Conceptual Design

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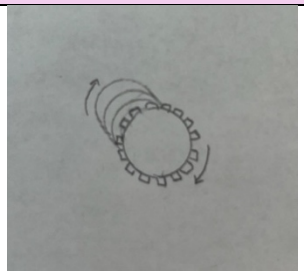
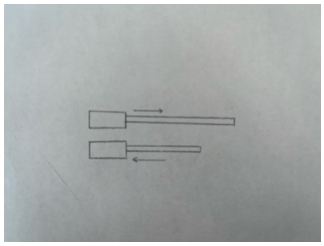
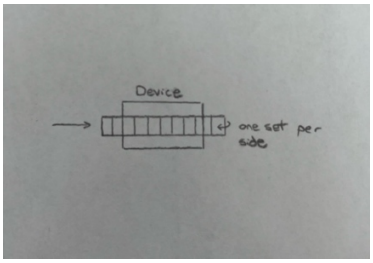
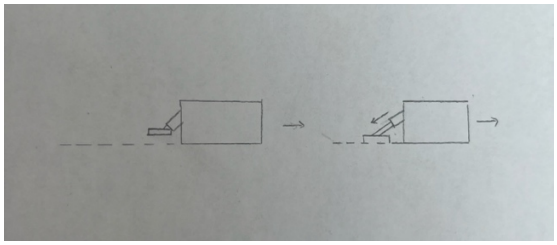
February 9, 2025

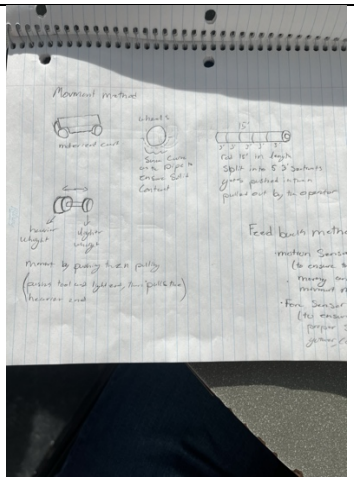
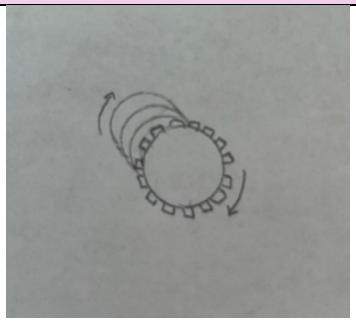
Table of Contents

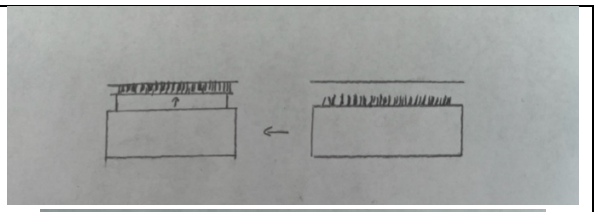
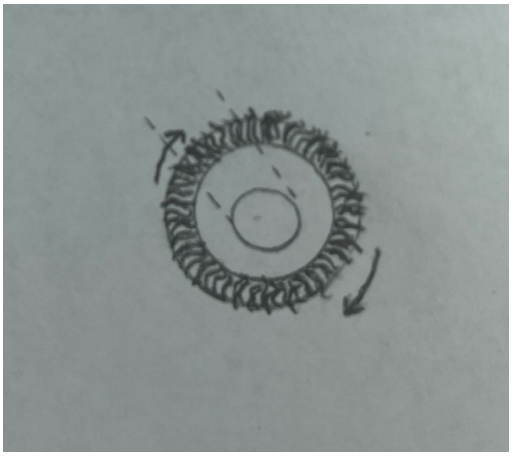
Introduction

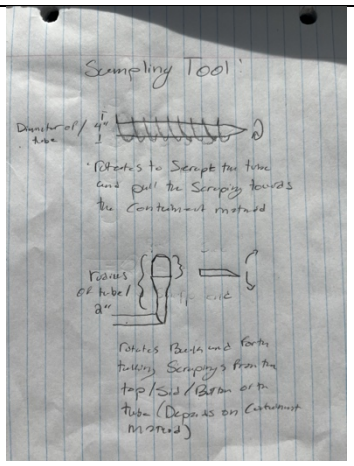
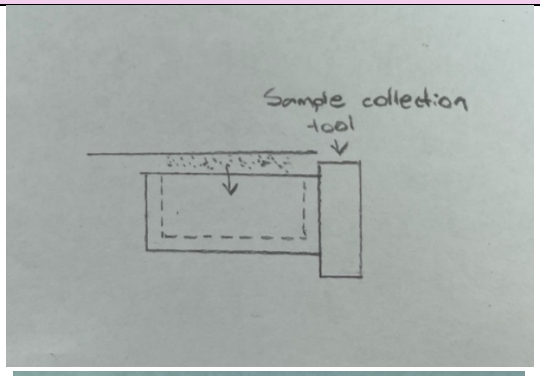
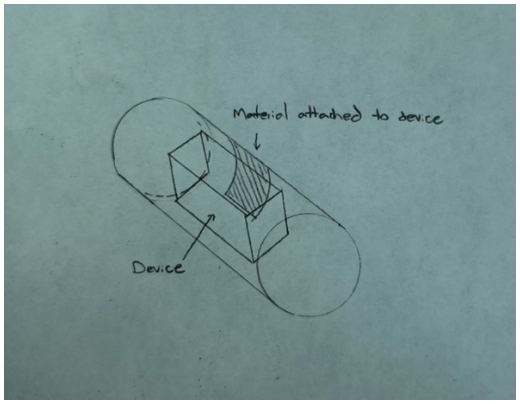
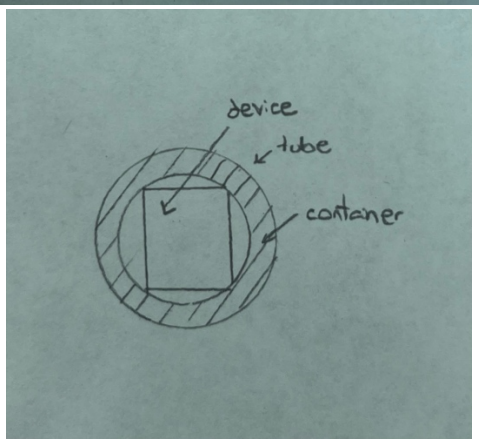
To make a device for any client, a series of stages are required for design. It is not possible to jump ahead and create a properly functioning product, that both fulfills the client's needs and exceeds them, without first considering the product from different perspectives. Once the concepts are generated, they are then analyzed and evaluated so that they can function with the different constraints the device will have. The purpose of this document is to create a final solution for the product by improving different ideas to make something better.

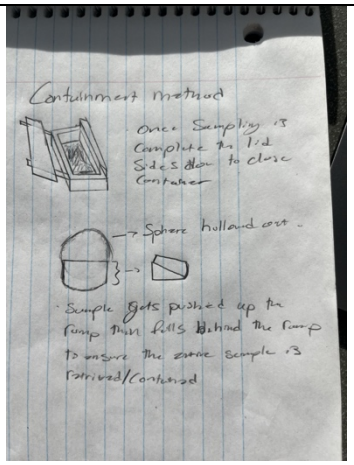
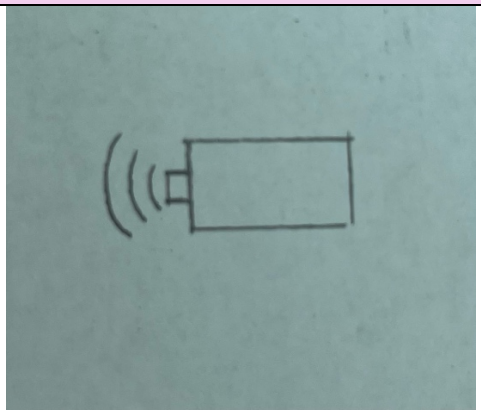
Generated Concepts

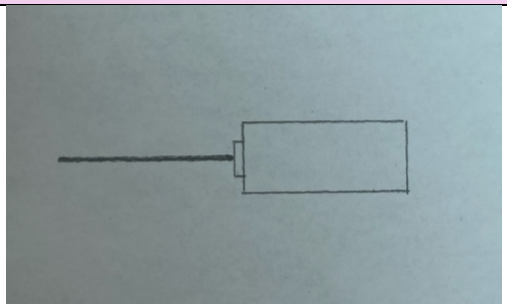
Team Member	Concept	Sketch/Diagram
Locomotion		
Eva C.	1. Helical front that spins in a spiral motion, similar to an auger drill, that will also act as the sample collection tool once it reaches 15 ft. The first edges are serrated for scraping or chipping. 2. A push rod or linear actuator attached to the device that is at least 15 ft. It can be both pushed and pulled using a control system. 3. A continuous track system (treads) placed on a side(s) of the device. 4. Device similar to a linear actuator, located behind the device, that uses friction on the bottom of the tub to push forward. 5. Lead screw	   

Wilson O.	1. Push-pull system, with integrated tracks for precise movement in the given space	
Mo S.	1. Caterpillar-treads like to ensure maximum traction inside the pipe 2. An enclosed sampling container attached to the device 3. An extendible arm-like that can reach inside the pipe	
Brennon B.	1. Motorized cart to push/ pull the sampling tool 2. To two sections that push and then pull each other through the tube 3. 15' rod split into 5-3' sections that connect tightly to push the tool in then pull it out	
Sample collection		
Eva C.	1. An auger drill that is the same diameter as the pipe 2. A steel wool brush placed on the front or sides of the device 3. A crimped wire wheel roughly the same diameter as the	

	pipe, mounted on the front	 
Wilson O.	1. A mechanical claw that grips and retrieves the samples, motor to provide gripping force, sensors to enforce accuracy and prevent excessive pressure.	
Mo S.	1. An excavator like bucket 2. Teeth mounted at the front to scrape and collect samples 3. A vacuum-operated tube inside the bucket to collect all samples to the tube	

Brennon B.	1. Screw like design to scrape the sides of the pipe and pull the shavings towards the containment method 2. Razor like blade to scrape the top of the tube creating shavings that then fall to the bottom of the tube	
Containment		
Eva C.	1. A sample container placed behind the sample scraper, with a lid that will seal on top (without contact with the operator) once the sample collection is complete. 2. Soft or sticky material that will temporarily hold the sample, which will then be placed into the container (like gunshot residue collection). 3. A container that surrounds the sample collection method, and then seals.	  

Wilson O.	1. Vacuum sealed chamber, a two part system after the metal samples have been mined. A secondary system will vacuum the samples.	
Mo S.	1. The container is attached to the device with a mechanism that does not allow sample to fall out	
Brennon B.	1. Container to that is in contact with the bottom of the tube (ramp/wedge) to collect any samples pushed towards it 2. A short container the width of the tube is set under the sampling tool to collect any samples that are falling	
Communication		
Eva C.	1. A buzzer that indicates the device has traveled 15 ft, and therefore begun sample collection. Another buzzer that communicates when the device has collected a proper sample, and that collection should be stopped (determine how long the tool	

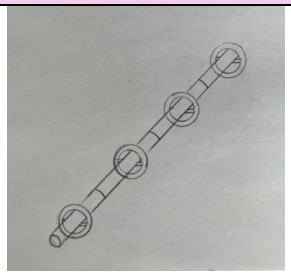
	take to collect using prototype tests).	
Wilson O.	1. Wireless sensor transmission, sending real time data to a monitor	
Mo S.	- Sensor that triggers a colour switching LED in the control	
Brennon B.	1. Force sensor to weigh the sample during collection and sending the force back to a computer ensuring the sampling is working 2. Motion sensor during the travel in and out of the tube to ensure the tool is moving	
Failsafe		
Eva C.	- Cable attached to the back of the device to pull it back. - A kill switch for mechanical parts (each moving parts stops automatically if something goes wrong).	
Wilson O.	1. Automatic locking system, any malfunctions during the sample retrieval process, will cause the system to shutdown and stop moving	
Mo S.	1. A metal wire attached at the back	

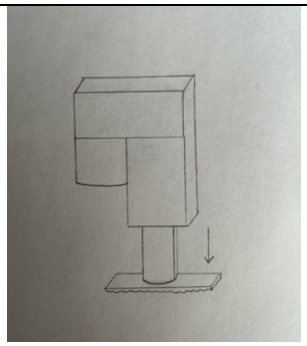
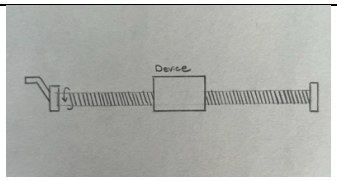
	of the device to pull it if anything failed	
Brennon B.	1. Rope/cable attached to the widest part of the tool to ensure all parts are retrieved out of the pipe in case of part separation	

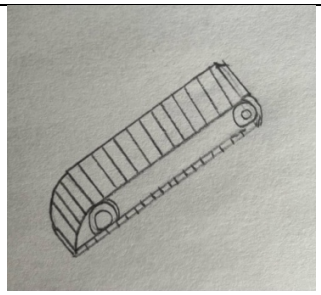
Questions for the client:

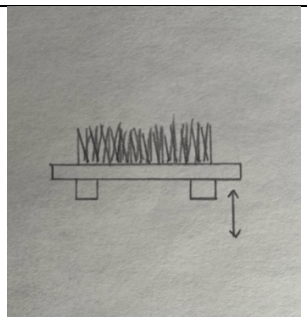
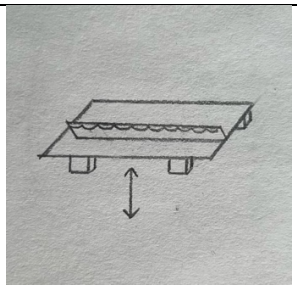
1. Does the sample need to be isolated within the container, or can it be given with another material(s)?
2. How much contact can there be with the device?
    a. Can we push it in?
    b. Can we cap the sample?
    c. Etc.
3. How advanced does the communication of each stage have to be?

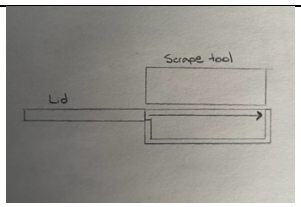
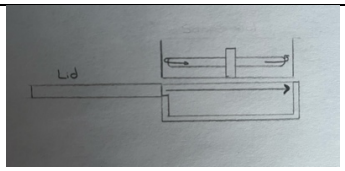
Refining Subsystems

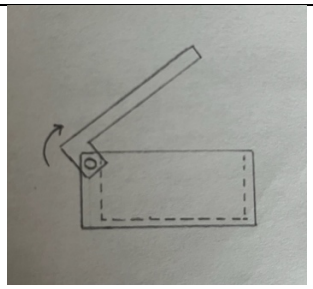
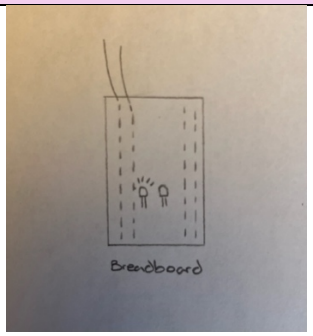
Subsystem	**Concept Description**	**Sketch**	**Advantages**	**Drawbacks**
Locomotion				
Separated rod	A rod that is divided into sections that make up a minimum of 15 ft. The first piece is attached firmly to the sampling device, and the others are gradually added on, in order to		The rod can be moved both forwards and backwards in the pipe, with minimal operative skill. The design is simple and eliminates the need for	The movement of the device is based on the operator, which may result in a clumsy or imprecise scraping movement. It also requires constant

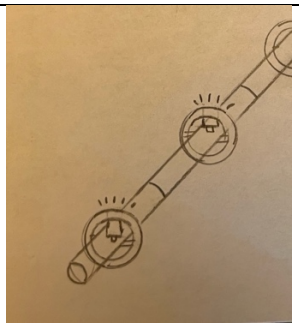
	push the tool further into the pipe. Sections of the pipe have concentric guides to keep the path stable.		a complex construction and design.	contact and supervision from the operator, as each part needs to be attached manually.
Push mechanism	The device has a mechanism similar to a linear actuator located on the back. The part is attached to a piece of material that has high traction, such as rubber, which is pressed into the floor of the pipe, to push the tool forward. The movements would be repeated until the device reaches the required depth.		The mechanism would prevent contact with the operator. The distance traveled can be determined using testing.	The device would have to be removed from the pipe using a different method. It is also more likely to encounter error due to the repetitive and uncontrollable movements.
Rod with crank	The device has an attachment on the bottom that connects it to a threaded rod (a minimum of 15 ft), that is		The movement is easy to control, and the device remains stable. The device can	The tube takes up vertical space in the pipe. It also will be awkward to transport due to its length.

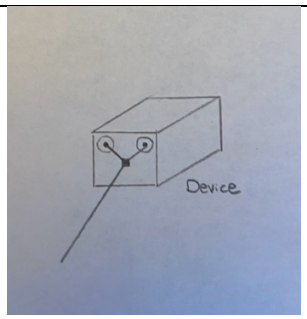
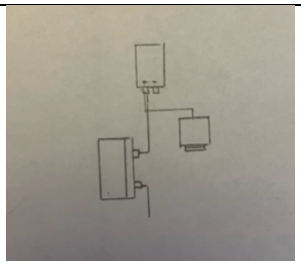
	placed into the pipe. The device then moves forward when the tube is turned by a crank, like a leadscrew. There is a stabilizing part on the very end of the rod, to keep it in place.		be moved forwards and backwards.	If the tube is divided into sections, it becomes more unreliable when assembled.
Continuous track	The scraping tool is contained within a section of continuous track, leaving open space on the sides for sampling collection. The track movement is controlled by gears.		The device can move in both directions and is faster than the other methods. It doesn't require constant contact, as it would be controlled remotely.	The tool would need to scrape the sides of the tube, which would make it harder to collect samples. The track mechanisms would also take up a lot of space in the tube, considering the pipe has a diameter of 4 inches.
Sample Collection				

Steel wool brush	A section of steel wool bristles is attached to a small platform, which can be raised or lowered when needed. The steel would then scrape the top of the tube when the device moves forwards or backwards.		The abrasive material of the steel wool is good for removing debris and scratching hard metals.	The sample particles can get stuck in the bristles, and it is unknown if the brush can be contained and submitted to the lab for analysis. The scraping also relies on the movement and speed of the device's transportation system, which may affect the force.
Razor	A flat, wide razor blade, that roughly spans the top of the fuel channel. It is raised and lowered as required and scrapes along the top as the device moves. The razor is located above a container, so that the samples will fall into it.		The blade will collect a larger amount of sample due to its width. It will also be easier for the sample to get into the container, as it is less likely to get caught on the razor.	The razor may break or fall out of its position due to its low strength and thickness, and the force required for scraping. It will also be difficult to angle it precisely.
Containment				

Container placed underneath tool	If the steel wool bristles are used for scraping, the platform will have holes to allow the sample particles to fall through and enter the container. If the razor is used, it will be located underneath the edge of the razor. The container will have an open top. Grooves will be etched into the sides so that the lid (located next to the container) will slide firmly on top of it, with a simple pushing motion.		The container is located as close as possible to the tool, which minimises both loss of the sample and the time needed to complete the collection. It also allows the container to seal without contact with the operator.	The containment method relies solely on gravity, and the only way to measure the amount of sample in the container is using estimates based on tests. The lid and container will have to be positioned perfectly, which may be difficult as the container needs to be detachable.
Vacuum	A small fan is located in front of the container, to move the sample directly into the container.		The fan will use some force to move the samples into the container, instead of relying on gravity.	The fan blades may collect too much of the sample or deflect it from the container. Furthermore, there is no way of

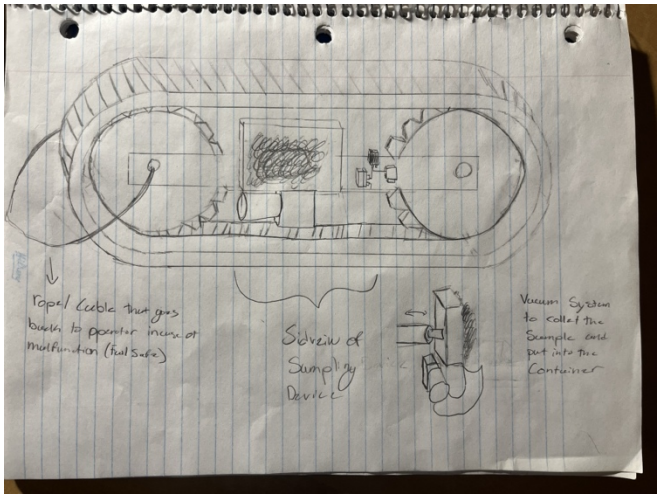
				knowing when the amount of sample is sufficient besides being based on tests.
Container with a cap	The container has a lid that is positioned upright until the device is finished collecting the tool. Once complete, the lid is pushed down, and a simple locking mechanism seals the container closed.		The locking mechanism will allow for a better seal, improving the level of containment. The lid will be attached to the container.	The lid's upright position takes up vertical space, meaning the container will have to be placed lower than the tool, increasing the possibility for sample loss.
Communication				
Sensors and LEDs in a circuit.	The system has a combination of sensors and LEDS to communicate each stage. When the device is moving, the LED will flash in a cycle. When the tool is being used, it will stay on constantly. A		LEDs are simple to use and easy to understand. It does not require a lot of interpretation on the operator's part.	The components required for the circuit (wires, connecting cables, etc.) may be difficult to incorporate, as it will be used over long distances and may

	weight sensor is located directly underneath the container, and once the container and the sample reach a predetermined weight limit, an LED of a different color will flash, indicating collection is complete.			disconnect or malfunction.
Motion sensors located on the rods.	At various checkpoints, motion sensors will be located on the guides of the rod used to move the device. Once the device has reached the sensor, a buzzer will sound.		The buzzers are a simple method to communicate what is happening to the operator. If the device encounters an error, the buzzers will take longer to go off, and if it is working properly, they will be fairly consistent.	The components required for the circuit (wires, connecting cables, etc.) may be difficult to incorporate, as it will be used over long distances and may disconnect or malfunction.
Failsafe				

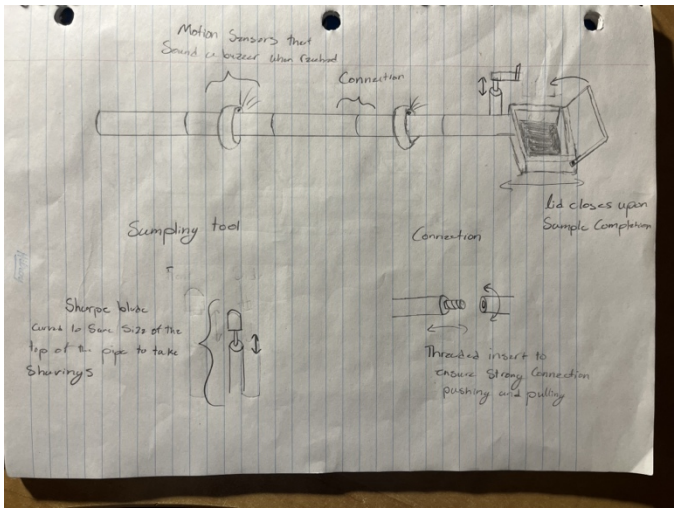
Cable	A cable is split and attached to the back of the device at two points.		The device can easily be pulled back if there is an issue. The two points will distribute the pulling force more.	If the device breaks, then some pieces of the tool may be left behind.
Kill switch mechanism	A kill switch system is incorporated into any mechanical parts.		The kill switch prevents any further damage to the device.	The kill switch system cannot recover any parts. It may be difficult to include in the design due to the distance within the pipe.

Functional Solutions

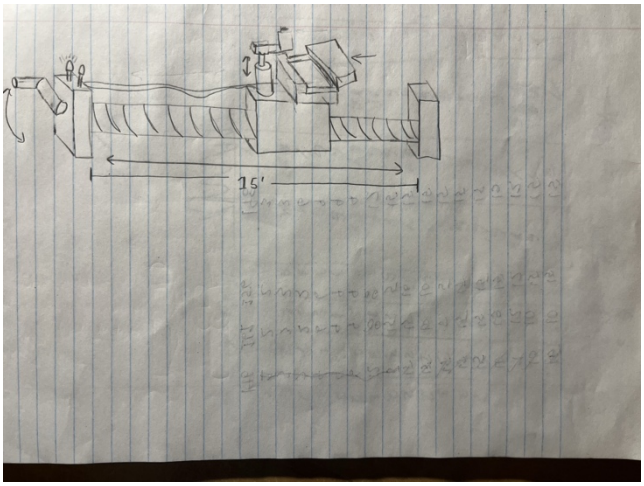
Solution 1



Solution 2



Solution 3



Analysis

Design Criteria	importance	Solution 1	Solution 2	Solution 3
Sensors and output	5	Motion sensor Scale G	Scale Y	Scale Auto stopping at final length G
Scale / Airtight container	5	Sealed container scale in container G	Sealed container scale in container G	Sealed container scale in container G
Basic controls and functions	4	All Robotic components controlled with a remote Y	Operator controlled Sampling deployed remotely G	Operator controlled Sampling deployed remotely G

Strong, inflexible material Guidance rails or shell	5	Sturdy shell with a flexible track Y	Inflexible rod split into sections with threaded connections G	inflexible material with a short platform G
Minimum length (15 ft)	5	Can travel various distances (<15') G	Fully constructed (15') G	Fully constructed (15') G
Weight detection Complete containment Accurate sampling	5	Scale Container with a lid Y	Scale Container with a lid Y	Scale Container with a lid Y
Fail-safe cable	5	Yes G	No R	No R
Battery powered	5	Entire system G	Deployment of sampling tool Y	Deployment of sampling tool Y
Maximum diameter (<4 in)	5	Yes G	Yes G	Yes G
Container release Connect sections	5	Small design Container release G	Container release Brakes into pieces G	Container release R
Minimal friction guidance rails Fail-safe cable	4	Fial safe cable and two-way motion G	Minimal friction materials Y	Guidance rail Y
Container release	3	Yes, but hard to get to due to size Y	Yes G	Yes G
Durable materials Replaceable materials Detachable components	3	Detachable container and durable materials G	Detachable container and rail connections Durable materials G	Durable materials and detachable container G
Weight (lbs)	3	Light weight due to size G	Heavy due to length and amount of materials but can be dismantled R	Heavy due to length and amount of materials Y
Cost ($)	2	cost of robotic components and sensors R	Cost of the materials and sensor R	Cost of materials and sensor R
Original design	1	Yes G	Yes G	Yes G
Durable materials	1	Yes, but many small components Y	In delivery system Y	Yes G
Total	198	178	158	157

	(Max score)			

Green = 3, Yellow = 2, Red = 1, * importance weight (1-5)

Solution 1

The first solution uses a track system driven by gears to move in and out of the tube with a fail-safe cable attached to the back of the device in case of failure. The sampling system is a steel wool brush that scrapes the side of the wall with a vacuum system that collects the sample and transports it to the container. Due to the design, it is light weight and uses few materials while also incorporating different sensors to communicate the different stages with the operator. With the added sensors and complex design, the cost to produce this device is relatively high compared to the given budget, but uses less materials compared to the other two solutions. The size of the device helps with the portability but also creates added problems with detaching the container. However, when overall compared to the other solutions and design criteria this solution is the best.

Solution 2

Solution 2 uses a rod split into various equal length sections that are connected with a threaded inset system comparable to a nut and bolt system. Due to the rod being 15 feet there is no need for a retrieval fail safe, but this increases the cost of construction for this solution. The sampling tool uses a razor-like design to scrape at the top of the pipe when it is pushed forward and back with the container directly below. This allows the sample to fall directly into the container and upon completion of sampling the container has a cap to automatically seal the container. As well as raising the cost of this option, the amount of materials also increases the weight of the design, possibly leading to damage of the fuel channel. Due to both the weight and the lack of sensors communicating with the operator, this solution is not the best when compared to the other solutions.

Solution 3

The third and final solution uses a 15 feet long threaded rod with a platform attached to it, holding the sampling tool and container. This platform travels back and forth, remaining upright when the rod is turned to ensure the sample is contained securely. The sampling tool consists of a razor blade-like scraping tool that is directly above the container so that the samples fall directly into the container. Upon completion of sampling the containers lid is pushed back over the container to properly seal the sample. However, due to the amount of materials needed and the lack of disassembly, this increases the cost while also decreasing the portability of this solution.

Furthermore, the amount of materials makes this design very heavy, increasing the risk of damage to the fuel channels. As a result, the third solution is not the best design for this problem when compared to the other two designs.

Conclusion

When comparing the three final design concepts with the design criteria, and considering the importance of each criterion, the first functional solution is the best of the three solutions.