Design Criteria and Target Specifications

Franco Barreto, Felipe Pedrosa, Adam Peever, Logan Tutert, Omar Al-Juboori

January 30, 2025

Introduction:

In the development of a modular pipe scraper designed to extract precise metal samples from a 15-foot-long, 4-inch-diameter tube, it is essential to establish clear design criteria and specifications. This document outlines the prioritized design criteria, technical benchmarking of existing products, and target specifications that will guide the final solution. By analyzing user needs and industry benchmarks, we aim to develop a portable scraping tool that meets the defined operational requirements. Additionally, insights gained from client feedback have been incorporated to refine key design considerations, ensuring that the final product aligns with both technical constraints and user expectations. The client emphasized the importance of fail-safe mechanisms and sample containment, elevating their priority in our design criteria. Additionally, real-time feedback integration was requested, and while we have identified potential solutions, further research is required to refine its implementation.

Prioritized Design Criteria

Need from Deliverable B	Design Criterion	Type	Priority	Constraints	Metric
Ensure 15 ft. sampling depth	Reach 15 ft. in 4-inch-wide tube	Functional	5	Minimal length bend	Distance (ft)
Operate in vertical/horizontal tubes	Adapt to tube orientation	Functional	5	Functional strength at joints	Orientation tolerance
Collect 30-80 mg samples	Precise sample weight control	Functional	5		Weight (mg)
Fail-safe retrieval	Automatic stop on release	Functional	4	Automatic activation	Response time (sec)
Modularity/portability	Disassembles for transport	Non-functional	3	Modularity cant compromise structural integrity	Assembly time (min)
Real time feedback	Efficient operator communication	nonfunctional	2	Near instant response to user (<150ms)	Response time (sec)
Emphasize cleanability for maintenance.	Easy and safe dis/reassembly	functional	3	Modularity cant compromise structural integrity	N/A

Priority list:

Low (2): Desirable but optional enhancements.
Medium (3): Valuable for usability and maintenance but not critical to core functionality.
High (4): Important for operational reliability and user safety
Critical (5): Essential for core functionality, safety, or compliance.

Technical Benchmarking

Existing Product	Key Features	Needs Addressed	Gaps/Shortcomings
Chimney sweep drill (Amazon)	Modular, drill-powered scraping	- Depth reach - Modularity	- durability
Picote Maxi power+ pipe descaler	Powerful Durable	- Scraping mechanism	- Imprecise - Heavy contamination
Articulated Inspection Cameras	Flexible and modular design	- Allows for horizontal/vertical orientation - Real time feedback	- Fragile - Mechanically complex
Fishing Rod with Drag System	A tension-release mechanism could ensure the tool retracts safely if it encounters excessive resistance (e.g., jamming	- Fail-safe mechanism - Retrieval method	- Limited force regulation - Not designed to pull the tool itself just present the line from breaking
Telescopic ladders	Collapsible design allows for easy portability	- Portability	- Bulky and potentially heavy - Not designed for small scale operation - Complex assembly
Smart Agriculture Sensors	Real-time data transmission (e.g., moisture, temperature). Wireless connectivity Low-power operation.	- Real time feedback	- Complex integration with mechanical systems. - Limited durability in harsh environments.

While our initial benchmarking has identified existing products that address certain design needs, we recognize that further research is required to refine key aspects of the design, particularly in the implementation of a real-time feedback system. This feature is crucial for ensuring precise sample collection and improving operator control but presents significant challenges in terms of feasibility, integration, and usability.

One potential solution involves the use of high-definition (HD) inspection cameras. These cameras are commonly used in pipeline maintenance and industrial inspection, providing real-time visual feedback of internal conditions. Implementing such a system could allow operators to monitor scraping progress and verify sample collection, but challenges include space constraints, durability, and power requirements.

Another option under consideration is Magnetic Flux Leakage (MFL) sensors, a non-destructive testing method used to detect variations in metal surfaces. MFL sensors could provide valuable data on the sample site's surface characteristics before and after scraping. However, integrating this into a compact, portable tool while maintaining cost-effectiveness will require further investigation.

We acknowledge that incorporating advanced feedback mechanisms will be one of the more difficult aspects of our design. The trade-off between accuracy, reliability, and portability must be carefully evaluated. As we progress, our team will continue researching the viability of these solutions, exploring alternative sensor technologies, and refining our approach to ensure the best balance between functionality and practicality within our design constraints.

Target Specifications

Metric	Target Value/Range	Justification
Sampling depth	15 ft	CNL's operational requirement
Sample weight	30-80 mg	CNL's operation requirement
Fail-safe response time	≤2 seconds	Client prioritizes operator safety, time range is the average human response time
Assembly time	≤10 minutes	Realistic time range for a tool setup given the aimed complexity

---

Task	Description	Assigned To	Deadline	Buffer Time
Research Benchmarking	Identify and analyze 3 more existing products per need	Franco	2/2/2025	+2 days
Define Design Criteria	Establish prioritized design requirements.	Omar	4/2/2025	+2 days
Develop Initial Concept	Sketch/outline possible scraper mechanisms.	Felipe and Franco	7/2/2025	+3 days
Define Material & Component Selection	List potential materials and components that align with budget and performance goals.	Nolan	9/2/2025	+2 days
Prototype Feedback System	Explore potential feedback mechanisms.	Franco and Adam	11/2/2025	+2 days
Fail-Safe Mechanism Analysis	Research and propose retrieval solutions.	Omar and Nolan	14/2/2025	+3 days
Target Specifications	Define numerical performance metrics.	Adam	16/2/2025	+2 days