A black and white photograph of a complex industrial pipe system. The pipes are arranged in a dense network with several 90-degree elbows. On the left side, two electrical control boxes are mounted on a textured wall. The overall scene is industrial and technical.

Autonomous In-pipe Inspection & Maintenance Robot

The Pitch

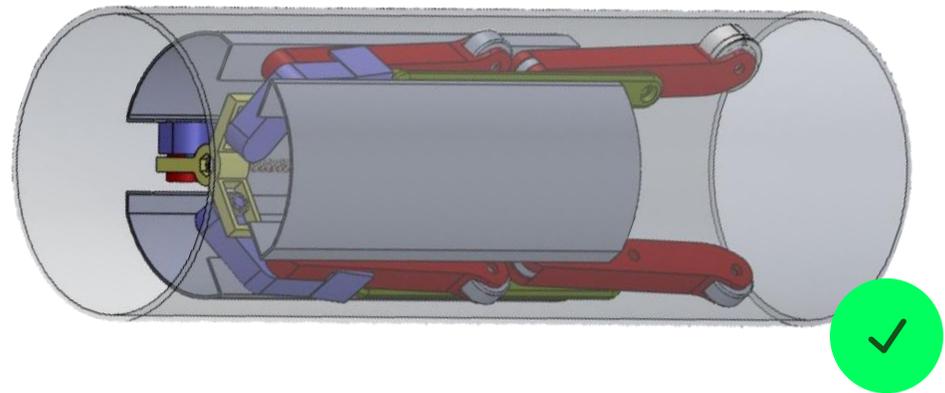
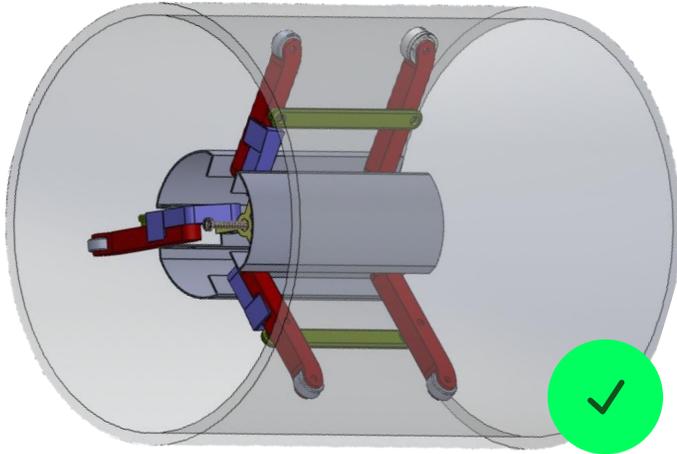
The Problem

- Pipeline inspection is often:
 - manual
 - time-consuming
- Affects oil & gas, water management, and sewage systems, leading to:
 - increased maintenance
 - service disruptions



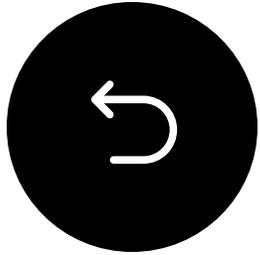
The Solution

- An in-pipe inspection robot, which unlike existing robots, has:
 - real-time CV detection
 - adaptive design for a range of pipeline diameters
 - autonomous movement



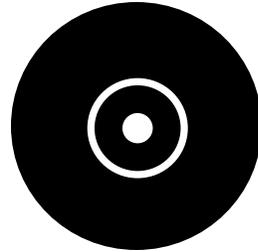
Constraints

Constraints



Retrievability

- Essential for quick intervention.
- Facilitates maintenance, reducing downtime.
- Enhances adaptability for various pipe configurations.



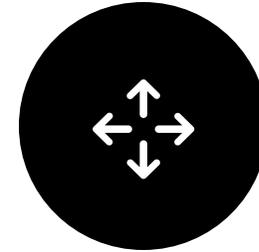
Stability

- Ensures central positioning for consistent inspection.
- Vital for accurate results.
- Minimizes collision risk.



Reliability

- Seamless interaction with control station.
- Precise navigation and task execution.
- Guarantees uninterrupted operation and data collection.



Flexibility

- Must traverse diverse pipe configurations.
- Essential for comprehensive inspections.
- Ensures effectiveness across varying pipe structures.

Specifications

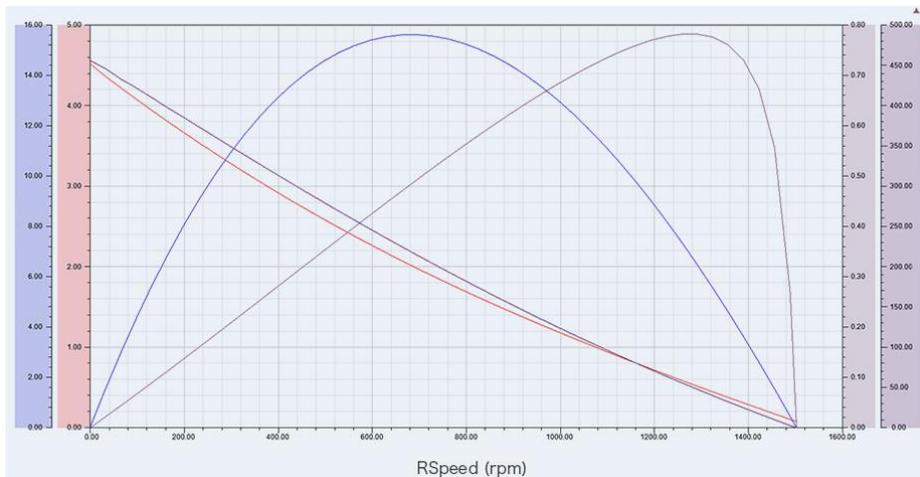
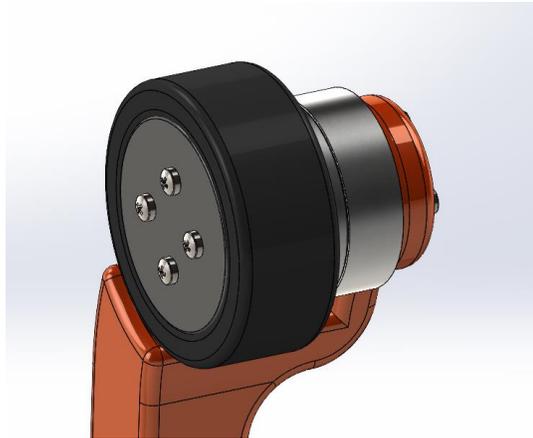
Target Specifications

Number of Sensors	2 (Encoder+ Camera)
Overall Latency	<34 ms per frame (30 fps)
Defect Detection mAP	>80%
Supported Pipeline Diameters	10 – 15 inches
Functional Attachment Weight	<1.5 kg
Longevity	5 years
Price	<15K SAR

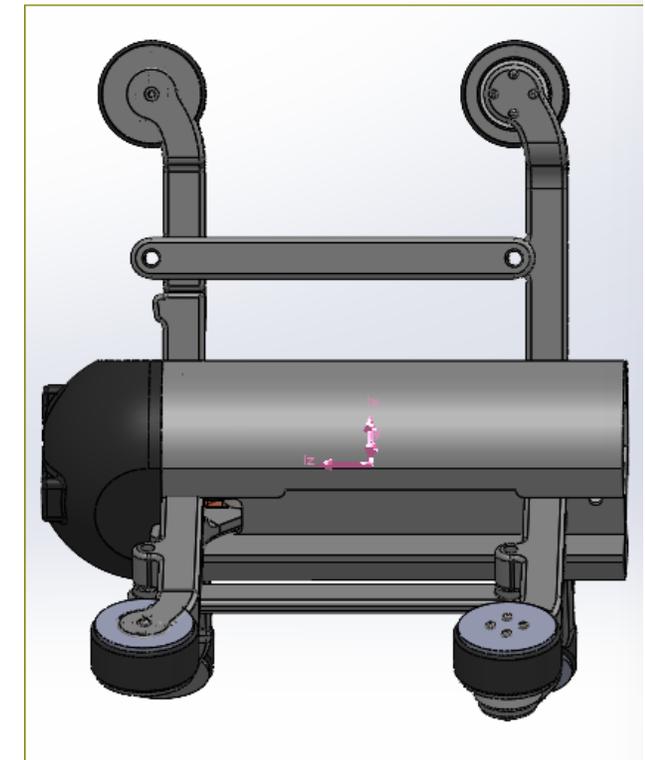
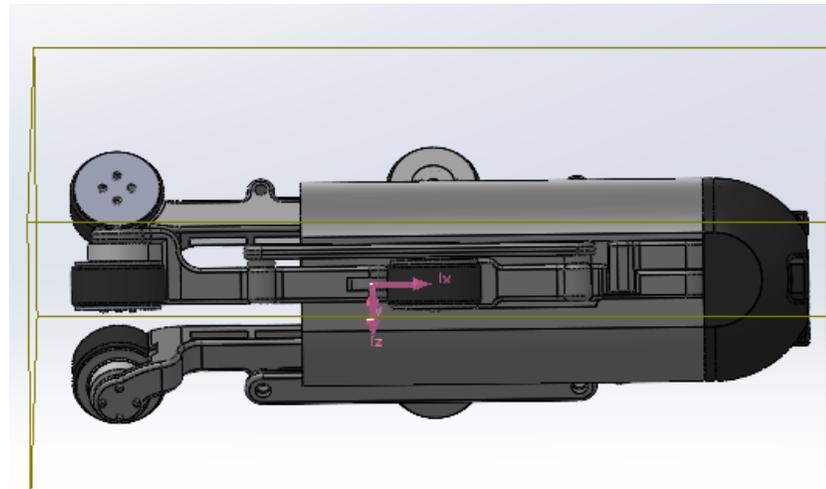
Final Design

Locomotion System

- Direct Drive Wheels

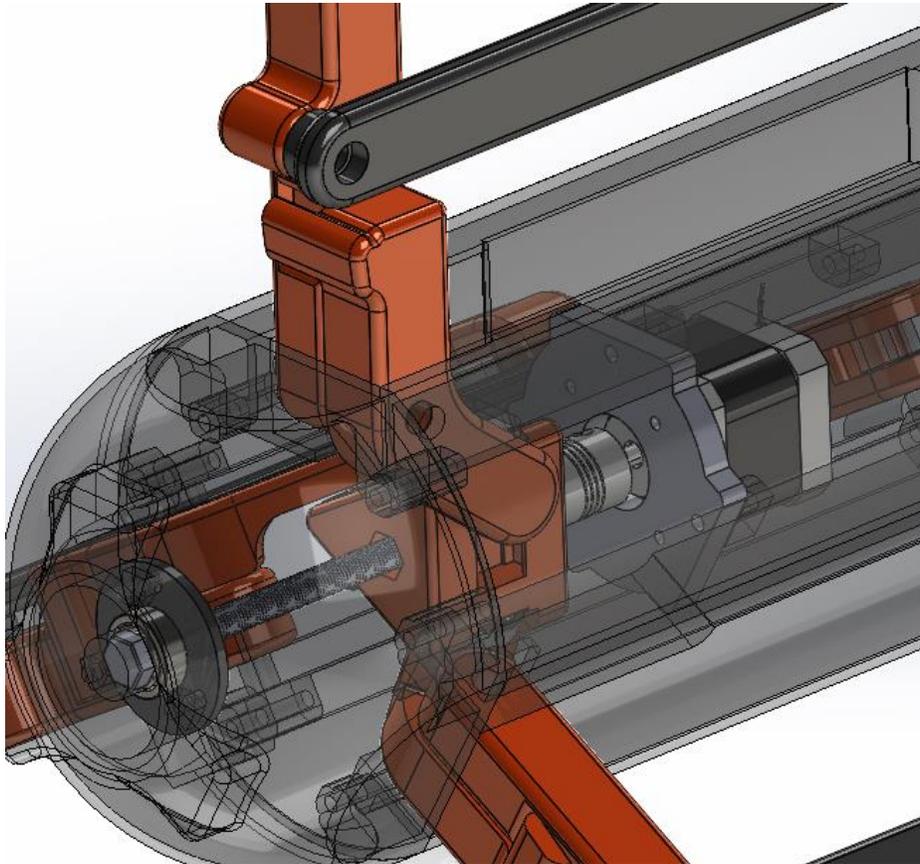


- Stability



Expansion System

- Umbrella Mechanism

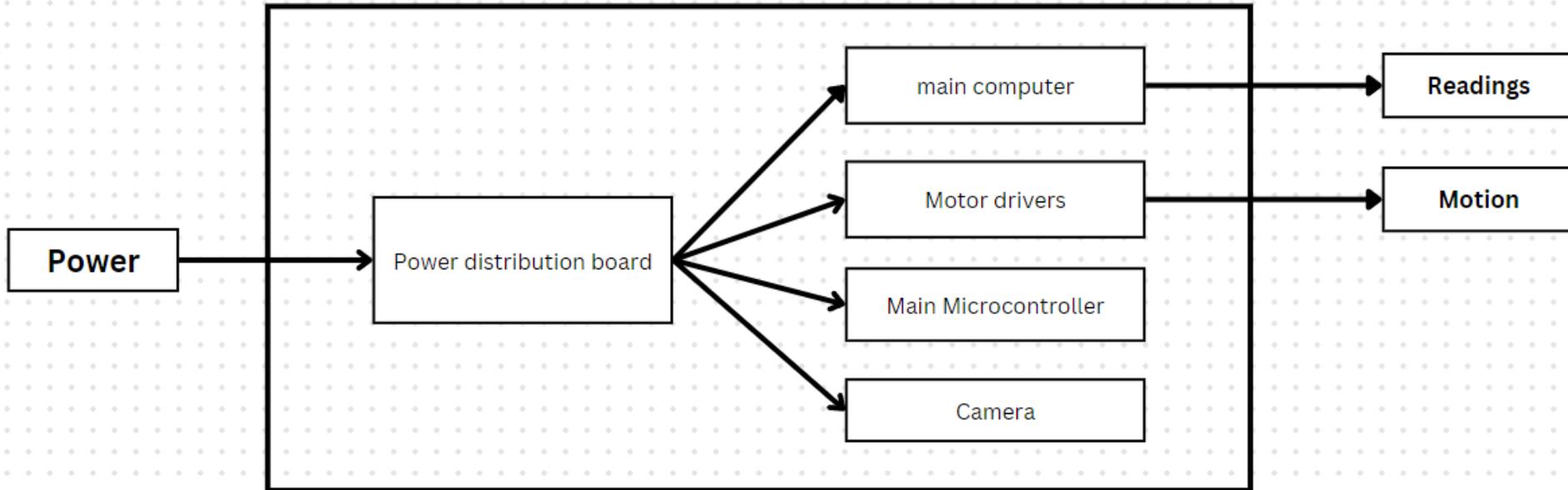


- Lead Screw

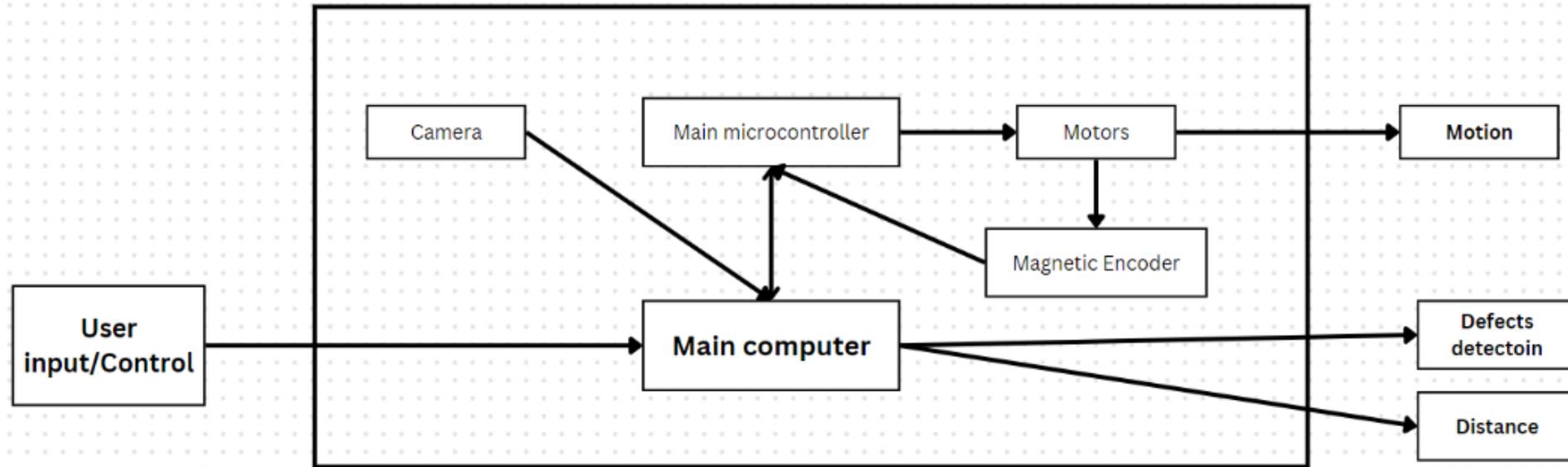


$$T = F \frac{d_m}{2} \left[\frac{l + f\pi d_m \sec(\alpha)}{\pi d_m - fl \sec(\alpha)} \right]$$

Power System

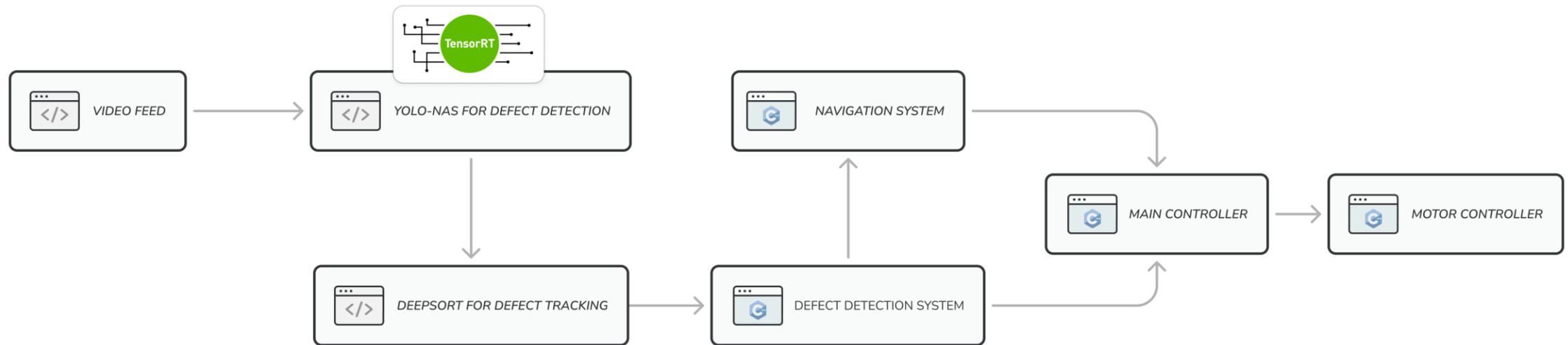


Communication System

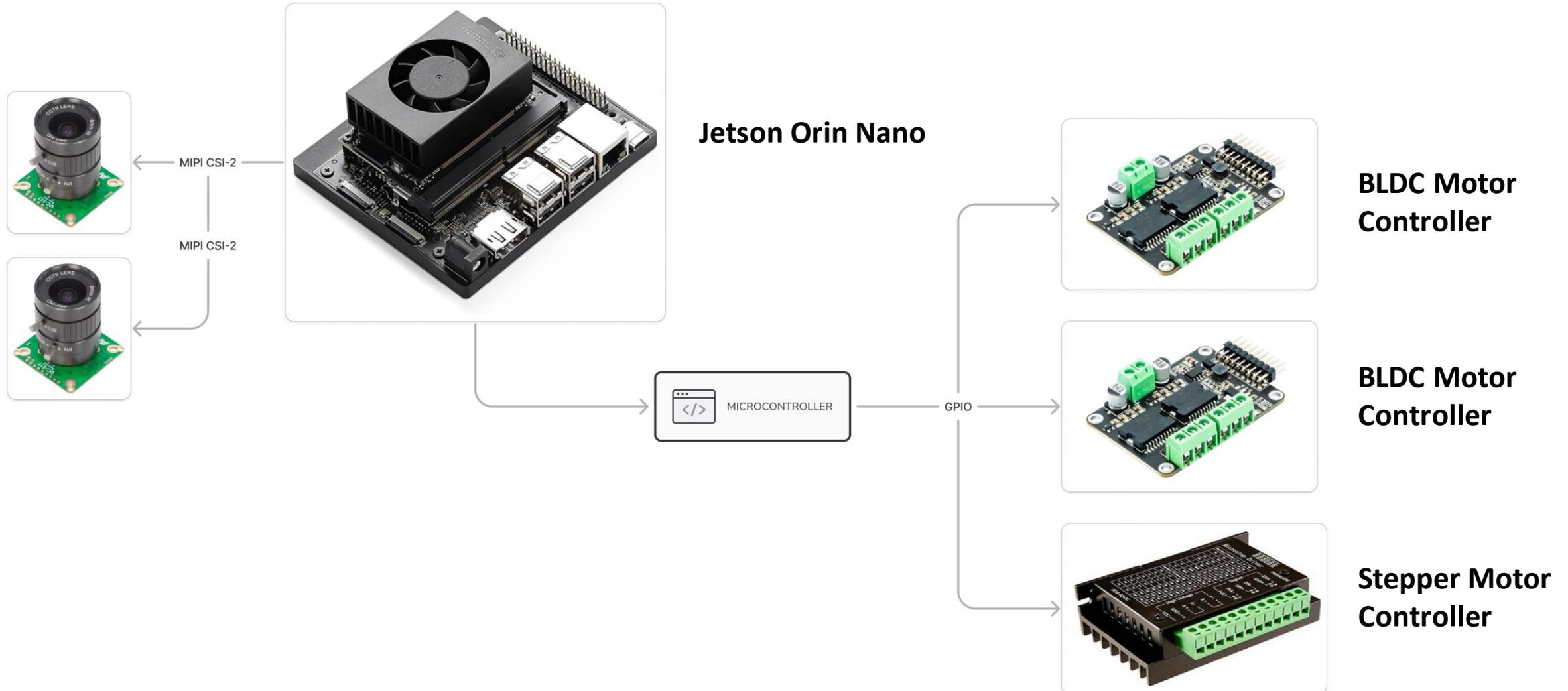


Software Architecture

- Robot Operating System (ROS) framework



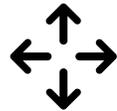
Computer Hardware Architecture



Creativity & Novelty

Creativity & Novelty

Versatility

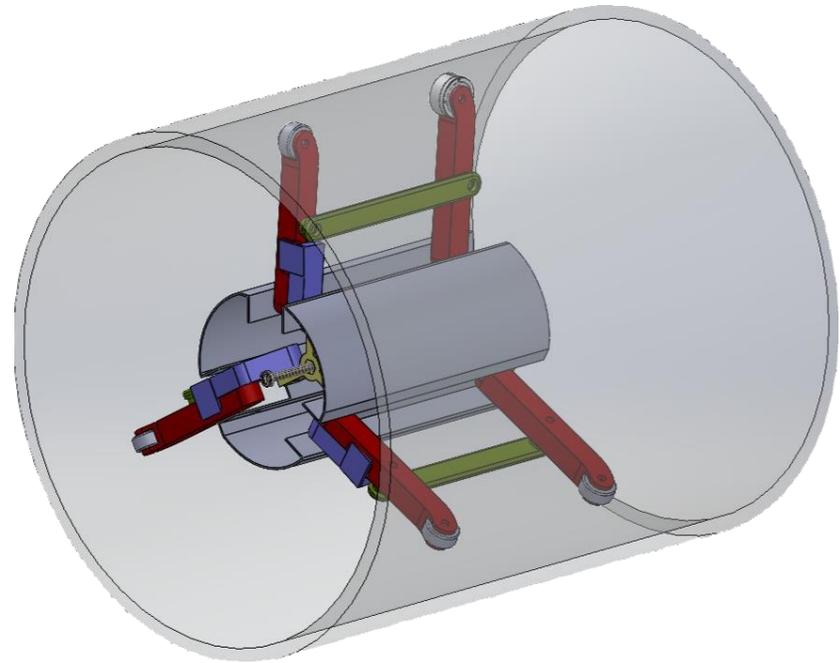
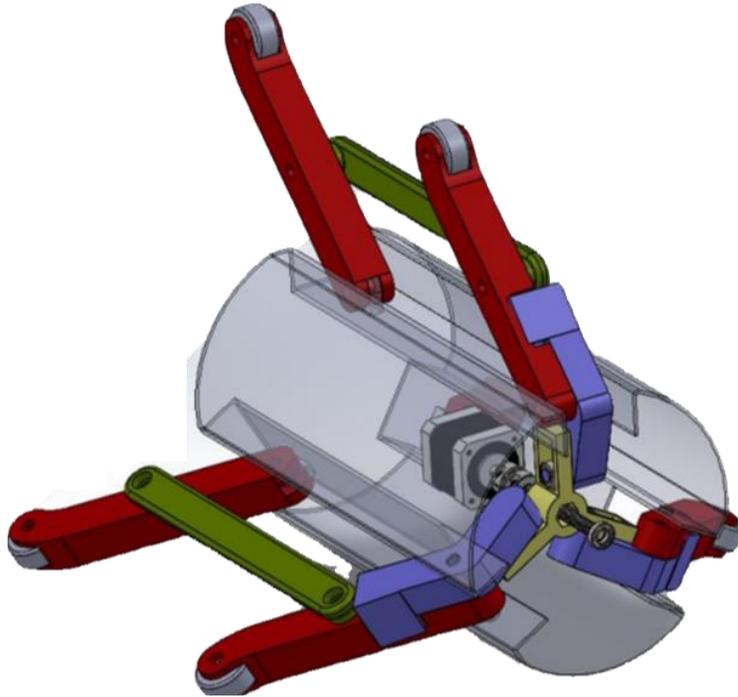


Autonomy



Versatility

- Versatility in operation via expansion mechanism

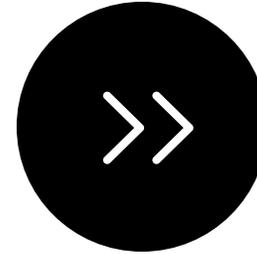


Autonomy



Autonomous Detection

- Autonomous operation via on-device inference to **detect** and **classify** defects

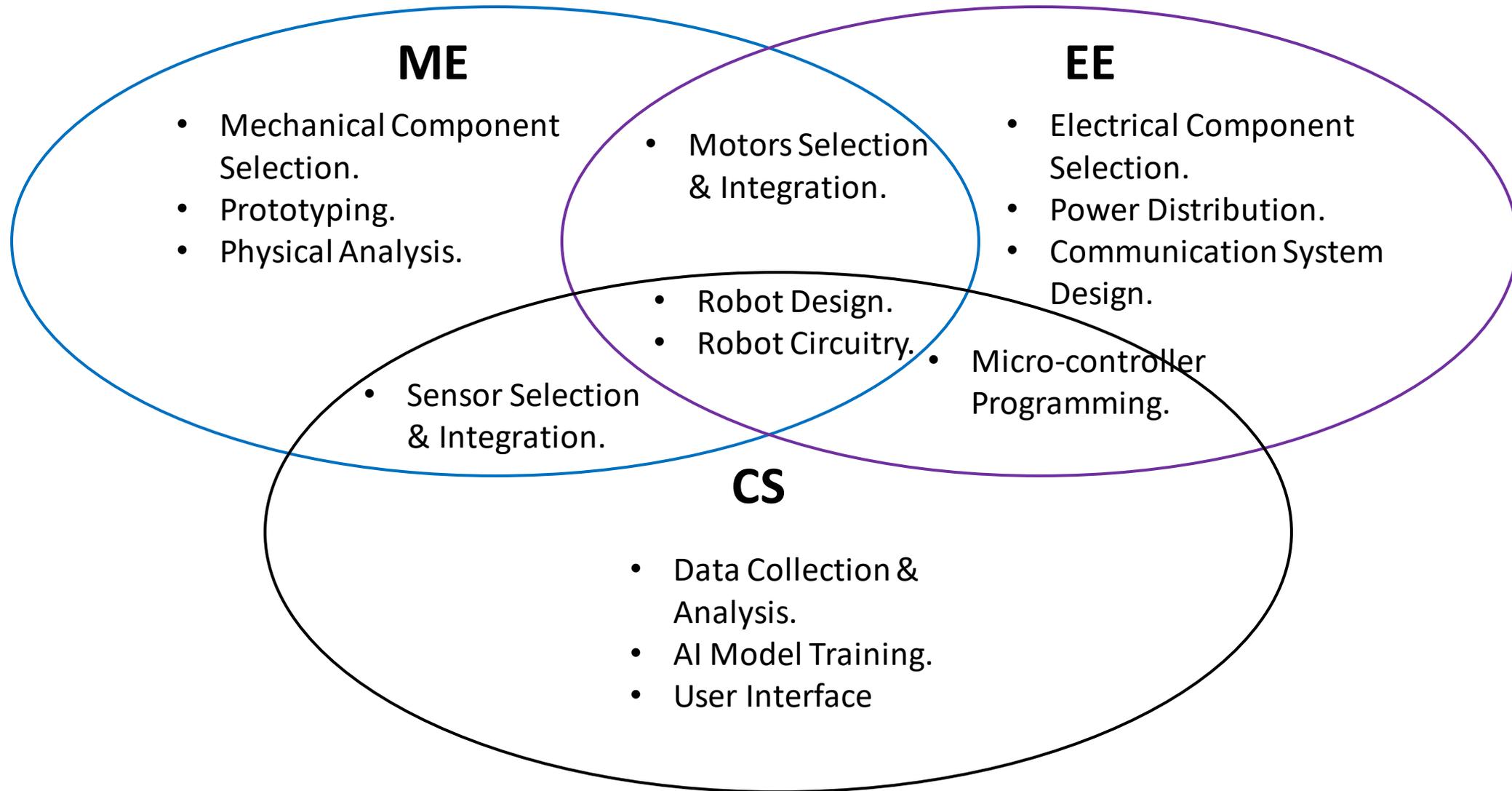


Autonomous Locomotion

- Autonomous locomotion within pipelines
- Encoder for cost-efficient in-pipe positioning

Responsibilities

Multidisciplinary Responsibilities



Team Roles & Main Responsibilities

Ahmed R.

- Robot Design.
- Prototyping.

Salman

- Stepper Motor Selection & Integration.
- Power Distribution.
- Communication System.

Bassel

- Data Collection & Analysis.
- Sensor Selection & Integration.

Ahmed H.

- Mechanical Component Selection.
- Analysis.

Fahad

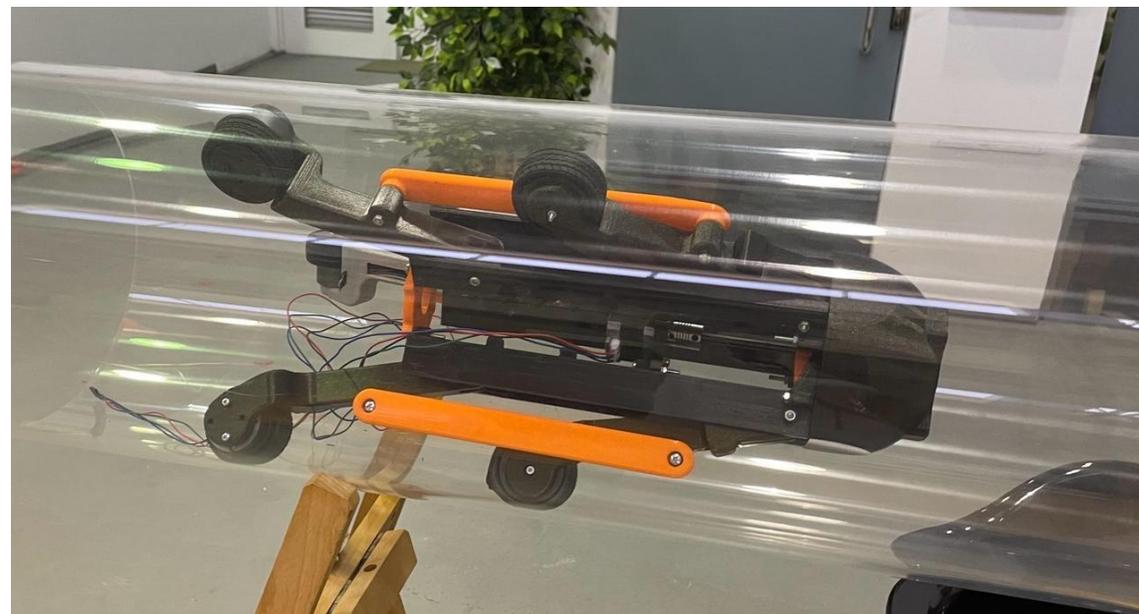
- BLDC Motor Selection & Integration.
- Micro-controller programming.
- Communication System.

Mohammed

- Model Development & Training.
- User Interface.

Prototype

Physical Prototype



Meeting Specifications

Meeting Specifications

1

Number of sensors

2

1. Encoder: Tracks movement for positioning.
2. Camera: Provides visual inspection data.

3

Defect Detection mAP

>80%

Measure the mean Average Precision score of the model and ensure it exceeds 80%.

- Evaluated on CCTV-dataset

2

Overall Latency

<34 ms per frame (30 fps)

Yolov8m + TensorRT*

Orin Nano 8GB

Latency at batch size = 1

24.3 ms

*On COCO

4

Supported Diameters

10-15 inches

We designed the robot with expandable arms, this is done with the help of the stepper motor.

Meeting Specifications

5

Longevity

5 Years

Selection of components with a warranty or expected lifetime of more than 5 years.

6

Price

<15K SAR

Ensure the total cost of all components is below 15K SAR.

7

Functional Attachment Weight

1.5 Kg

Optimize the design to distribute the weight evenly across the robot's structure, ensuring that the center of gravity remains stable and within a safe range to withstand the specified weight limit of 1.5 kg.



Thank you!