Prototype I and Customer Feedback

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I. Introduction & Objectives

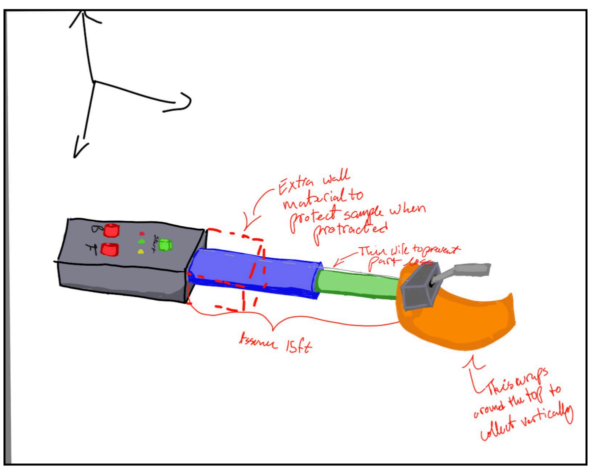
This deliverable documents the development of our first prototype—a proof-of-concept model to validate our approach while integrating client feedback. Building on the foundation of our earlier work (as detailed in our Project Schedule and Cost deliverable), this document outlines the prototype's design, the critical feedback gathered from our client meeting, and a comprehensive test plan to refine Prototype II.

II. Prototype I Design & Development

Prototype Overview:
Our prototype has four core subsystems that address the primary functions identified in our design drawing. The design features an extendable sampling blade driven by a DC motor, an Arduino-based feedback mechanism for real-time monitoring, a telescoping rod system for precise extension and retraction, and safety lines as a failsafe.

Design Overview & Drawing:

Fig 1.



Description:
The design drawing (see Figure 1) illustrates the integration of the sampling mechanism, the feedback sensor module, the extension/retraction system, and failsafe. The extendable blade is engineered to make a precise cut into the pipe wall, while the attached collection tray collects the sample in a sealed tray.

- **Critical Subsystems:**
  - *Sampling Mechanism:*
    A sharp, extendable blade, driven by a DC motor, initiates the cut. The blade is coupled with a cover that collects samples as they fall. The knife mechanism is ran by a code ensuring accurate extraction.
  - *Feedback Integration*
    An Arduino Uno controls sensor feedback, enabling the operator to monitor the blade's movement and ensure accurate sample retrieval. The system provides visual and auditory alerts when operating parameters are reached.

- *Extension/Retraction System:*
  A telescopic rod with a belt mechanism is employed to guarantee uniform extension and retraction. This design minimizes mechanical discrepancies during operation.
- *Failsafe:*
  Safety lines attached along each mechanism of our tool shall ensure no part will be lost in the fuel pipe in the event of a breakage or loss of power.

- **Supporting Analysis & Component Justification:**
  Preliminary tests confirm that our low-cost design meets the basic operational criteria. Component selections were made based on cost, reliability, and ease of integration. For instance, our choice of a micro servo for blade actuation is supported by its rapid response time and compact form factor.

III. Customer Feedback Analysis

Feedback Overview:
Following the client meeting held on February 10, 2025, feedback was gathered that influenced our design iteration. The client praised some concepts, compared concepts to their solution, and mentioned that other concepts would not work well.

- **Key Feedback Insights:**
  - The client noted that the cameras are not viable long-term, as radiation will degrade the camera's functionality
  - Creating a repeatable, calibratable process is the highest priority
  - The client recommended sticking to simpler subsystems, as the more advanced they are, they have higher chances of failing they have
  - The telescopic rod was complimented, as a very similar part was used for their solution
  - In our designs, the dremel and the sandpaper ideas were discouraged as they would not generate a large enough and constantly sized sample
  - We were also told to ensure our design was as cost efficient as possible
- **Implications for Design Iteration:**
  Based on the feedback, we decided to switch our collection method to a curved blade/file. We also decided to change our feedback system to be communicated via Arduino, which will be attached to various sensors monitoring the operation. We will continue on with our telescoping deployment system, however, instead of circular, the flat face will be a square. This will minimize the surface area whilst not compromising stability. No changes were made to the failsafe system.
- **Addressing Alternative Perspectives:**
  While the client's feedback was largely positive, he also made the suggestion that less is more in this project, to keep it simple. Other than this clarification, the client stated that we appear to be on the right track.

IV. Prototyping Test Plan for Prototype II

Prototype Plan Overview:
To prepare for the development of Prototype II, we have devised a detailed test plan that focuses on validating the performance of the subsystems in a higher fidelity. This plan will guide our iterative process and ensure that all design parameters are rigorously evaluated.

- **Test Plan & Objectives:**
  Our test plan is designed to assess the sampling efficiency, retrieval functionality, feedback quality, and structural integrity of the extension system. Each test is aimed at verifying that the prototype meets or exceeds predetermined performance metrics.

Detailed Test Procedures & Metrics:

Test No.	Test Title	Objective	Test Description	Analysis Method	Metrics & Target
1	Sampling Efficiency	Validate sample collection capability	Bench test using a metal pipe mock-up; activate the extendable blade and vacuum system over multiple cycles.	Measure sample mass per cycle using a precision scale.	30–80 mg per cycle; consistent performanc e
2	Retrieval Mechanis m Function	Confirm rapid and safe retraction of the tool	Activate the spring-loaded retraction system; record the time taken to retract the prototype.	Use digital timers and sensors; conduct 5 repeated trials.	Target retraction time: <5 seconds
3	Feedback Quality	Ensure real-time monitoring is accurate and reliable	Operate the feedback system under varied lighting conditions; assess clarity and response times of data output.	Compare sensor output with visual observations; analyze	

				resolution scores.	
4	Extension System Integrity	Verify the smooth operation and durability of the rod	Repeatedly extend and retract the telescopic rod over 10 cycles; apply minimal loads to simulate operational stress.	Record extension/retraction speeds; inspect for mechanical issues.	Uniform motion without failure across cycles

- **Stopping Criteria:**
  Testing will conclude once each test yields consistent results over three consecutive cycles. Should any significant failures occur, testing will be paused to reassess and refine the design.

V. Updated Project Task Plan & Schedule

Taskings Overview:
In light of the customer feedback and initial test results, we updated our project task plan to reflect necessary design revisions and extended testing periods. This updated schedule ensures that all team members are aligned with the upcoming work and deadlines.

- **Task Plan Overview:**
  The revised task plan includes detailed responsibilities and timelines for finalizing the design, procuring materials, refining the prototype, and conducting comprehensive tests. Adjustments have been made to accommodate additional testing and component upgrades based on client feedback.

Sample Task List & Responsibilities:

Task	Duration	Assigned To	Details
Finalize Detailed Design Drawing	3 days	Felippe	Refine schematics; incorporate feedback on blade control.

Update Trello & Task Board	1 day	Franco	Revise tasks based on updated design and extended tests.
Procure Enhanced Components	5 days	Felipe	Source new display modules and reinforcement materials.
Prototype – Sampling Subsystem	7 days	Nolan	Rebuild blade mechanism; integrate improved motor control.
Prototype – Feedback Integration	5 days	Franco and Adam	Upgrade Arduino sensor integration display unit, and work on the code
Prototype – Extension Subsystem	5 days	Omar and Felippe	Reinforce telescopic rod; test for durability under load.
System Integration & Testing	7 days	Entire Team	Integrate subsystems; conduct full-prototype tests.
Risk Review & Contingency Planning	2 days	Project Manager (PM)	Identify new risks; update contingency plans as necessary.

VI. Conclusion

In conclusion, this deliverable has successfully demonstrated the development and evaluation of our first prototype. The direct customer feedback provided critical insights that will drive improvements in Prototype II. Our prototype effectively demonstrates the core functions of the sampling, feedback, and extension systems, meeting the preliminary performance criteria.
The client's constructive feedback has been instrumental in identifying areas for enhancement, particularly in retaining the simplicity of the design and what parts to use. Moving forward, the updated test plan and task schedule will ensure that we systematically address all identified issues and prepare a more refined, higher fidelity prototype for the next phase.