GNG1103

Design Project User and Product Manual

S.C.R.A.P Pipe Sampler

Submitted by:

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Table of Contents

Table of Contents ii

List of Figures iv

List of Tables v

List of Acronyms and Glossary vi

1 Introduction 1

2 Overview 1

2.1 Cautions & Warnings 3

3 Getting started 3

3.1 Configuration Considerations 6

4.1 User Access Considerations 7

4.2 Accessing/setting up the System 7

4.3 System Organization & Navigation 7

4.4 Exiting the System 7

5 Using the System 8

5.1 Drive 8

5.2 Sampling 9

5.3 Retrieval 9

6 Troubleshooting & Support 10

6.1 Error Messages or Behaviors 10

6.2 Special Considerations 11

6.3 Maintenance 11
6.4 Support 11
7 Product Documentation 13
8 Completed Prototype Testing 13
8.1.1 BOM (Bill of Materials) 16
8.1.2 Equipment list 16
8.2 Testing & Validation 17
9 Conclusions and Recommendations for Future Work 19
APPENDICES 20
10 APPENDIX I: Design Files 20

List of Figures

Figure 1: Completed Prototype
Figure 2: User Interface Prototype
Figure 3: Front Plate Prototype
Figure 4: Final User Interface

List of Tables

Table 1. Acronyms vi

Table 2. Referenced Documents 20

List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
S.C.R.A.P	Sample Collection & Retrieval Automatic Probe
UPM	User and Product Manual
BOM	Bill of Materials

1 Introduction

This User and Product Manual (UPM) provides the information necessary for chemical plants to effectively use the Sample Collection & Retrieval Automatic Probe (S.C.R.A.P) and for prototype documentation.
The followings are the tasks had been completed to deliver the final prototype:

- Client research and product benchmarking
- Problem defines
- Ideation
- Dividing entire conceptual design into several prototypes, make test plans for each functional performance

This UPM includes the overview of the project for brief background introduction; the progresses implemented to ensure the reproducibility so the audiences who might want to reproduce the prototype; prototype system introduction for users/potential users who want to reproduce the prototype; trouble shooting includes addition instructions; and future works describe the possible plans and ideas that could help optimizing the current prototype.

2 Overview

A tool is needed that can reach up to 15 ft deep inside a fuel line that has 4 inches of inner diameter to obtain pipe samples; to avoid the unnecessary cost of replacing the pipe, the tool should only collect 30 to 80 mg of the sample per operation. The sample needs to be isolated upon collection until the examination stage, the sample should be stored in a container once collected.

To ensure user safety the user must never encounter the collected sample. To prevent contact the scraping head is connected to a sheet metal sleeve which covers the sample after the spring has been actuated and the sample has been collected in the sample tray. Once the sampling process is complete, the wire can be removed from the device and the whole device can be shipped for sample testing. The user also has access to failsafe systems in case of device failure. The device also does not cause any significant damage to the reactor when collecting a sample which extends the time before needing to make any replacements in the reactor.

The main difference between S.C.R.A.P and other similar products is that our product uses wheels and an interface to effortlessly move down the pipe without any need for manual work. This allows for any one trained employee to operate the device. The device is also very light and cost

effective which allow for users to easily transport the device, and have a backup while tests are being run in case of needing further testing.

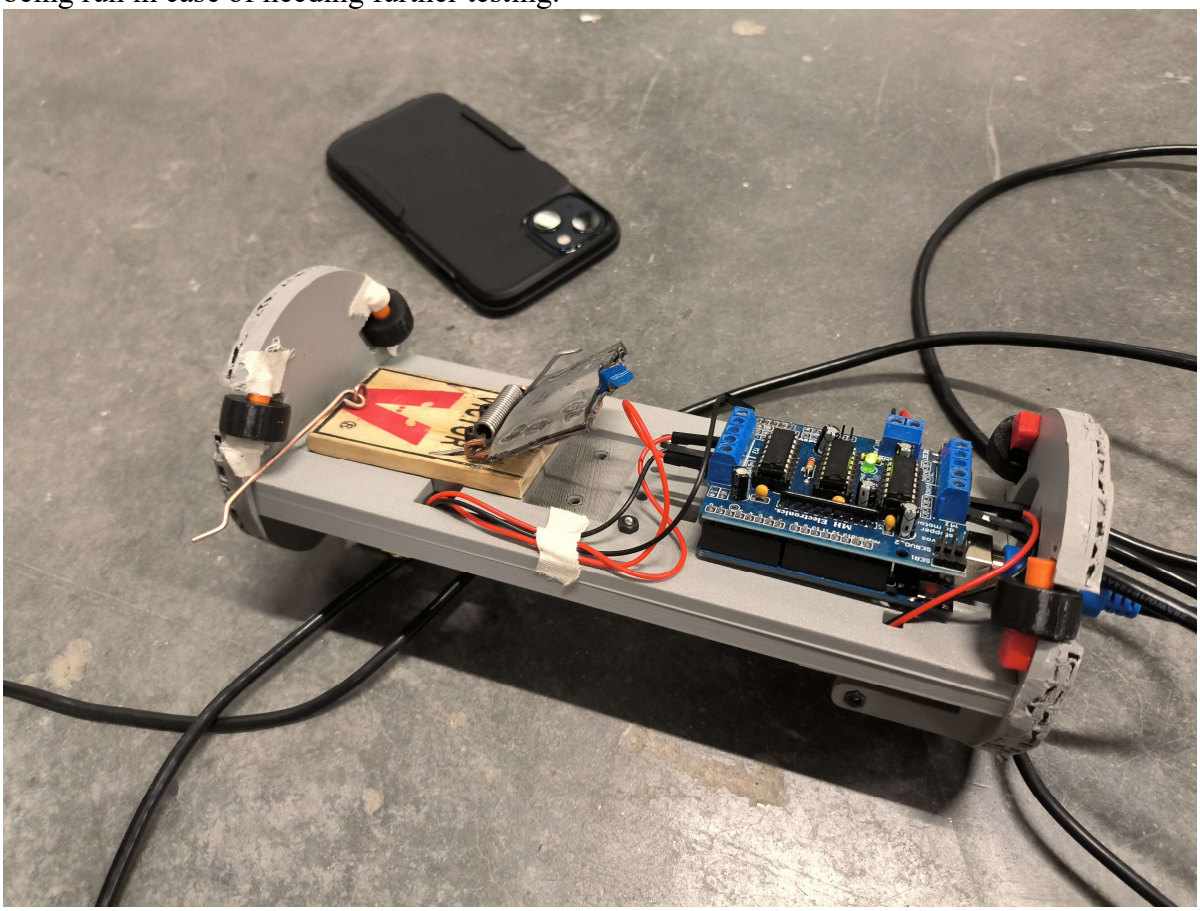


Figure 2.1 final prototype

S.C.R.A.P is designed with efficiency and ease-of-use in mind. Its key functions include deep pipe access up to 15 feet, precise sample collection (30–80 mg), and secure sample containment. The device isolates the collected material immediately after retrieval, ensuring no user contact. The built-in failsafe system provides reliability in case of malfunction, and its minimal impact on the pipe walls helps extend the lifespan of the reactor. The tool's mobility system allows it to move effortlessly through the pipe, reducing manual labor and enabling operation by a single trained user. Its lightweight and cost-effective build make it ideal for field use and easy transport.

The system features a durable and lightweight PLA frame with wheels that guide it smoothly through the pipe. A spring-loaded mechanism controls the scraper head for precise sample

collection, which is then sealed inside a sample tray. The device includes a simple user interface. Once deployed, no complex setup is required: the user simply inserts the tool, activates the system, and retrieves it once sampling is complete. In the event of failure, accessible failsafe measures ensure recovery without safety risk. The tool is designed to be shipped directly to a lab with the sample safely sealed inside, avoiding unnecessary handling or contamination.

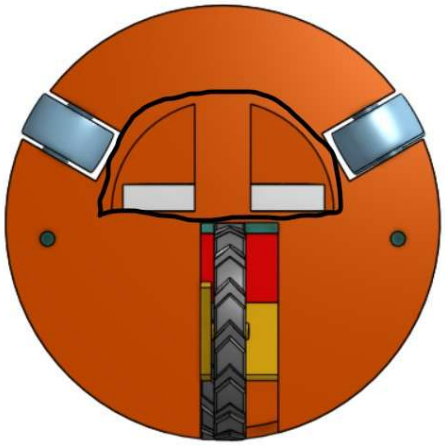
2.1 Cautions & Warnings

The CANDU 6 Pipe Sampler includes moving parts, electrical components, and a high-tension torsion spring from a mouse trap, which can be hazardous if triggered unexpectedly. Keep hands away from the sampling mechanism and DC motors when the device is powered. Always disconnect power before performing maintenance. Designed for use in 4-inch diameter pipes, improper operation may lead to damage or injury. The system is not waterproof, so avoid exposure to moisture. Maintain a safe operating distance of at least 15 feet and fully retract the probe before handling. Users are responsible for safe usage, and modifications may require approval from component manufacturers.

3 Getting started

1. To begin using S.C.R.A.P., first plug in the USB-B cable into your computer and the device, launch the UI and test the motors outside of the pipe by clicking on the FORWARD and BACKWARD buttons.

2. If extended, reel back in the spool rope.
3. Tie the rope from the spool onto the back bulkhead of the device and plug in the Arduino through the same hole.



4. Carefully, arm the mousetrap by placing the wire under the metal plate and place the device in the pipe, with the motorized wheel down and rollers on top.
5. Hold the FORWARD button on the UI until the 15th black marking on the rope, and release.
6. Press down on the Sample button in the UI.
7. Hold the BACKWARD button in the UI, until the device can be retrieved by hand.
8. If the device gets stuck in the tube, reel the device back in using the retrieval spool.

STEPS 5 AND 7 ARE ASSUMING HORIZONTAL ORIENTATION: For vertical orientation, slowly extend the available rope on the spool until the 15th black marking on the rope is reached.

9. Send the device in to the lab for testing, DO NOT OPEN THE MOUSETRAP WHILE SAMPLE IS INSIDE.
10. When the device is returned, ensure to press the RESET button to reset the sampling motor.

3.1 Configuration Considerations

The CANDU 6 Pipe Sampler is a remotely operated device designed to collect metal samples from inside a 4-inch diameter pipe. It consists of several key components:

- **Drive System:** Uses DC motors and traction wheels to move through the pipe.
- **Sampling System:** A high-tension torsion spring (from a mouse trap) collects metal shavings when activated.
- **Collection System:** Securely stores the sample after retrieval.
- **Electronics:** An Arduino Uno R3 controls the motors and sampling mechanism via a motor shield.
- **User Interface:** A computer-based GUI allows the operator to send commands and receive feedback.
- **Retrieval System**: A spool used to reel out the device if the drive system fails.

4 Setup Requirements:

- **Tools Needed:** Screwdrivers, pliers (for maintenance), and a computer for GUI operation.
- **Connections:** Powered by an external battery pack, communicating with the Arduino via USB.

4.1 User Access Considerations

The prototype was designed for operators who have knowledge of basic mechanical systems, the only potential risk of this prototype being the sampling component, since it consists of quite strong spring trigger with a welded lathe bit that able to cut steel, the user group should know how to avoid the undesirable damage from the prototype.

4.2 Accessing/setting up the System

To operate the physical prototypes, the user needs to download [] to access the Arduino, there is a software that developed for this prototype. Through the software, users can control the system moving and triggering the sampling system.

4.3 System Organization & Navigation

This prototype consists of one R3 Arduino board, one motor controller, four motors, one sampling component, one battery mount, one usb-B cable, two bulk heads, and one electronic tray. Assembly each part by following the instructions, before formal operation, manually set up sampling system is necessary.

4.4 Exiting the System

To exit the system, the user can directly control the prototype back up via software. If the prototype gets stuck in the pipe, the user could pull the failsafe tether by rolling the spool to withdraw it.

If the user never triggers the sampling component, please be careful when touching the prototype, and release the sampling component carefully if manual operation is necessary.

5 Using the System

The Sample Collection and Retrieval Automated Probe has various user functions to complete its sampling procedure. User functions are controlled through the UI, however the mousetrap must be set manually. These user functions are divided into the following subsections: Drive, sampling, retrieval.

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of S.C.R.A.P.

5.1 Drive

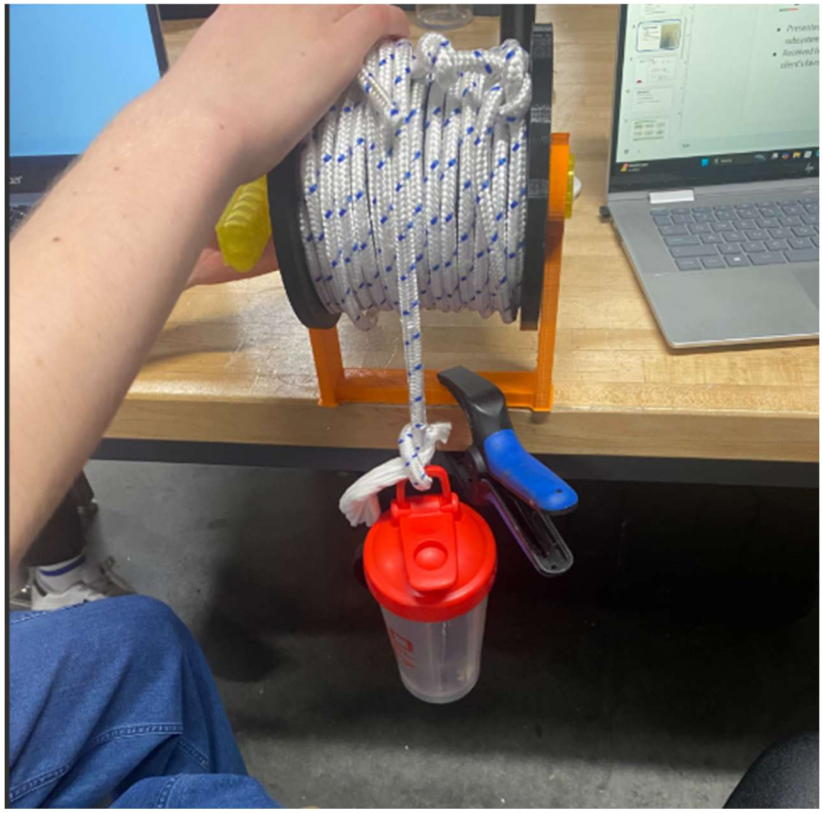
S.C.R.A.P. relies on a motorized drive system to reach 15 feet into the pipe in the horizontal orientation. This drive system is controlled through two buttons on the UI, FORWARD and BACKWARD. As expected, FORWARD causes the wheels to carry the device forward into the pipe, while BACKWARD causes the wheels to carry the device backwards out of the pipe.

***IMPORTANT: THE BUTTONS ARE NOT TOGGLED AND MUST BE HELD DOWN TO FUNCTION**

5.2 Sampling

To collect a sample, the device uses a mousetrap to generate enough force to knock a metal bur off the pipe. The sampling mousetrap must be cautiously armed manually right before placing the device in the tube. When the device is 15 feet into the pipe, press the Sample button on the UI to activate it. Following the retrieval of the device, ensure to press the RESET button to give the sampling activation string enough slack to rearm the mousetrap.

5.3 Retrieval



In the event of a drive failure, the retraction device must be used to retrieve S.C.R.A.P. The rope must be tightly wrapped around the spool and tied onto the back bulkhead beside the

Arduino connection cable. The rope will extend as the device goes into the pipe and can be reeled back in using the handle on the spool upon any failures in the drive system.

In the vertical orientation, the retraction system is also used in replacement of the motorized wheels in the drive system. The rope must slowly be extended, reeling the device into the pipe until the 15-foot mark, where then the sampling procedure is done as in the horizontal orientation.

6 Troubleshooting & Support

Drive Issues

1. If wheels don't spin, check connections and battery charge.
2. If one wheel doesn't spin, check connections and motors.
3. If wheels spin, ensure they spin the same direction. If not swap the connectors on the motors.
4. If the wheels spin with low power, charge batteries.
5. Check if wheels are being blocked by anything and clear it (Cables/loose PLA)

Sampling Issues

1. If mousetrap doesn't actuate, tighten the sampling string and check sampling motor.
2. If the mousetrap spring is not strong enough, replace mousetrap.
3. Carbide bit may dull and need to be replaced after repeated use.

6.1 Error Messages or Behaviors

- Mousetrap will become weaker over time, creating the need for a replacement. This will be indicated by less force being required to set the trap.

- If the wheels spin in opposite directions swap polarity (switch the connection between the two motors to the Arduino)
- If the wheels sound like they are spinning non-uniformly, check for blockages in the wheel well and motor strength.

6.2 Special Considerations

If the pipe is sagging or has a connection, the bulkheads may need to be sanded down to fit through the pipe. Additionally, large bumps in the pipe may set off the mousetrap, requiring the plate holding the wire to be bent in

6.3 Maintenance

- The spring in the mousetrap will need to be replaced after some use. This will vary, however will be required after around 15 uses.
- Motors will gradually lose power until they will no longer be able to traverse the pipe. At this point they will need to be replaced.
- Batteries will need to be recharged often, and replaced when the motors will no longer have the power to traverse the pipe.

6.4 Support

For additional support, consult the MakerRepo entry for S.C.R.A.P. If more support is required, email your problem to Ben Krzymien at bkrzy104@uottawa.ca. Identify the problem

clearly in the email and make sure to include any modifications made to the design or troubleshooting already completed.

If hit by the mousetrap and you suspect that your finger is broken, go to your nearest emergency room immediately.

7 Product Documentation

After our meeting with the client our design underwent some changes. The client was concerned about our wheels slipping upon entering the pipe, which would make calculating the proper distance travelled difficult. As a result, we decided to add a tether which is exactly 15 feet so the sampler cannot overshoot and doubles as a failsafe method. We also used his feedback to finalize some of our concepts which we would include in our final design. In our second meeting our client was worried about our sampling system not being able to scrape steel with a motor. After further testing we have landed upon a mousetrap design for our sampling system.

Drive:

The drive system for our design includes wheels which allow the device to move further into the pipe when the pipe is oriented horizontally. There will be 2 motors which spin the bottom wheels the desired direction and 4 rollers to line up with each of the motors. When the pipe is oriented vertically the device will be lowered with the spool and will use gravity and the tether to reach the 15-foot target.

Collection:

For our collection system we will be using gravity and the momentum of the mouse trap, once the sampling is completed the sample will fall into a indent in the electronics tray and be ready to be retrieved. The mousetraps will lead have sheet metal over the arm which will act as a lid when the design is closed.

Feedback:

During each stage of the collection process the interface will update to show the current stage. This information will be displayed on a laptop and will be retrieved through a long chord which will run from the device to the laptop. The interface also controls the device itself, it controls whether the wheels turn clockwise or counterclockwise. The interface also has a stop function which can be used to automatically stop the device from progressing further down the pipe, in case of tether failure.

8 Completed Prototype Testing

Prototype	Name	Date Finished	Testing Description	Result
1	Spool	March 1	Tested if the spool and rope could pull up a ~800g mass, by tying a water filled bottle to the tether and trying to reel it in.	Spool was successful. Determined the spool handle was in an inconvenient position and remodel to put it on the outside. Parts all fit together well.

2	Interface	March 1	Tested whether the interface would make the motors spin the selected direction and stop when the buttons were pressed.	Wheels sometimes failed. Decided to make the interface more visually appealing by adding a background. Was successfully able to make test motors move.
3	Updated Spool	March 8	Completed the same 800g mass test but tried to reel as fast as possible.	Spool was successful with minimal slack in the rope once reeled in. Using this design for the final project but reprinting all the parts at rocketry for an improved part quality.
4	Major Components Case	March 8	Tested whether the case could fit inside the 4-inch pipe and whether all of our internal components could fit inside.	The case was able to fit inside the pipe and all the of the components can fit inside.
5	Updated Interface	March 8	Tested whether the interface could make the motors move, asked how it could be improved.	The interface was still able to make the motors move/stop. Feedback was given to change the buttons to say forward/backward instead of clockwise and counterclockwise.
7	Drive System	March 12	Test if the device can move through 15 feet of the pipe and return safely	Other than some minor resistance from the weld line, the device was very efficient in conversing down

				the pipe. We may need to make a small adjustment where the device rubs against the weld line.
8	Vertical Test	March 15	Propel the device down the pipe 15 feet then see if the spool can pull it back out.	The spool was able to easily pull the weight of the device in and out of the tube, we learned that the spool being as high as possible works best for vertical, and being perfectly in line with the tube works best for horizontal
9	Sampling System	March 18	Test if the sampling system can sample steel, by manually scraping the steel, then trying with the mouse trap.	We have great difficulty scraping the pipe, even manually. We tried many different materials, and none were able to get a solid burr.
10	Collection System	March 19	Try collecting the sample taken with the sampling system in	The collection system would have worked well if we had a large enough sample. But

			both the vertical and horizontal orientation	the system worked well with the sample size we had.
11	Operator Response	Mar 21	Test the operator response system combined with the rest of the prototype.	As expected, the operator response worked well. The next step is to implement some more feedback.

8.1.1 BOM (Bill of Materials)

	Electronics			Hardware			Material			Misc	
Item	Cost	Spent	Item	Cost	Spent	Item	Cost	Spent	Item	Cost	Spent
Arduino	$6.25	$0	Epoxy	$9.99	$0	3D-Filament	$19.90	0	50 ft rope	$3.45	$3.45
Cable	$13.59	$13.59	M3 Screws	$1.20	$0				Mouse Tra	$4.07	$2.93
Motors	$5.29	$5.29	M3 Nuts	$1.20	$0				Lathe Bit	$12.42	$12.42
Shield	$4.20	$4.20									
Batteries	$32.25	$32.25									
Subtotal	$74.13										
Total	**$83.77**										

8.1.2 Equipment list

- 3D Printer
- Laptop
- Spot Welder
- Clamps
- Philips Screwdriver

8.2 Testing & Validation

The following tests were conducted to validate the design of our prototype and ensure it met the required performance criteria. Below are the details of each test, including results, observations, and any necessary design modifications.

1. Spool Test

Date Finished: March 1
Description: Tested if the spool and rope could pull up a ~800g mass by tying a water-filled bottle to the tether and reeling it in.
Results:

- The spool successfully lifted the mass.
- The spool handle was inconveniently positioned, prompting a redesign to place it on the outside.
- Parts fit together well.

2. Interface Test

Date Finished: March 1
Description: Verified whether the interface could control motor direction and stop when buttons were pressed.
Results:

- Motors successfully moved, but wheels occasionally failed.
- Decided to improve the visual design by adding a background.
- Test motors moved as expected.

3. Updated Spool Test

Date Finished: March 8
Description: Re-tested the 800g mass but attempted to reel in as fast as possible.
Results:

- Spool performed successfully with minimal slack.
- This design was chosen for the final project.
- Planned reprinting at rocketry for improved part quality.

4. Major Components Case Test

Date Finished: March 8
Description: Checked whether the case could fit inside the 4-inch pipe and accommodate internal components.
Results:

- The case fit within the pipe.
- All components fit inside successfully.

5. Updated Interface Test

Date Finished: March 8
Description: Verified motor control functionality and gathered user feedback.
Results:

- Motors moved/stopped as intended.
- Feedback led to a label change from "clockwise/counterclockwise" to "forward/backward."

6. Drive System Test

Date Finished: March 12
Description: Tested if the device could traverse 15 feet of pipe and return safely.
Results:

- Device moved efficiently through the pipe.
- Minor resistance was detected due to the weld line.
- Possible minor adjustments needed to reduce rubbing against the weld line.

7. Vertical Test
8. Sampling System Test
9. Collection System Test
10. Operator Response Test

9 Conclusions and Recommendations for Future Work

One major takeaway from this project was that our initial choice of using a lathe bit on a mouse trap for sampling proved inefficient. The lathe bit didn’t generate enough cutting force, which hindered the sampling process. If we had more time, switching to a drill bit would have provided a more effective, consistent method for collecting metal samples.

In terms of project management, a more efficient use of time would have been beneficial. Testing the prototype earlier in the development process would have allowed us to identify issues sooner, like the inadequacy of the sampling mechanism, and adjust before running out of time. Early testing would have also given us more room to fine-tune the design, ultimately improving the system's overall performance.

If this project had been given a few more months, focusing on refining the sampling mechanism, improving motor control, and testing various actuation methods would have been the top priorities. Future teams should prioritize early-stage testing and time management to ensure a smoother development process and a more polished final product.

APPENDICES

10 APPENDIX I: Design Files

Table 2. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Deliverable E - Project Plan and Cost Estimate	Project Plan and Cost Estimation	2025/02/16
Deliverable F – Prototype I and Customer Feedback	Prototype I and Customer Feedback	2025/03/02
Deliverable G – Prototype II and Customer Feedback	Prototype II and Customer Feedback	2025/03/09
Deliverable H – Prototype III	Prototype III	2025/03/25
Arduino and Processing code	Arduino and Processing code	2025/03/25

[1]