Project Deliverable G:

Prototype II and Customer Feedback

Group 16: The Sample Snatchers

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Abstract

This report presents the second phase of prototyping that focuses on testing the sampling and containment mechanisms of the device. Two distinct prototypes were considered: Prototype II, designed to evaluate the scraping method for the sample collected, and Prototype III, aimed at testing the containment system to ensure sample security. The document addresses the feedback from the client, a detailed prototyping plan for the sample method, the development of the containment system's prototype with a critical analysis of results, and preparing to develop the fourth prototype given a structured test and task plan.

The sampling mechanism's testing assesses its efficiency in material collection, motor functionality, and overall feasibility. The corresponding test plan has been established and simulated, though physical testing is pending due to the arrival of parts. Similarly, the containment system's design and functionality have been examined to ensure a securely stored sample while minimizing operator contamination.

The team is preparing for the fourth prototype, Prototype IV, focusing on the movement subsystem. This phase aims to ensure smooth navigation within the pressure tube while adhering to the target design specifications.

Overall, this document details the successful progression towards analyzing the prototypes focused on critical subsystems. Further development of these prototypes will lead to many iterative tests to ensure functionality and feasibility for completing the fully developed prototype for Design Day.

1.0 Introduction

This report details the second phase of prototyping, which aims to test the device's sampling method and evaluate its ability to contain it. Two prototypes have been developed: one for the sampling method (Prototype II) and one for the containment method (Prototype III).

This document aims to demonstrate the development process of these prototypes and provide a detailed test plan for the next, the fourth (prototype IV). As the team has obtained feedback from the client pitch presentation, we have taken comments and concerns into account for further improvements made towards our selected design. As the team proceeds, the required adjustments to the target specifications, detailed design, and Bill of Materials (BOM) have been made accordingly.

The test plan developed for the sampling prototype highlights the targeted objectives for evaluating the sample's performance measurement through three testing phases. Although the performance of this prototype cannot yet be complete, given the arrival of the components, the critical sub-steps to physically test the prototype have been thoroughly evaluated throughout this document. Given the third prototype, a detailed description of the separate elements of the containment system is presented alongside the feasibility of opening and closing the device.

Once the sampling method performs well and the container functions as desired, the team will proceed with prototyping the device's movement subsystem. Thus, preparing these plans is vital to easing the assessment and preparing for development. These prototyping test plans aim to obtain feedback on ideas and evaluate feasibility while analyzing the determined subsystems to reduce risk and uncertainty. As depicted throughout, the plan clearly articulates the why, how, what, and when, along with the critical results and interpretation.

Overall, this report provides insight into the development of our design's prototyping and testing phase through this second phase, given two prototypes of different subsystems, while making proper preparations for the fourth prototype.

2.0 Feedback

2.1 Client Pitch Presentation Feedback

Based on the client pitch presentation, the client expressed concerns regarding the movement system of our design for a vertically oriented pressure tube. Based on this feedback, the team has refined the chosen design's subsystem for movement from an inflatable tube to wheels. This alteration reduces the mechanical complexity while adhering to the budget.

As the team presented the first prototype assessing the sample measurement, the client expressed no verbal or visual concerns about the test's performance. However, based on feedback to other teams regarding the sampling method, the client expressed concerns about the actuator controlling the mechanism. No notable concerns were expressed as we demonstrated our plan for the second prototype.

Therefore, the team will proceed with the newly revised design, which includes a more simplistic movement system. At this stage, the team will continue prototyping the sampling method.

2.2 Prior Client Feedback

Prior feedback from the client will remain at the forefront of our considerations as we continue to progress designing and developing. In brief, several interpreted notes were taken from prior meetings with the client:

- He is not interested in excessive mechanical work.
- He liked the wide variety of ideations.
- He found the clarity of sketches very helpful.
- He prefers a more straightforward design with fewer components.
- He will be satisfied if the device reaches the sample site and returns a 30 to 80 mg sample.
- He would like additional speculation and testing oriented around the operation from start to finish.

3.0 Prototyping II - Scraping Test Plan and Simulation

3.1 Prototype Test Plan

For this prototype, we are assessing the efficacy of our scraping method. This testing will be conducted from March 10th to March 14th when the arbor and lathe bit arrive. Aspects that will be analyzed include:

1. The lathe bit and its ability to cut.
2. The motor and its ability to drive the lathe bit.
3. Sample size collected from the scraping rotation.

We will first test the bit's ability to scrape using manual scraping. After that test, the motor will be used with the designed motor mounts and arbor holder to test its ability to drive the lathe bit. This motor will rotate the component along a path that was digitally modelled and calculated to cut 65mg of material. The digital model took the cross sections of the overlapping radius of the motor's armature, with the pipe wall. A model like this was also very helpful in giving us a visualization of the volume of material that we are extracting.

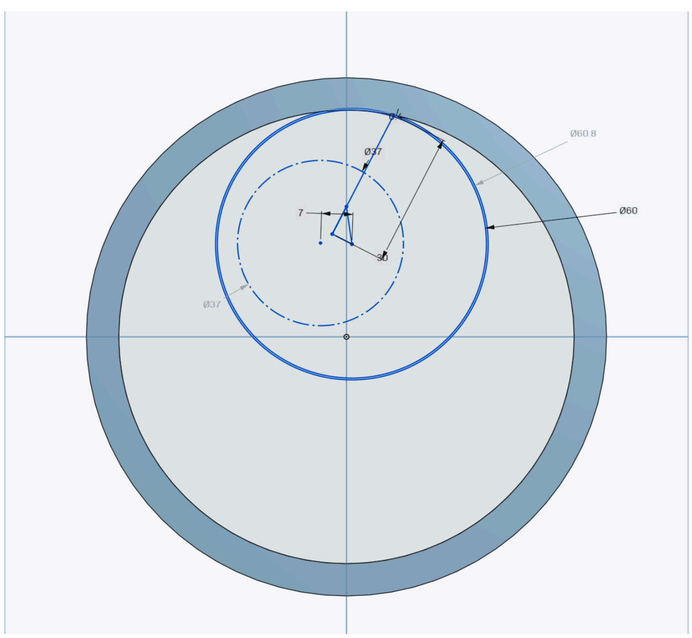


Figure 3.1-1: Creating the Cross Section

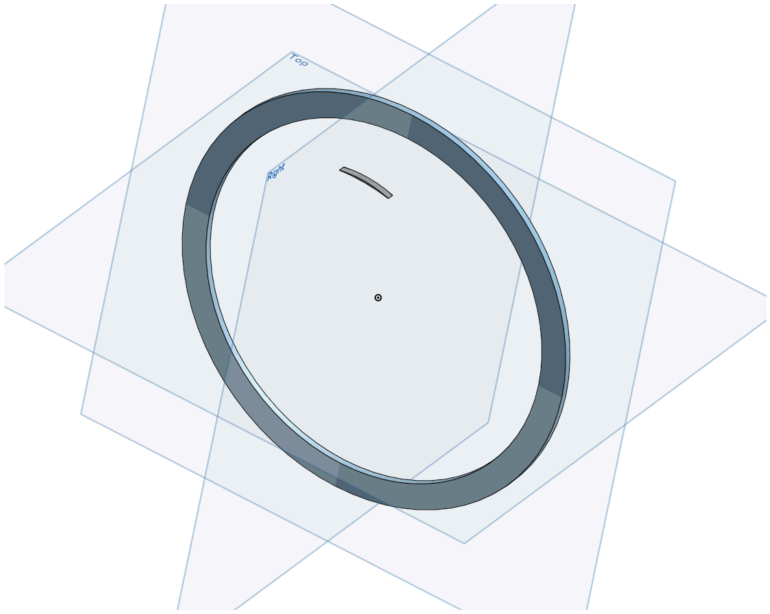


Figure 3.1-2: Cross Section Extrusion

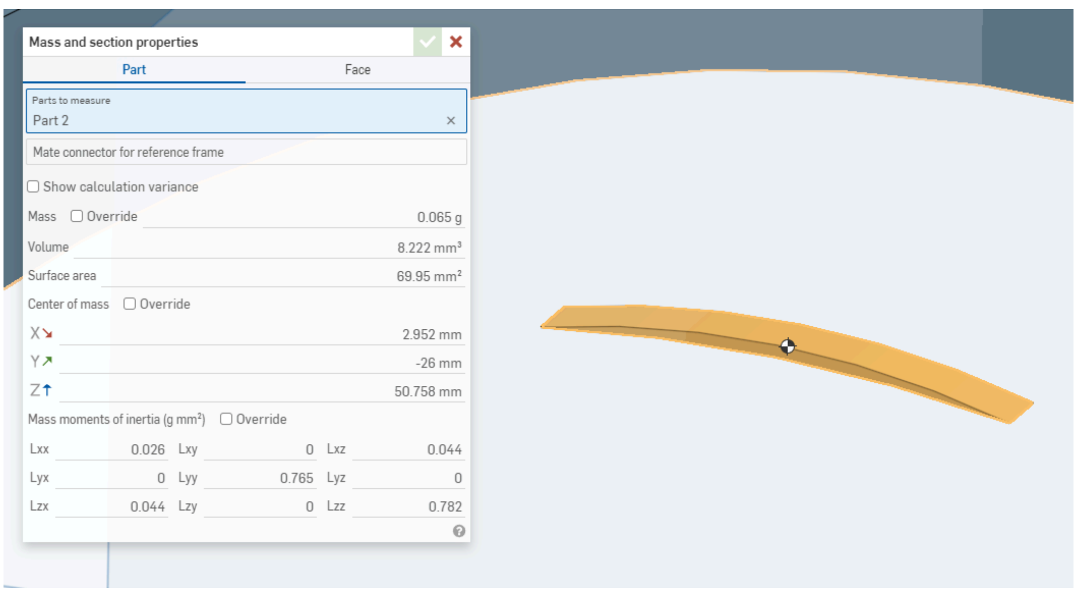


Figure 3.1-3: Cross Section Mass

If any of the three tests should fail, we will adjust the parameters that affect the ability to scrape. This includes changing to a different scraping bit, using a higher torque motor, or changing the scraping path to have a shallower path through the pipe wall.

3.2 Prototype Assembly

The scraper assembly will contain the following components. Depending on our ability to access the pressure tubes in the lab, we may adjust the testing bracket; however, the electronics will be implemented as shown in Figure 3.1-3. In the final design, instead of powering the motor with a 12V DC barrel jack, we will have connectors from the battery management system connecting directly to the motor driver. An ESP32 will be used instead of an Arduino, and a buck converter will drop the voltage from the battery to 5V for the VIN on the ESP32. The ESP32 will be able to regulate this to 3.3V while also giving us a 5V connection for all other electronics necessary.

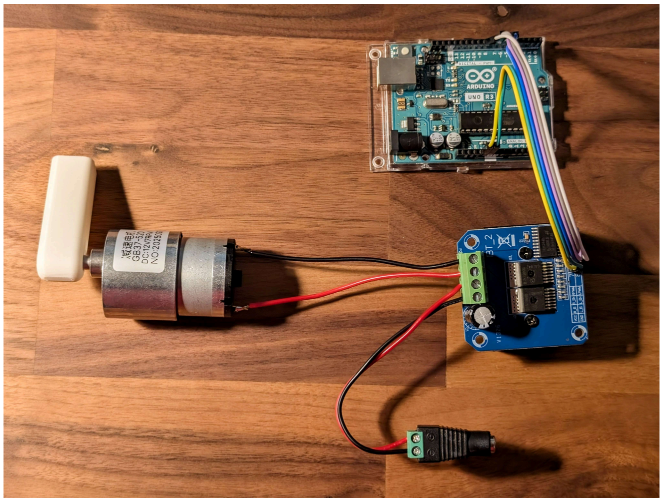


Figure 3.1-3: Motor and Driver Assembly

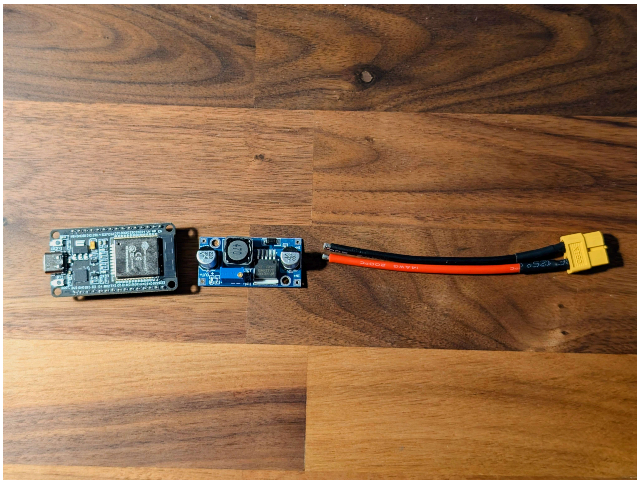


Figure 3.1-4: ESP32 and Buck Converter

4.0 Prototype III - Containment Test Plan & Results

4.1 Design Concept

Prototype III consists of 4 main parts, a shell, lid, sample box and load cell. When the device enters the device chassis, a notch at the top of the container lid gets caught on the roof of the chassis. Pins on the bottom of the chassis floor lock the shell in the device. As the device is pushed into position, the lid retracts along the rail and is pulled to the back of the shell. Once a sample is collected, and the device is removed from the chassis, springs positioned on the shell rails force the lid over the sample box, sealing the sample box to minimize operator contamination.

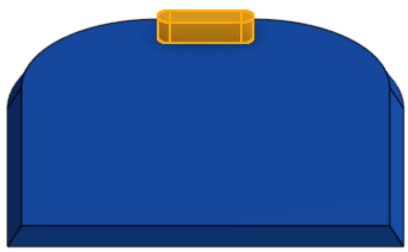


Figure 4.0-1: Container Lid

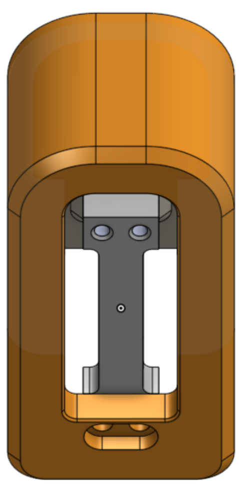


Figure 4.0-2: Container Shell and Load Cell Assembly (Bottom View)

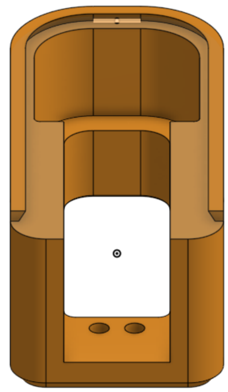


Figure 4.0-3: Container Shell (Front View)

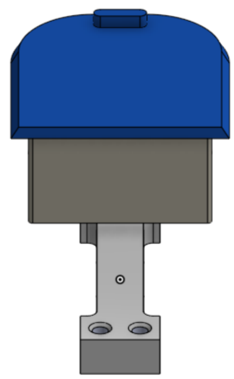


Figure 4.0-3: Sample Box and Load Cell Assembly (Front View)

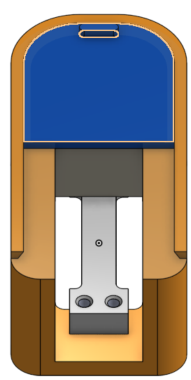


Figure 4.0-4: Containment Subsystem (Front View)

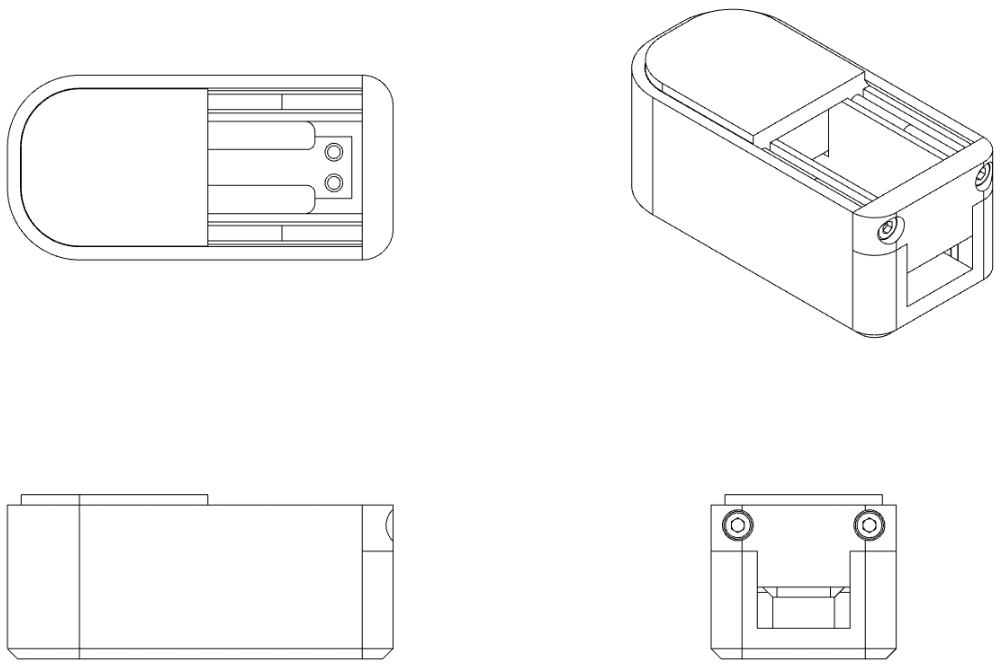


Figure 4.0-5: Container Final CAD Design (Four Views)

4.2 Prototype Test

The parts' tolerances are most important to the functionality of this prototype. We made several adjustments to the container and its sliding mechanism to smooth the movement. We found that three springs were needed on either rail to move the lid effectively. Initially, magnets were attempted to be used, which caused severe accuracy issues with the load cell.

Figure 4.0-6: Container Tests

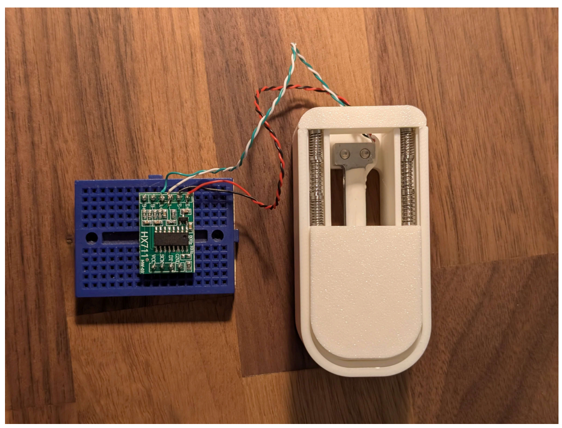


Figure 4.0-7: Container Final Prototype

4.3 Prototype III Conclusion

We must adjust the spacing between the lid and container body to ensure the mechanism works well. However, the rest of the design works as expected, and the bottom lip of the container will be sufficient for clipping into our final design. The prototyping test plan illustrates further results.

5.0 Updates to Specifications and Design

5.1 BOM

Below is the updated BOM. It has been organized to label components for future deliverables and documentation and sorted by section.

Table 5.1: Updated Bill of Materials

Sample Snatchers - Bill of Materials						
Components that come in bulk quantity have had their price modified to the amount that will realistically be used. This amount will generally be estimated to be higher than lower. Each section has a name scheme to identify components later on quickly. Quantities will be updated more accurately as the final design is developed.						
Battery and Power Delivery (PDXX)						
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**	**Link for Purchase**
PD01	22 awg Wire	Amazon	Wires for connecting components to circuit	1	CA$0.80	Generic
PD02	XT60 Connectors	Aliexpress	Connectors for battery pack	1	CA$1.60	Link
PD03	16 awg Wire	Amazon	Wires for 12v components	1	CA$0.80	Generic
PD04	P42A Molicel Battery 21700	18650 Battery	For battery pack assembly	3	CA$15.00	Link
PD05	3S Battery Management System	Aliexpress	For safety	1	CA$2.94	Link
PD06	Power button	Aliexpress	Push button for power	1	CA$1.85	Link
PD07	LM2596	Aliexpress	Step down buck converter, 36V/24V/12V/5V/3V	1	CA$0.45	Link
PD08	USB-C PD Trigger Card	Aliexpress	Allows for PD charging to the BMS	1	CA$2.49	Link
PD09	Resistors + Capacitors	Aliexpress	Various resistors + Capacitors	1	CA$0.30	Generic
PD10	Kapton Tape	Aliexpress	Tape for sealing battery cells in pack safely	1	CA$1.00	Generic
Control and Logic (CLXX)						
Item #	**Part**	**Vendor**	**Description**	**Qty**	**Cost**	**Link for Purchase**
CL01	ESP32-WROOM-C3	Elegoo	Controller w/ Wifi + BT	1	CA$9.99	Link
CL02	H-Bridge Motor Driver BTS7960	Aliexpress	Driving 12V motor for scraping	1	CA$7.41	Link
CL03	HX711 Sensor	Aliexpress	Strain gauge for mass analysis	1	CA$1.80	Link

Measurement (MXX)						
Item #	Part	Vendor	Description	Qty	Cost	Link for Purchase
M01	100g Load Cell	Aliexpress	Strain gauge to measure mass	1	CA$4.93	Link
Structural Components (SCXX)						
Item #	Part	Vendor	Description	Qty	Cost	Link for Purchase
SC01	PLA - ~0.5 KG	Bambu	Filament for chassis	1	CA$7.99	Link
SC02	M3 Female Threaded Insert	Aliexpress	Heat set threaded inserts for chassis	1	CA$0.80	Link
SC03	M3/M4 Machine Screws	Aliexpress	Various length M3 Machine Screws	1	CA$1.00	Generic
SC04	608 ZZ 608RS	Aliexpress	Ball bearings	3	CA$1.80	Link
Sampling Tooling Components (STXX)						
Item #	Part	Vendor	Description	Qty	Cost	Link for Purchase
ST01	MGEHR1212 + Bits	Aliexpress	Lathe Bit and armature	1	CA$9.28	Link
ST02	GB37-520 7rpm 12v Motor	Aliexpress	For moving the armature with lathe bit	1	CA$11.28	Link
Total	**CA$83.51**					

5.2 Changes to Design

We've adjusted the design to utilize the motorized wheels to move the device. This eliminated the inflatable tube as the movement system. This has significant cost savings and reduces complexity, allowing us more time to focus on the user interactions with the device than the function of the device moving.

However, as these alterations have been made to the design, further considerations must be made regarding the movement system's function as it operates depending on the configuration of the vertical versus horizontal pressure tube. Ideally, the device will be fully motorized so that a horizontal tube can navigate to and from the sample site. For this configuration, the failsafe mechanism will be a rope attached to the device, considering the possibility of a loss of power, so it can manually be extracted from the tube. In contrast, we will drop the device from the top using the failsafe tether for the vertical orientation. We will unlikely have the power to climb the tube within our budget, so it’s easier to utilize the tether and allow the motors to act as a guide in this scenario.

5.3 Changes to Target Design Specifications

At this time, our design specifications remain unchanged.

Table 5.3-1: EDS - Functional Requirements

	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
	Functional Requirements				
1	Collect a metal sample from the tube wall	=	30-80	mg	Test
2	Completely Removable	=	Yes	N/A	Test
3	Enclosed Sample	=	Yes	N/A	Test
4	Stage Reporting	=	Yes	N/A	Test
5	Visual for process	=	Yes	in, dpi	Test
6	Device speed	<	7	min	Test
7	Power source included	=	Yes	N/A	Analysis
8	Distance Travelled	=	15	ft	Test

Table 5.3-2: EDS - Constraints

	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method
	Constraints				
1	Weight	<		kg	Analysis
2	Size (Diameter)	<	4	in	Analysis
3	Size (Length)	<	4	ft	Analysis
4	Sample Exposure	<	Yes	N/A	Test
5	Sample Collection	=	30 - 80	mg	Test

Table 5.3-3: EDS - Non-Functional Requirements

Design Specifications		Relation (=, < or >)	Value	Units	Verification Method
	Non-Functional Requirements				
1	Aesthetics	=	Yes	N/A	Survey
2	Safety	=	Yes	N/A	Analysis
3	Corrosion Resistant	=	Yes	N/A	Analysis
4	Operation Time	<	10	mins	Test
5	Creative Solution	=	Yes	N/A	Analysis

6.0 Prototype IV Plan - Movement System

The team plans to test the device's movement system for the fourth prototype. As previously stated, the team has modified this critical component by utilizing wheels actuated by a motor rather than an inflatable device to navigate through the pressure tube. Therefore, the prototyping test and task plan must be adjusted to incorporate the new movement component.

6.1 Prototype IV Test Plan

In the prototyping task plan, the team followed the template's procedure to answer the guiding questions of how, what, when, and why. Additionally, spaces have been allocated for results, interpretation, feedback, and expanded notes based on the analysis of the test performed. In brief, the prototype will be a physical Lo-Fi prototype that strives to position itself to and from the sample site by measuring the task time (seconds) and the distance covered (feet). *(Prototyping Test Plan appended at the end of the document)*

6.2 Prototype IV Task Plan

In the prototyping task plan, the necessary modifications have been made to include the critical sub-tasks for the newly designed movement system's prototype development. Following the same guidelines as the previous prototype's task plans, the plan outlines specific tasks with detailed descriptions, estimated time frames, and assigned responsibilities while also considering potential risks and alternative strategies for backup. *(Prototyping Task Plan appended at the end of the document)*

We are currently designing a movement device (in CAD) that will enable our scraper and containment system to move in and out of the tube via wheels and provide power to these components. The device will consist of motors (possibly N20 motors or bigger), wheels, a battery pack, and an outer shell containing these parts. The outer shell will connect the rest of the device (the containment system, scraper, etc.). We currently do not have a final design for the movement device, which will be heavily influenced by the design of the other components. The shape and size of these parts will dictate the dimensions of the outer shell and the placement of parts in the movement device. After most of the other elements have been modelled, we expect to have a proper design for this component by next week.

7.0 Conclusion

7.1 Completed Objectives

This document outlines the second phase of the group's prototyping, which speculates the device's sampling method and evaluates its ability to contain it. The document details the two prototypes that have been constructed thus far; prototype II, focused on evaluating the scraping method for the sample collection process, and prototype III, focused on assessing the containment system. Moreover, the document provides a development process for these prototypes and a detailed test plan for prototype IV, which will focus on the movement subsystem. Finally, the document further expands and updates the team's BOM, prototype test plan, and task plan, explaining additional changes to the device's design.

7.2 Trello: Task Plan Update

The team's general task board has been updated using Trello, including descriptions, time durations, missing objectives, assigned responsibilities, and additional critical details to ensure effective project management. Further, a GANTT chart outlining the team timeline of said tasks and requirements has been attached to the submission.

Appendices

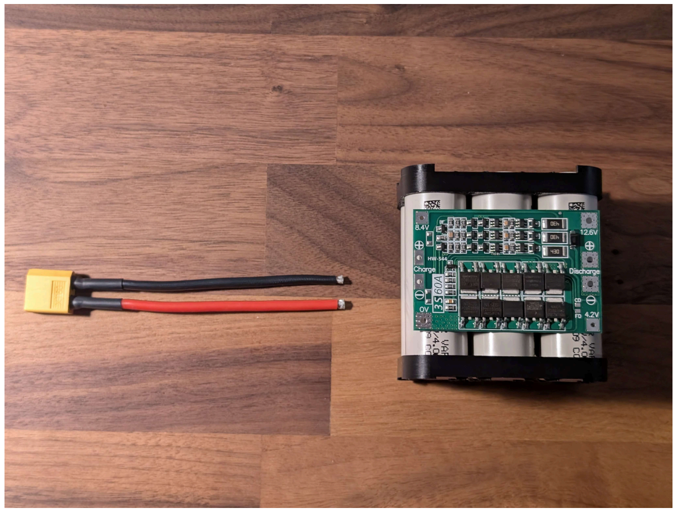
Appendix A: Code in Arduino IDE (C) for IBT2 Motor Driver

```
#define RPWM 5
#define LPWM 6
#define REN 7
#define LEN 8

void setup() {
  pinMode(RPWM, OUTPUT);
  pinMode(LPWM, OUTPUT);
  pinMode(REN, OUTPUT);
  pinMode(LEN, OUTPUT);

  // Enable both sides of the IBT-2
  digitalWrite(REN, HIGH);
  digitalWrite(LEN, HIGH);
}

void loop() {
  // Forward at 50% speed
  analogWrite(RPWM, 127);  // 127 out of 255 (50%)
  analogWrite(LPWM, 0);    // No reverse
  delay(3000);             // Run for 3 seconds

  // Stop
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);
  delay(1000);

  // Reverse at 75% speed
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 191);  // 191 out of 255 (~75%)
  delay(3000);

  // Stop
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);
  delay(1000);
}
```

Appendix B: Code in Arduino IDE (C) for L293 Motor Driver

```
#define IN1 9  // L293D Input 1
#define IN2 10 // L293D Input 2
#define ENA 11 // Enable pin (PWM for speed control)

void setup() {
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(ENA, OUTPUT);

  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  analogWrite(ENA, 255);  // Full speed (0-255)
}

void loop() {
  // Forward
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  delay(2000);

  // Stop
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  delay(1000);

  // Reverse
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  delay(2000);

  // Stop
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  delay(1000);
}
```

Appendix C: Electronic Layout Photos



Appendix D: Task Plan & Test Plans

The following pages sequentially show the updates to the Prototyping Task Plan and the Prototyping Test Plan, demonstrating results from previous prototypes and the plans for the following prototype.