Prototype II and Customer Feedback

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I. Introduction & Objectives

This deliverable documents the development and evaluation of our second prototype, building upon the results and client feedback from Prototype I. The objectives of Prototype II are to refine critical subsystems, integrate improvements based on client insights, and validate performance metrics through targeted testing. Furthermore, this document outlines our updated testing procedures and customer feedback that will inform the final prototype.

II. Feedback from Prototype I

During our client meeting on March 5, 2025, key feedback was collected regarding our first prototype, guiding our design modifications for Prototype II.

Key Feedback Insights & Implementation:

- **Camera Viability:** No feedback.
- **Process Repeatability & Calibration:** The importance of this was stressed in the feedback.
- **Subsystem Complexity:** No further feedback.
- **Sampling Method:** Received feedback that our current plan for a sampling mechanism would have multiple failures.
- **Cost Efficiency:** No further feedback was given.

III. Prototype II Development

Prototype II Overview:

Prototype II focuses on refining the sampling mechanism and enhancing sensor integration to improve performance reliability.

Design Changes & Subsystem Updates:

1. **Sampling Mechanism:**
    - Modified the deployment system to push the blade directly against the pipe.
2. **Feedback & Monitoring System:**
    - Testing newly written code
3. **Telescoping Deployment System:**
    - Modified the system to be more compact, with increased stability when deployed.
4. **Failsafe Enhancements:**
    - Ensured all components are secured with safety lines to prevent accidental loss in the pipe.

IV. Analytical & Experimental Model

To validate Prototype II, we employed an analytical model to predict mechanical loads and an experimental setup to measure subsystem performance.

1. **Analytical Model:**
    - Conducted force analysis on the sampling blade to ensure structural integrity during operation.
    - Simulated extension/retraction forces to confirm smooth deployment within acceptable stress limits.
2. **Experimental Model:**
    - Tested sensor feedback accuracy under operational conditions.
    - Performed sample collection trials on metal pipe mock-ups to assess blade efficiency.

V. Prototyping Test Plan & Results

Test Plan Objectives:

The primary objectives of Prototype II testing are to verify the efficiency of the new sampling mechanism, ensure accurate feedback integration, and confirm smooth deployment and retrieval.

Detailed Test Procedures & Metrics:

Test No.	Test Title	Objective	Test Description	Analysis Method	Metrics & Target
1	Sampling Efficiency	Validate sample collection consistency	Conduct trials on metal pipe mock-ups using the curved blade/file system	Measure sample mass per cycle	30-80 mg per cycle
2	Blade Actuation Accuracy	Ensure precise control over sampling motion	Test the stepper motor actuation with controlled movements	Compare expected vs. actual blade position	Deviation < 1 mm
3	Feedback System Response	Assess real-time monitoring reliability	Operate system under varied conditions and analyze sensor accuracy	Cross-check sensor output with manual observations	< 5% error margin
4	Deployment Stability	Confirm uniform extension/retraction	Extend/retract system under load conditions	Measure displacement uniformity and response time	No jamming, consistent operation

Stopping Criteria:

Testing will conclude once each test yields consistent results over three consecutive cycles. Any major failures will prompt a reassessment and design refinement before further testing.

VI. Test Plan for Prototype III

Prototype III Objectives:

The next prototype will integrate further refinements based on feedback, aiming to:

- Achieve full system integration with real-time monitoring.
- Optimize sample collection reliability and actuation accuracy.
- Further improve deployment system responsiveness.

Prototype III Test Plan:

Test No.	Test Title	Objective	Test Description	Metrics & Target
1	System Integration	Validate full prototype functionality	Conduct full-scale operational tests with all subsystems integrated	Complete a full cycle with < 5% error
2	Sample Consistency	Ensure sample collection is repeatable	Conduct multiple extraction cycles under identical conditions	Mass deviation < 5%
3	Sensor Data Accuracy	Validate real-time data feedback	Compare Arduino sensor output with physical measurements	< 3% discrepancy

Stopping Criteria:

Testing will stop once each test produces stable, repeatable results over three trials. Any major failures will be addressed before further development.

VII. Conclusion

In conclusion, this deliverable has highlighted crucial feedback received in our third client meeting, as well as how we integrated this feedback into our second and third prototypes. Our second prototype's higher fidelity allowed us to gain more accurate results through testing. These test results are currently being taken into account for the design of the third prototype. We will move forward in fabricating our third prototype, so that we shall be able to complete our final tests for our tool.