# RC-XD

Pipe inspection robot

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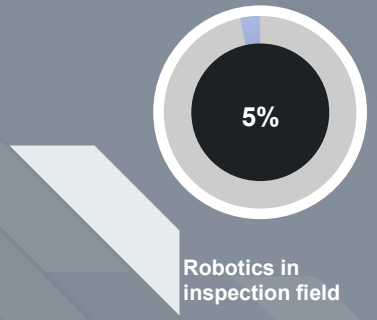
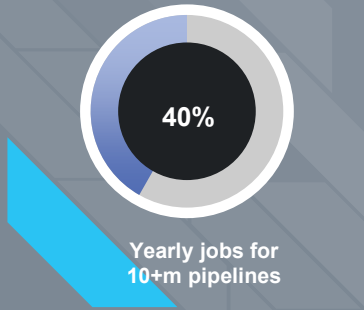
# TOC

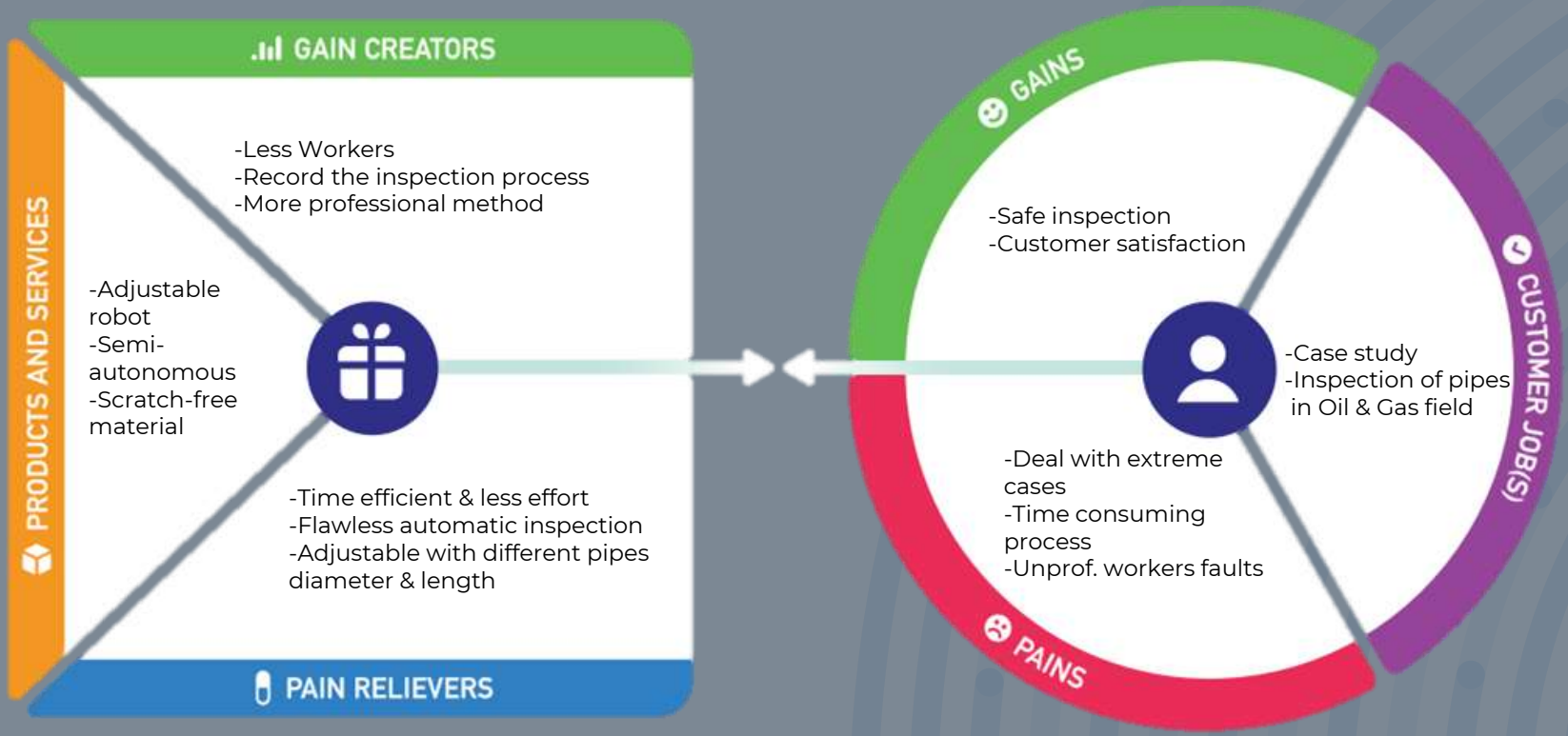
# Statistics and surveys

- Egyptian market has more than 50 companies in the inspection field excluding petroleum companies.
- Less than 5% of them use robotics in their field.
- More than 40% of yearly jobs deal with pipelines with more than 10 meters in length with different diameters.
- Normal inspection jobs take 3-4 days in average.
- Average small companies take 80+ jobs/year.

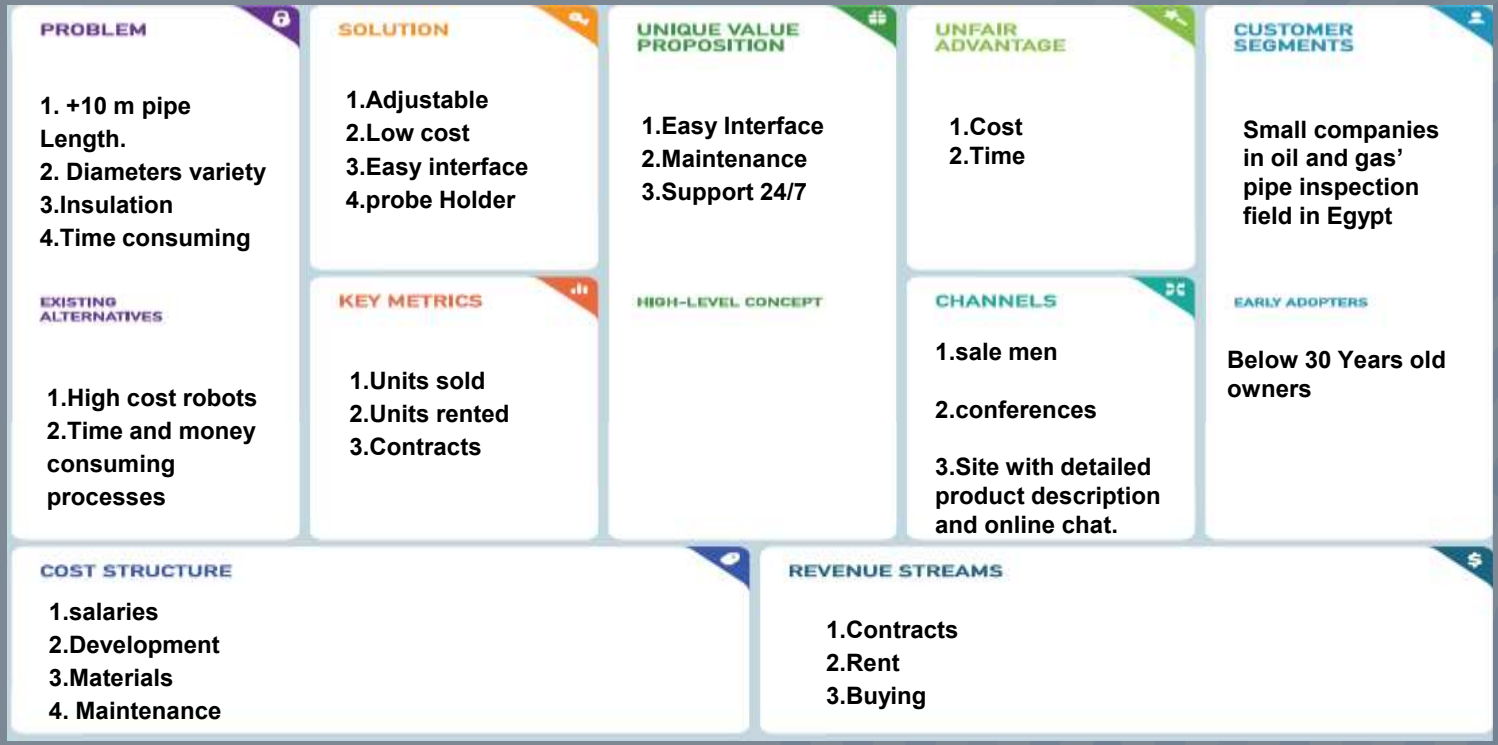


# Value Proposition Canvas



# Lean canvas model



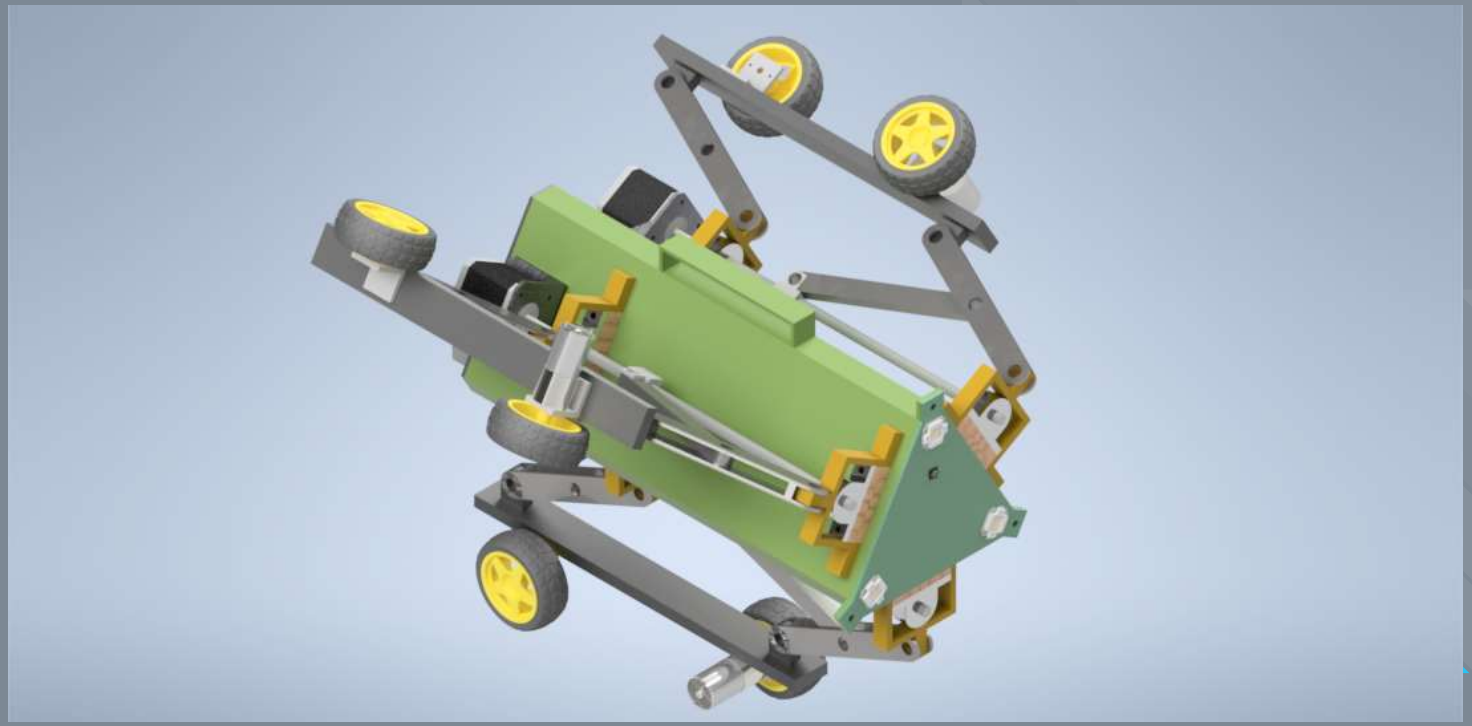
# Product description

- Pipeline systems deteriorate progressively over time through various means.
- This product aims to create a pipeline inspection robot that has an **adaptable** structure to the pipe diameter, and **cheap** at the same time.
- Pipeline inspection robots are designed to **act in inaccessible environment** and also to **remove the human factor from labour intensive or dangerous work environments**.
- Our challenge is to make this robot adaptable to pipe diameters varying from **450mm to 700mm** with an adjustable probe mount.

# Features

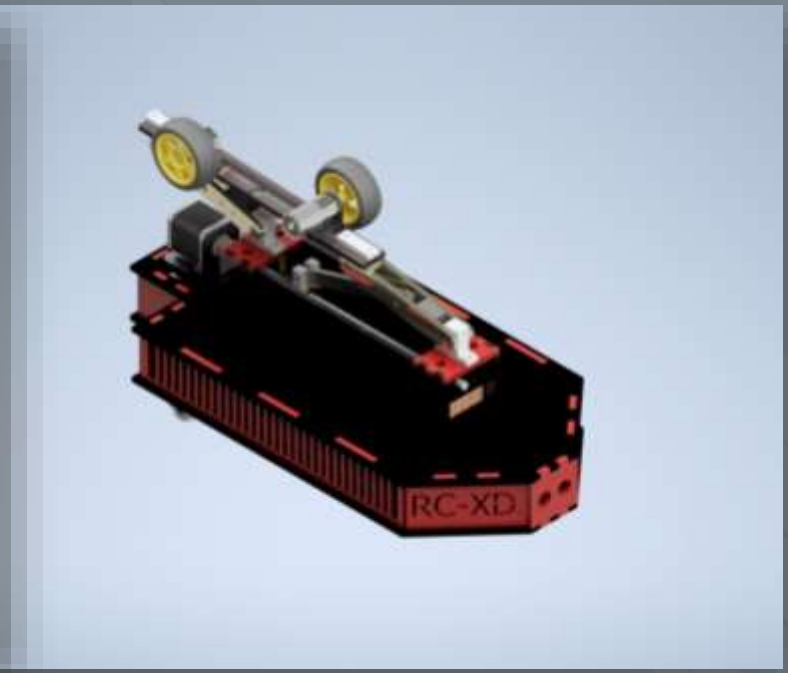
- Adjustable diameter range (45-70 cm)
- Long travel ranges up to 30m
- Crack identification
- Shape identification for cracks
- Locating crack places
- Live video record
- Electrically insulated
- Scratch free wheels and safe to pipes insulation materials
- Easy to transport
- Easy interface

# Original Mechanical Design



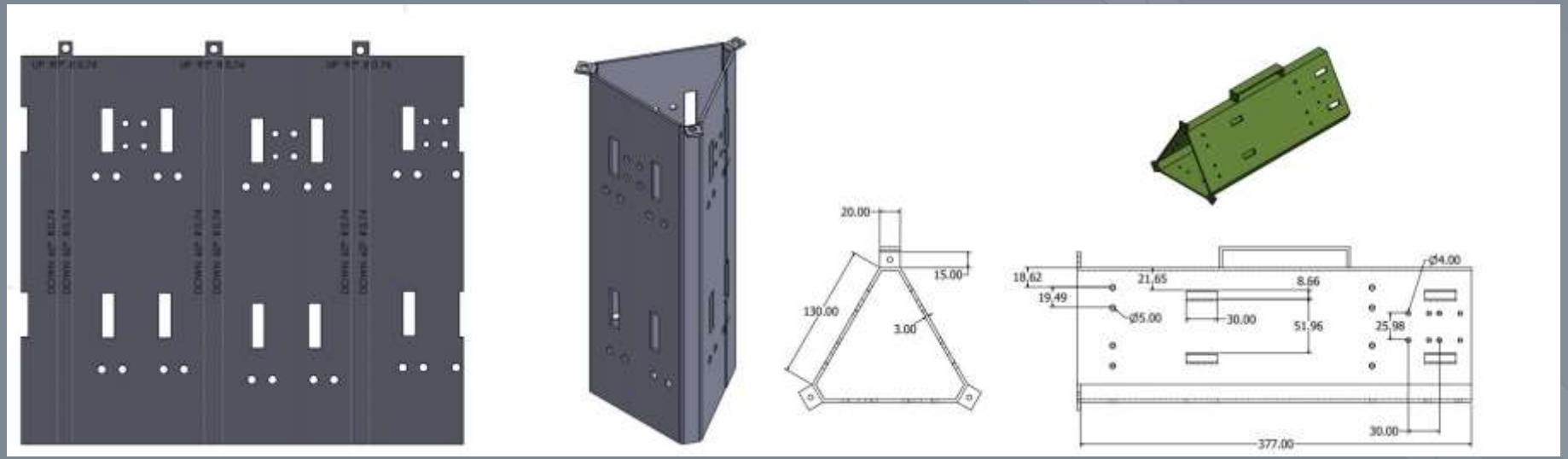
# Original Mechanical Design

# Prototype Mechanical Design

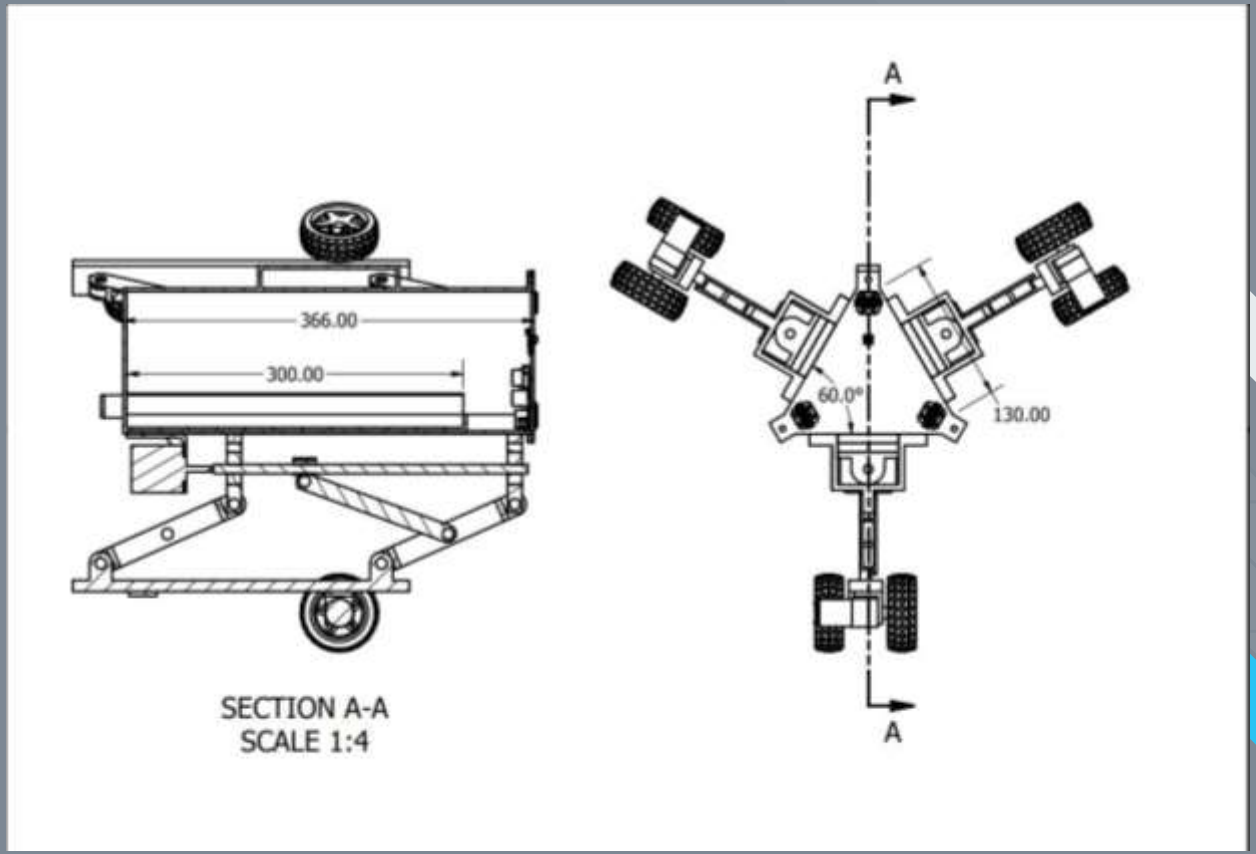



# Main Body Working Drawing

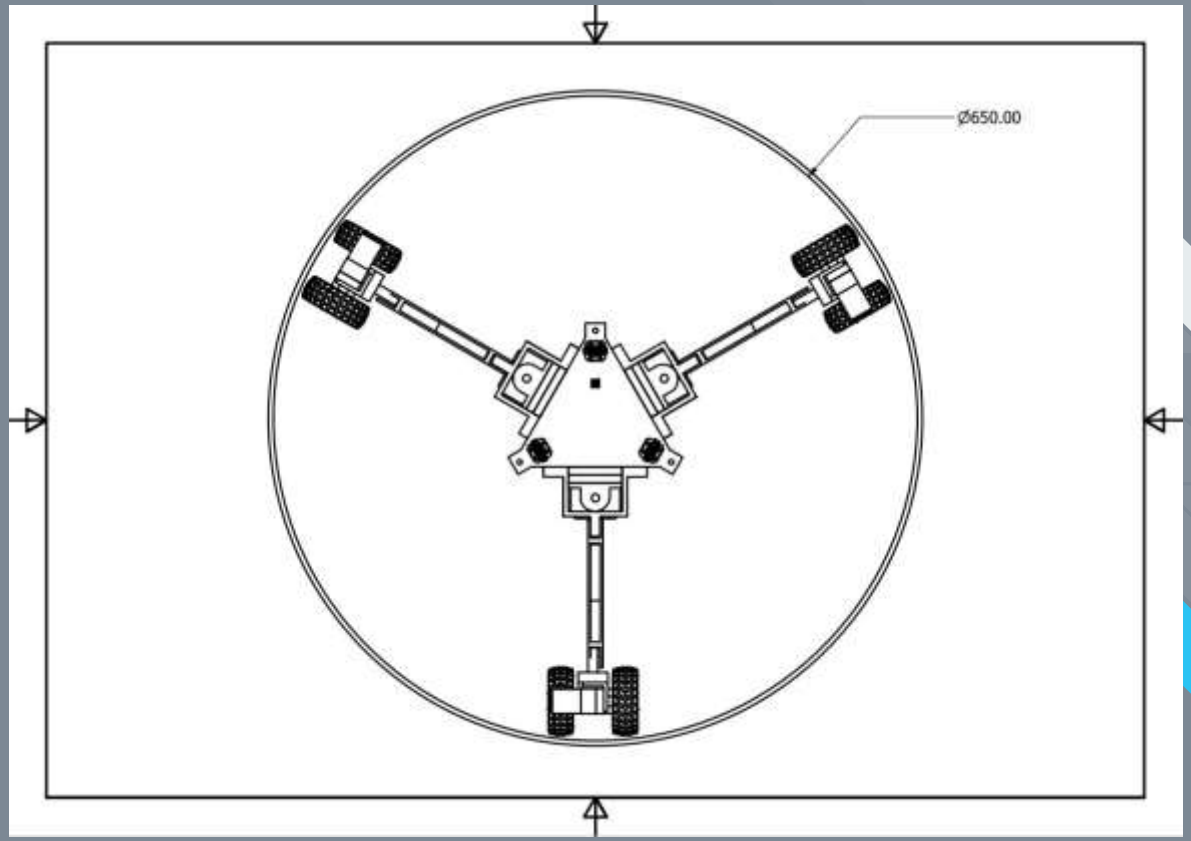
- In sheet Metal working drawings aren’t needed as it Is made by laser cutting and bending machines , so they require either a PDF file or a Dxf. file - in order to get the flat pattern view - according to the manufacturer



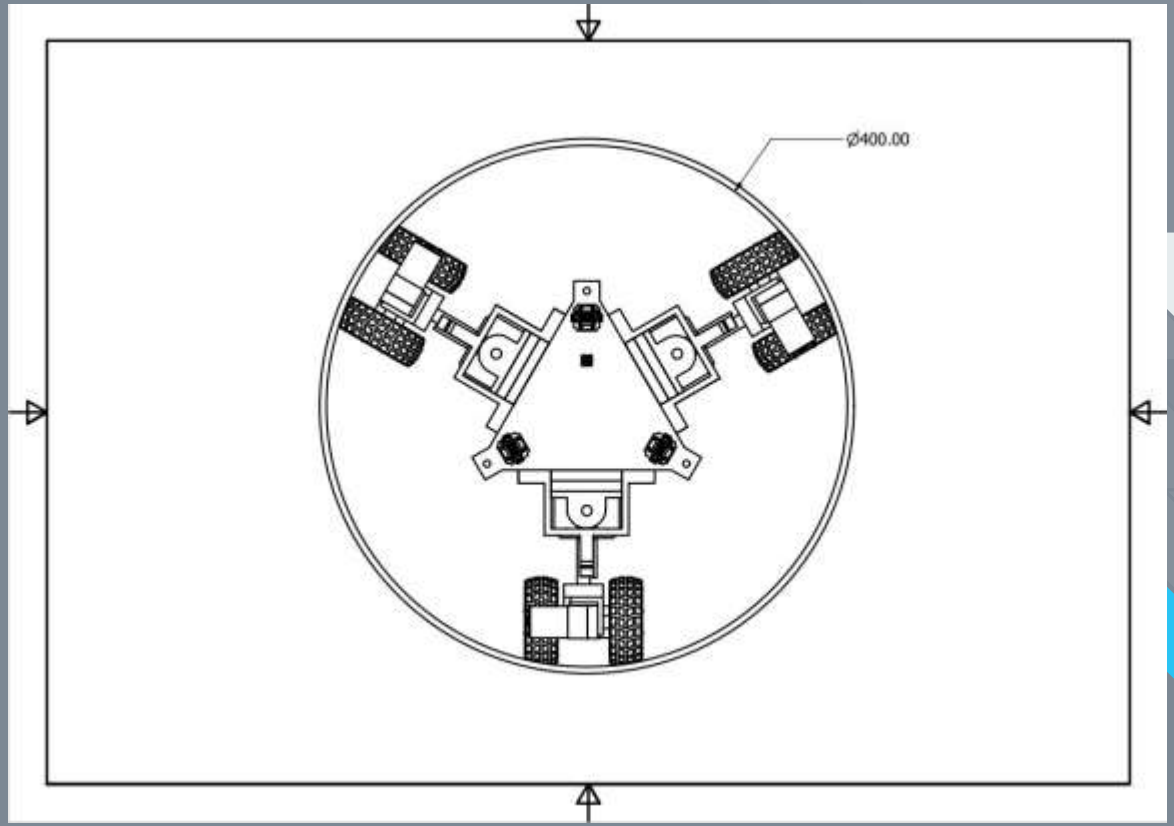
# Overall Dimensions



# Maximum Diameter



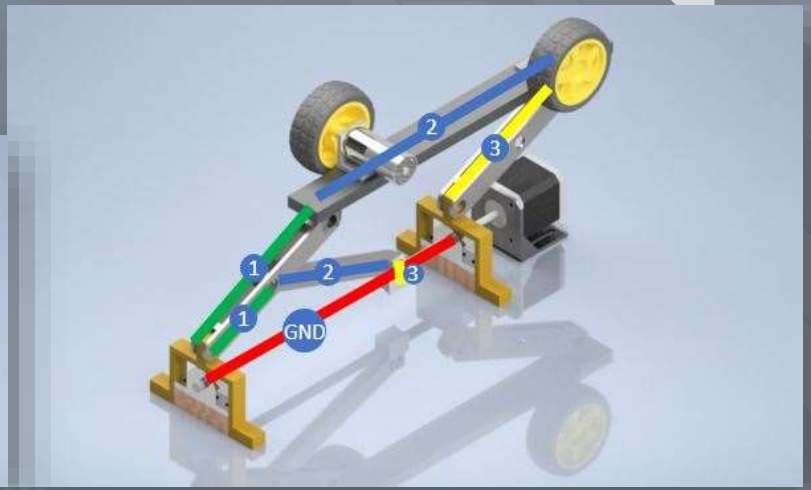
# Minimum Diameter



# Diameter Adjustment Mechanism

In a nutshell we used a **4bar** mechanism to actuate a **4bar** mechanism.

- The power screw rotates with the set angle moving the bushes a certain distance.
- The bushes moves a rectangular link attached to it that moves relative to a hinged link in the joint fixed to the base.
- Attached to the moving links the main link connected to the arms holding the wheels so moving the link changes the angle of the hinged links changing the central distance of the wheel.



# Wheel Assembly

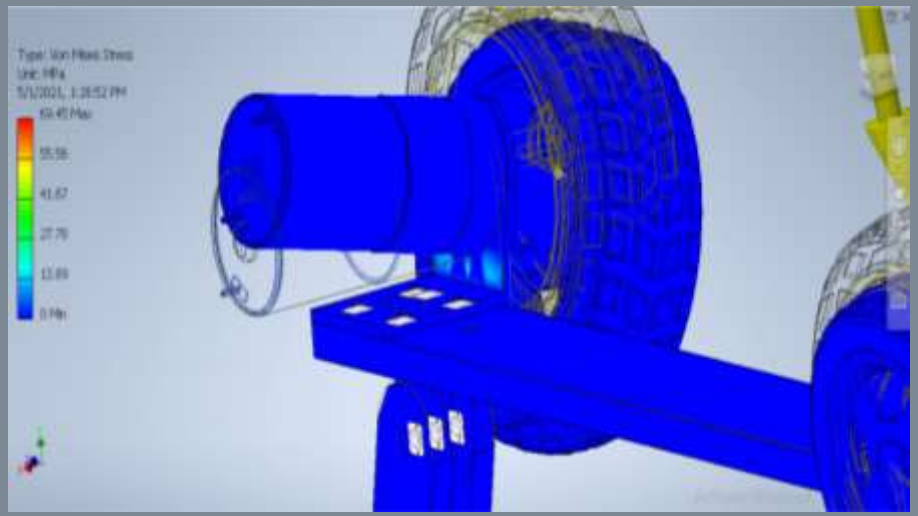
- DC motor is bolted with a L-stand with M4 bolts and then both are bolted with the main link.
- Rubber wheels are used to protect the pipes from scratches

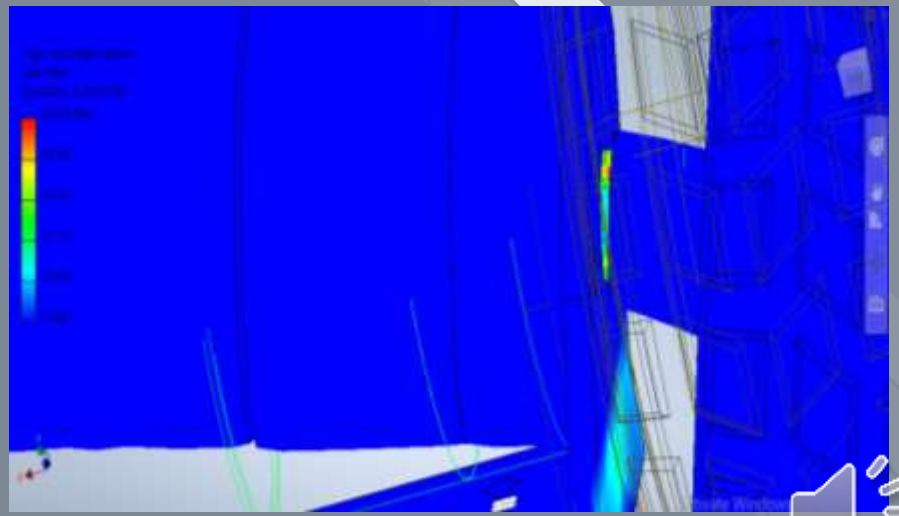

# Stress Analysis

Assuming Worst Case:

- Robot's weight is 10 kg
- Only two wheel carries the whole weight
- Motor Radial Load = 60 N.m (From datasheet)
- Minimum safety factor of 5 which pretty safe

| Standard gearbox shaft : see dimensions | | | | |
|---|---|---|---|---|
| **General characteristics** | | | | |
| Motor | | 82 810 0 | 82 810 0 | 82 810 0 |
| Gearbox | | 81 035 0 | 81 035 0 | 81 035 0 |
| Maximum permitted torque on gearbox for continuous rating | N.m | 5 | 5 | 5 |
| Radial load (dynamic) | daN | 6 | 6 | 6 |
| Nominal usable power | W | 9.4 | 8.7 | 8.2 |
| Gearbox case temperature rise | °C | 45 | 46 | 45 |
| Weight | g | 820 | 820 | 820 |





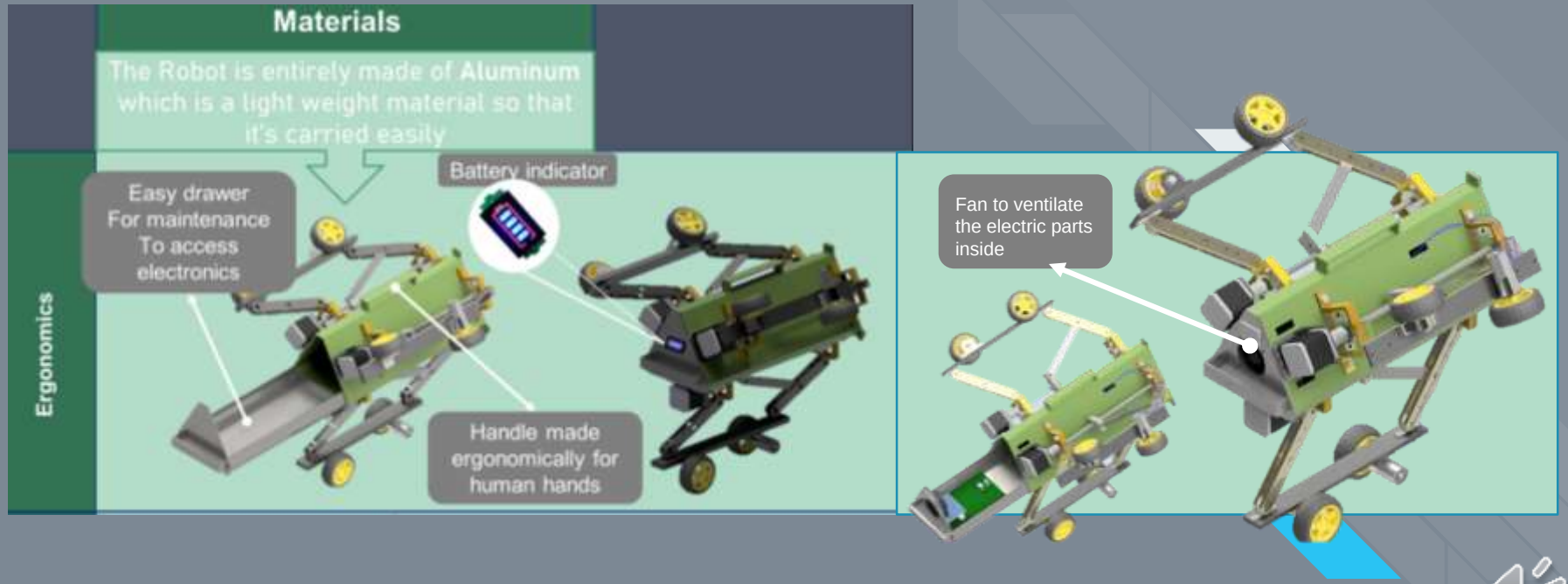
# Mechanical BOM

| No. | Part Name | Qty | Description | Price EGP/1 | Total Price |
|---|---|---|---|---|---|
| 1 | Central Base | 1 | Sheet Metal | 400 | 400 |
| 2 | Front Cover | 1 | Sheet Metal | 250 | 500 |
| 3 | Control Box Drawer | 1 | Sheet Metal | 100 | 200 |
| 4 | Main Link | 3 | Sheet Metal | 20 | 240 |
| 5 | Side Link | 6 | Sheet Metal | 150 | 900 |
| 6 | Middle Link | 3 | Sheet Metal | 600 | 600 |
| 7 | Power Screw | 3 | Purchasing | 120 | 360 |
| 8 | Bearing House 8mm | 0 | Purchasing | 40 | 40 |
| 9 | Coupler | 3 | Purchasing | 30 | 30 |
| 10 | Wheels | 6 | Purchasing | 15 | 120 |
| 11 | DC motor mount | 3 | Purchasing | 40 | 80 |
| 12 | Stepper motor mount | 3 | Purchasing | 50 | 150 |
| 13 | Power Screw Nut | 3 | Purchasing | 50 | 150 |
| 14 | Nut Housing | 3 | Purchasing | 50 | 150 |
| 15 | Spacers | 18 | Purchasing | 30 | 30 |
| Total | | | | | |

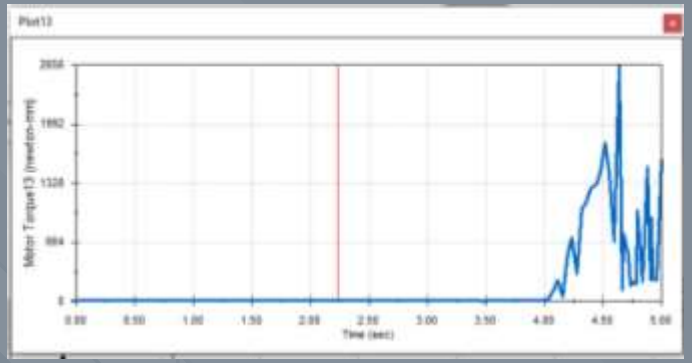
# Control Box

- Control box contains the PCB & the Battery.
- While the raspberry pi is attached to the front cover.

# Ergonomics


Materials
The Robot is entirely made of Aluminum which is a light weight material so that it's carried easily
Ergonomics
Easy drawer For maintenance To access electronics
Battery indicator
Handle made ergonomically for human hands
Fan to ventilate the electric parts inside

# Actuator Sizing




Estimated total weight from CAD is 10 kg driven by two DC motors and the two actuated wheels have the same parameters and conditions.

Wheel outer diameter = 66 mm

Assumed wheel mass = 0.3 kg

Rolling Coefficient of friction between wheel and pipe = 0.3

Assume all pipes has no inclination.

Assumed fixed speed operation = 2 rad/sec

$t_{acc}$= 1 sec

$J_{tot}=J_m+J_{eff}$ (on each actuated wheel)

$J_{actuated\ wheel} = (0.5*m*r\hat{}2)=(0.5*0.3*(66\times10^{-3}/2)^2)= 1.6335*10^{-4}\ kg{\cdot}m^2$

Using kinetic conversion theorem:

- $J_{body} = m*r^2=10*(66\times10^{-3}/2)^2= 10.89*10^{-3}\ kg{\cdot}m^2$
- $J_{rolling\ wheel} = 0.5*m*r^2= 0.5*0.3*(66\times10^{-3}/2)^2= 1.6335*10^{-4}\ kg{\cdot}m^2$

$J_{eff} = 1.6335*10^{-4} + 10.89*10^{-3} + 1.6335*10^{-4} = 11.22*10^{-3}$

$J_{tot}=J_m+J_{eff} = 11.22*10^{-3} + 11.22*10^{-3} = 0.02243\ kg{\cdot}m^2$

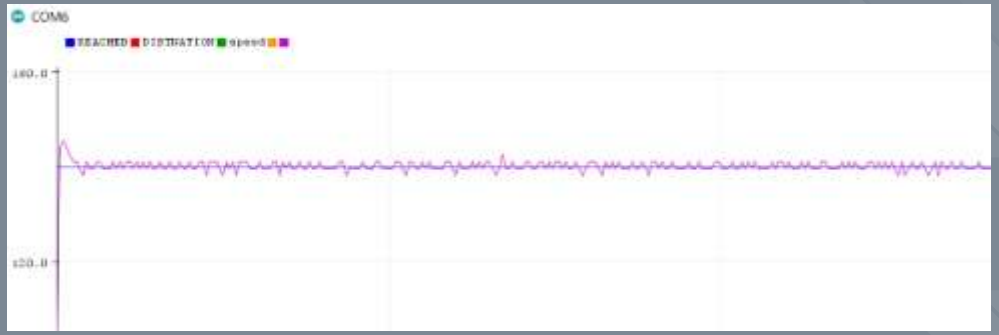
$T_r$ (assumed resistive torque) $= 9.8(5+(0.3*3))*0.3*(66\times10^{-3}/2) = 0.57$ Nm

$\ddot{\theta}_{acc} = 2/0.1=20$ rad/sec

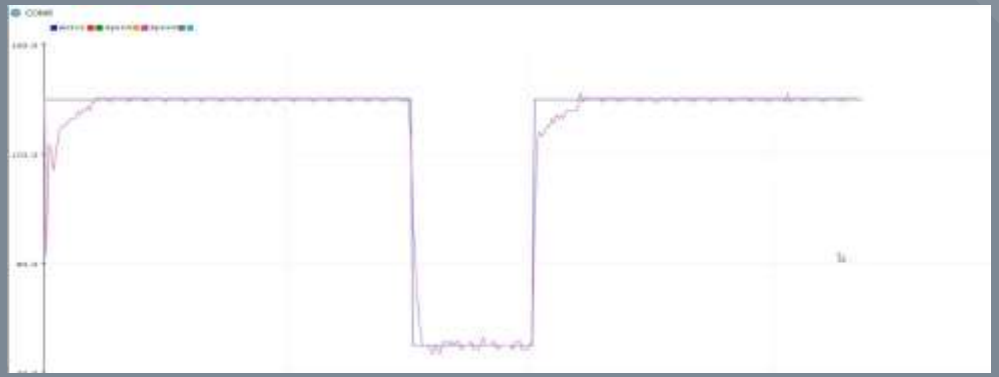
Peak torque required = $T_{max} = 0.02243*20 + 0.57 = 1.5$ Nm

# PID GRAPHS

- PID In **no load** condition




- PID In **normal loading** conditions



# Battery Sizing

**Average current draw by each component:**

- Arduino uno board 0.05 A
- Raspberry pi 2.5 A
- Three driving DC motors 3.5 A
- Power screw three Stepper motor 5.25 A
- Ultrasonic sensor 0.015A
- Camera 0.5A

For motors I(amp) = (Nω*2π/V*60)

Consumed Power = ((0.05+2.5+0.015+0.5)*5) +((3.5+5.25)*12) = 120 W

Assumed total power losses 10 W

Total power = 130 W

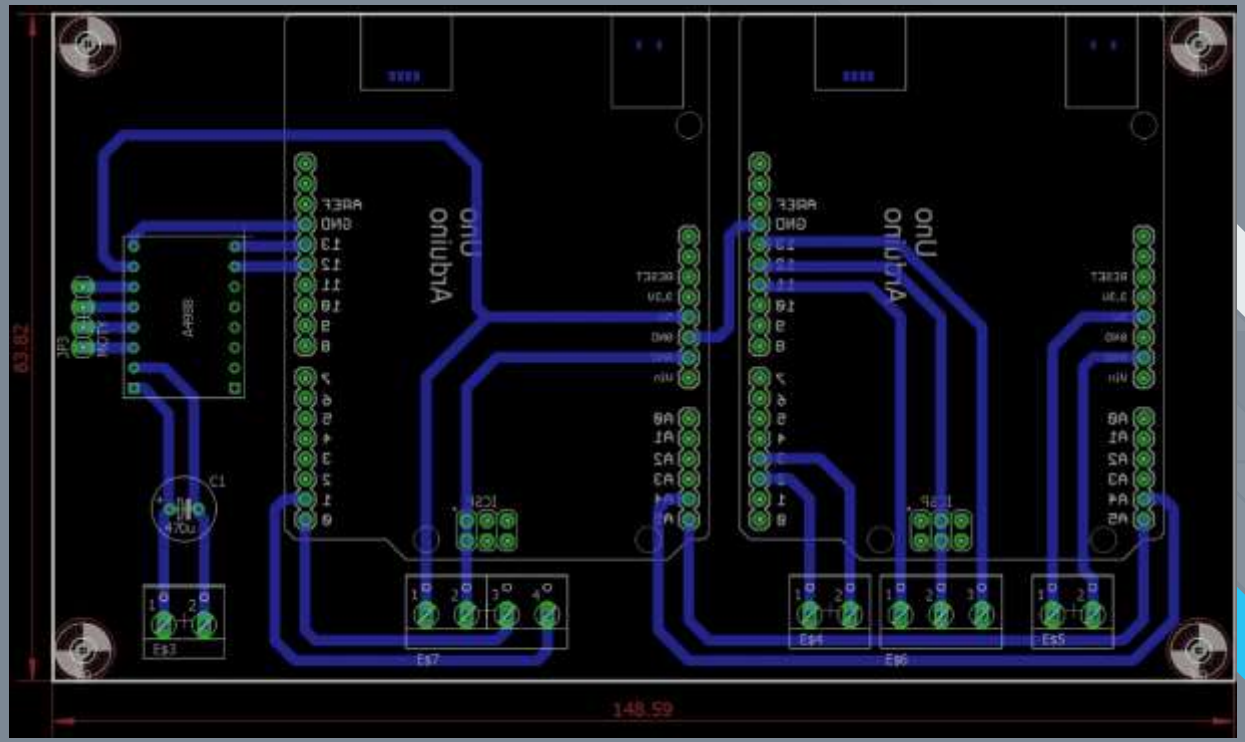
Battery Voltage 12V

Total current = 10 A

Operating time 30 minutes

Battery size = 5 Ah

# PCB Board



# PCB Board in Real Life

# Electrical BOM

| No. | Part Name | Qty | Price EGP/1 | Total Price |
|---|---|---|---|---|
| 1 | Raspberry PI | 1 | 1250 | 1250 |
| 2 | DC Motor | 3 | 200 | 600 |
| 4 | PI Camera | 1 | 450 | 450 |
| 5 | Battery | 1 | 750 | 750 |
| 6 | Charging Port | 1 | 50 | 50 |
| 7 | Start/Stop Button | 2 | 20 | 40 |
| 8 | Arduino uno | 2 | 160 | 320 |
| 9 | PCB | 1 | 200 | 200 |
| Total | | | | 3500 |

# Electrical Design

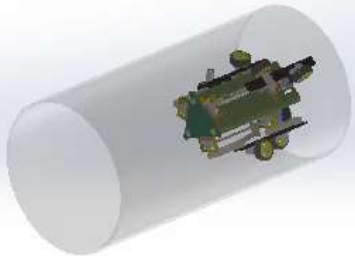
## Sensor Selection:

- **RC-XD** uses five sensors, three encoders for each motor for position feedback, one camera to detect the cracks and an ultrasonic to detect blockage in pipes.

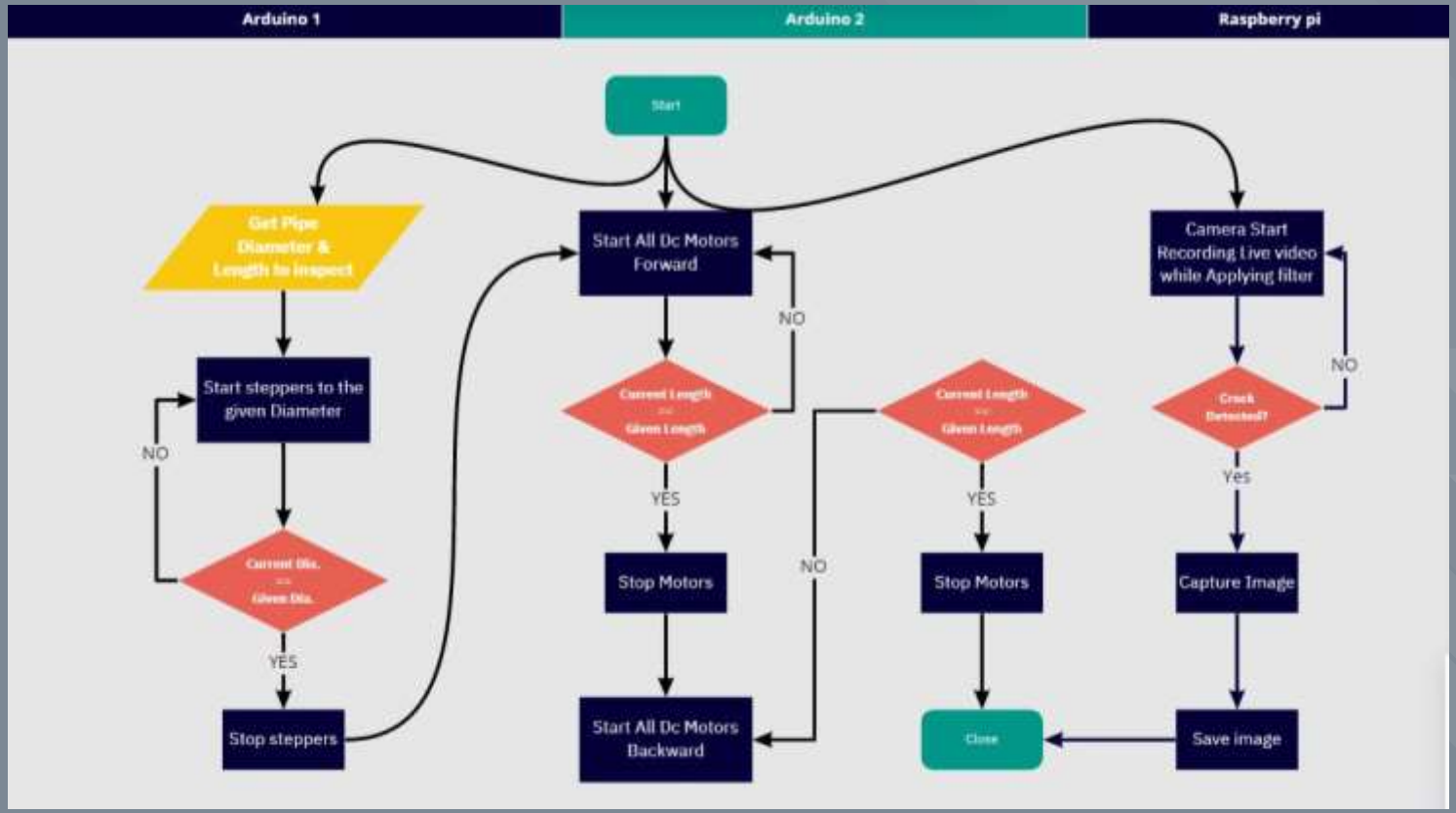
## Used Sensors:

- Raspberry PI Camera NV
- Ultrasonic sensor
- DC Motor Encoder

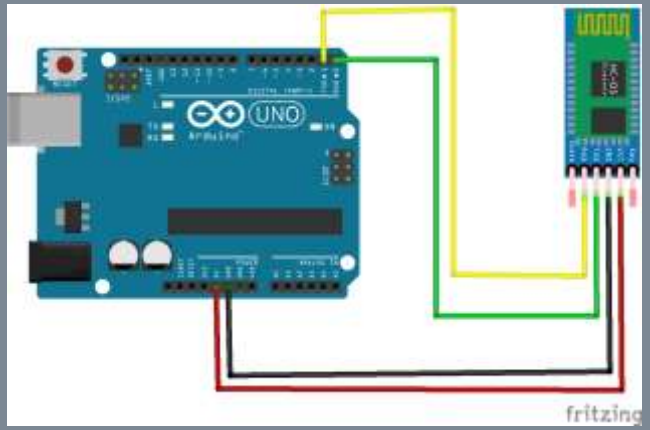
# Simulation in SW



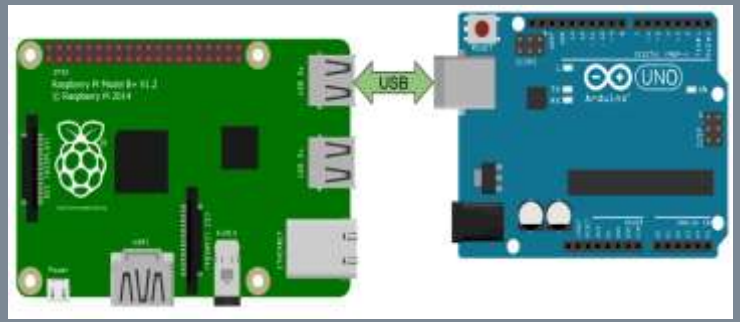
# FlowChart


Arduino 1
Arduino 2
Raspberry pi
Start
Get Pipe Diameter & Length to inspect
Start steppers to the given Diameter
Current Dia. = Given Dia.
NO
YES
Stop steppers
Start All Dc Motors Forward
Current Length = Given Length
NO
YES
Stop Motors
Start All Dc Motors Backward
Current Length = Given Length
NO
YES
Stop Motors
Close
Camera Start Recording Live video while Applying filter
Crack Detected?
NO
Yes
Capture Image
Save image

# Communication Protocols

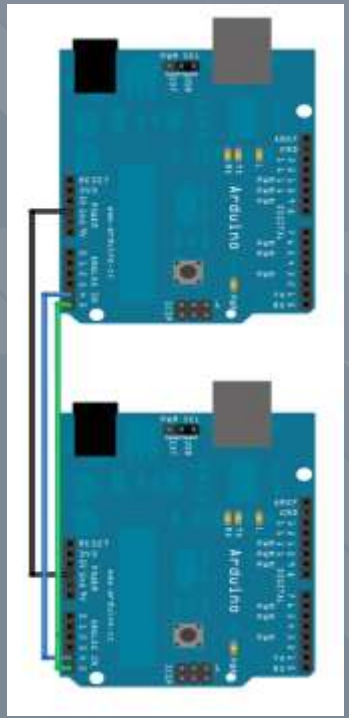



Bluetooth Module with Arduino1
**UART**




Raspberry Pi with Arduino2
**UART**

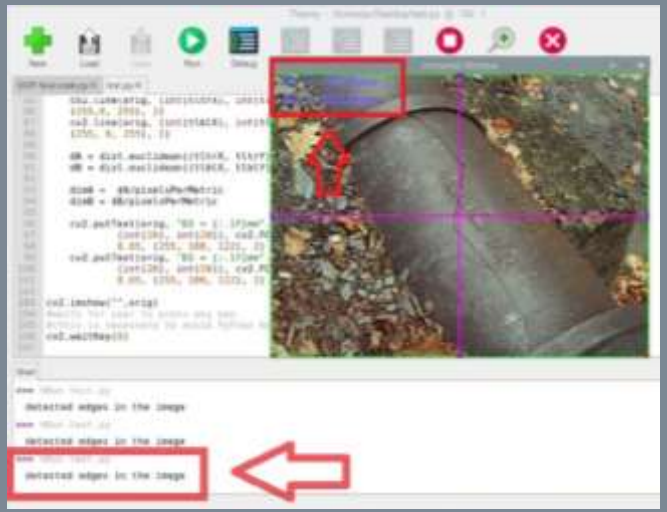
Arduino with Arduino **I2C**

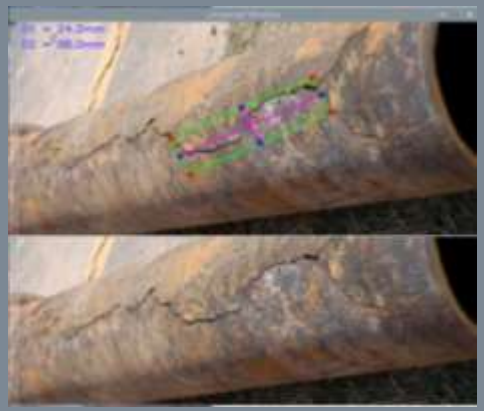


# Vision

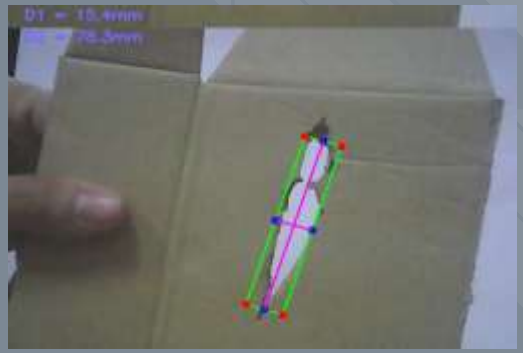
- **RC-XD's main purpose is to identify any crack, locate its position, get its shape and save photos named with the identified crack position and degree with its dimensions.**

- Test Case Photos

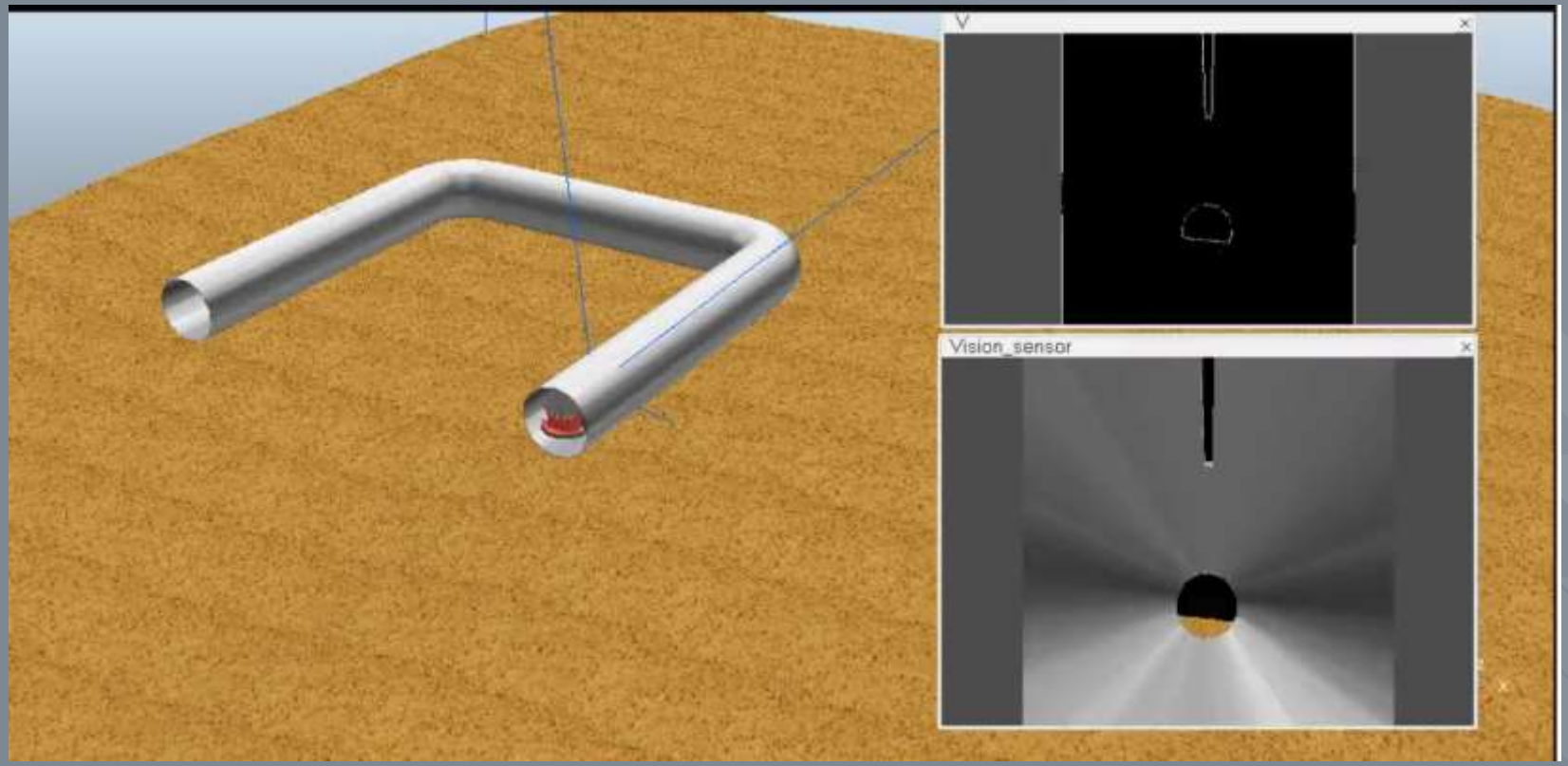




- Real Case Photos



# V-REP Simulation



# Full Functioning Prototype Video Test Cases

# Thank you!