GNG1103F

**Design Project User and Product Manual**

**Metal Sampling Inside a Tube**

Submitted by:

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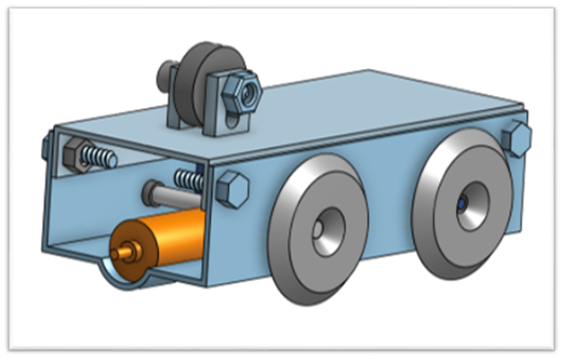
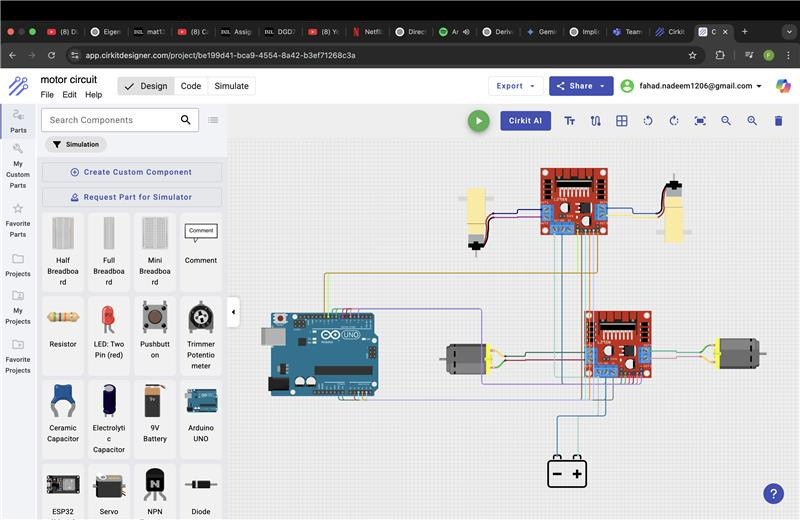
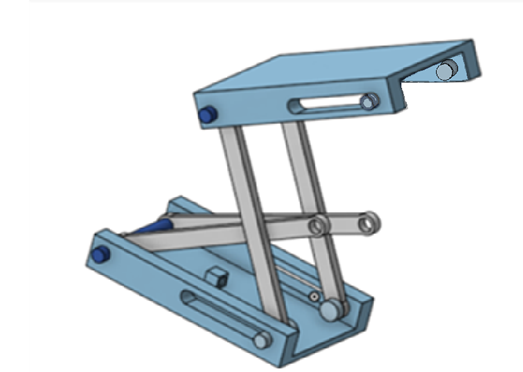
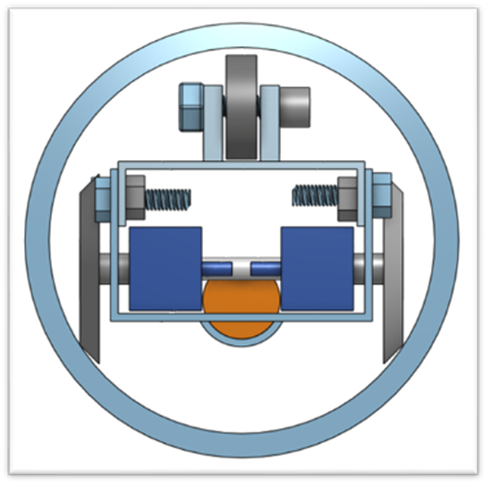
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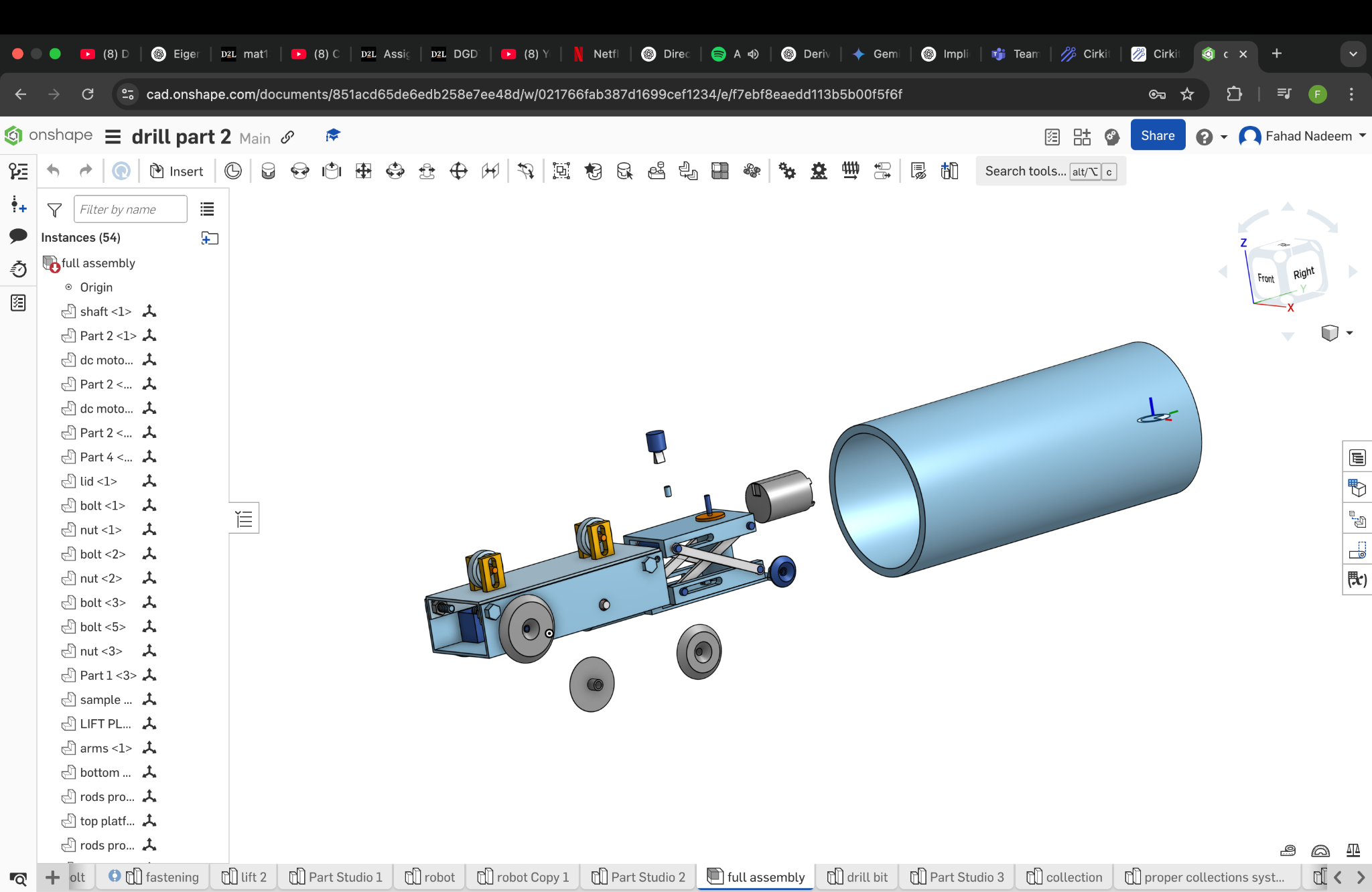
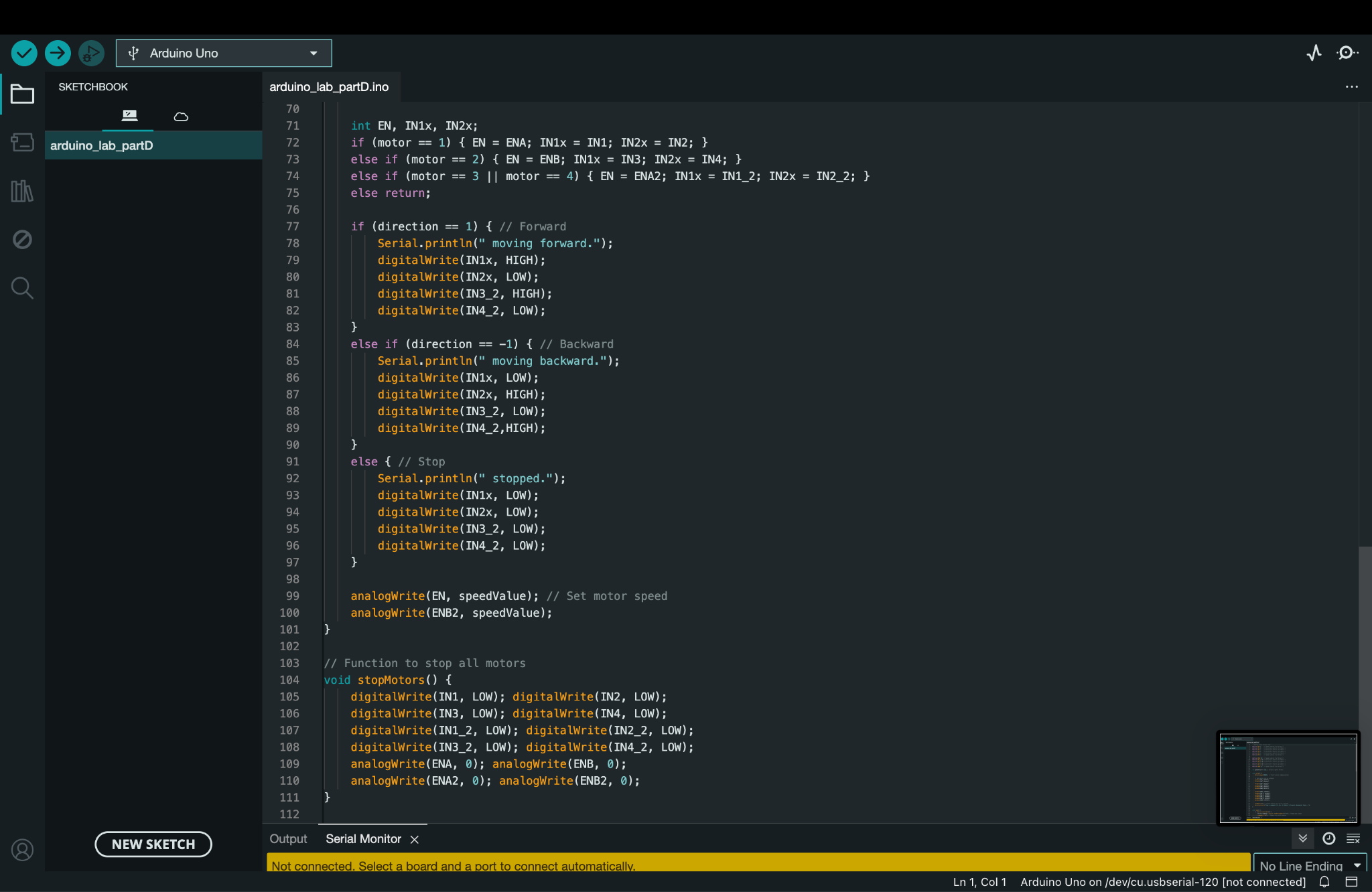
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**List of Acronyms and Glossary**

Table 1. Acronyms

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| CNL | Canadian Nuclear Laboratories |
| BOM | Bill of Materials |
| PLA | Polylactic Acid |

Table 2. Glossary

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Scissor Lift | A mechanical lifting mechanism used to raise or lower an object vertically. |
| Piezoelectric Sensor | A sensor that detects pressure or vibration changes. |
| Arduino | A microcontroller platform for simple automation and control of electronic components. |

# Introduction

This User and Product Manual documents the design, operation, and maintenance of a prototype created for Canadian Nuclear Laboratories (CNL), addressing the challenge of collecting metal samples from the interior of nuclear storage tubes. These tubes are often located in high-radiation or restricted-access environments, where traditional sampling techniques are unsafe or inefficient. The prototype is a mobile, modular system for safely extracting metal samples from inside nuclear storage tubes, especially in high-radiation or low-access environments.

Designed for safe use by technical operators, this guide enables anyone — regardless of engineering background — to set up, use, troubleshoot, or replicate the device. Its modular construction and documented circuits/software ensure it can be adapted, scaled, or improved by future users.

This manual is intended for use by CNL engineers, technical staff, or future developers who may operate, repair, or improve the prototype. The design emphasizes safe remote operation, modular construction, compact size, and the ability to store collected samples without contamination.

It includes:

* Setup and operating procedures
* Troubleshooting and maintenance guides
* Detailed subsystem documentation
* Recommendations for future enhancements

The aim is to provide a fully transparent, reproducible design that supports CNL’s mission in advancing nuclear safety and innovation.

# Overview

### Project Context

CNL requires a portable, fail-safe tool to extract small metal samples (30–80 mg) from deep inside 4.572 m (15 ft) nuclear storage tubes with a 101.6 mm (4 in) diameter. These tubes may be vertical or horizontal. Existing sampling methods pose contamination, radiation, and accessibility risks.

### Design Objectives

* Store samples in a container without operator contact
* Adjust sampling depth remotely
* Provide feedback on sample weight
* Be modular and fail-safe for easy removal and transport
* Include all necessary power sources

**Key Features**

* Compact, motorized mobility system
* Modular scissor-lift with a mounted drill
* Two 3D-printed sample collection systems
* Piezoelectric sensor for real-time sample feedback
* Arduino-based circuit with full motor controlA toy train on a black surface

  AI-generated content may be incorrect.

## Conventions

* Action: indicates steps the user should perform
* Measurements are in metric (unless noted otherwise)

## Cautions & Warnings

* Do not operate near water or high heat
* Keep hands clear of drill and lift during operation
* Disconnect power before handling wires or motors
* Ensure correct polarity on motor drivers to avoid failure

# Getting started

This section explains how to set up and operate the prototype from unpacking to shutdown. It is written so that non-technical users at CNL can follow the steps without needing engineering knowledge.

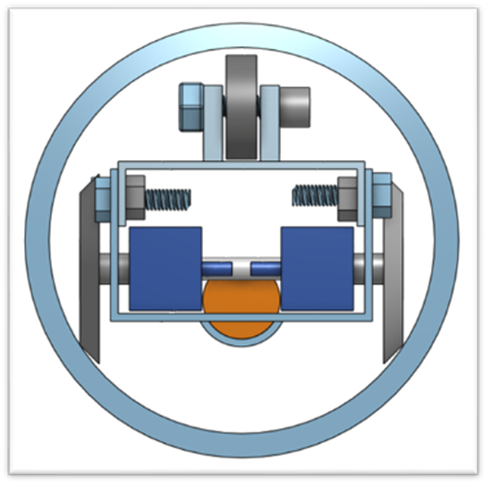
## Configuration Considerations

This is a physical prototype intended for metal sampling inside of 4-inch tubes.

Setup needed:

* Dry workspace
* Wall power (optional but preferable)

Tools:

* Laptop/Computer
* Arduino IDE

*Figure 1: System preview inside of the tube*

## User Access Considerations

Describe the different users and/or user groups that could be using the prototype, and the restrictions placed on accessibility or use for each.

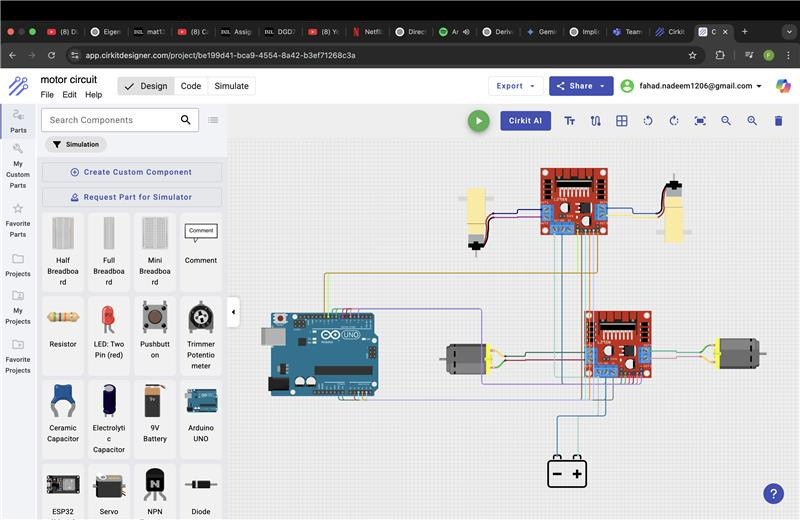
|  |  |
| --- | --- |
| User Role | Responsibility |
| Operator | Places the rover at the entry of the tube and runs the prototype using pre-installed code |
| Maintainer | Modify code and services wiring/components |

Operators interact only with physical controls. Only maintainers should attend to the code and rewire circuits if needed.

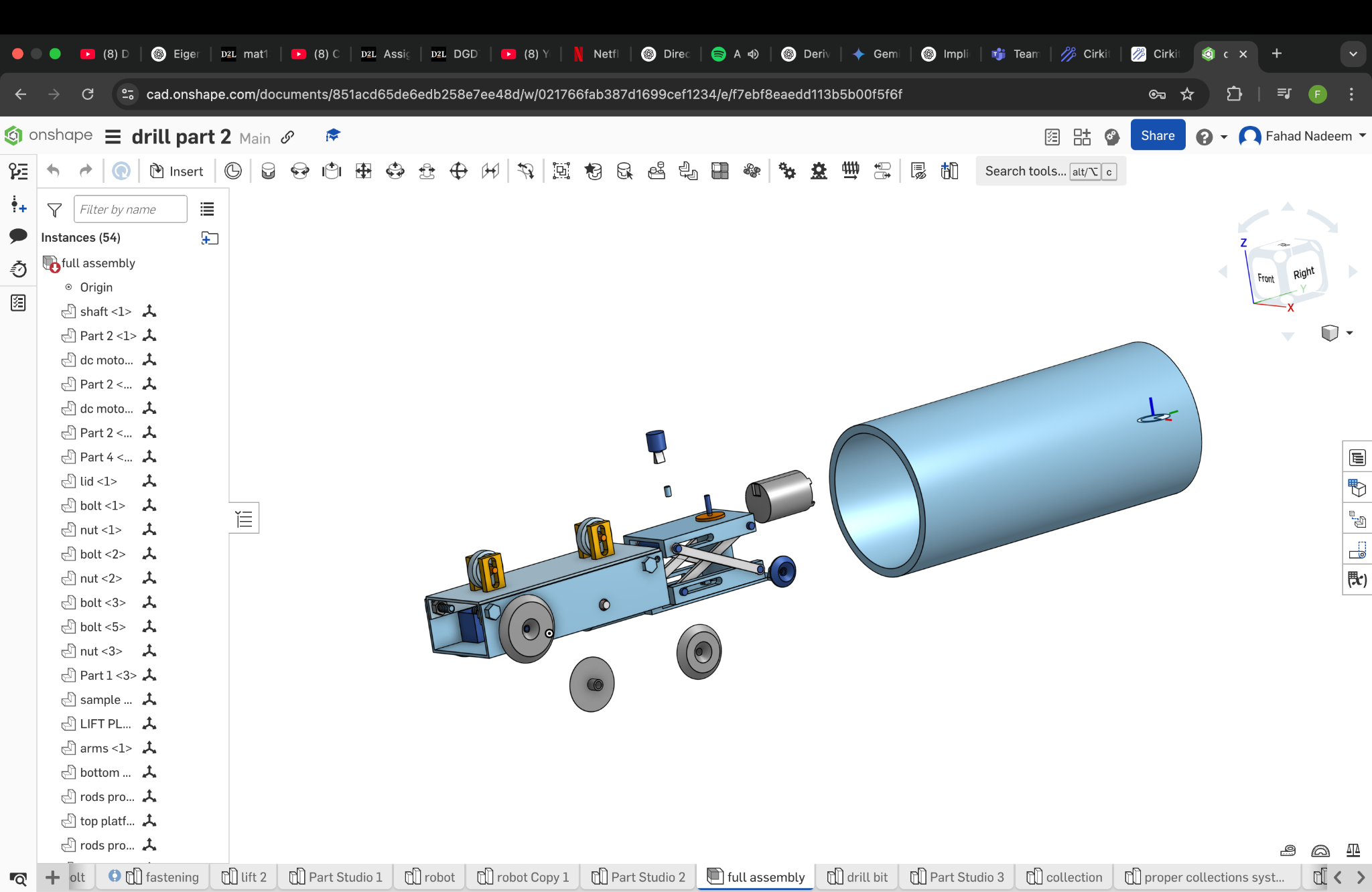
## Accessing/setting up the System

**Step 1: Assemble Arduino Circuit**

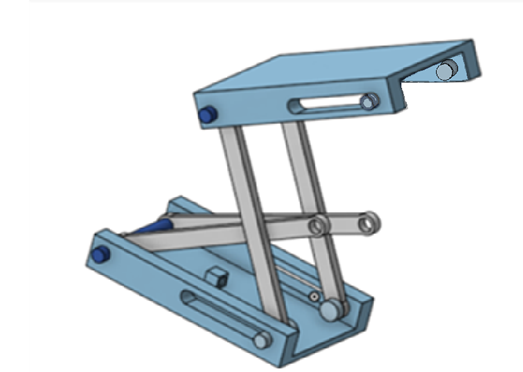
**Action:** Reproduce schema below (Figure 2). Ensure each pin is in the correct spot and if they’re all in place.

*Figure 2: Schema of Arduino Circuit (bigger picture available* [*here*](https://ibb.co/zWM6X1Hy)*)*

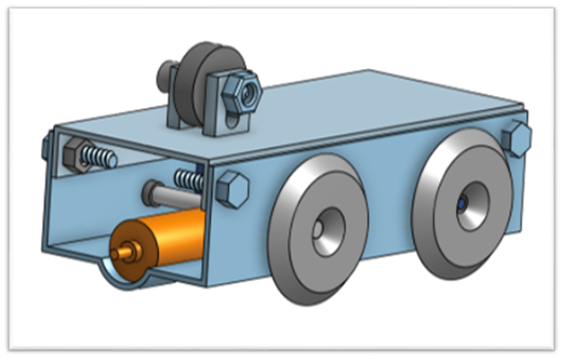
**Step 2: Assemble chassis** **Action:** Reproduce figure below (Figure 3).

****

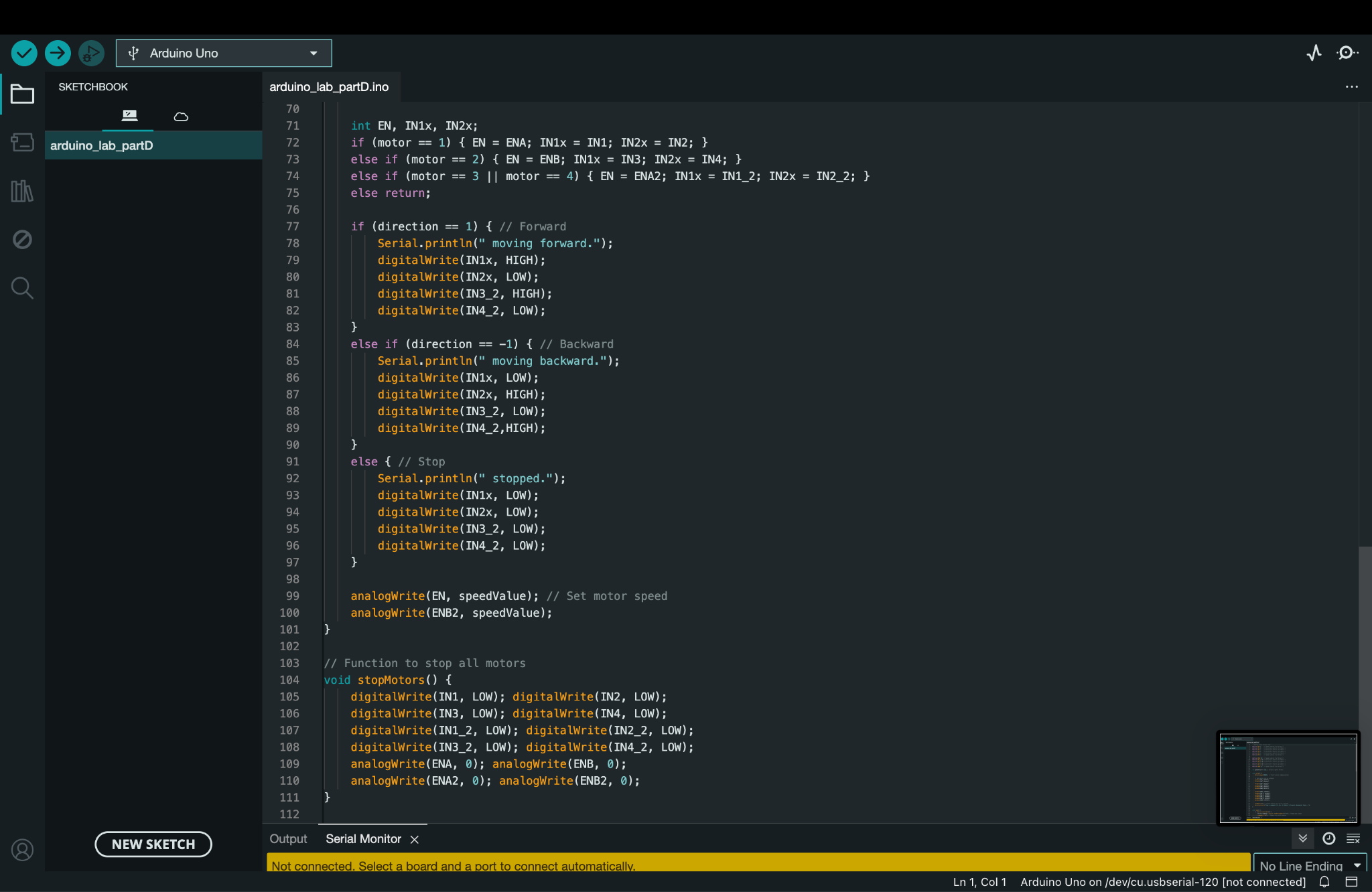
*Figure 3: Chassis assembled*

**Step 3: Assemble Frame  
Action:** Bolt 3D-printed chassis and scissor lift in place.

*Figure 4: Scissor lift assembled*

*Figure 5: chassis assembled*

**Step 4: Upload Arduino Code**

**Action:** Connect the Arduino circuit to your laptop/computer and upload the pre-installed code into Arduino IDE. 

*Figure 6: Preview of the Arduino code in Arduino IDE*

**Step 5: Position System**

**Action:** Insert robot at the entry of tube. Ensure it's aligned and unblocked.

**Step 6: Begin Operation**

**Action:** Power motors through wall-power (preferable) or through the power supply.

## System Organization & Navigation

### 3.4.1 Scissor Lift

The front holes are held together with a solid metal rod to keep the scissor arms fixed in place. At the back, the arms are attached with screws through sliding slots, which allows the mechanism to expand and contract for vertical movement. The motor is glued to a lead screw that is threaded through a nut. The bottom screws are glued to said nut which makes it possible to move up and down.

### 3.4.2 Wheels

Rear wheels are both connected to motors while the front wheels are connected to each other with 3D printed rods (same ones used in assembling the scissor lift). Top wheels are loosely screwed to 3d-printed parts glued onto the top of the robot. All wheels have a rubber layer to ensure proper friction inside of the tube.

### 3.4.3 Arduino Circuit

Each motor is soldered to the circuit via 20-feet braided speaker wires. These wires double as fail-safe in case of failure for the robot to come back by itself. The circuit itself is powered by a power supply or by power from the wall.

## Exiting the System

After the sample is drilled and safely stored, entering “B3” in the Arduino IDE terminal will make the robot move backward and come back. In case of failure to come back, you can gently pull onto the braided wires to retrieve it. You can now close Arduino IDE, unplug from your laptop/computer and finally unplug from the power.

# Using the System

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

## Movement and drilling

There is no way to graphically represent how to use the machine as the machine itself is very simple in nature. The wires at the rear of the robot are run into a circuit that is connected to a computer. On this computer there is code sent to the Arduino that gives instructions the machine. The command F1 for example moves motor 1 to move forward. On the contrary B2 would make motor 2 move backwards. There are 4 motors. 2 are located on the back wheels, one controls the scissor lift and the fourth controls the drilling piece. The only other function is the response of the sensor to a weight being put onto it. This output is transferred back to the computer screen. The computer does not matter if it is attached to the circuit and can run the required code.

# Troubleshooting & Support

The next section will describe the error conditions and error behaviours of the mechanism. The subsections of this category include error behaviours, maintenance, and support. How these errors are encountered and how to fix them is this section's focus.

## Error Messages or Behaviors

The first error message/sign that will appear is if the robot stops moving. This can be a failure to move backwards or forwards. Another error that can appear is the failure of the lift system. This is connected to the failure to drill which is also a basic electrical failure. Most problems that will arise are electrical and circuit related. These problems would most likely be fixed by reconnecting part of the circuit back together. The main way to retrieve the machine in case of failure is to pull on the fail safe (The rope at the rear of the robot).

## Special Considerations

There aren’t any special considerations during errors. This robot is a very simple design to use effectively.

## Maintenance

Maintenance is not a very important part of this robot. Basic maintenance must be performed if a piece is broken or is damaged in any way. Most parts are 3D printed and thus must be reprinted if they are compromised. The circuit should be replaced after extended periods of use due to the wires getting loose, frayed, and worn out. Other than this, the maintenance on this robot is minimal.

## Support

If further support is needed, then the creators of the machine must be contacted. Feel free to contact.

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phone number: \_\_\_\_\_\_\_\_

# Product Documentation

Three weeks before Design Day, we unfortunately lost a crucial member of our team. With little time and quite the small budget we decided to do a whole redesign after debating on the feasibility of our original prototype. We settled on this robot with a scissor lift mechanism to be able to move back and forth inside of the tube without scraping it all the way.

At first, we went with a 20-feet ethernet cable to connect the motors with the Arduino circuit as it was quite cheap. However, we couldn’t make the system work due to the wires being too thin. After searching for an alternative, we found speaker wires which fit perfectly what we needed with a big plus on the fact that it was similar in price to the ethernet cable.

We were very insistent on the system being wired compared to some other teams who decided to go wireless as it was generally cheaper and less of a headache. The reason we wanted it to be wired was, due to the radiation in the tube, wireless connectivity is quite unreliable, which would be unacceptable for our client. Since our goal was to create a realistic and functional prototype that meets the client’s needs, we explored different ways to implement a wired system. In the end, we successfully made it work while staying within our budget.

We split our prototype into two subsystems: mechanical subsystem and electrical subsystem

## Mechanical Subsystem

### BOM (Bill of Materials)

|  |  |  |
| --- | --- | --- |
| Material | Cost | Link |
| PLA Filament | $7.00 | [Makerstore](https://makerstore.ca/products/pla-filament?pr_prod_strat=collection_fallback&pr_rec_id=d83a55469&pr_rec_pid=10478015709240&pr_ref_pid=10478018363448&pr_seq=uniform) |
| Super Glue | $3.99 | [Amazon](https://www.amazon.ca/CYAFIXED-All-Purpose-Superglue-Cyanoacrylate-Adhesive/dp/B0CJ7WPJN2/ref=sr_1_3_sspa?crid=1OUSZE0FIIYUO&dib=eyJ2IjoiMSJ9.Lk4aMrg_0favAkpZLu5QsYDJYulvP3pfZS8a_yQUu-d_yo1MzB9ttKkqNHX5CFXKBmsd4zuotKVDp8MdmgbyO_3lS-AE_npqfBdE8xwbaVtbxQCrB1zIYlGJHRoyXUsFAsKAxCQBBTJwGWquU08fwVar9tfMD8IhCM4iQa3kXxzd8VanFbpO-d2RnuE3Ti62BkSXKjzna-2LSu-6iR1Od3mtEQ28QKfcs9eYt3oudAJGLEL8yjQ1EWnIA0TDh3FFixKuNBfPwNEzndGF9-hYOA9JLSDeO63IZVK2pnh2yyg.fOfkmqbySKfUPgprYxSiPsAQUP82Ft4xxuwGAi6qqkE&dib_tag=se&keywords=plastic%2Bglue&qid=1740973568&s=toys&sprefix=plastic%2Bglue%2Ctoys%2C137&sr=1-3-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&th=1) |
| Burr Dril Bit | $10.99 | [Amazon](https://www.amazon.ca/Tungsten-Carbide-Rotary-Double-Grinder/dp/B0878S2KN4/ref=sr_1_2_sspa?crid=17WCJEULDVNNH&dib=eyJ2IjoiMSJ9.xwvxrP0H2LXl32fplB_e-Bp-0zJymrF7lqxMhqD_17B_jDgwv49Y3jlW-gBldDJrLRRXTruN6V3j_Z6YvA94GTmw09SMSdbrdb2IDvL1VpS_z4M2qL0XNceACD8vFqWq52TGe6sCoA8S2UdB0OoP_EvNqpJqeZd1v1pGoqgqRQ2VS1527huPOrbUwbQnADdqReTnhFcGPacszrzHb56B_pxRaP05F9mmOAHNOLUBJ1NvWrxOT34UDcTk9wQgTxn-zlkxLsPtOIZ55QrfDMrAYrDL77ALNsv0QqfONQovVNk.SkpPt3LUr7CxaMWTqk3YNTBDKaHm2beLzWWDDDIeYxM&dib_tag=se&keywords=carbide+burr+drill+bit+round&qid=1742430128&refinements=p_85%3A5690392011&rnid=5690384011&rps=1&s=industrial&sprefix=carbide+burr+drill+bit+round%2Cindustrial%2C210&sr=1-2-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1) |

### Equipment list

* 3D printer
* Miller machine (or anything that can cut metal)
* Hand tools (screwdrivers, file, etc)

## 6.2 Electrical Subsystem

### 6.2.1 BOM (Bill of Materials)

|  |  |  |
| --- | --- | --- |
| Material | Cost | Link |
| 12v DC Motor 200 RPM | $7.00 | [Amazon](https://www.amazon.ca/gp/product/B08G7ZZL8G/ref=ox_sc_saved_title_7?smid=A3JOHF46I0Y2WZ&psc=1) |
| 12 Volt DC Motor 100 RPM | $11.99 | [Amazon](https://www.amazon.ca/Electric-Gear-Torque-Reduction-Engine/dp/B08G8DQ8DC/ref=sr_1_10?crid=KIS27PFV6V88&qid=1743990028&s=toys&sprefix=12+volt+dc+motor+%2C100+rpm%2Ctoys%2C138&sr=1-10) |
| Speaker Wire | $11.00 | [Amazon](https://www.amazon.ca/AmazonBasics-16-Gauge-Speaker-Wire-Feet/dp/B006LW0W5Y/ref=sr_1_5?crid=2KRII6IBNJP3P&dib=eyJ2IjoiMSJ9.ViyS_w0a5jI7HGiNi9ofWJkSVZ8ztWS16u9m4pY3DS6-e-9ECDsYyCOpX_zlxlT2Q-5DOj1G5IuDWJTWUBK3jyJmDi2cgr9L2sdaKmFv-qol8cf3z9wwNoZW18OgiFXnvxl85o9uqEmrIcXxs2wcRgyBznnL46fTuFyjo4dj_1TNX2-kmlVENT_f74wBQ67gVD0I2Z48QFodWB988bTz8mZVwIymhaGxN6X1OpVLIbaA5I-uoGlwxtmwNTeRC4h1k2hlds7fo4DGedxZJUpz0eyhqpFQgUd5vJWJRMN1714.7nJAC3IYkQJQDkEdm1OACyHIzxXfnmjVXdOOiMqNqBQ&dib_tag=se&keywords=speaker%2Bwire&qid=1743988864&sprefix=speaker%2B%2Caps%2C115&sr=8-5&th=1) |
| Arduino Uno R3 | $15.25 | [Makerstore](https://makerstore.ca/products/arduino-uno-r3-clone) |
| Bread Board | $5.00 | [Makerstore](https://makerstore.ca/products/breadboard?variant=50851844849720) |
| 2pcs Wishiot Motor Kit with L298N Driver | 13.99 | [Amazon](https://www.amazon.ca/gp/product/B09T2N6R53/ref=ox_sc_saved_image_1?smid=A25YCO081YQ7C&psc=1) |
| Jumper Cables | $2.00 | [Makerstore](https://makerstore.ca/products/jumper-cables-pack-of-10?_pos=1&_sid=71ee4921f&_ss=r) |
| Piezoelectric Vibration Sensor 5pcs | $14.59 | [Amazon](https://www.amazon.ca/FainWan-Piezoelectric-Vibration-Piezoelectricity-Compatible/dp/B09V3C5TXZ/ref=sr_1_1_sspa?crid=QKOEJR26OHB1&dib=eyJ2IjoiMSJ9.2iiAgHRxzzYB2aVfGsRaL8UV43NvunZhgG5MFTznymThPFMT598YWL9u5t6zTyoZOVytYUmebr7O-2XZpvPTkLF5gVLUVuSzWuSFFPTD_B9AKZ2FPtJ6CxdXQUumyd3LvpXEoXt5j149EEel-wb8HGiNhZHA_xVMQtV8dVHkcUlRC32xEyClmG3zlpPVf-wJg3YvqIXG4L8lI--Mbjoyd66LdxMwpE49kwECXKMcsFCQ2MITjPsnKvbofB4b7IlDbG7kCP3Xou5NgYkrs7gtFp3509oVcTTEKcgmmvrUlHc.EB4qqRHg2QLSbyttTJSKsce_gdnjF-EcHPWQ2VHKaOY&dib_tag=se&keywords=piezoelectric+Ceramic+Vibration+Sensor+piezo+3.3V%2F5V&qid=1742427730&s=industrial&sprefix=piezoelectric+ceramic+vibration+sensor+piezo+3+3v%2F5v%2Cindustrial%2C108&sr=1-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1) |

### 6.2.2 Equipment list

* Soldering machine
* Hand tools (screwdrivers, etc)
* Wire stripper

## 6.3 Testing & Validation

|  |  |  |
| --- | --- | --- |
| **Test Ran** | **Results** | **Action to Take** |
| Robot can move down the tube and safely come back (horizontal sampling) | No issues encountered | None |
| Controlled Drilling  Mechanism | No issues encountered | None |
| Collection Mechanism | No issues encountered | None |
| Test durability of ethernet cable | No issues encountered | None |
| Testing piezoelectric sensor to see if it works correctly and is not defective | No issues encountered | None |
| Arduino code working correctly | Issue encountered when uploading code sometimes | Close the Arduino IDE and disconnect the circuit from your computer. Then, reopen the Arduino IDE, reconnect the Arduino to your computer, and upload the code again. |

# Conclusions and Recommendations for Future Work

Lessons Learned

We first went with another concept which didn’t come to fruition. The idea was dropped and with a bit more than 2 weeks remaining before Design Day and we, as a group, came up with this redesign. During the design process we were at times unsure about the direction we were going, we should have reacted faster and taken more initiatives. The extra time would have made it possible to come up with a better and more polished prototype. We thought about how to get proper feedback with the piezoelectric sensor but as we were short on time we couldn’t integrate it into our prototype. We did test it to see how it would have worked and found that with more time, this feedback method would have worked.

Future Improvements:

* Improve code to get feedback from sensor
* Add compact casing and dust protection for Arduino circuit
* Get a smaller motor for the drill bit
* Get feedback to know how deep inside of the tube we are
* Could make a pulley for esthetic purposes when doing vertical scraping

**APPENDICES**

# APPENDIX I: Design Files

All design files (CAD, Arduino code, STL, and wiring diagram) are available on MakerRepo [here](https://makerepo.com/Aymeric03/2535.metal-scrapping-robot).