
   - Upload a ***.PDF** copy of the *Wk-8 (Fall) - P2 Milestone 2 Worksheets INDIVIDUAL* document to *Avenue Dropbox* titled **P2 Milestone 2 (Individual - Computation)**
     → Use the following naming convention: **macID_P2_Milestone2.pdf**
     → The Project Administrator must submit a copy as well, if applicable
3. **Project Administrator 1 and Project Administrator 2 ONLY**:
   - Upload a ***.PDF** file of the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM* document to *Avenue Dropbox* titled **P2 Milestone 2 (Computation Sub-Team) – *Day***
     → Use the naming convention: **DSDay-##_P2_Milestone2 (Computation).pdf**
     → This is a sub-*team* submission that is the responsibility of the Project *Administrator 1*
   - Upload a ***.PDF** file of the *Wk-8 (Fall) - P2 Milestone 2 Worksheets TEAM* document to *Avenue Dropbox* titled **P2 Milestone 2 (Modelling Sub-Team) – *Day***
     → Use the naming convention: **DSDay-##_P2_Milestone2 (Modelling).pdf**
     → This is a sub-*team* submission that is the responsibility of the Project *Administrator 2*

Grading of Milestone Two

Milestone Two is worth **1/10 marks of your total Project-2 grade (10%)**. Each sub-team member will receive their own grade for Objectives 1 or 2 of the Milestone (**5%**). All sub-team members will receive the same grade for Objectives 3 or 4 of the Milestone (**5%**).

MILESTONE THREE: PRELIMINARY DESIGN

Assessment Type: Individual + Team
Time Allotted: ***Prior to*** and ***During*** Week 9 Design Studio (DS-9)
Submission Deadline: End of DS-9

Objectives and Requirements

For Milestone Three, your team will begin configuring design sub-components. Working in your sub-teams, you are required to: 1) configure design details of the sterilization container through creating and evaluating solid models in Inventor (Modelling Sub-Team), and 2) plan how each of the program tasks will be executed, identifying the inputs, processes, and outputs (Computation Sub-Team).

1. **Preliminary Solid Model (Prior to DS-9, Modelling Sub-Team ONLY)**: *Each team member* of the *Modelling Sub-Team* is required to create a preliminary solid model of their proposed sterilization container design in Autodesk Inventor.
   → Take multiple screenshots of each solid model, ***including the Inventor browser on the left side of the screen***, save as an image file, and insert each image file as a Picture on the **Preliminary Solid Model worksheet** located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets INDIVIDUAL.docx* document.
      i. Your screenshots ***must*** include the Inventor browser so the TA can see the modelling history. Failure to do so will result in lost marks!
2. **Preliminary Program Tasks (Prior to DS-9, Computation Sub-Team ONLY)**: *Each team member* of the *Computation Sub-Team* is required to write a function in Python that achieves the following tasks identified in Project Objective #3: 1) *Identify Autoclave Bin Location* and 2) *Move End-Effector*.
   → Each team member should write a function for one of the above tasks
   → For teams of 3, 2 team members may write a function for the same task (they should still be completed individually)
   → Take multiple screenshots of your Python program, save as an image file, and insert each image file as a Picture on the **Preliminary Program Tasks worksheet** located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets INDIVIDUAL.docx* document.
3. **Sterilization Container Design Evaluation (During DS-9, Modelling Sub-Team ONLY)**: The *Modelling Sub-Team* is required to compile a list of criteria for evaluating the design of the sterilization container. Refer to the finalized **List of Objectives, Constraints, and Functions** that your team came up with in Milestone 1 to inform your list of criteria. Evaluate the preliminary solid models against a baseline using a Pugh Matrix, and propose design refinements to their sterilization container.
   → Complete your evaluation on the **Pugh Matrix worksheet** located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM.docx* document., including your list of criteria for

evaluation as well as conclusions from the evaluation – specifically a proposal of design refinements

4. **Detailed Plan of Entire Program (During DS-9, Computation Sub-Team ONLY)**: The *Computation Sub-Team* members are required to exchange their Python programs for their assigned tasks and attempt to run the code, documenting any errors and/or observations. Together, members of the *Computation Sub-Team* are required to plan all *remaining* program tasks, identifying the inputs, processes, and outputs (if applicable) for each. Your plan should describe the detailed processes involved in the execution of these tasks in the form of pseudocode. Unlike Milestone 2, it should not be limited to only listing the functions.
   → Document any errors and/or observations on the **Code Peer-Review worksheet** located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM.docx document.*
   → Write out the pseudocode for each of the remaining tasks on the **Program Task Pseudocode worksheet**, again located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM.docx* document.
5. **Preliminary Design Pitches (During DS-9, Both Sub-Teams)**: Each s*ub-team* is required to spend 5 minutes showcasing their preliminary designs and giving a progress update to the TA and the other team members. At this stage you will want to consider the constraints and functionality of each sub-team's design. Document any feedback and propose further refinements to your designs on the **Design Pitches worksheet** located in the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM.docx* document.

Submission Details

1. **Each Team Member (Modelling Sub-Team ONLY)**:
   - Upload a ***.ZIP** file combining your *INDIVIDUAL* work to the *Avenue Dropbox* titled **P2 Milestone 3 (Individual - Modelling)**
     → Use the naming convention: **macID_P2_Milestone3.zip** and include:
       - *Wk-9 (Fall) - P2 Milestone 3 Worksheets INDIVIDUAL (*.pdf)
       - Preliminary Solid Model (*.ipt)
     → The Project Administrator must submit a copy as well, if applicable
2. **Each Team Member (Computation Sub-Team ONLY)**:
   - Upload a ***.ZIP** file combining your *INDIVIDUAL* work to the *Avenue Dropbox* titled **P2 Milestone 3 (Individual - Computation)**
     → Use the naming convention: **macID_P2_Milestone3.zip** and include:
       - *Wk-9 (Fall) - P2 Milestone 3 Worksheets INDIVIDUAL* (*.pdf)
       - Program Task Code (*.py)
     → The Project Administrator must submit a copy as well, if applicable

3. **Project Administrator 1 and Project Administrator 2 ONLY**:
    - Upload a ***.PDF** file of the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM* document to *Avenue Dropbox* titled **P2 Milestone 3 (Computation Sub-Team) – *Day***
        → Use the naming convention: **DSDay-##_P2_Milestone3 (Computation).pdf**
        → This is a sub-*team* submission that is the responsibility of the Project *Administrator 1*
    - Upload a ***.PDF** file of the *Wk-9 (Fall) - P2 Milestone 3 Worksheets TEAM* document to *Avenue Dropbox* titled **P2 Milestone 3 (Modelling Sub-Team) – *Day***
        → Use the naming convention: **DSDay-##_P2_Milestone3 (Modelling).pdf**
        → This is a sub-*team* submission that is the responsibility of the Project *Administrator 2*

Grading of Milestone Three

Milestone Three is graded on a **Pass/Fail** basis. You will still receive a score on Avenue (out of 3 for the *Individual* portion and out of 7 for the *Team* portion). However, you will receive a Pass for this Milestone, regardless of your Avenue score, so long as your submission is complete. That is to say, just do it and you'll get the Pass. Don't worry about losing marks! Any team and/or team member who does not complete this Milestone **will be penalized 10% of their Project 2 grade**.

MILESTONE FOUR: DETAIL DESIGN (DESIGN REVIEW AND FEEDBACK)

Assessment Type: Team
Time Allotted: Own Time / Week 10 Design Studio (DS-10)
Submission Deadline: End of DS-10

Objectives and Requirements

For Milestone Four, your team will submit part of your design to your mentors for feedback. This milestone serves as an important gateway to either finalizing your design or refining/correcting any design parameters that have been identified by your mentors as potentially problematic.

1. **Finalized Design of Sterilization Container (Prior to DS-10, Modelling Sub-Team ONLY)**: The *Modelling Sub-Team* is required to finalize their sterilization container design, modelling all components in Autodesk Inventor and generating their G-code for 3D printing.
2. **Framework of Python Program (Prior to DS-10, Computation Sub-Team ONLY)**: The *Computation Sub-Team* is required to write part of their Computer Program in Python for demonstration. It is not expected to have your entire Program written. However, your Program should at the very least execute each of the tasks outlined in Project Objective #3 for a single cycle (i.e., pick-up, transfer, and drop-off of a *single* container).
3. **Design Review (During DS-10)**: Each *Sub-Team* will present their design to their mentors for feedback. Mentors and sub-teams will go through the checklists provided on this week's worksheet **together** to ensure the team is on the right track to meet project expectations. You are required to document your reviewers' feedback for submission and to list any proposed "Action Items" for design refinement. Document feedback on the **Design Review Feedback** worksheets located in the *Wk-10 (Fall) - P2 Milestone 4 Worksheets.docx* document (there is a worksheet for each sub-team).
   → The *Modelling Sub-Team* will receive feedback based on design objectives and the estimated time required to 3D print all components.
   → The *Computation Sub-Team* will receive feedback based on the execution of their code in the Q-Labs environment.
   → Subgroups may be asked to complete a mandatory second design review during DS-11 if there is any concern regarding their current progress.

Submission Details

1. **Project Administrator 1 ONLY**:
   - Upload a ***.ZIP** file of your sub-team's files to the *Avenue Dropbox* titled **P2 Milestone 4 (Computation Sub-Team) – *Day***
     → Use the following naming convention: **DSDay-##_P2_Milestone4 (Computation).zip** being sure to include the following:
       - Wk-10 (Fall) - P2 Milestone 4 Worksheets TEAM (*.pdf)

        - The current version of your computer program
            - Save all python (*.py) files to a single folder

2. **Project Administrator 2 ONLY**:
    - Upload a ***.ZIP** file of your sub-team's files to the *Avenue Dropbox* titled **P2 Milestone 4 (Modelling Sub-Team) – *Day***
        → Use the following naming convention: **DSDay-##_P2_Milestone4 (Modelling).zip** being sure to include the following:
            - Wk-10 (Fall) - P2 Milestone 4 Worksheets TEAM (*.pdf)
            - The current version of your sterilization container design
                - "Pack and Go" any assemblies and save all files (*.IPT and *.IAM) to a single folder

If the Modelling Sub-Team receives an **Approval to Print** on their Design Review, they may submit their approved G-code to the *Avenue Dropbox* titled **P2 Files for 3D Printing – *Day***. All Modelling Sub-Teams (regardless of Approval to Print) may modify their design as per their Action Items and submit their G-code to this *Avenue Dropbox* at their own discretion to be printed.

- Prompt submission ensures your design can be fabricated in a timely manner

You may also submit your modelling files (*.IPT and *.IAM, if applicable) as a *.ZIP file to the *Avenue Dropbox* titled **P2 Sterilization Container Design – *Day

Grading of Milestone Four

Each Sub-Team will be graded only on the feasible list of **Action Items** given by the TA. Each sub-team will receive one of the following:

→ ***Feasible Action Items***
→ ***Poor Action Items***
→ ***No Action Items***

Subgroups who are asked to participate in a second design review are required to show progress in their action items for the following week. Subgroups who do not show productive progress as instructed by their TA's and their action items will be penalized with a **10% deduction to their final project grade.**

FINAL SUBMISSION: DESIGN DEMONSTRATION AND VERIFICATION

Assessment Type: Individual / Team
Time Allotted: Own Time
Submission Deadline: ***Prior to*** Week 12 Design Studio (DS-12)

Objectives and Requirements

As a *team*, you are required to present your design during a scheduled *informal* **Project Interview**. This includes presenting both the **sterilization container design** and your **computer program**.

1. ***Sterilization Container Design***: Modelling Sub-Team **only**
   For the *Modelling Sub-Team*, you are required to create a *Solid Model* (in *Autodesk Inventor*) of your sterilization container, documenting your model through a set of full dimensioned *Engineering Drawings* (which will be submitted as part of your *Design Project Report*). The solid model should be properly constrained to hold the provided surgical tool as well as meet the criteria outlined in Project Objective #2. You will be expected to fabricate a *3D-Printed Prototype* of your sterilization container for design verification.
   → You will be expected to open up your Autodesk Inventor file(s) in front of your TA and briefly describe to them how you created specific components
   → A member of the ENGINEER 1P13 Instructional Team will verify your 3D-printed prototype to determine the extent to which it securely holds a surgical tool in place
   → *Each team member* can expect that the IAI/TA will ask questions related to your solid model, such as how you modelled certain features or why you made certain decisions

   To ensure your sterilization container design can be fabricated as a 3D-print and verified during your scheduled **Project Interview**, the Modelling Sub-Team ***must*** submit the completed G-code of their design (modified from Milestone 4, if necessary) to the *Avenue Dropbox* titled **P2 Files for 3D Printing – *Day***.
   - Use the following naming convention: **DSDay-##_P2_GCode.gcode**
   - **Your G-code must be submitted *at least 72 hours prior* to your scheduled Project Interview** (submission is responsibility of *Project Administrator 2*
   - This window ensures your IAI will have time to print your design ahead of the interview

2. ***Computer Program***: Computation Sub-Team **only**
   For the *Computation Sub-Team*, you are required to design a *Computer Program*, written in Python, that meets the criteria outlined in Project Objective #3. Your program should be written in a single Python file (excluding any libraries you will import). Indicate the team member who was responsible for each task by including their name, in comments, at the top of the respective function.

→ You will be expected to run your Python file in front of the IAI/TA, interfacing with the Q-Labs environment, and briefly describe how the program works (beyond what is simply displayed on the screen as the program executes)
→ *Each team member* can expect that the IAI/TA will ask questions related to your program, such as how code is executed or why certain design decisions were made.

As a component of the *Project Interview*, each *team member* will also be asked 2-3 questions related to your design. Each member of a specific sub-team (Modelling Sub-Team or Computation Sub-Team) must be able to answer questions about any aspect of their deliverable. All members must be present for the Project Interview.

Submission Details

1. ***Computer Program***: Computation Group **only**
   → **Your Sub-Team**: demonstrate your Python program during your Project Interview
   → **Your Sub-Team**: include the following in your *Design Project Report*
      - A screenshot of your *Computer Program* as written in Python (include the *Appendices* section)
   → **Project Administrator 1 ONLY**: upload your Python file to the *Avenue Dropbox* titled **P2 Computer Program – *Day***
      - Save files to a single *.ZIP folder (**DSDay-##_P2_Python_Program.zip**)
      - Submission is responsibility of *Project Administrator 1*

2. ***Sterilization Container Design***: Modelling Sub-Team **only**
   → **Your Sub-Team**: demonstrate both your solid model and your 3D-printed prototype during your scheduled Project Interview
   → **Your Sub-Team**: include the following in your *Design Project Report*
      - Image(s) of your Sterilization Container
      - A complete set of dimensioned Engineering Drawings of your Sterilization Container (include the *Appendices* section)
   → **Project Administrator 2 ONLY**: upload your Autodesk Inventor file(s) to the *Avenue Dropbox* titled **P2 Sterilization Container Design – *Day***
      - Save files to a single *.ZIP folder (**DSDay-##_P2_CAD_Files.zip**)
      - Submission is responsibility of *Project Administrator 2*

Grading of Final Submission

1. ***Sterilization Container Design***: Modelling Sub-Team **only**
   The Sterilization Container Design is worth **5/10 marks of your total Project-2 grade (50%)**, with marks evenly distributed between evaluation of the CAD file / 3D-printed prototype and the Project Interview. Your CAD file grade will be based on the creativity and appropriateness

of your design, the level of detail and use of appropriate modelling tools, and the extent to which your design securely holds a surgical tool in place. The Project Interview component is based on how well team members answer questions (each receives their own grade).

2. ***Computer Program***: Computation Sub-Team **only**
   The Computer Program is worth **5/10 marks of your total Project-2 grade (50%)**, with marks evenly distributed between evaluation of the Python file and the Project Interview. Your grade will be based on the correctness and succinctness of your code, the adequacy of commenting, and the layout and execution of your program. The Project Interview component is based on how well each team member answers questions (team members receive their own grade).

FINAL SUBMISSION: INDEPENDENT MATERIALS RESEARCH SUMMARY

Assessment Type: Individual
Time Allotted: Own Time
Submission Deadline: Sunday November 28th, 2021

Objectives and Requirements

It is evident that much consideration goes into the shape of the sterilization containers used to prepare medical and surgical equipment for use in a procedure. Much consideration must also be given to the material itself for those containers, as not all materials are autoclavable. Materials selection is very important in the biomedical field because every biomedical device that contacts a person needs to be thoroughly researched, ensuring its biocompatibility and successful performance.

Each team member is required to write an *Independent Research Summary* relating to a topic from one of the categories outlined in the table below. Students may choose one of the exemplary topics or choose their own. Multiple students may choose topics from the same category, as long as each team member addresses a *different* topic. **The research summary is expected to focus on the materials science aspect of the topic**. The research summary should be written in paragraph form with no use of bullet points and/or lists.

List of Independent Research Summary Topics

Category	Topic examples
Materials for equipment used during medical procedures	• Endoscopes • Electrocautery tools
Materials required for transmitting or sensing data	• ECG electrodes • Continuous glucose monitors
Materials of implantable medical devices	• Cochlear implants • Hip implants
Materials of other medical devices	• Contact lenses • Catheters
Heat resistant plastics compatible with autoclave sterilization	• Polypropylene • Silicone

Your *Independent Research Summary* should include:

1. **Executive Summary**: A brief overview of relevant findings and typical materials relating to the topic
   → Summarize general information and discuss the materials science aspect of the topic
   → A ***300-word limit*** is strictly enforced
   → The summary should take information from at least 3 recent (2010 to present) and relevant peer-reviewed sources

Granta may be helpful to research materials associated with your chosen topic. You may look for materials using the Level 1 database (same as for P-1), or you may choose to access the Medical Device Database in Granta EduPack 2021, which can be found on Avenue:

- **Content > 4-Design Projects > Student Resources >** *1P13_Granta_Medical_Device_Database_Guide.pdf*
- **Content > 4-Design Projects > Student Resources >** *1P13_Granta_Medical_Device_Database_Guide.mp4*

2. **Reference List**: A properly cited list of the peer-reviewed articles used to write the summary
   → Adhere to IEEE format
   → Must have at least 3 recent (2010 to present) and relevant peer-reviewed sources

You are required to complete your Research Summary using the template Word document that has been provided to you on Avenue-to-Learn. Follow the template formatting explicitly!

- **Content > 4-Design Projects > Student Resources >** *1P13_Independent_Research_Summary_Template.docx*

Submission Details

1. **Each Team Member**: upload your Independent Research Summary as a **PDF** to the *Avenue Dropbox* titled **P2 Independent Research Summary**
   → Use the following naming convention: **macID_P2_ResearchSummary.pdf**
   → Use and adhere to the template provided to you
   → Include your MacID and Team Number on the Header
   → Your summary should be written in paragraph form
   → Adhere to IEEE referencing and citation standards (your submission WILL be evaluated and checked for plagiarism)
   → You CANNOT use direct quotations, even if cited correctly
   → A ***300-word limit*** (excluding the reference list) is strictly enforced

Grading of Final Submission

The Independent Research Summary is worth **2/10 marks of your total Project-2 grade (20%)**. Your grade will be based on adherence to formatting and word count, writing quality, citations, and spelling and grammar (refer to the rubric). Each team member will receive their own grade.

REMINDER: While at McMaster, you have free access to a very large database of peer-reviewed articles.

FINAL SUBMISSION: DESIGN PROJECT REPORT

Assessment Type: Team
Time Allotted: Own Time
Submission Deadline: Wednesday December 8th, 2021

Objectives and Requirements

As a *team*, you are required to consolidate and present your work in a *Design Project Report*. Your report should: 1) concisely summarize your design solution, 2) include all deliverables related to administrative responsibilities, 3) include all design studio worksheets, and 4) document any other work relevant to your design in an appendix.

> You are required to complete your Design Project Report using the template Word document that has been provided to you on Avenue-to-Learn
> - **Content > 4-Design Projects > Student Resources >** *1P13_Project_Report_Template.docx*
>
> Follow the template formatting explicitly!

Your report should include the following sections:

→ *Executive Summary* (All Members):
- A concise summary (500 words or less, strictly enforced) that clearly outlines the motivation for the project and presents the design solution

→ *List of Sources*:
Source Materials Database (Administrator 2)

→ *Appendices*:
- *Supporting Documents:*
  - Screenshots of your solid model and computer program
  - Fully-dimensioned Engineering Drawings of your container design
- *Project Schedule*:
  - Preliminary Gantt Chart (Manager)
  - Final Gantt Charts (Administrator 1)
  - Logbook of Additional Meetings and Discussions (Coordinator)
- *Scheduled Weekly Meetings*:
  - Weekly Design Studio Agendas (Manager)
  - Weekly Design Studio Meeting Minutes (Coordinator)
- *Independent Research Summaries:*
  - Each student is responsible for their own summary
- *Design Studio Worksheets*:
  - Worksheets for all Design Studio Milestone's, both those submitted as a team (Administrator 2) and those submitted individually

Submission Details

1. **Project Administrator 2 ONLY**: upload your Design Project Report as a **PDF** to the *Avenue Dropbox* titled **P2 Design Report – *Day***
   → Use the following naming convention: **DSDay-##_P2_DesignReport.pdf**
   → Note that Turnitin.com will be used to check for plagiarism
   → This is a *team* submission that is the responsibility of *Project Administrator 2*

Grading of Final Submission

1. ***Design Project Report***:
   The Design Project Report is worth **1.5/10 marks of your total Project-2 grade (15%)**. Your grade will be based on the executive summary and adherence to proper formatting and inclusion of all documents outlined above.

LEARNING PORTFOLIO ENTRY

Assessment Type: Individual
Time Allotted: Own Time
Submission Deadline: Thursday December 9th, 2021

Objectives and Requirements

Complete your **online learning portfolio** for Project-2. Remember that the goal of the online learning portfolio is to showcase the ways in which your project is unique, as well as the technical and non-technical skills you developed throughout the completion of the project. The online learning portfolio is a summary, highlighting the most crucial aspects of the project. Media should be used to help support your project description.

Submission Details

Each Team Member: ensure your online web Portfolio is complete and up to date

→ Content should be uploaded to the appropriate subpage under the P2 project page. Follow the same structure you did for your P1 online learning portfolio entry. Refer to the "Online Learning Portfolio (Notion) Instructions" document if necessary. For example, your P2 project page may look as follows:
- *Summary* subpage
- *Skills* subpage
- *Design Process* subpage

→ Go to share (upper left corner) and ensure that "Anyone with the link can view" is turned on to reflect your changes online
- Remember, check this *every time* you make changes to your website
- In addition, make sure you are sharing from your main page and not one of the subpages

→ *You do not need to resubmit any work already submitted**!***

Grading of Learning Portfolio

Your Learning Portfolio is graded on a **Pass/Fail** basis. Any team member who does not complete their learning portfolio will be penalized 5% of their Project-2 grade.

SELF-AND PEER-EVALUATION

Assessment Type: Individual
Time Allotted: Own Time
Submission Deadline: Thursday December 9th, 2021

Objectives and Requirements

Each team member is expected to contribute equitably and effectively to the team's overall performance, throughout the duration of the project. This contribution is evaluated through both a *self-evaluation* and a *peer-evaluation*. Team members will also be asked to provide peer feedback.

(1) Self- and Peer-Evaluation: Each team member will evaluate themselves and their peers on the following dimensions:

→ Contributing to team's work
→ Interacting with teammates
→ Keeping the team on track
→ Expecting quality
→ Having relevant KSAs (Knowledge, Skills, and Abilities)

(2) Peer-to-Peer Comments: Each team member will be asked to provide comments to their peers based on the project experience. You are expected to adhere to the following:

→ Before you start writing, reflect on the project experience and evaluation you just completed.
→ Comments should include both positive feedback and constructive criticism.
→ Constructive criticism should not be overtly negative, should not include profanity, should be given with a purpose, and should focus on what your peer can do to improve in the future.

While writing Peer-to-Peer comments, consider the following resources:

→ **Belbin Team Roles Inventories**: This inventory recognizes that every team member brings different strengths and weaknesses to the team. Consider using the language and inventories in this document to provide feedback to your team members and yourself.
  - Belbin Inventories Reference Article

→ **Constructive Criticism**: These websites provide tips and tricks on what should be included in constructive criticism.
  - Tips for Giving Constructive Feedback
  - What is Constructive Feedback + Examples

Submission Details

Complete your self- and peer-evaluation using the URL that will be emailed out.

Grading of Self- and Peer-Evaluation

Each team member will have a peer-evaluation score calculated as part of the self- and peer-evaluation. Depending on your own self-evaluation and your team members peer-evaluation, your peer-evaluation score can **add or deduct a maximum of 10% towards your overall Project-2 grade** at the discretion of the instructional team.

Team members are expected to take the self- and peer-evaluation process seriously. This is an important learning opportunity in terms of being able to evaluate one's own work as well as give and receive feedback on the work of others. It is not intended as an exercise in padding each other's marks! Team members may be expected to justify their peer evaluation scores in a meeting with the Course Instructors, individually or as a team. Failure to justify your peer evaluation may result in an adjustment to your peer-evaluation score.