GNG1103: Tube-Scraping Machine

By Group 18

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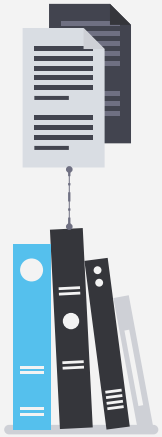
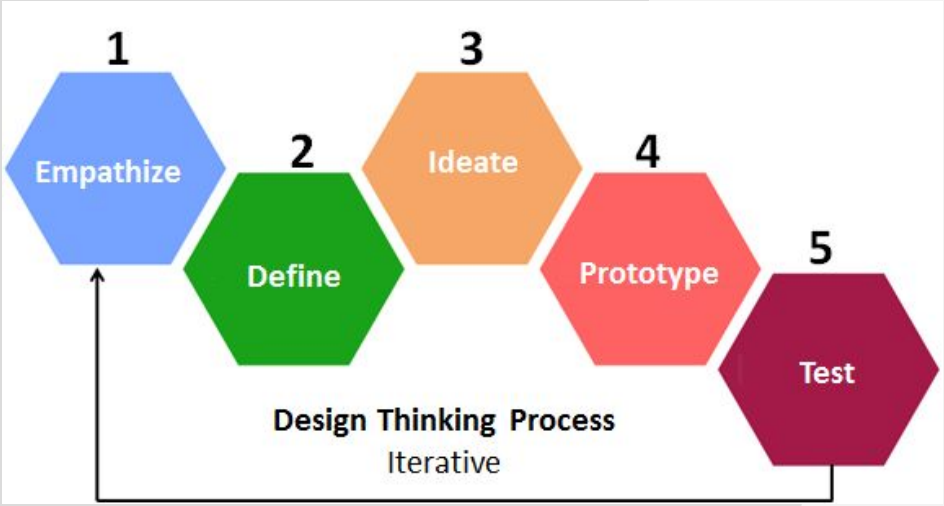
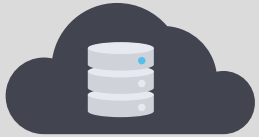




01 Design Process

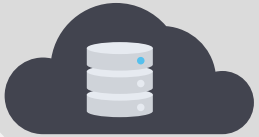
Empathize



We identified the following customer needs and sorted them into high, medium and low priorities. . .

- ➔ The machine needs to be able to stably retrieve samples from 15 ft away.
- ➔ The metal sample gathered from the tube must be 30-80 mg in mass.
- ➔ The sample must be stored in a suitable container to avoid direct contact from the operator.
- ➔ The device must provide feedback to the operator to confirm the device's integrity and process status.
- ➔ The device must be failsafe in case of a breakdown mid-sample retrieval.
- ➔ The device must be able to be broken down into man-portable sizes and transported.
- ➔ The device should be budget-friendly.
- ➔ The retrieval process should be quick.
- ➔ The device should be easy to use without prior experience with similar products.

Define



During the define phase we went over the following design criteria. . .

- Customers Requirements
  - Essential
    - 15ft, 30-80mg, modular, portable
  - Non-Essential
- Constraints
  - 10kg max weight
  - Must operate in STP
- Target Specifications
  - Length ~ 4.57m
  - Weight < 15 lbs or 6.80 kg
  - Avoid high-power electronics

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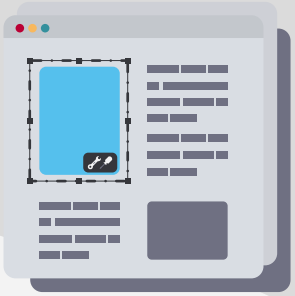
Define

Technical Benchmarking

Customer Need	Priority	Machine Core Features	Rating	Competitor 1 (CWEST)	Rating	Competitor 2 (ALFRED) Features	Rating
Retrieval Distance & Stability	High	Operates up to 15 ft in vertical/horizontal positions with manual/Arduino control	4	Fully automated precise 15 ft operation	5	High-precision robotics with flexibility	5
Sample Size	High	Arduino-controlled scraping mechanism to ensure 30-80 mg precision	4	Sensor-controlled highly precise	5	Pneumatic sampling with feedback	5
Sample Containment	High	Airtight container (manual handling; limited shielding and temperature control)	3	Radiation-shielded, airtight, temperature regulated	5	Industrial-grade containment system	5
Quality Control	Medium	Arduino feedback for configuration integrity	4	Full process monitoring via automation	5	Advanced sensors for real-time feedback	5
Retrieval Failsafe	Medium	Lightweight manual retrieval mechanism	3	Failsafe integrated into automated system	5	Robust failsafe mechanisms	5
Transportability	Medium	Modular design manually portable (<15lbs)	5	Larger, requires special tools/equipment for movement	3	Moderately portable, but has a complex breakdown process	4
Price	Low	≤ $100 CAD; simple components and DIY build	5	~$10,000+	2	~$5000+	3
Ease of Use	Low	Simple Arduino interface; minimal training required	4	Fully automated easy to use	5	Some technical expertise/experience required	3
Totals	**N/A**	**36/45**	**N/A**	**40/45**	**N/A**	**40/45**	**N/A**



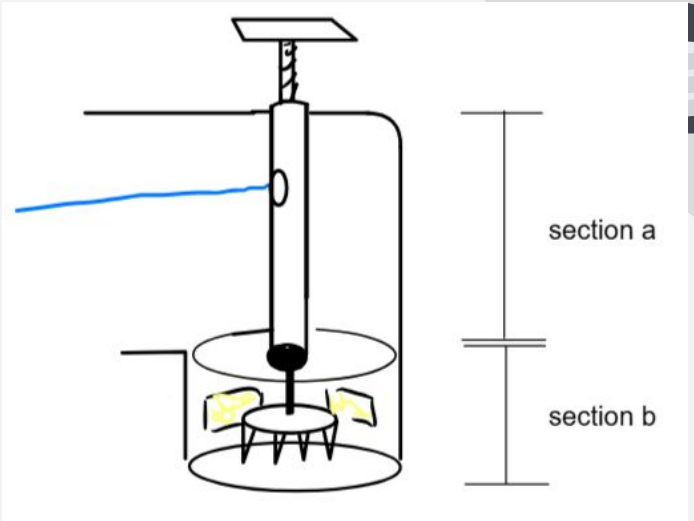
Problem Statement

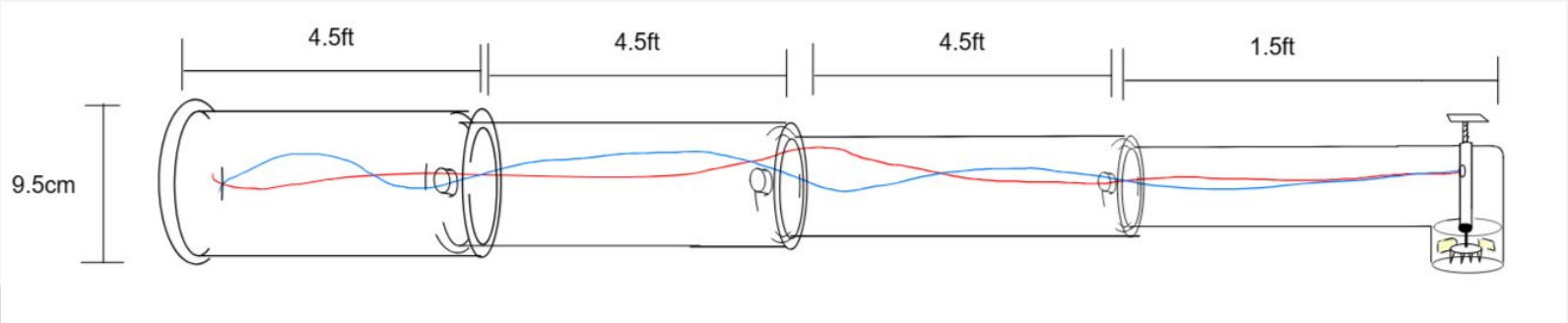
“Canadian Nuclear Labs requires a safe and precise method to take a 30-80 mg sample of metal from CANDU reactor fuel tubes 15 ft long and analyze their hydrogen and deuterium concentrations”

Design 1

The concept

- **Body**: telescopic rod extending into the pipe
- **Collection**:Rotary dremel scratches the tube interior. Magnet collects the dust

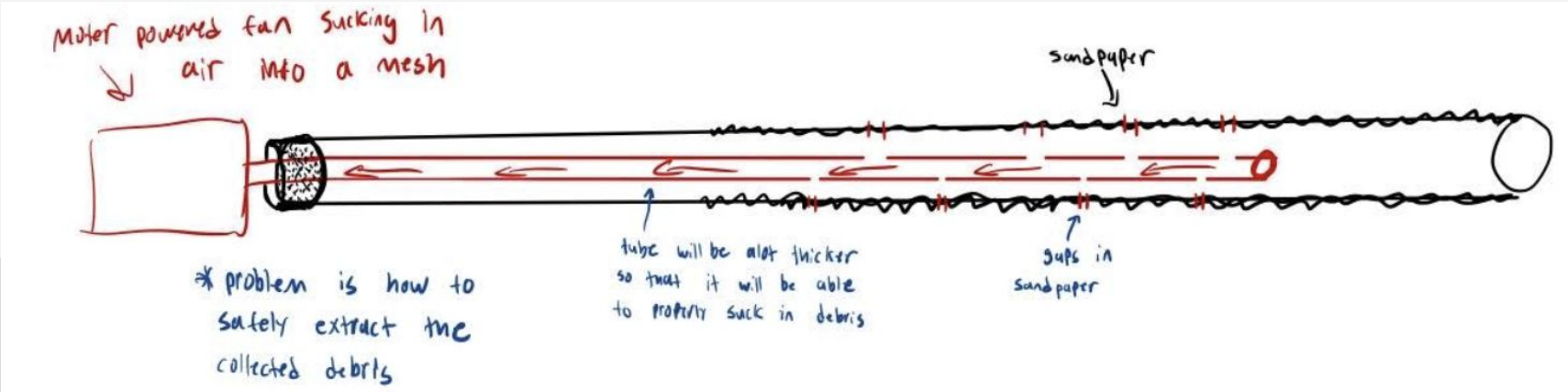




Design 2

The Concept

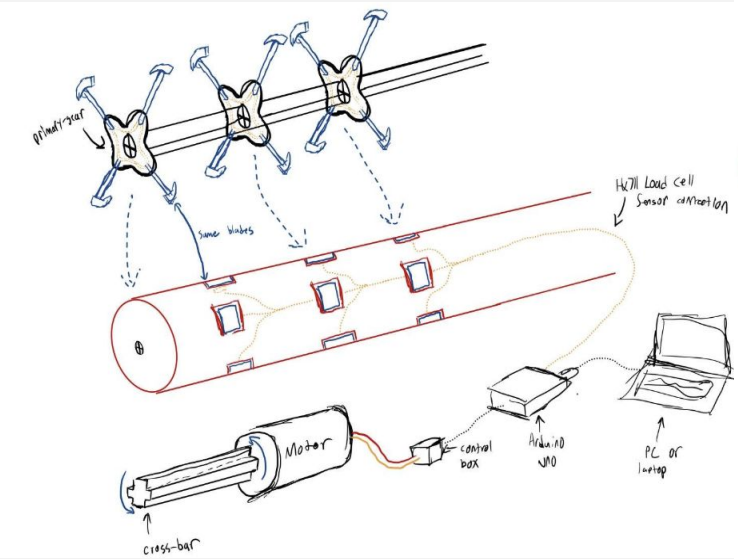
- Sand paper cover
- Vacuum system/magnets to collect dust sample

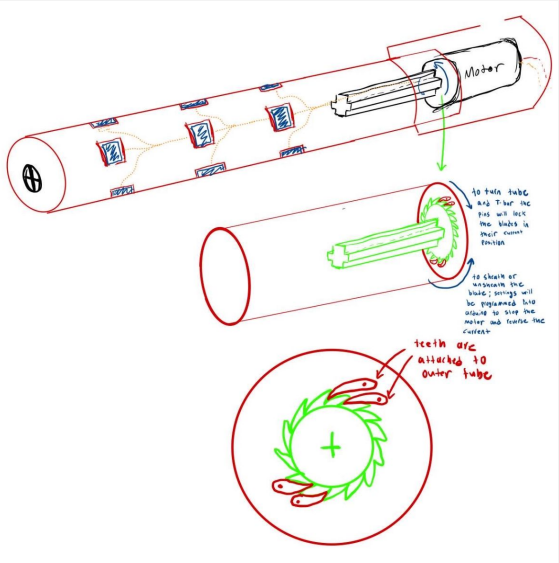


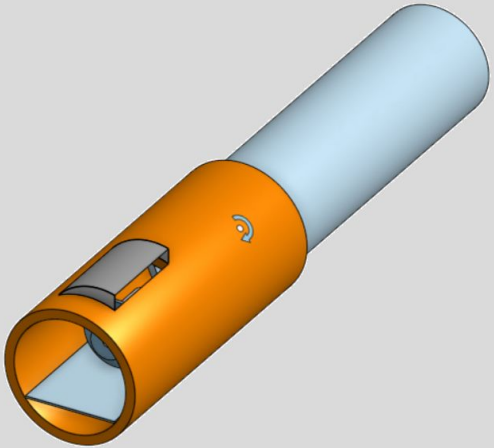
Design 3

The Concept

- T-bar which is connected to a saw-toothed gear
- Sample is collected in the blades
- The T-bar would spin in the opposite direction to retract the blades







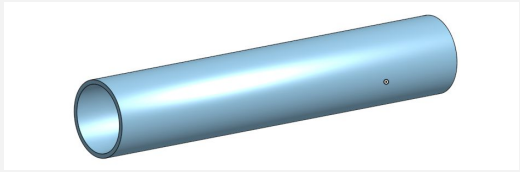
02

Final Design

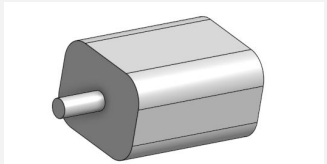
Final Design Layout

Part List

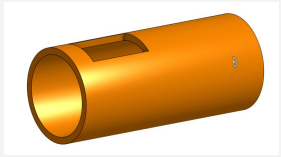
- Stable Body (3D printed)



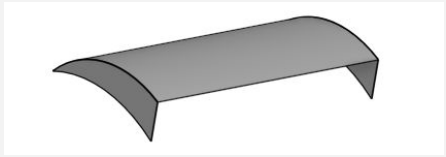
- Servo Motor



- Rotating Body (PVC)



- Blade

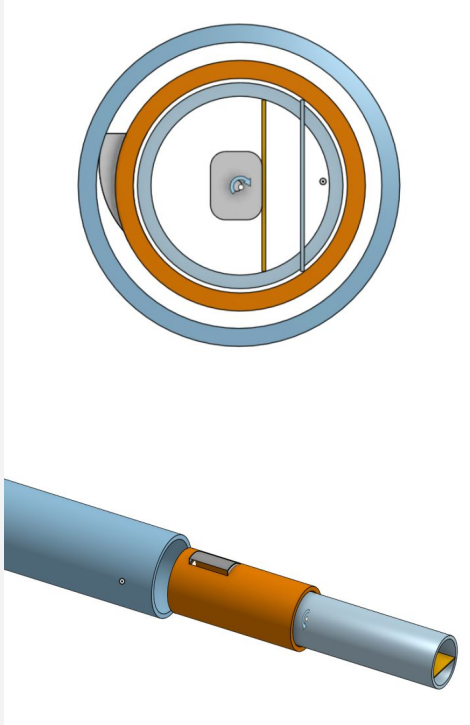


NOT CADDED:

- Wheels
- Processing unit
- Display
- Laptop
- Collection tray

Prototype 1: (CAD model)

- Expected fidelity level
  - High fidelity in terms of dimensions
  - Low-medium fidelity when calculating the loads, since it does not account for real-world variables (not as good as a physical prototype).
- Tests done
  - **Test 1**: Design's dimensions fit, leaving room for wiring and possible adjustments.
  - **Test 2**: Find the exact theoretical volume of debris collected (not mass, since we don't know the material).
  - **Test 3**: After a theoretical load evaluation, all of the systems remain stable (the axis of the motor doesn't break, the blade does not lodge the system on the outer tube, etc).
- Note: Old design, includes slip ring.



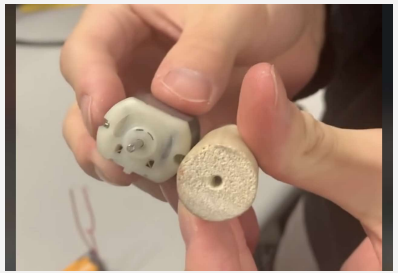
Prototype 2

Test code

Tests purpose:

- Determination of the motor's strength and whether or not it is strong enough to scrape a metallic sample
- Determination of the code's operational status, and debugging.

- This prototype has a medium-low expected fidelity because it's heavily theoretical



Users > debaefosa-igbinovia > C PrototypeCode.c > setup()

```c
#include "HX711.h" // Load cell library

#define MOTOR_PIN 9       // Motor control pin
#define START_SWITCH 4    // Switch to start motor
#define ENCA 2            // Encoder A pin
#define ENCB 3            // Encoder B pin
#define LOAD_CELL_DOUT 6  // HX711 data pin
#define LOAD_CELL_SCK 7   // HX711 clock pin

HX711 scale;
volatile int encoderCount = 0;
const int targetRevolutions = 15;
bool motorRunning = false;

void setup() {
    Serial.begin(9600);

    pinMode(MOTOR_PIN, OUTPUT);
    pinMode(START_SWITCH, INPUT_PULLUP); // Internal pull-up resistor
    pinMode(ENCA, INPUT);
    pinMode(ENCB, INPUT);

    attachInterrupt(digitalPinToInterrupt(ENCA), countEncoder, RISING);

    scale.begin(LOAD_CELL_DOUT, LOAD_CELL_SCK);
    scale.set_scale(2280.0); // Adjust calibration factor
    scale.tare(); // Reset weight readings

    digitalWrite(MOTOR_PIN, LOW); // Ensure motor starts off
}

void loop() {
    // Start motor if user inputs 'S' or presses switch
    if (Serial.available() > 0) {
        char command = Serial.read();
        if (command == 'S') {
            startMotor();
        }
    }

    if (digitalRead(START_SWITCH) == LOW) {
```

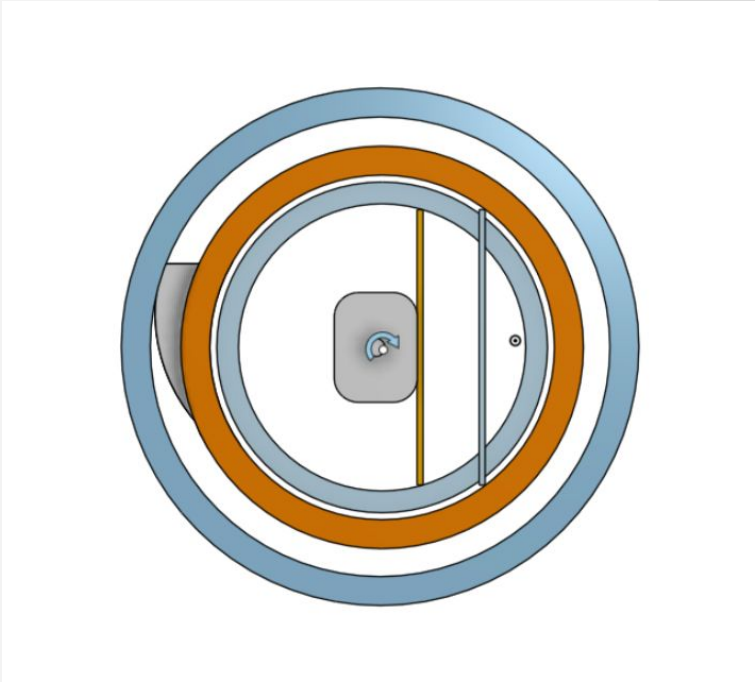
Prototype 3 (TBD)

The Concept

- Testing a physical prototype with additional stabilizing components

Test purpose:

- Determining:
  - the optimal angle and design for the blade
  - Functionality of the design
  - The mass of the collected sample
  - Feasibility of insertion
- Low friction tape to help stabilize the 2 parts
- Changing the collection method
- No slip-ring



Prototype 3

The concept

- Test purpose:
  - Making sure the motor stops rotating at the right orientation to collect the sample
  - Switching from high RPM, low torque to low RPM with high torque for more consistent sample collection
  - Debugging, and testing the code in conjunction with the Arduino board.

```
#include <Servo.h>

Servo myServo;  // Create a servo object

const int servoPin = 9;  // Pin connected to the SG90 signal wire
const int rotations = 15; // Number of full 360° turns
const int rotationTime = 1200; // Approximate time (ms) for one full rotation

void setup() {
    Serial.begin(9600);
    myServo.attach(servoPin);
}

void loop() {
    Serial.println("Press 'r' and Enter to start rotations...");

    while (Serial.available() == 0) {
        // Wait for user input
    }

    char input = Serial.read();
    if (input == 'r') {
        Serial.println("Starting 15 full rotations...");

        for (int i = 0; i < rotations; i++) {
            myServo.write(0);  // Move at max speed in one direction
            delay(rotationTime);  // Wait for one full turn
        }

        myServo.write(90); // Stop the servo (neutral position)
        Serial.println("Rotations complete!");
        delay(1000);
    }
}
```

03

Bill of Materials

Total Material List			
Material	**Amount**	**Cost (CAD)**	**Link**
Onshape CAD design tool	-	-	-
12 Volt Motor	1	1.99	https://www.princessauto.c
Servo Motor	1	27.99	
Hook up wire	1ft (just for motor testing)	-	IEEE
Sheet of metal	3"x3	17.49	home depot
wheels	12	12.99	https://www.amazon.ca/Ad
PVC pipe 3 inch id	8" length	-	home depot
3d printed pipe	10" length	-	makerstore
hook up wire	30ft	-	https://www.amazon.ca/VI
Primary processing unit	1	-	IEEE
Secondary processing unit	1	12	
Carbon Fiber Mix	65 g	9.1	https://makerstore.ca/produ
12V batteries	1	-	BAJA
TOTAL		81.56	

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Conclusions & Next Steps

Conclusions

- The final design successfully meets the main customer requirements (15 feet length, 30-80 mg of sample collection, portability and modularity).
- Design process revealed the importance of balancing precision, durability, and ease of use.
- Initial designs were too complex. Striking a balance between keeping the design simple and adding functionality is key.
- Prototyping in CAD early on was an important step in determining challenges relating to mechanical and electrical systems.
- Key Takeaways:
    - **Material Selection:** Finding the right balance between material durability and cost efficiency is crucial.
    - **Power & Control:** Ensuring electronics are reliable and efficient.
    - **Failure Points:** Identifying potential weaknesses in the design.

Next Steps

1. Test out prototype 3 (March 20, 2025)

2. Keep optimizing and running tests until the device runs smoothly
    a. Functionality tests with makeshift collected pipe (March 22, 2025)
    b. Upgrade 3D printed component to a stronger 3D printed material (to ensure integrity on design day).

3. Prepare for Design Day!!!! (March 27, 2025)

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Questions