# Conceptual Design

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**Introduction:**

It is impossible to build a prototype, let alone a final product without first creating a conceptual design. This is because a conceptual design serves as the foundation in which to visualize the core functionality of a system. In our assigned project design a tool to scrape a metal sample from the inside of a 4-inch pipe, our group has found that there are 4 different subsystems which must be designed. If we were to design the tool as a whole, there would certainly be a subsystem overlooked, this is why this group has created a set of 20 conceptual designs spread across the 4 subsystems which can later be combined into a complete assembly. This will ensure that we are able to prototype and modify each existing design without affecting the whole, and that we are able to better focus our energy into designs that will work. For these reasons it is crucial to come up with conceptual designs in engineering.

**Subsystems**

Based on our research in the previous deliverables, our team has identified 4 different subsystems which come together to form the complete tool. These subsystems are:

1. **The Sampling Mechanism** (How the metal is scraped and collected)
2. **The Fail-Safe** (Ensures safe tool recovery no matter what)
3. **The Feedback & Monitoring System** (Real-time updates to the operator)
4. **The Extension and Retraction System** (How it will reach the 15 feet length)

**Generation of concepts for each subsystem:**

Each group member has designed a different concept for each subsystem. This ensures that each our group is able to determine the best aspects of each concept, so that we might be able to incorporate these aspects into the final design. Each group members' concepts are listed below.

**Adam:**

**Paint Scraper**

- Materials: Metal paint scraper
- Pros: Sample is collected as a small metal piece, not a powder.

- Cons: Tool will become worn down over time, force generated must not snap the paint scrapper.

**Expanding Insert**

- Materials: Some rigid material roughly the same diameter as the pipe
- Pros: Catches all of the tool, as well as preventing it from falling further into the pipe,
- Cons: Bulky, takes some force to remove from the pipe.

**Continuity Sensor**

- Materials: Continuity sensor attached to our tool, as well as the side of the pipe
- Pros: Simple
- Cons: Non-precise in the feedback provided, only telling when the scraper is in contact with the pipe, requires conductive material from the scraper to the place where the continuity tester is placed, pipe may not be made of a conductive material.

**Balloon Tube**

- Materials: Flexible, Air-tight material formed into a tube.
- Pros: Very stable when fully inflated, fail-proof (unlikely to ever become unretrievable)
- Cons: Expensive, requires an air compressor to be deployed quickly, difficult to mount the collection tool upon it.

**Felipe:**

**Drill-Powered Scraper** (Inspired by chimney cleaning tools)

- *Pros:* Effective scraping, modular
- *Cons:* Might be difficult to control weight of collected sample

**Spring-Loaded Retraction Mechanism** (Inspired by fishing rod drag system)

- *Pros:* Automatic retrieval, minimizes jamming risk
- *Cons:* Requires precise tension adjustment

**Distance Sensor**

- *Pros:* Determines the safest spot to collect from
- *Cons:* Does not give information about the operation of the tool

**Hydraulic Expander**

- *Pros:* Stable and Reliable

- *Cons:* Not portable, Expensive

**Franco:**

**Inspection Camera**

- *Pros:* Direct visual feedback of sampling process
- *Cons:* Needs protection from debris/damage

**3D-Printed Modular Segments**

- Materials: 3D-printed PLA connectors, PVC tubes.
- Pros: Customizable for different tube sizes.
- Cons: Assembly takes time.

**Manual Pulley System**

- Materials: Pulley system, nylon rope, 3D-printed guide.
- Pros: No moving parts, ultra-cheap.
- Cons: Requires manual control.

**Sandpaper Roller Scraper**

- Mechanism: A rotating drum wrapped in sandpaper scrapes the metal while turning.
- Materials: PVC drum, fine sandpaper, manual crank or drill attachment.
- Pros: Even sample removal, simple.
- Cons: Sandpaper wears out over time

**Nolan:**

**Extendable Blade with Vacuum Collection**

- *Pros:* Ensures containment, allows precise control over sample size
- *Cons:* Requires additional power for vacuum function

**Vibration Feedback**

- Materials: Spring, small vibration motor
- Pros: Simple tactile feedback.
- Cons: No real-time digital data.

**Velcro-Activated Emergency Pull Tab**

- Mechanism: A Velcro strap releases the tool when pulled with force.
- Materials: Velcro, nylon tether, plastic casing.
- Pros: Super cheap, lightweight.
- Cons: Requires manual force, limited reusability.

**Foldable Hinged Segments**

- Mechanism: Multiple segments joined by hinges unfold to full length.
- Materials: Plastic/metal segments, hinge pins.
- Pros: Super compact, durable.
- Cons: Takes longer to assemble.

**Omar:**

**Collapsible Telescopic Rod**

- Materials: Plastic rod, screw-lock segments.
- Pros: Portable, cheap.
- Cons: May need reinforcement.

**Magnetic Attachment with Quick-Release**

- *Pros:* Strong hold but allows emergency disengagement
- *Cons:* Might require non-ferrous sampling material

**Thin Wire Brush Abrasion**

- Mechanism: A thin, high-density wire brush scrapes the tube's interior as it rotates
- Materials: Steel wire brush head, rotating shaft.
- Pros: Works well on varied metal surfaces.

**Audible Click System**

- Mechanism: A clicking sound is produced every time a sample is removed.
- Materials: Spring-loaded ratchet mechanism, metal bead.
- Pros: Simple, no power needed.
- Cons: Requires operator to listen closely.

**Generation of final concepts:**

**Concept 1: High Precision & Full Monitoring**

- **Sampling Mechanism:** Extendable Blade with Vacuum Collection (Nolan)
- **Fail-Safe & Retrieval System:** Spring-Loaded Retraction Mechanism (Felipe)
- **Feedback & Monitoring:** Inspection Camera (Franco)
- **Extension & Retraction:** Collapsible Telescopic Rod (Omar)

**Pros**

- Precise and contained sample collection (vacuum prevents loss of metal particles).
- Live feedback via an inspection camera allows for real-time adjustments.
- Spring-loaded retrieval ensures safe removal.
- Collapsible telescopic rod makes it highly portable.

**Cons:**

- Vacuum requires a small power source.
- Inspection camera needs protection from the magnetite.

**Concept 2: Strongest Fail-Safe & Reliability**

- **Sampling Mechanism:** Drill-Powered Scraper (Felipe)
- **Fail-Safe & Retrieval System:** Magnetic Attachment with Quick-Release (Omar)
- **Feedback & Monitoring:** Continuity Sensor (Adam)
- **Extension & Retraction:** Foldable Hinged Segments (Nolan)

**Pros :**

- Motorized scraping ensures efficient sample collection.
- Magnetic attachment allows instant tool retrieval.
- Continuity sensor provides direct confirmation of contact with the pipe.
- Hinged segments make extension easy and highly durable

**Cons:**

- The magnetic attachment requires a ferromagnetic pipe.
- Hinged segments take longer to set up than a telescopic rod.

**Concept 3: Best for Cost & Simplicity**

- **Sampling Mechanism:** Paint Scraper (Adam)
- **Fail-Safe & Retrieval System:** Velcro-Activated Emergency Pull Tab (Nolan)
- **Feedback & Monitoring:** Audible Click System (Omar)
- **Extension & Retraction:** 3D-Printed Modular Segments (Franco)

**Pros :**

- Extremely cheap yet highly effective.
- Velcro retrieval is simple and lightweight.
- Audible click system provides instant mechanical feedback.
- 3D-printed modular segments allow size customization.

**Cons:**

- Velcro may not be strong enough for emergency retrieval.
- Paint scraper may wear down over time.

**Concept 4: Best for Stability & Tube Compatibility**

- **Sampling Mechanism:** Thin Wire Brush Abrasion (Omar)
- **Fail-Safe & Retrieval System:** Expanding Insert (Adam)
- **Feedback & Monitoring:** Vibration Feedback (Nolan)
- **Extension & Retraction:** Collapsible Telescopic Rod (Omar)

**Pros :**

- Brush abrasion works on various pipe materials
- Expanding insert prevents tool from being lost inside the tube.
- Vibration feedback provides a simple yet effective monitoring system.
- Collapsible telescopic rod keeps the tool highly portable.

**Cons:**

- Expanding insert may be difficult to remove from the tube.
- Brush might require frequent replacement.

**Evaluation with a Selection Matrix**

| Need from Deliverable B | Priority defined in Deliverable C | How well each solution meets these goals | | | |
|---|---|---|---|---|---|
| | | Solution 1 | Solution 2 | Solution 3 | Solution 4 |
| 15 ft. sampling depth | 5 | 4 | 4 | 5 | 5 |
| Operation in vertical / horizontal tubes | 5 | 5 | 4 | 5 | 5 |
| Collection of 30-80mg samples | 5 | 5 | 5 | 4 | 5 |
| Fail-safe retrieval | 4 | 5 | 3 | 2 | 5 |
| Modularity / Portability | 3 | 4 | 5 | 5 | 4 |
| Real time feedback | 2 | 5 | 4 | 2 | 2 |
| Cleanability / Maintenance. | 3 | 3 | 4 | 5 | 4 |
| Design rating (Efficacy * Weight) | | 121 | 112 | 112 | 123 |

**Justification of the Final Selection:**

The design that we selected was solution 4. We chose this one because it preformed the best in our selection matrix. One thing to note is that this selection is only as good as the accuracy of the weights in the selection matrix. This selection may be re-evaluated after the client meeting, as then we will have more in-depth picture of what our client is looking for. The client's feedback may also cause us to change one of the individual subsystems of the design, but this is an advantage of dividing the project into subsystems, we can change a subsystem with the others remaining the exact same.