# Workspace Design (Point A)

## Task Requirements

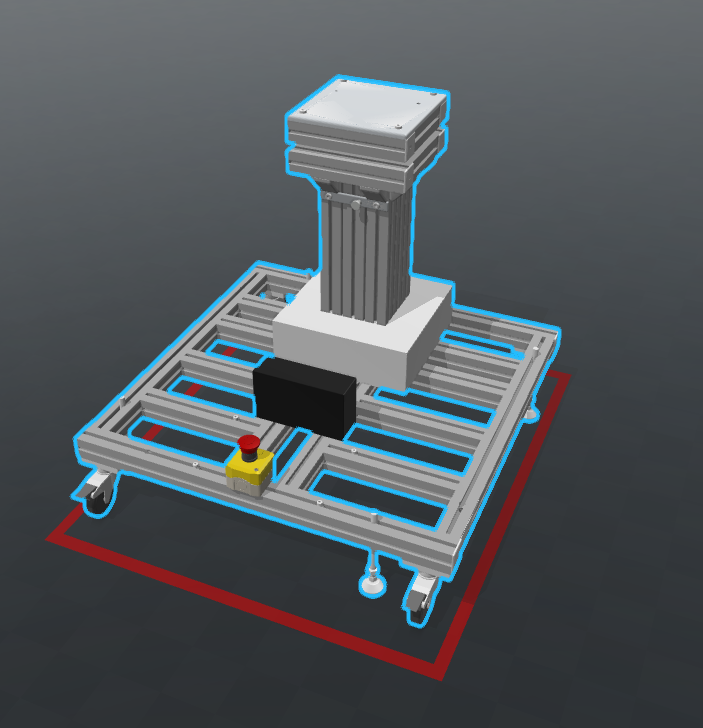
The overall task requirement is to assemble a PCB into its housing. That is, place a PCB into an enclosure and close it off.

The specific task details are as follows:

* Locate box containing the housing tops.
* Derive and move to a joint position that would allow successful grasping of the part.
* Move the arm back to a position that will allow the other arm to place a PCB into the housing without it falling out.
* The second arm should locate the box containing the PCB’s.
* Derive and move to a joint position that would allow successful grasping of the part.
* Move the PCB into the housing top
* Locate the box containing housing bottoms
* Derive and move to a joint position that would allow successful grasping of the part.
* Bring the housing bottom to the join position to close in the PCB and finish the assembly.
* The first arm should place the completed part into a drop off bin.
* PERFORM THE TASKS SAFELY

To accomplish these tasks safely, we here at SafeCo have designed a workspace for the Sawyers to work in:

Firstly, the base. The Sawyer is to sit on the following base during movement and operation. The base will provide stability during operation and ease of manoeuvrability. This is to protect the users back when moving the sawyer from place to place. The Base also features an Estop (pictured) that can be used in emergencies.



# Risk Assessment (Point B)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Hazard | Consequence | Probability | Severity | Overall Risk | Control |
| Human Robot Collision | Possible injury to person, Possible damage to robot | Med | Med – High | Med | Enable all Sawyer Safety Features. No Person allowed in Sawyer work zone. E-Stops, sawyer must be off when approached |
| Robot-Robot Collision | Possible Damage to Robot | Low | High | Med | Software Checks and bounds on control system. Safe work Zones. Operator with access to quick and eStops. |
| Robot-Environment Collision | Damage to Robot, Environment and assembly parts | Low | High | Med | Software Checks and bounds on control system. Safe work Zones. Operator with access to quick and eStops |
| Part Misalignment | Inadequate part quality | Low | Low | Low | Quality assurance checks at the end to make sure parts were made properly. |

## Safe Work Method Statement

# Use of the Sawyer arm in Manufacturing (Point C)

## Appropriateness

The sawyer arm features a 7DOF arm. This arm allows the Sawyer robot to reach any point within its workspace and at an orientation. This capability allows the Sawyer to be less restrictive in where each of the parts is to be placed and its orientation to those parts. This will also allow the Sawyers to be applied to many other manufacturing operations. For this task, specifically, the parts will be placed loosely in a box. That is, the parts can be at any orientation and transform. The grabbing mechanism will need to be able to compensate to perform this task. That is where the Sawyer arm is the most appropriate.

Another aspect is the Sawyers attention to Safety. The safety of the Sawyer is inherent in its design. The motors have been selected and tuned so that the torques are kept very low. The gear boxes used are very efficient allowing the user to easily push away and overcome the robots power. Finally, the series elastic actuator joint design provides a spring at every joint that can absorb some kinetic impact.

## Limitations

The Sawyer’s joints can be quite elastic meaning that there would a lot of wobble during movements. This results in higher deviation between movements and can lead to high error between expected end effector position and actual position. This can make the Sawyer inappropriate if precision is required. This will also mean that better control of the Sawyers joint states will be needed when joining the PCB with the housing top and bottom parts to allow for this error.

Also, due to the safety aspect of the motors, if the needs of the company change and new production is required. The Sawyer will have a very low payload capability meaning that it won’t be able to be used to do any heavy lifting. That means that the Sawyer will also not be able to lift away the box of completed parts. Another solution will be required for that.

# MATLAB and the Robotics Toolbox (Point D)

Due to the low processing power requirement of the MATLAB is very appropriate for our uses. The mathematical capabilities of MATLAB coupled with the available capabilities of the Robotics toolbox will allow for quick development of a demonstrable working solution. However, the Robotics toolbox has no communication capabilities of talking with the Sawyer itself. A communication protocol that can send messages over ROS will be required to be able to actuate the physical robot. This protocol will need to be able to take in the outputs of the robotics toolbox and covert it to a ROS message.

# Precision Required and Robot Control (Point E)

Given the nature of the parts that we will be assembling. The precision required to pick up the parts will not need to be highly precise. Just generally moving the end effector to have the same pose as the part that is being picked up then closing the gripper to securely pick up the part will be enough. What will be important is the gripper not damaging the part as it closes to pick up the part and the two parts joining together. The PCB fits snuggly into the housing, meaning there isn’t much wiggle room. This coupled with the springiness of the motors means that joining the parts together might be more difficult. As such, the control of the system will be to slow the process down as the end point is approached. That way the springiness of the motor joints can be decreases allowing for more accurate movement.

# Sensing and Grasping Challenges (Point F)

Currently the assumption made is that the location and the transform of the part is known well and that it will always be in that exact point and orientation. We have also assumed that when the end effector reaches the location of the part that it will “successfully gripped”. These two assumptions are not the case in the real world. There are several challenges that will need to be overcome to be able to do this task accurately with the physical robot. They are:

* **Localising the parts –** We have a box of loose parts, that is, we do not know the transform of any part at all. We have the location of the box and the dimensions of the box, this location can be hard coded into control software but it would mean that the box must be in the right spot. It won’t be able to find the box on its own. Even though we know the position of the box the parts inside are still a mystery, we need to be able to look inside the box, possible using an eye in hand type system or a camera facing down above each of the boxes. This way we may be able to find the location of the part without just randomly placing the gripper into the box and hoping we caught something.
* **Gripping the part –** Due to the capabilities of the gripper and the parts themselves, you cannot grab the part from any position. For example, grabbing the part in a way that blocks the slot that the PCB would sit in would make the assembly impossible. Or gripping the PCB in a position that might cause damages would also be unacceptable. This is where accurate localisation of the part would be vital. Knowing the exact location and orientation of the part along with allowable gripping positions would allow better path planning to avoid the box, the other parts and manoeuvre into a position that allows the gripper to pick up the part. There may even need to be decision making processes involved, if there is no way to pick up the part in a way that would make assembly possible it would need to flip the part and then grab it.
* **Safe Gripping –** Once it has gripped the part it needs to know if it has safely gripped the part. Is it applying enough force to hold the part but not so much that it breaks the part. It also needs to know if the part has slipped from its grip so that it doesn’t ruin the assembly process. Finally, when it places the part down, how has it placed it? Did it just drop the part into a box, will that break the part, is that the optimal way to place it? More likely it will need to neatly stack the part. That means working out the best way to place the part down.

# Robot Safety (Point G)

Robotic safety is major factor that needs to be considered during the life of this project and any subsequent project. Not just to the human workers around the robot but to the robot itself and the environment around it. Robots themselves are essentially blind, and the physical movements of the robots may collide with each other, the environment or the people walking around in the environment. That is why safety precautions must be taken when dealing with the two Sawyer arms.

Firstly, self-collision. This involves collision with itself and the other robot in its workspace. The Sawyer arms need to have a good grasp of where each other’s arms and their own will be in the environment that they share. They decision making process for the required joint trajectories will need to take these into consideration and plan accordingly. Another method would be to set working zones, that is, hard coded safe boxes around the robot where the robot can move freely within that environment but move outside of it. However, there will be significant challenges mating the compounds as this is where possible collision is most likely. Safe and slow movements will need to be considered to mate the two parts without collision. If this isn’t considered, then the safety of the robots themselves is compromised and the robots may be damaged during operation.

Another aspect is the collision with the environment, once again, as the arm is moving around it may collide with a physical object in the environment. This could cause damage to both the robot and the environment itself. Once again this could be solved by outlining safe working zones that the robot can move freely in and only should move carefully and slowly when grasping a part. As this is the situation that is most likely to cause a collision with the environment. At the same time, this will make the environment very static others its dangerous. Using an array of sensors to calculate the location of objects will allow for a more dynamic environment but more difficult engineering and slower production.

Finally, human safety. The robots may collide with humans if they can walk amongst the robot as they work. Due to the fast and hard to predict movements of humans it will be safer for now to not allow the robots to operate while a person is within their environment. That is why the robot must be safely stopped prior to a person entering. This can be done through a software stop prior but there will be an E-Stop wired into the door that would cause the robots to stop moving if the door is opened. There will also be other E-stops in easy to reach locations as redundancy.