MTE481 – DESIGN CONSTRAINTS
PIPE DESCALING ROBOT FOR PIPES ⌀100-150MM

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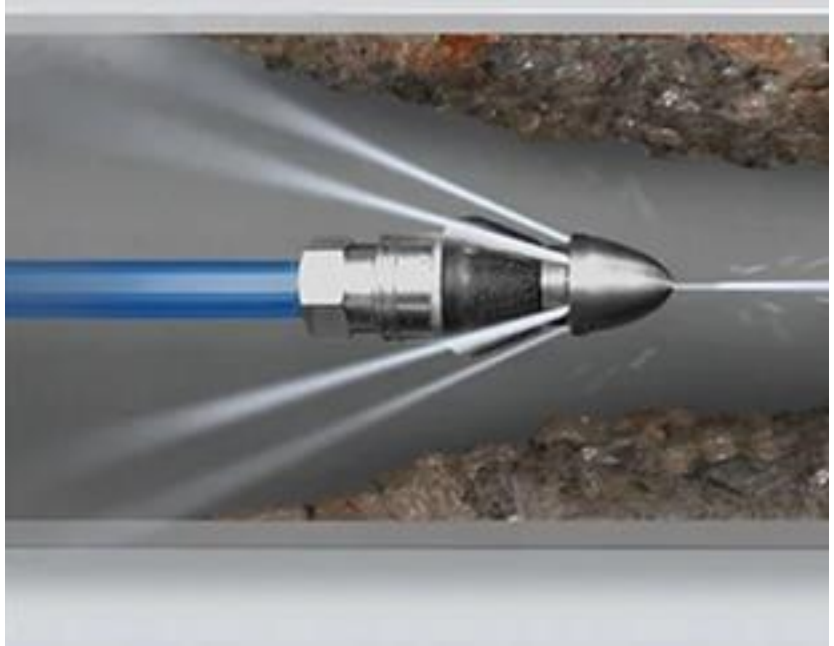
BACKGROUND: Current Pipe Descaling Methods

Pigging

Chemical Cleaning



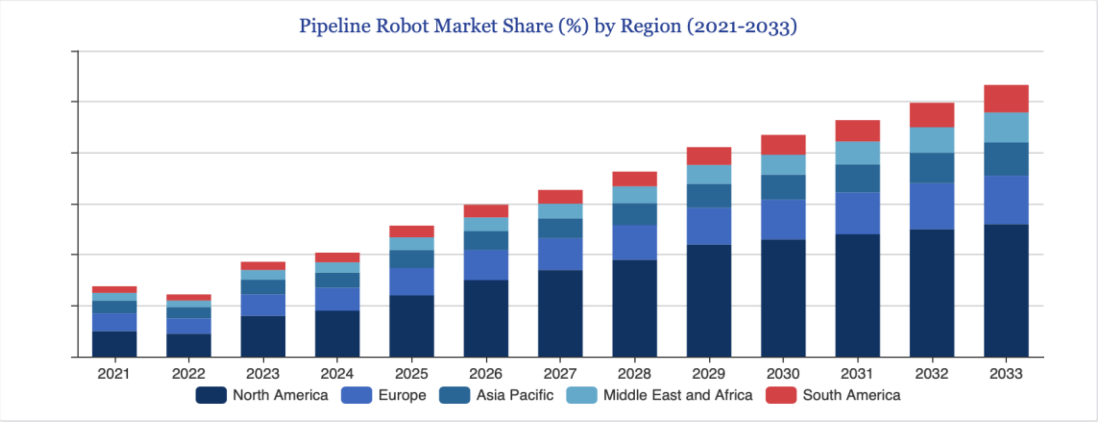
Water Jetting

BACKGROUND: Literature Review

- Pipeline robotics is a growing market **6.59%** Compound Annual Growth Rate (CAGR) [10]
- Water jetting – high energy and water cost (**10k-40k psi pumps, 1,500-3,000 L/hr**) [2]
- Pigging is unusable for **40-60%** of pipes [1]
- Downtime costs of **$20k-$100k/hr** [10]
- For smaller diameter pipes, most solutions involve inspection, not descaling
- Current robots have difficulty navigating 90-degree bends

Report Attribute/Metric	Details
Market Size 2024	9.53 (USD Billion)
Market Size 2025	10.15 (USD Billion)
Market Size 2034	18.46 (USD Billion)
Compound Annual Growth Rate (CAGR)	6.59% (2025 - 2034)

Source: Market Research Future



Source: Cognitive Market Research

BACKGROUND: Why hasn’t this been done?

- Large robotics solutions exist for large diameter pipes
- Smaller diameter pipes (100-150mm) presents packaging constraints for electronics and mechanical components
- Sharp bends/T-junctions pose a mechanical challenge
- Hard to get enough mechanical leverage from a smaller robot to descale
- High initial R&D costs
- Some solutions show feasibility of biologically inspired designs

Source: General Electric

BACKGROUND: Challenges and Potential Shortcomings

Robot sizing

- Size constraints may make it difficult to descale as chassis may not generate enough force.
- Smaller motors/actuators are at risk of overheating especially during heavy descaling loads.

Pipe constraints

- Difference in pipe material and contents may affect robot performance (e.g. friction). Varying temperature and pressure in pipe may be an issue.
- Mobility through curved and 90° bends while cleaning will be difficult.
- Pipe damage and erosion is possible.

Safety

- Robot must be cleaned after use to de-risk cross-contamination with other pipes.
- Use of high-pressure water must be monitored.

BACKGROUND: Work Breakdown

Mechanical: Material selection, robot chassis, locomotion, and physical descaling mechanism.

Electrical: Motor/actuator control, sensor setup, power delivery, and waterproof wiring setup.

Software: Firmware for control, navigation code, data log setup, user interface with video streaming.

NEEDS ANALYSIS

Needs Statement:

Industrial and building systems require a safe, cost-effective and reliable method to remove mineral scale build-up from ⌀100-150mm pipes, where existing solutions such as chemical cleaning, pigging, and jetting are either hazardous, resource intensive or ineffective at hard deposits.

Problem Definition:

Design a low-cost robotic system that can navigate ⌀100-150mm pipe, mechanically remove scale and improve flow performance while being able to adapt to varying pipe sizes and geometries.

DESIGN SPECS: Criteria

Criteria	Reason
Size	Size of robot must be small enough to fit comfortably in ⌀90mm pipes
Mass	Light weight robot allows for easy transport
Speed	Move as efficient as a water jetting machine
Cost	Overall cost of the solution must be within budget
Manufacturability	Minimal number of parts and simple mechanism
Waterproofing	Work in damp/water splashing conditions
Mobility	Ability to move smoothly within pipes, including bends and junctions
Durability	Resistance to abrasion, chemicals, moisture
Precision	Ability to clean without damaging pipe walls

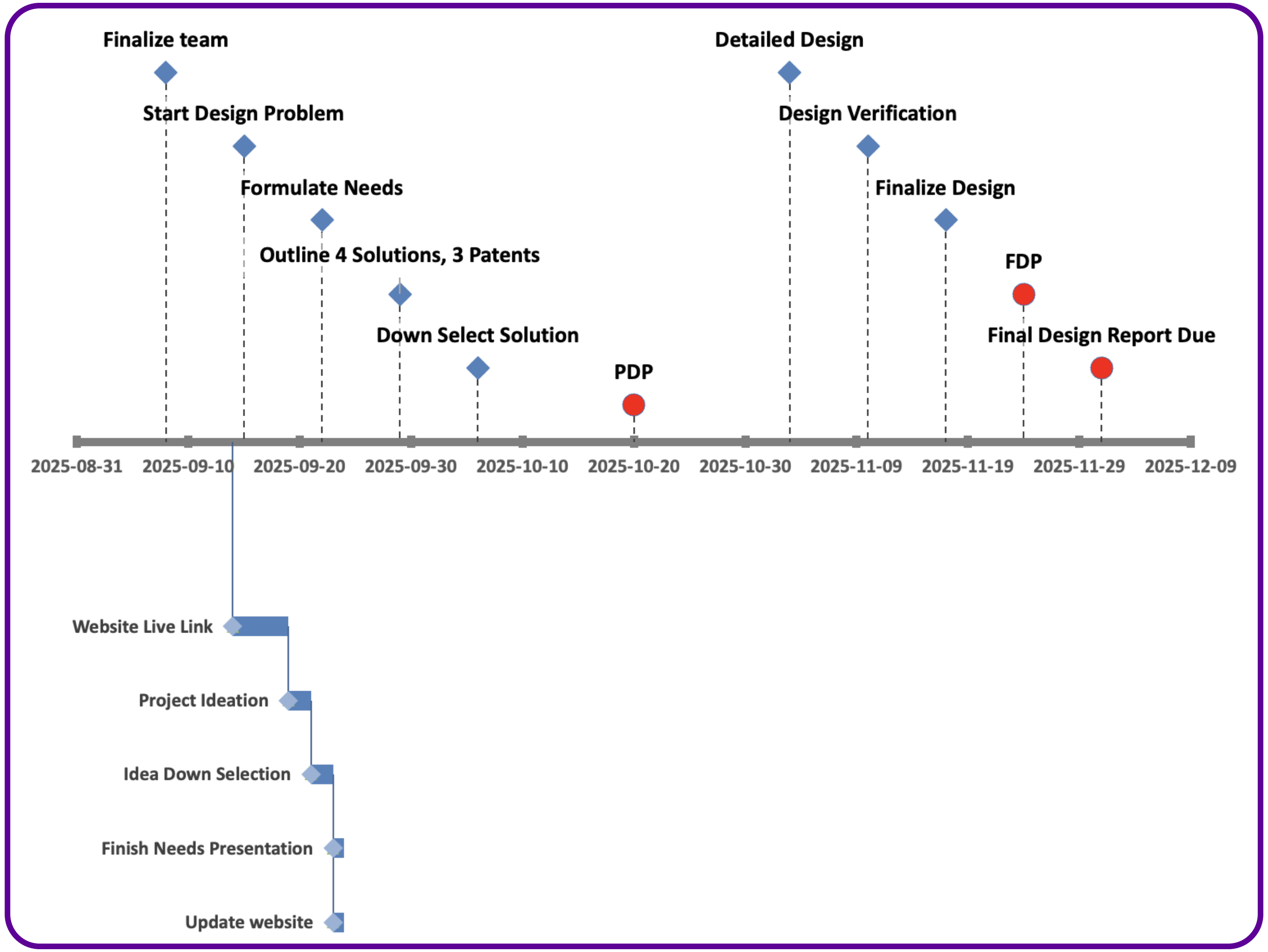
DESIGN SPECS: Constraints (needs)

Criteria	Constraint
Size/Operation	• The system must fit within ⌀100mm inner pipe diameter • The system must operate reliably in wet conditions
Cleaning Performance	• The system must mechanically remove >50% of simulated mineral scale • The system must complete one cleaning cycle without permanent pipe damage
Safety & Reliability	• The system must be retrievable via tether in the event of power loss or failure
Monitoring & Feedback	• The system must transmit live video

DESIGN SPECS: Objectives (targets)

Criteria	Objectives	Unit of Measurement	Notes
Pipe diameter compatibility	≤⌀90	mm	
Water sealed electronic enclosure	IP54	-	Solids (5): Dust protection Liquids (4): splashing water
Navigation of bends	90	Degrees	
T-Junction entry	≥80% success	%Trials	Ability to enter branch on demand
Scale removal effectiveness	≥50	%	Removal of $CaCO_3$/rust deposits
Cost	≤750	$	University allocated budget
Traction/adhesion force	≥5	N	Maintain grip while engaged
Movement speed	≥0.1	m/s	Continuous travel without stalling
Mass	<20	kg	Lightweight for retrieval and mobility
Live video transmission	480p, 10fps	pixels, fps	Assists in operator navigation of pipe system

PROJECT TIMELINE



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Next Steps

- Generate 4+ concept variation
  - Descaling mechanisms
    - Spinning wire brush/abrasive scrubber
    - Low-flow pressurized water jet
    - Razor scraper/chain knocker
  - T-junction/bend navigation mechanisms
    - Differential/tank tread drive
    - Articulated 4-bar crawler
    - Spring-loaded/pneumatic expansion

Next Steps

- Research appropriate cleaning rate x cm/min
- Research how to simulate scale build up in pipes
- Research any grants available

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QUESTIONS?