MTE481 – NEEDS PITCH
PIPE DESCALING ROBOT FOR PIPES ⌀100-150MM

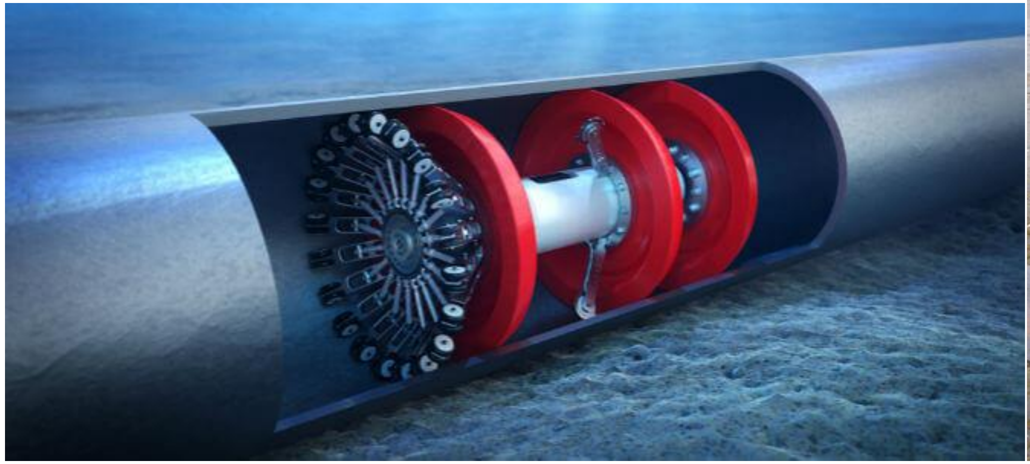
Angad, Annie, Francisco, Larry, Waris

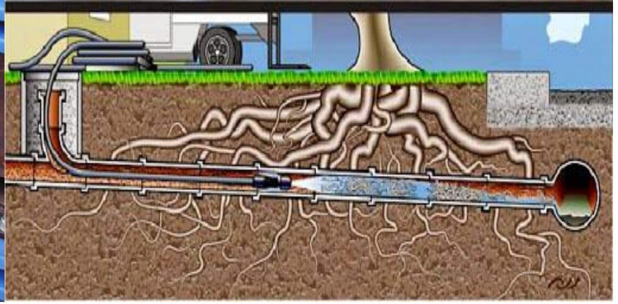
UNIVERSITY OF WATERLOO | FACULTY OF ENGINEERING

BACKGROUND

What is pipe descaling and the different methods currently used today?

- **Pigging**
- **Hydro-Jetting**
- **Chemical cleaning**





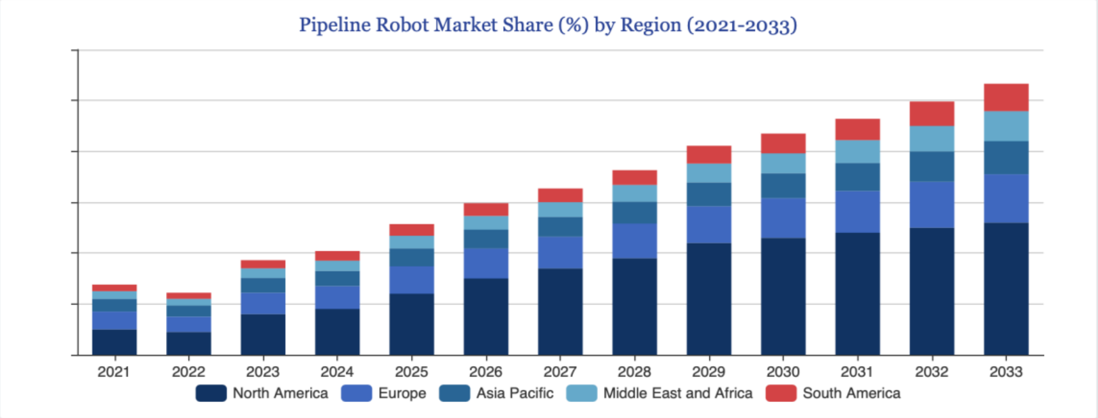
BACKGROUND

Literature Review

- **Pipeline robotics is a growing market**
- **Current descaling methods have disadvantages**
- **Most solutions involve inspection, not descaling**
- **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]**

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 it hasn't been done before?

- **Large robotics solutions exist for large diameter pipes**
- **Smaller diameter pipes (100-150mm) presents some challenges**
- **Few robotics solutions for smaller diameter pipes**
- **Sharp bends pose a mechanical challenge**
- **Hard to get enough leverage from a smaller robot**
- **Some solutions show feasibility of biologically inspired designs**

Source: General Electric

BACKGROUND

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.

BACKGROUND

Challenges and Potential Short Comings:

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^{o} 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: Criteria

Criteria	Numerical Value	Unit of Measurement	Notes
Pipe diameter compatibility	≤⌀90	mm	Must traverse both ⌀100 and ⌀150mm pipes
Water sealed electronic enclosure	IP54	-	Solids (5): Dust protection Liquids (4): splashing water
Navigation of bends	90	Degrees	Must traverse one 90-degree elbow
T-Junction entry	≥80% success	%Trials	Ability to enter branch on demand
Scale removal effectiveness	≥50	%	Removal of $CaCO_3$/rust deposits
Traction/adhesion force	≥5	N	Maintain grip while is engaged
Movement speed	≥0.2	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 piping

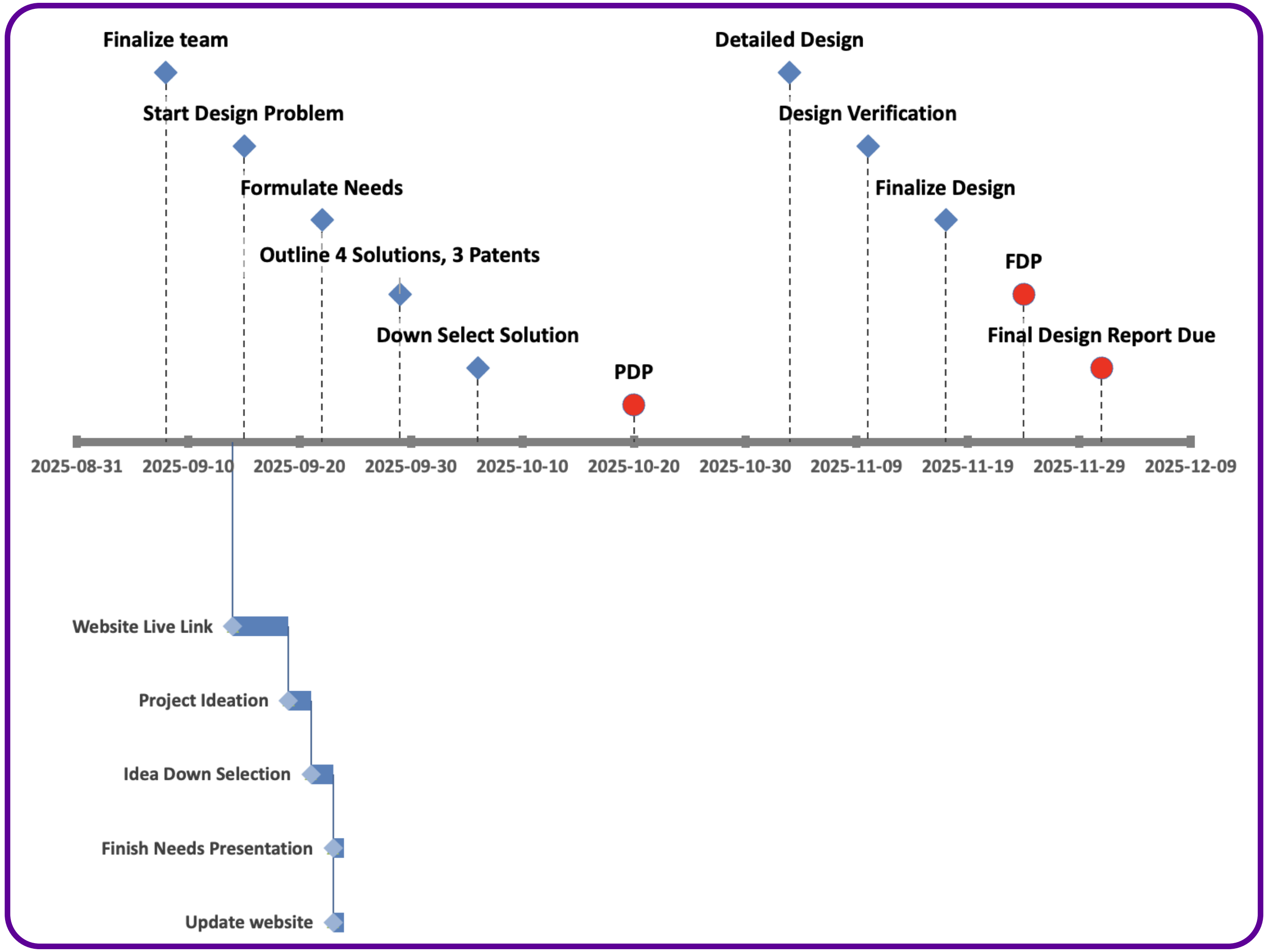
NEEDS ANALYSIS: Constraints (needs)

Constraint Category	Details
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

NEEDS ANALYSIS: Objectives (targets)

Constraint Category	Details
Performance	• The system should remove ≥80–90% of mineral scale deposits • The system should clean continuously for ≥15 minutes
Mobility	• The system should traverse at least one 90° bend without external assistance • The system should climb vertical sections ≥1 m without stalling • The system should adapt to both 100 mm and 150 mm pipe diameters without manual resizing
Usability	• The system should be operable by one technician with ≤30 minutes training. • The system should provide basic feedback and live monitoring • The system should allow tether retrieval while maintaining operator visibility and control
Cost & Development	• The system should be developed within a budget of ≤$750 CAD for materials and electronics. • The system should weigh ≤1.5 kg to enable easy deployment and recovery.
Autonomy (long-term)	• The system should include semi-autonomous features (e.g. automatic speed regulation, obstacle detection) future potential of full autonomy

Project Timeline



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?