# GNG 1103

# User and Product Manual

C08

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# List of Acronyms and Glossary

**Table 1. Acronyms**

| Acronym | Definition |
|---|---|
| USB | Standard used in numerous cables and connectors. |
| .jpg/.png | Picture file format |

**Table 2. Glossary**

| Term | Acronym | Definition |
|---|---|---|
| Graphical User Interface | GUI | A visual way of interacting with the robot arm using items such as windows, icons, and menus. |
| Inverse Kinematics | IK | It is the process/algorithm of calculating the required coordinates to make a robot arm have a particular orientation (pose). |
| RoboSandy Robotic Arm | RSRA | The name of the robotic arm that will be using our end effector and inverse kinematics solver. |
| User and Product Manual | UPM | The set of instructions that guides/instructs the user in how to properly operate the RoboSandy robotic arm effectively. |

# 1. Introduction

This User and Product Manual (UPM) provides the information necessary for customers and any new users to effectively use the RoboSandy Robotic Arm (RSRA) and for prototype documentation. This UPM provides an overview to the system, after which the "Getting Started" section gives a general walkthrough of the system along with setup and troubleshooting details. Read this UPM carefully for safe operation of the system. Keep this information on file for further reference. The unfair duplication of this document is prohibited in accordance with the Copyright Act.

# 2. Overview

The problem was to develop an inverse kinematics solution to program a robotic arm that will be used to carry out certain activities on the Halifax Class Frigate. We were also asked to design an end-effector for the arm. This problem was important because it would free up sailors to focus on other important tasks by automating the operation of minor tasks with the use of a robot arm.

The user required a user-friendly, reliable and durable end-effector for a robotic arm that will be required to either draw a shape or a logo, sand blast or water blast a grid area, inspect a low oxygen space in 360 degrees using a camera or a combination of all three. The inverse kinematics solution had to be open-sourced so it can be easily modified and reproduced.

Our product includes an orbital sander attached to our end effector by means of a twist-lock system. It can be used to sand down a grid area to remove rust and other impurities from the body of the ship. Our product also has swappable end effectors that makes it easy to switch from a sander to a paint gun that will paint the body of the ship. Our inverse kinematics solution is open-sourced which makes it easy to replicate.

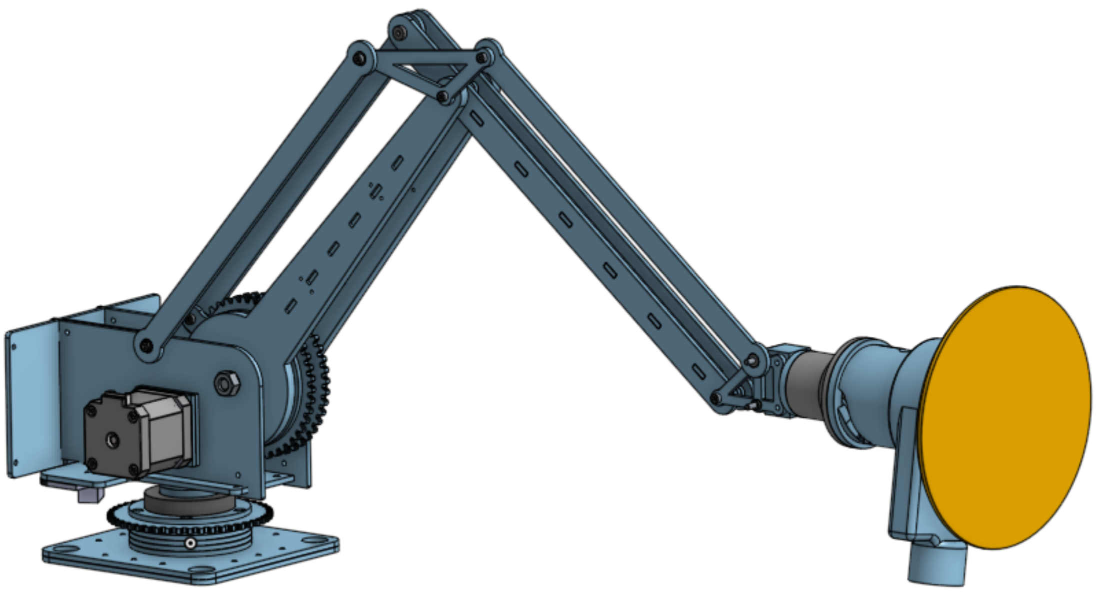

Figure 1: Sander attached to arm

Orbital Sander – a 3D-printed tool attached to an end effector used to clean off rust and impurities by means of abrasion.

Paint Gun – a 3D-printed tool attached to our end effector that is used to paint the walls of the ship. The paint is transferred through a tubing connected to the paint gun that goes through the end effector.

Infrared Ray Sensor – a device used to detect the proximity of people in the surroundings to the robotic arm.

Twist-lock System – used to hold the various end effectors in place including the orbital sander.

The system consists of an already assembled robotic arm to which a 3D-printed end effector is attached. This end effector is held in place by a twist-lock system. Multiple end-effectors are available. The end effectors are easily swappable and can be switched from an orbital sander for sanding an area to a paint gun by painting an area. These end-effectors are multi-purpose; sander can be turned into a buffer and paint gun into a pressure washer. The arm is programmed to move by an inverse kinematics solution which uses the desired orientation of the arm to determine coordinates for movement of the arm.

The Arduino Uno microcontroller is used to control and interact with digital devices by means of digital signals. An open-source IK software is used to control the movement of the arm to fulfill the purpose of the user. The purpose of the user is communicated to the robotic arm with the use of a GUI. The user enters their desired final position in terms of coordinates which the IK solver interpretes to generate the exact angles for the motion of the arm to be successful.

For the safety systems, an infrared ray sensor detects any obstructions in the surroundings of the robotic arm. If the arm approaches an object, the end-effector in use stops, the arm retracts and the system shuts down momentarily. After a certain time delay (configurable), the system resumes operation. The 3D-printed manual button is also attached to the arm to serve as a physical emergency stop to the arm.

## 2.1 Cautions & Warnings

Any reproduction of a component and/or software requires the permission of the team behind the RSRA. Please see **section 5.4** for contact details to qualify for fair use.

**Caution:** Repeated usage may cause overheating. The manufacturer is not liable for any incurred damages due to overheating.

**Warning:** Do not light fire close to the system. In case of incidental damage, call a technician immediately. Maintain distance when in use.

**KEEP OUT OF REACH OF CHILDREN.**

# 3. Getting started

## 3.1 Configuration Considerations

The use of swappable end-effectors allows quick and smooth switching between the different subsystems of the arm. All attachments use the “twist-lock” system to get attached to the arm.

The sander (see figure 2) is an attachment that allows for removal of rust. This sander is multi-purpose, as it can be used for buffering as well. Images below showcase the sander attached to the body of the arm and separated from the arm.

*Figure 2: Sander module*

The paint gun (see figure 3) is an attachment that allows for repainting the sanded area. This paint gun is multi-purpose, as it can be used for pressure washing as well. Images below showcase the paint gun attached to the body of the arm and separated from the arm.

*Figure 3: Paint Gun module*

## 3.2 User Access Considerations

Users with high-school level technical knowledge should refer to this handbook for guidelines on how to operate and upkeep the system. This serves as a guideline for what to do to ensure safe usage of this product.

Technicians may use this handbook to figure out specific problems that they may face during regular maintenance of this product.

## 3.3 Accessing/setting-up the System

Powering on the system requires the user to connect the robotic arm to their desktop using the attached USB connector or the user's own USB connector. This causes the arm to power up. To operate the arm, the user needs to access the RoboSandy GUI application using the Visual Studio Code app. No User ID or login is required.

## 3.4 System Organization & Navigation

The RSRA is a robotic arm with swappable end-effectors. To control the arm, the user needs to interact with RoboSandy GUI, made specifically to control this arm. As seen in the image below, the simple homepage of this application allows for easy control of the robotic arm.

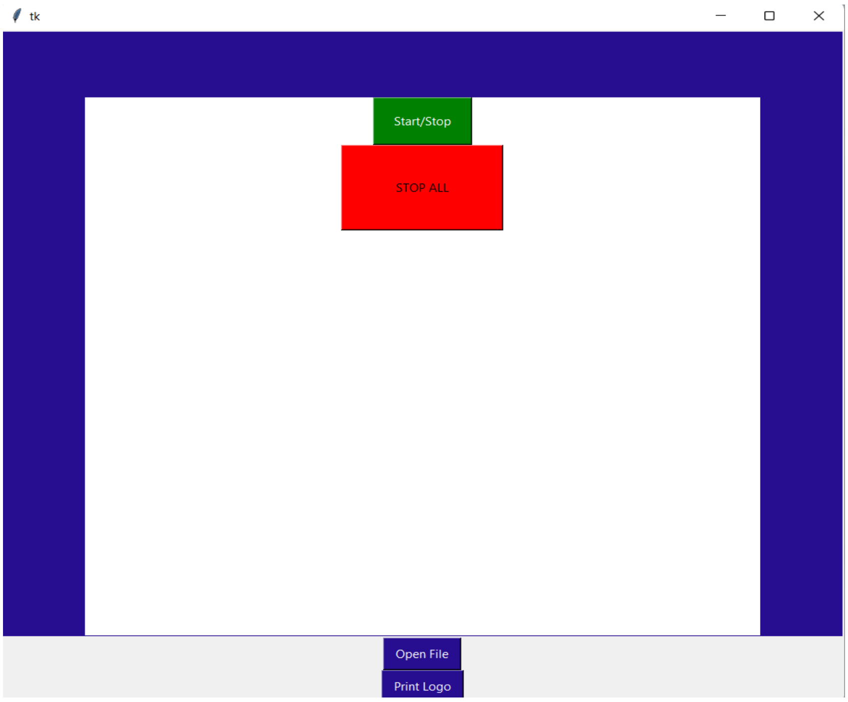


*Figure 4: Homepage of RoboSandy GUI Application*

This application gives the user options to start or stop the system, emergency stop labeled "STOP ALL" and to open an image file (.jpg or .png) and give instructions to the arm to print that image as a logo using the button "Print Logo".

## 3.5 Exiting the System

Powering off the system requires the system to be stopped, either physically or digitally. Plugging the USB connector from the user's desktop will cause the system to power off.

# 4. Using the System

## 4.1 GUI

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the GUI.

## 4.1.1 Opening a file

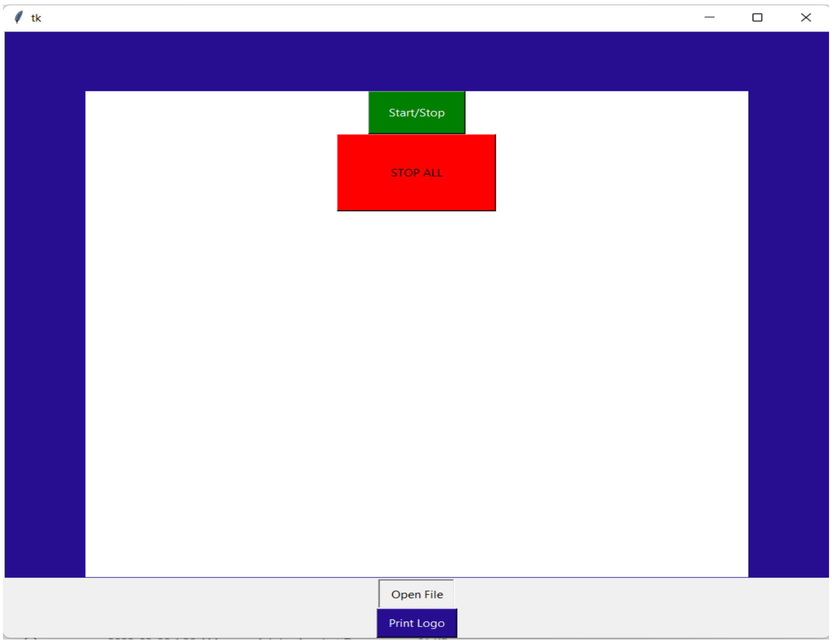


*Figure 5: Button labeled "Open File" pressed on RoboSandy GUI Application*

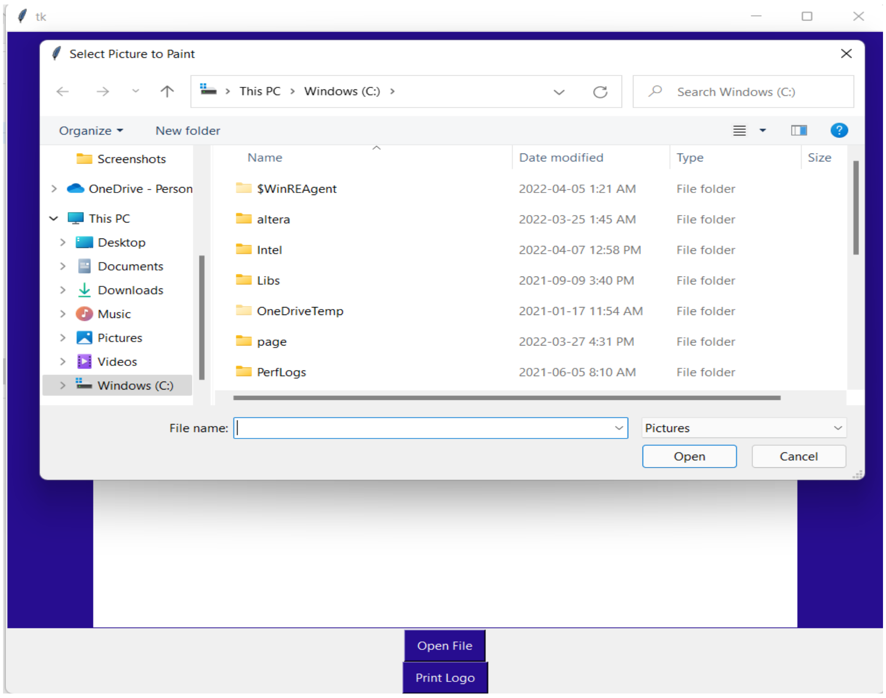


*Figure 6: Menu to choose Image file after button labeled "Open File" pressed on RoboSandy GUI Application*

## 4.1.2 Printing a logo

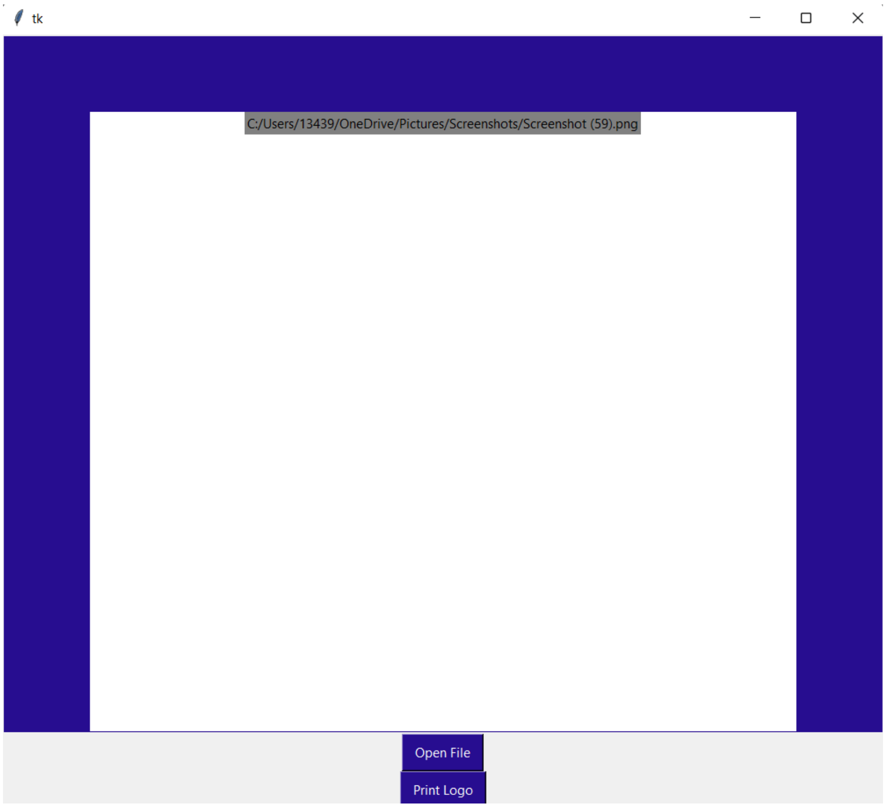


*Figure 7: Location of image file chosen showcased on RoboSandy GUI Application*

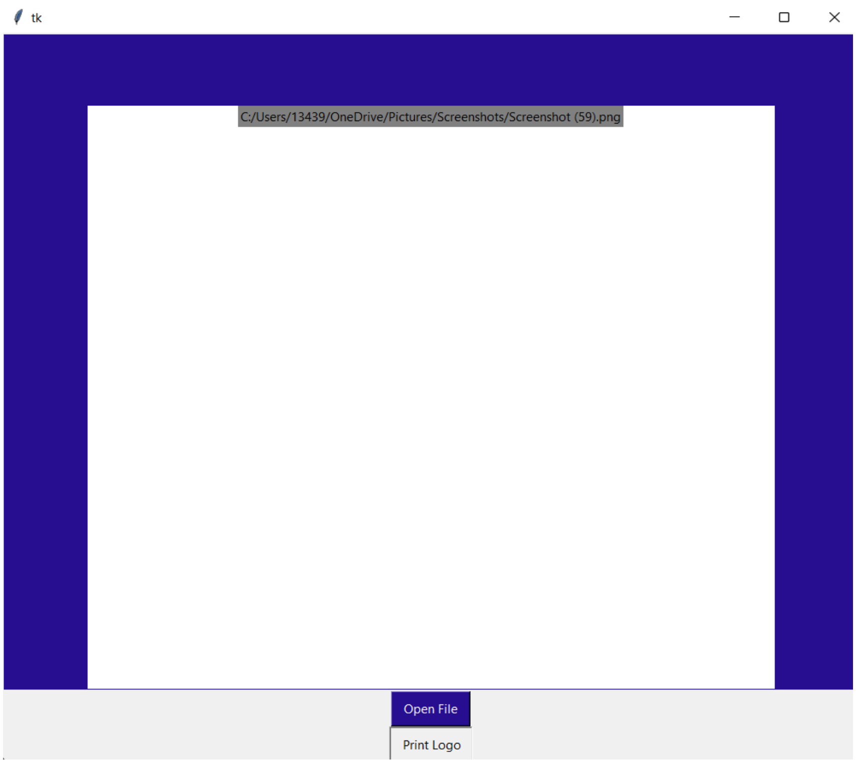


*Figure 8: Button labeled "Print Logo" pressed on RoboSandy GUI Application*

These steps will open an image file which gets passed onto the Arduino microcontroller, using coordinates to print the logo. The RSRA then using those final coordinates will print a logo utilizing the principles of Inverse Kinematics to justify the motion of the arm.

### 4.1.3 Exiting the GUI Application

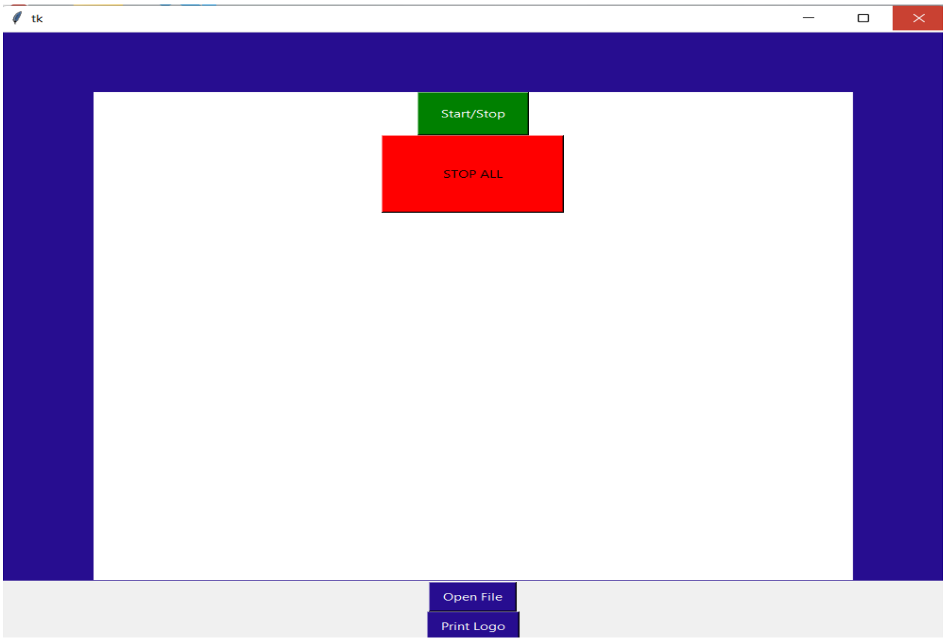


*Figure 9: Exit button pressed on RoboSandy GUI Application*

Pressing the red button marked "X" (see figure 9) will cause the user to exit the application.

## 4.2 Sander

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the **Sander.**

### 4.1.1 Powering on/off

Connecting the wires of the motor inside the sander to a 9V battery or a variable power supply will cause the sander to start spinning.

Disconnecting the wires of the motor from the power supply will cause the sander to stop spinning.

### 4.1.2 Rust Removal

Once coordinates are input to the Arduino microcontroller, the arm will cause the sander to move towards the rusted area. The sander will remove the level of rust according to the level of pressure desired by the user.

The sander will keep spinning after the sanding is done and it is the user's responsibility to disconnect the sander from the power source.

## 4.2 Paint Gun

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the **Paint gun.**

### 4.2.1 Powering on/off

Connecting the wires of the actuator inside the painter to a variable power supply and a pressure system(gas cylinder) will cause the painter to discharge paint.

Disconnecting the wires of the actuator inside the painter to a variable power supply and a pressure system(gas cylinder) will cause the painter to stop discharging paint.

### 4.2.2 Repainting

Once a logo is selected to be repainted using the GUI Application, the Arduino microcontroller will use the converted coordinate matrix to paint a logo according to the desired fidelity of the user.

The painter will stop painting after the logo is done and make an alert sound. It will be the user's responsibility to disconnect the painter from the power source.

## 4.3 Safety Systems

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the **safety systems.**

### 4.3.1 Automatic Stop

If the arm approaches an object, the end-effector in use stops, the arm retracts and the system shuts down momentarily. After a certain time delay (configurable), the system resumes operation. The same case applies when the physical emergency stop button is pressed.

### 4.3.2 Emergency Stop

A physical emergency stop button labeled "STOP" can also be found at the base of the arm, as seen in the image below.


Figure 10: Emergency Stop button labeled “STOP”

## 4.4 Twist-Lock System

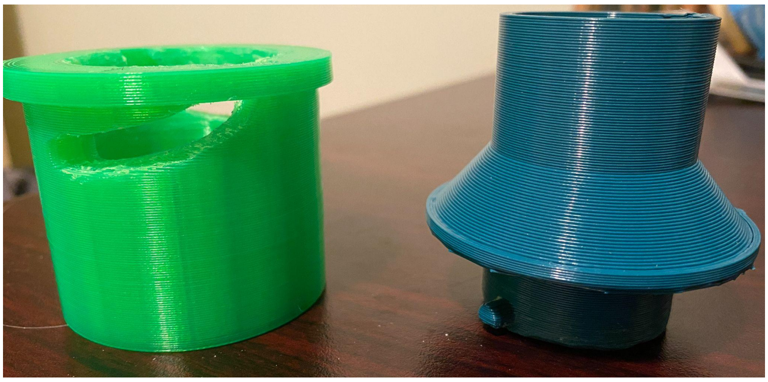

Figure 11: Twist lock (unlocked)

Figure 12: Twist lock (Locked)

The twist-lock system is a simple locking mechanism to attach whichever end-effector the user may need to use to the arm. Its use is simple. The male part of the arm is inserted in the female connector and secured by twisting them until the locking pins no longer move.

# 5. Troubleshooting & Support

The following section includes what a user should do if they are faced with the following malfunctions and tips for keeping the RSRA in running order.

## 5.1 Error Messages or Behaviors

- Warning: Motor overheating!

  Turn the sander off and give the motor a chance to cool down

- Warning: Overpressure on sander!

  Contact support desk for help

- Warning: Obstruction detected!

  Remove whatever object is in front of the IR sensor

- Warning: Paint tube blocked!

  Remove the paint tube and flush out with water or solvent

## 5.2 Special Considerations

The user should be aware of the tendency of the motor overheating on repeated usage. Should the user smell a sort of burning that means the motor may be burnt out and requires replacing. Contact the helpline for inquiries about replacements.

## 5.3 Maintenance

Before the sander is put away it should be wiped down with a wet cloth to remove any debris remaining on it. If the user desires the sand paper can be cleaned by rubbing it with a resin stick. The paint tube for the paint gun should be removed after every few uses and clean with water or a solvent like paint remover.

## 5.4 Support

Should the user come across a problem they are unable to fix, contact the Robosandy helpline at: 613-236-4656 or email at ljon070@uottawa.ca between the hours of 9 am – 5 pm EST, Monday to Friday.

# 6. Product Documentation

The following subsection includes the instructions on how to assemble the sander, bill of materials, equipment list, and the testing of the sander.

## 6.1 Sander

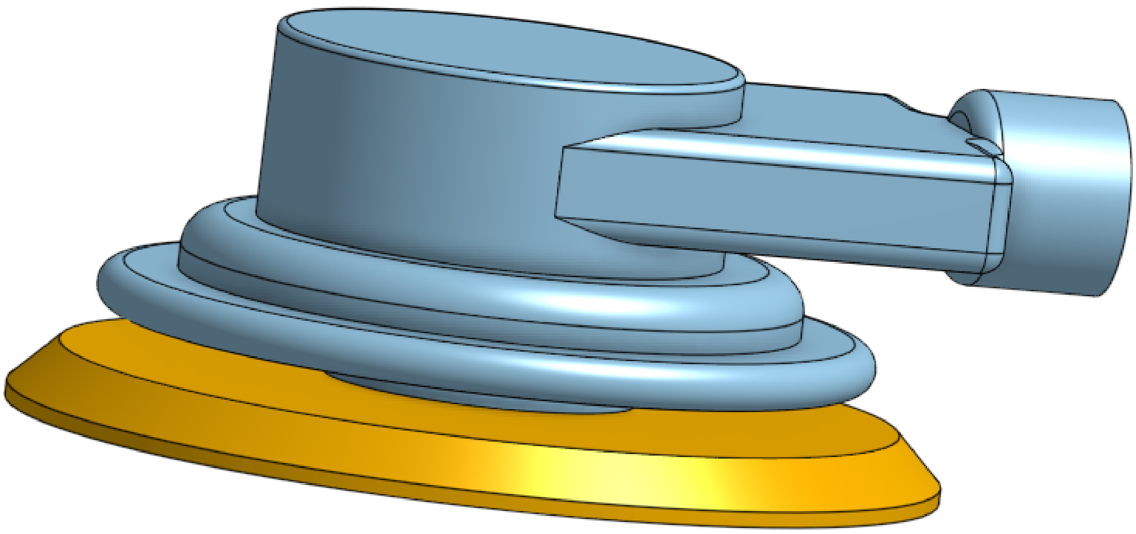

*Figure 13: 3D sander model*

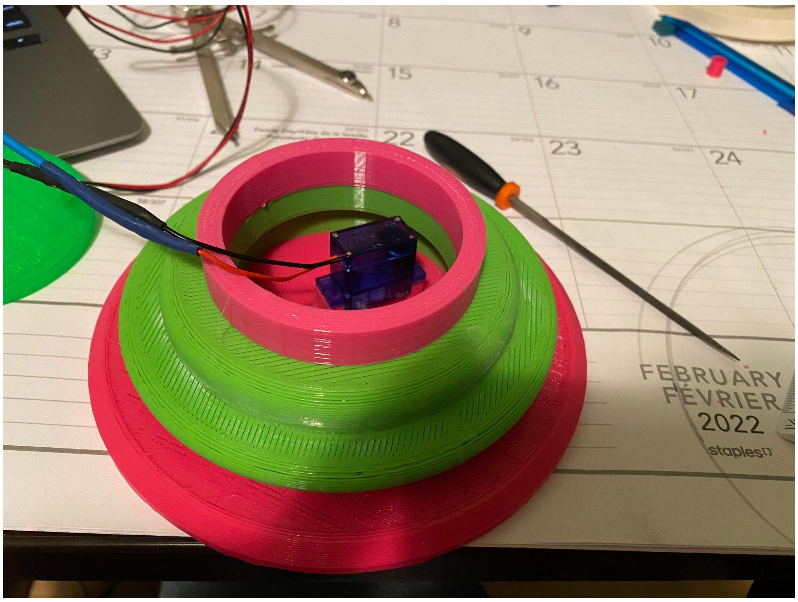


*Figure 14: Sander body with motor installed*

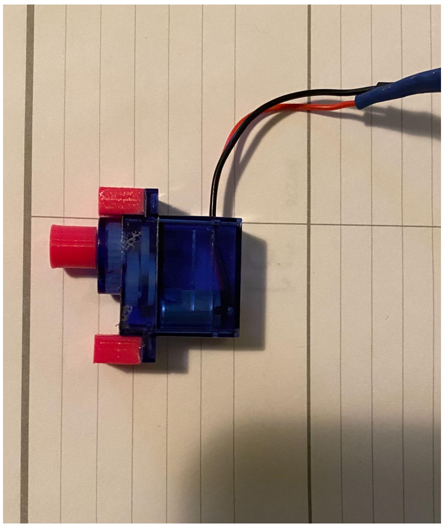

Figure 15: Motor with attached supports

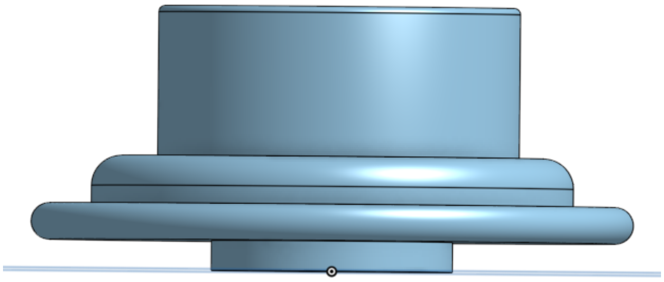

Figure 16: Sander body 3D model

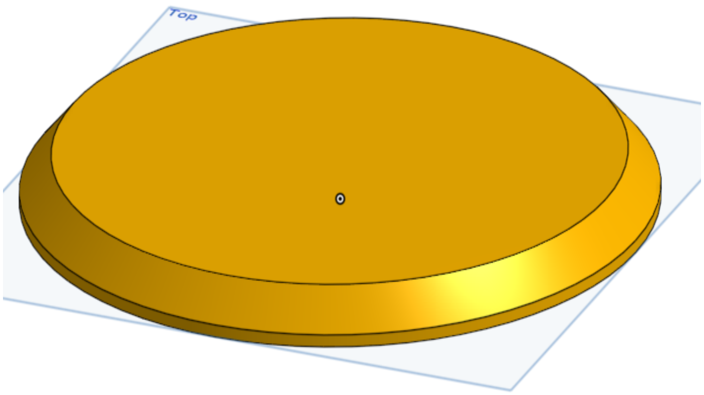


Figure 17: Sander pad 3D model

### 6.1.1 BOM (Bill of Materials)

- 6V DC motor (link: DC Motor)
- 3D printer and filament (cheap cost and relative strength)
- Onshape
- Ultimaker cura

### 6.1.2 Equipment list

- Super glue
- Hot glue gun & glue sticks
- Sand paper

### 6.1.3 Instructions

All the parts of the sander can be 3D printed or constructed from a rigid plastic. The following steps define the building process of the sander, should the user require legal fair use reproduction.

- Beginning with the body, the pieces of the body are printed in their separate rings or levels and then assembled with super glue.
- The sanding pad needs to be printed along with accompanying motor supports (as can be seen in figure 15). A hole will need to be drilled in the center of the sanding pad that only goes halfway through the pad.
- The hole should be filled with a small amount of hot glue and then the spindle of the motor should be inserted into the hole and secured.
- Once the motor is in place, center the body on the sanding pad and secure it to the motor.
- Proceed to the last step of installing the top cover of the sander and attaching the twist lock.

# 6.2 Paint Gun

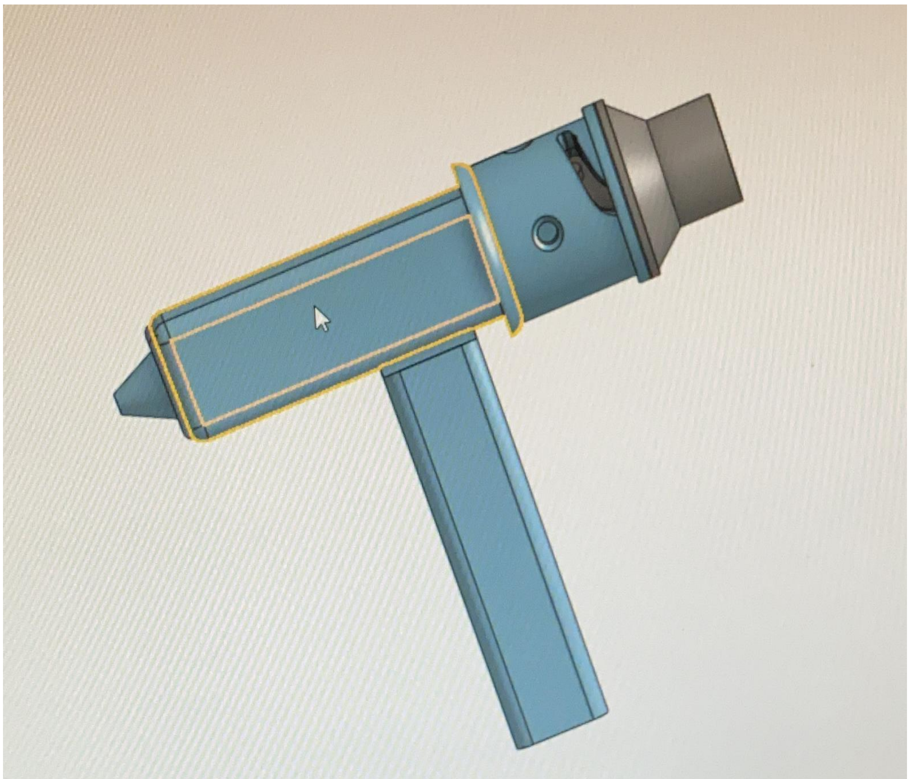

Figure 18: Paint gun 3D model

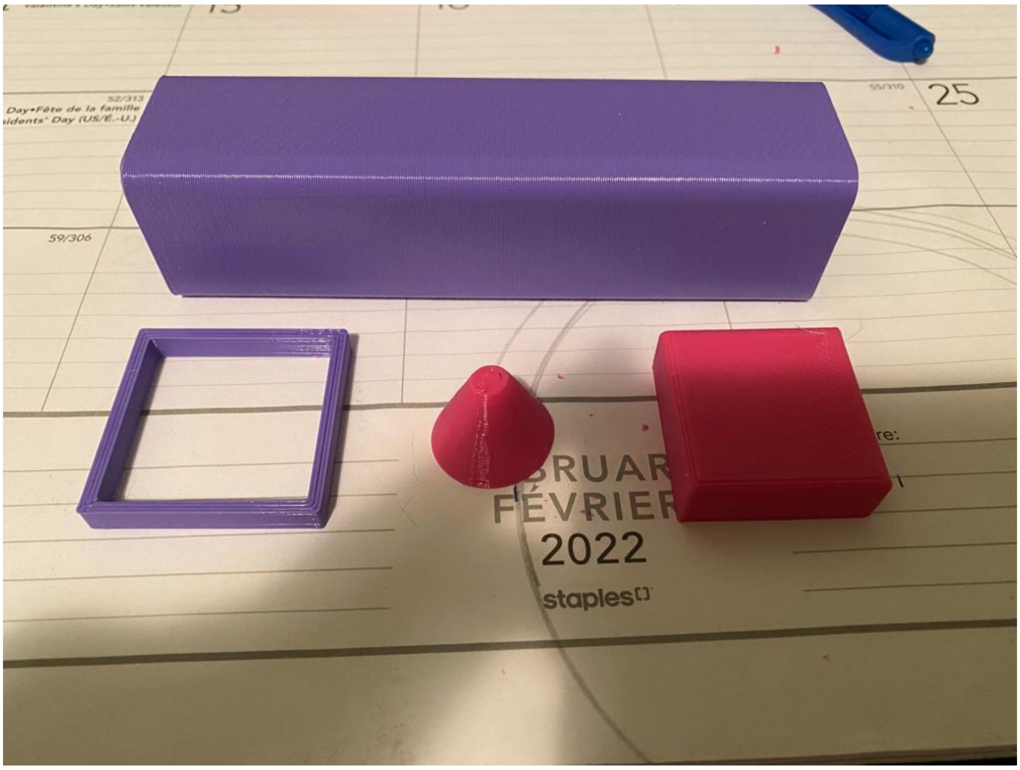


Figure 19: Individual body and nozzle parts

### 6.1.1 BOM (Bill of Materials)

- 3D printer and filament (cheap cost and relative strength)
- Onshape
- Ultimaker cura
- Tubes

### 6.1.2 Equipment list

- Super glue
- Hot glue gun & glue sticks

### 6.1.3 Instructions

All the parts of the paint gun can be 3D printed or constructed from a rigid plastic. The following steps define the building process of the paint gun, should the user require legal fair use reproduction.

- Beginning with the body, the pieces of the body are printed in their separate levels and then assembled with super glue.
- The nozzle of the paint gun is inserted into the body of the paint gun from the top, after smoothing out edges.
- The nozzle should then be holed at the top by a drill to accommodate for spraying.
- Once the nozzle is in place, secure it to the body of the paint gun by use of hot glue.
- Proceed to the last step of installing the cover of the paint gun and attaching the twist lock.

## 6.3 Testing & Validation

First the sander was subjected to a short test to determine whether or not it could run. Once determining the sander could run it was then subjected to a longer test to see if it could run for a prolonged amount of time. Once determining that the sander could run for a prolonged period of time the sander was then tested in conjunction with an IR sensor to test the safety programs of the sander upon which the motor burnt out and testing ceased. Please view details regarding these tests and their validation in documents “Deliverable F – Prototype 1 and Customer Feedback”, “Deliverable G – Prototype 2 and Customer Feedback” and “Deliverable H – Prototype 3 and Customer Feedback”, available on MakerRepo, links provided in APPENDIX I.

# 7. Conclusions and Recommendations for Future Work

The process of designing a robotic arm was challenging, but it taught us a lot. If we were given this project again, or if we had a few more months to work on it, we would focus more on the robotic arm's IK solution to work effectively with the GUI, and make sure that the end effector is able to apply the correct force against the rusted hull plates, causing effective sanding between the end effector and the rust. The IK solution component of the design process, as well as being able to correctly move around the arm to its proper spot whenever needed, was by far the most difficult part of the process. The major movement portion of the arm is complete once the general inverse kinematics is up and running, and the attention can be placed on the end effector and the GUI.

Overall, the most challenging element of this design process is ensuring that the arm and end effector can move as requested with the GUI to perform tasks. Building physical prototypes from scratch was definitely tough, along with the fact that all prototypes required upkeep and technical oversight to function well. The reader must understand that software is as important as hardware, if not more. Focusing on the software components of the RSRA first  is suggested for any future work or developments.

If given extra time, we would have spent the remainder of our time and effort on the end effector and its capacity to produce enough friction on the wall to remove the rust. We would also devote a significant amount of work to developing a more attractive and user-friendly interface with additional features to assist the end user. The idea of a mobile GUI was abandoned at the last minute, due to its inability to control the robot effectively. Mobile GUI integration along with extra safety considerations such as an ultrasound sensor installed in the end effectors would make the RSRA one of the best robotic arms on the market.

# 8. Bibliography

Copyright Act, Justice Law Website, Government of Canada, 1985. Accessed on: April 08, 2022. Available: Copyright Act (R.S.C., 1985, c. C-42)

# APPENDIX I: Design Files

See the MakerRepo repository for further details regarding this product; available: MakerRepo, published: March 18, 2022.

See the table below for details regarding this project's proposal. Also find links to relevant technical documentation.

**Table 3. Referenced Documents**

| Document Name | Document Location and/or URL | Issuance Date |
|---|---|---|
| Inverse Kinematic Solver Project Proposal | https://makerepo.com/project_proposals/266 | March 09, 2022 |
| Deliverables | Project Files | – |