CAIS: Culvert Autonomous Inspection Robotic System

Dr. Hung (Jim) La

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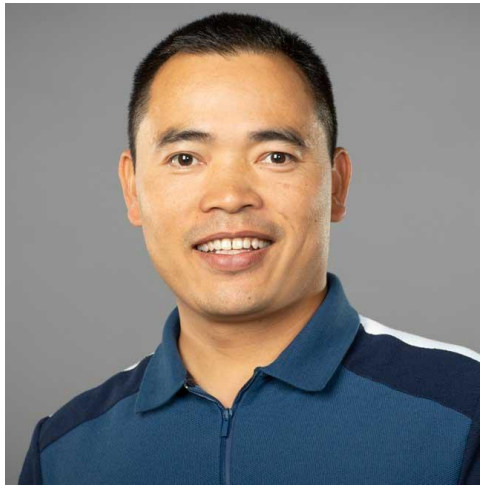
About the speaker

- **Hung (Jim) La, Associate Professor**
- **Department of Computer Science and Engineering**
- **Director, Advanced Robotics and Automation Lab**
  University of Nevada, Reno
- **NSF CAREER award**
- **Established Innovator Award**



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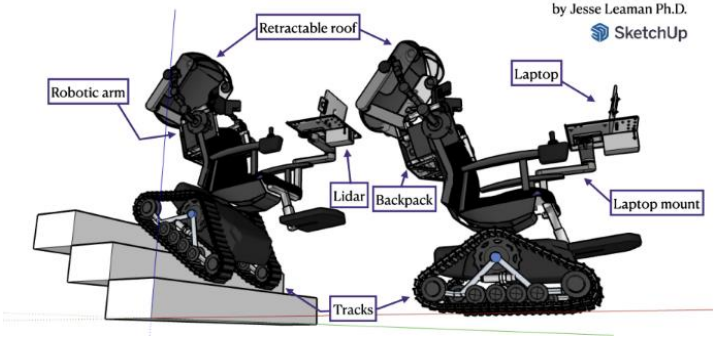
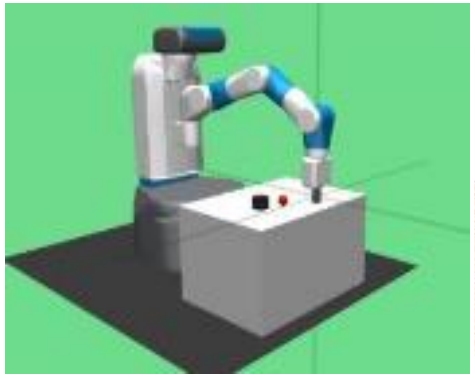
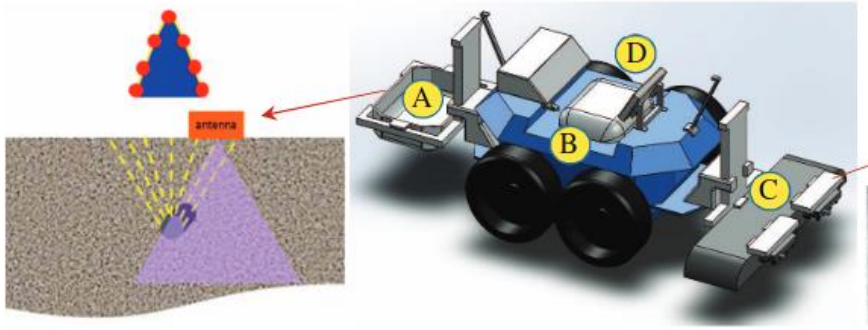
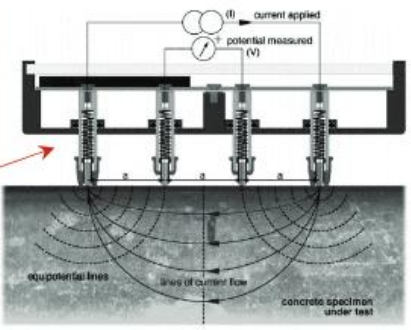
About ARA Lab

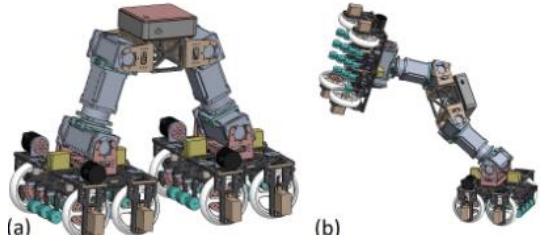
- Established in July 2014 by Dr. Jim La
- Research focus on autonomous systems, multi-robot systems, control systems, with emphasis on infrastructure inspection robots.

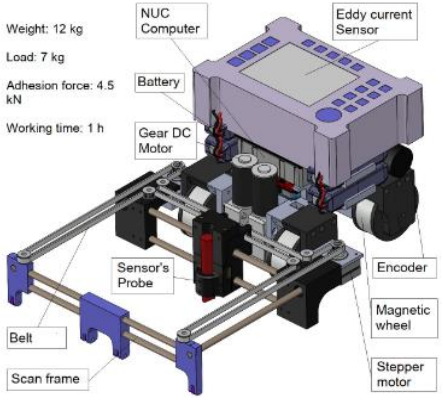


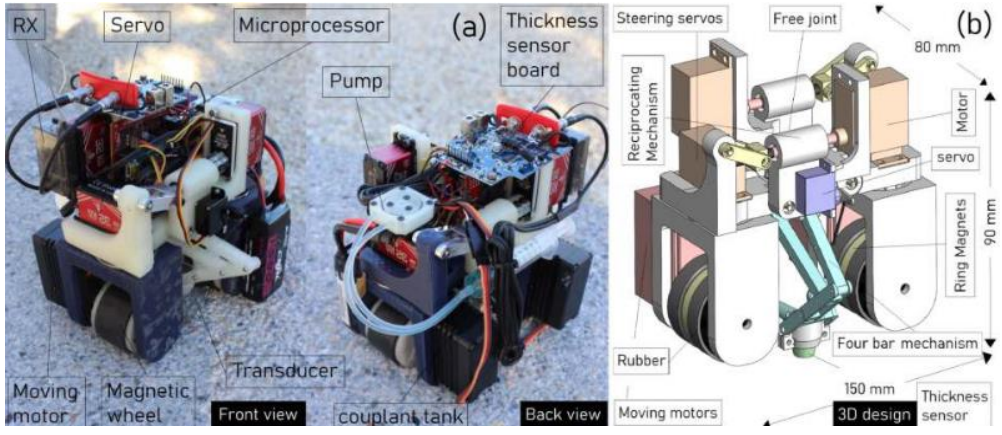












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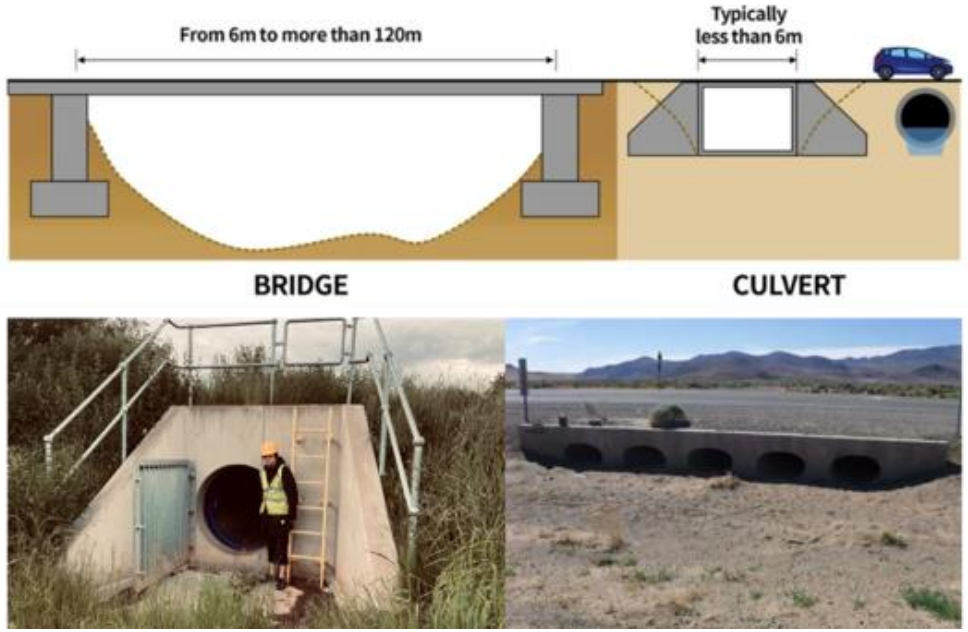
Motivation

Culvert inspections is important, but is challenging:

- Maneuverability & Danger
- Manpower and Speed
- Defect Localization
- Superficial Info



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Motivation: Maneuverability

- Culvert has rough terrain

Debris

Muddy

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Motivation: Danger ⚠

- Dusty & dirty
- Alligator attack!

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Current Methods

- MDOT:
  - Wooden robot with a 20-20 camera & LED.

- NDOT:
  - Inspector crawl into culvert with camera.

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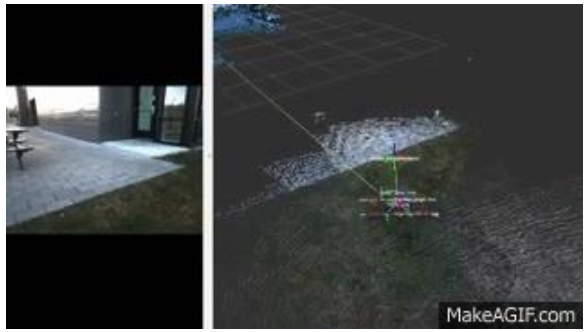
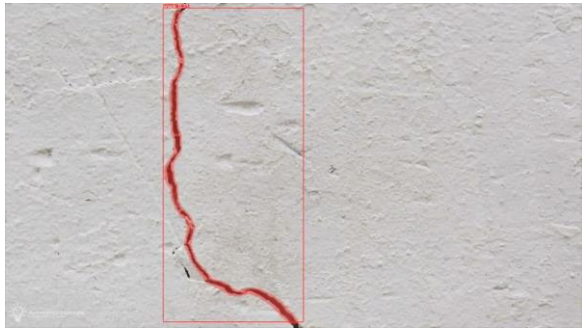
Our Solution

Design a Robotic Platform:

- 3D map the environment
- Detect and classify defects
- Assess defect's condition





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ENGINEER RESEARCH & DEVELOPMENT CENTER

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Testing Environments

Simulations

Indoor artificial culvert

Outdoor real culvert

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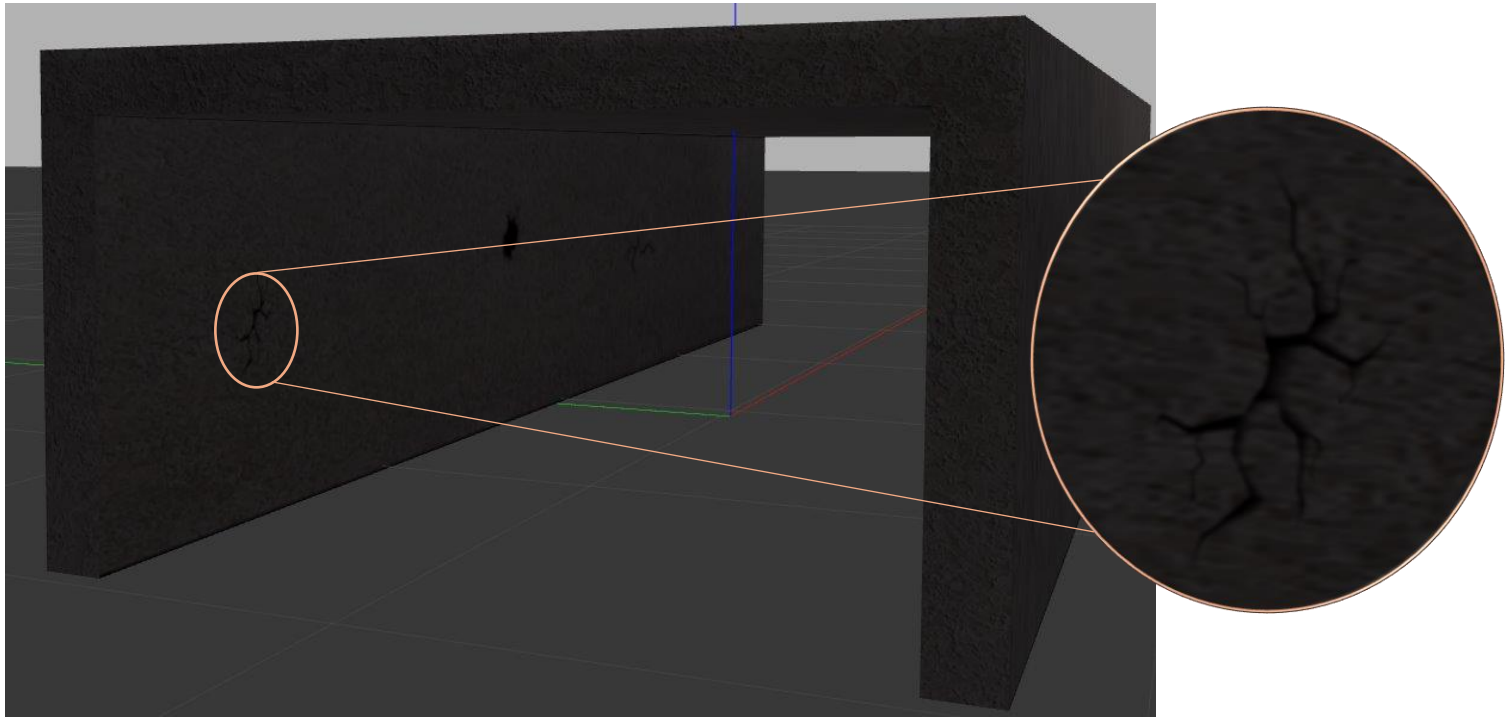
Testing Environments: Simulation



GAZEBO

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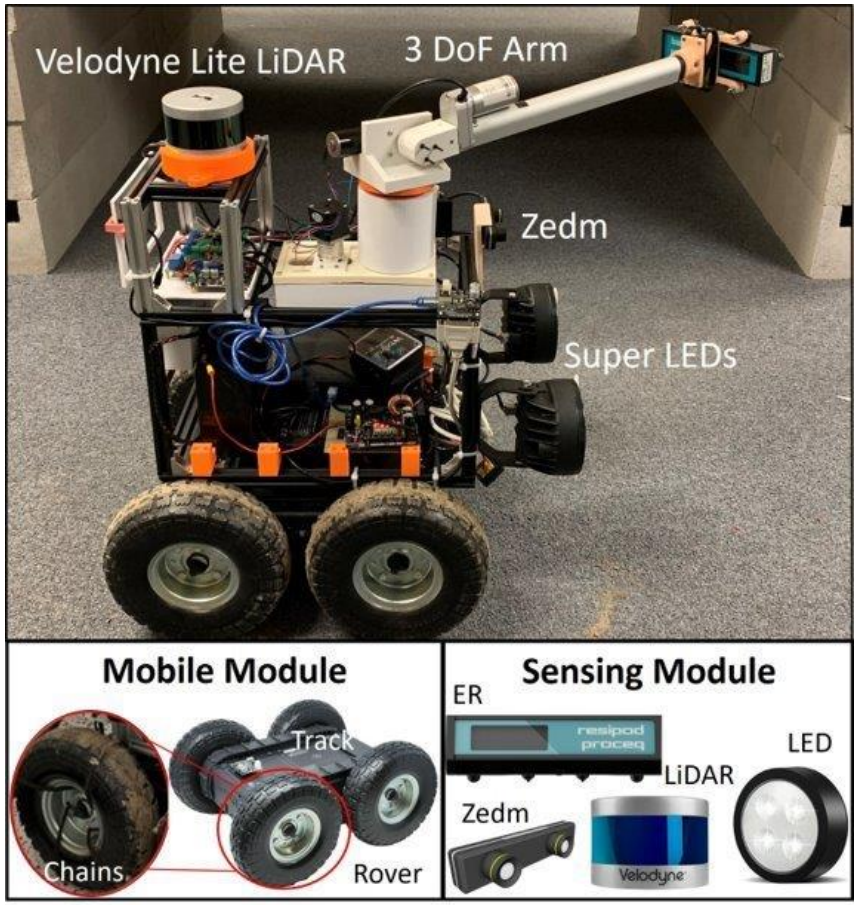
Our Solution: CAIS v1

AbuDhabi 2024 IROS

- Rover Robotic Platform
- Chained wheel
- 3 DoF Arm to assess condition
- RGBD & Lidar for perception
- Super LED for illuminate



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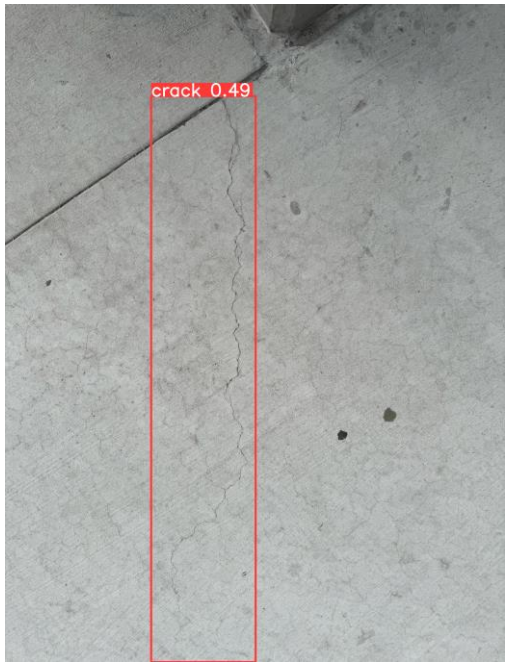
CAIS v1: Defect Detection

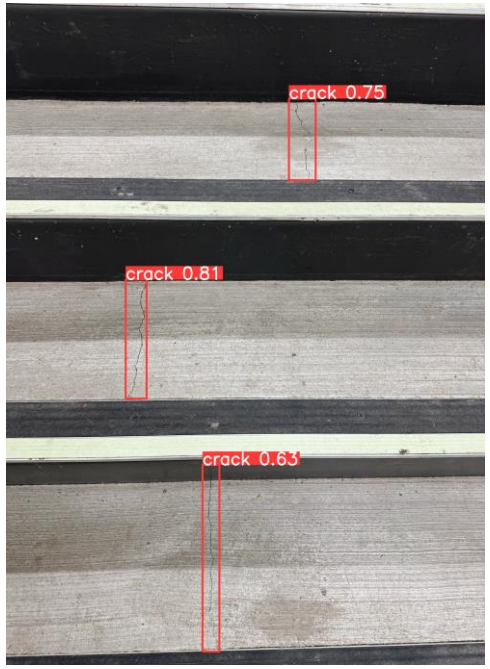
Image

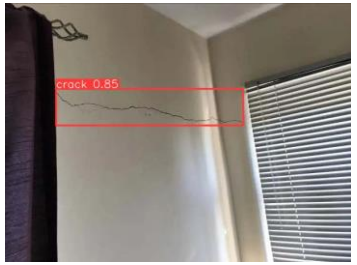
ultralytics YOLOv8

Detection Output

Training and Validation:







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CAIS v1: Defect Detection & Localization

Depth Map

Image

ultralytics YOLOv8

Pixel-to-3D Coordinate Mapping

Defect Position

(x_0, y_0, z_0)

.

.

.

(x_n, y_n, z_n)

Detection Output

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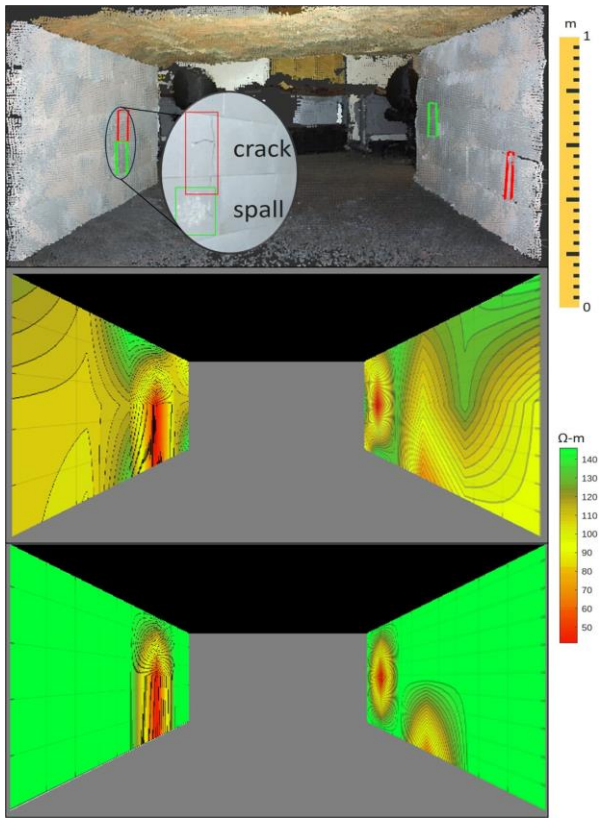
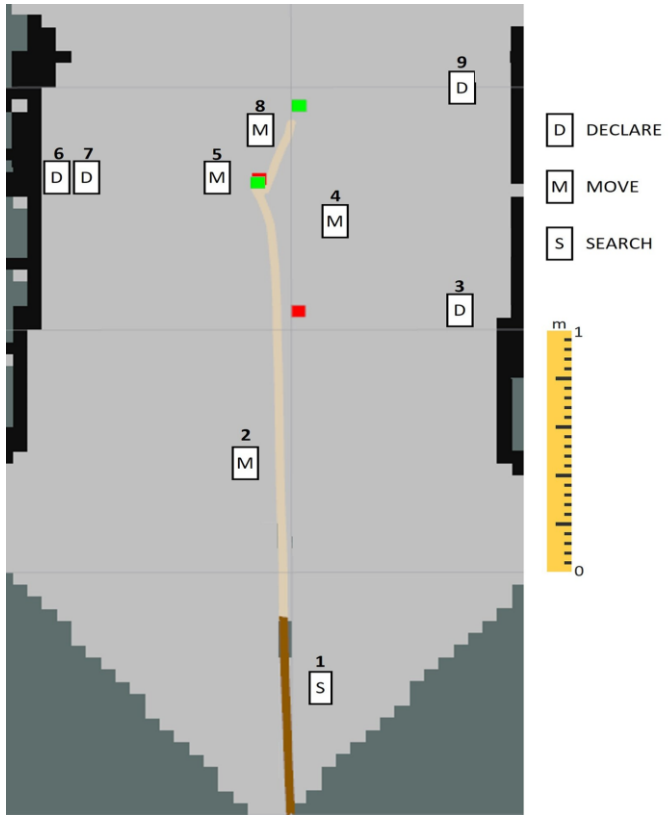
CAIS v1: Indoor Results

Indoor Culvert



Trajectory



ultralytics YOLOv8

cloudSLAM

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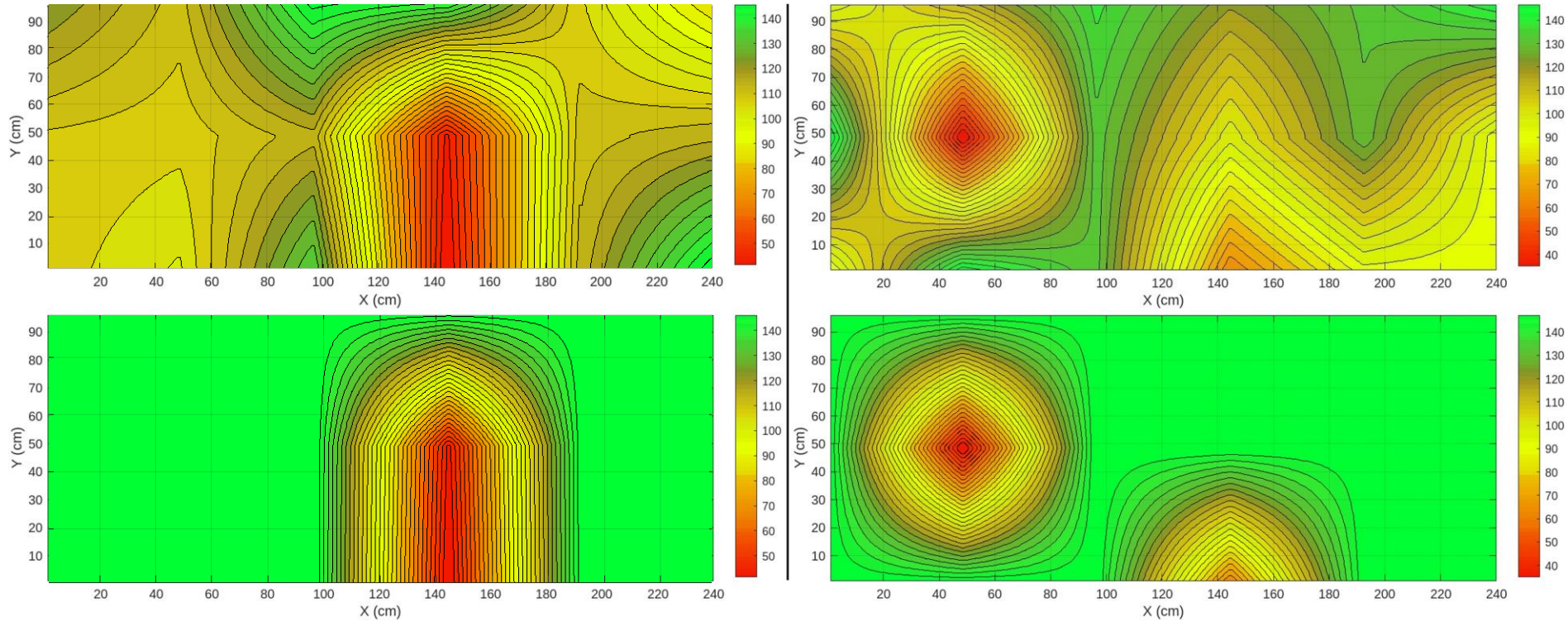
CAIS v1: ER Map Indoor



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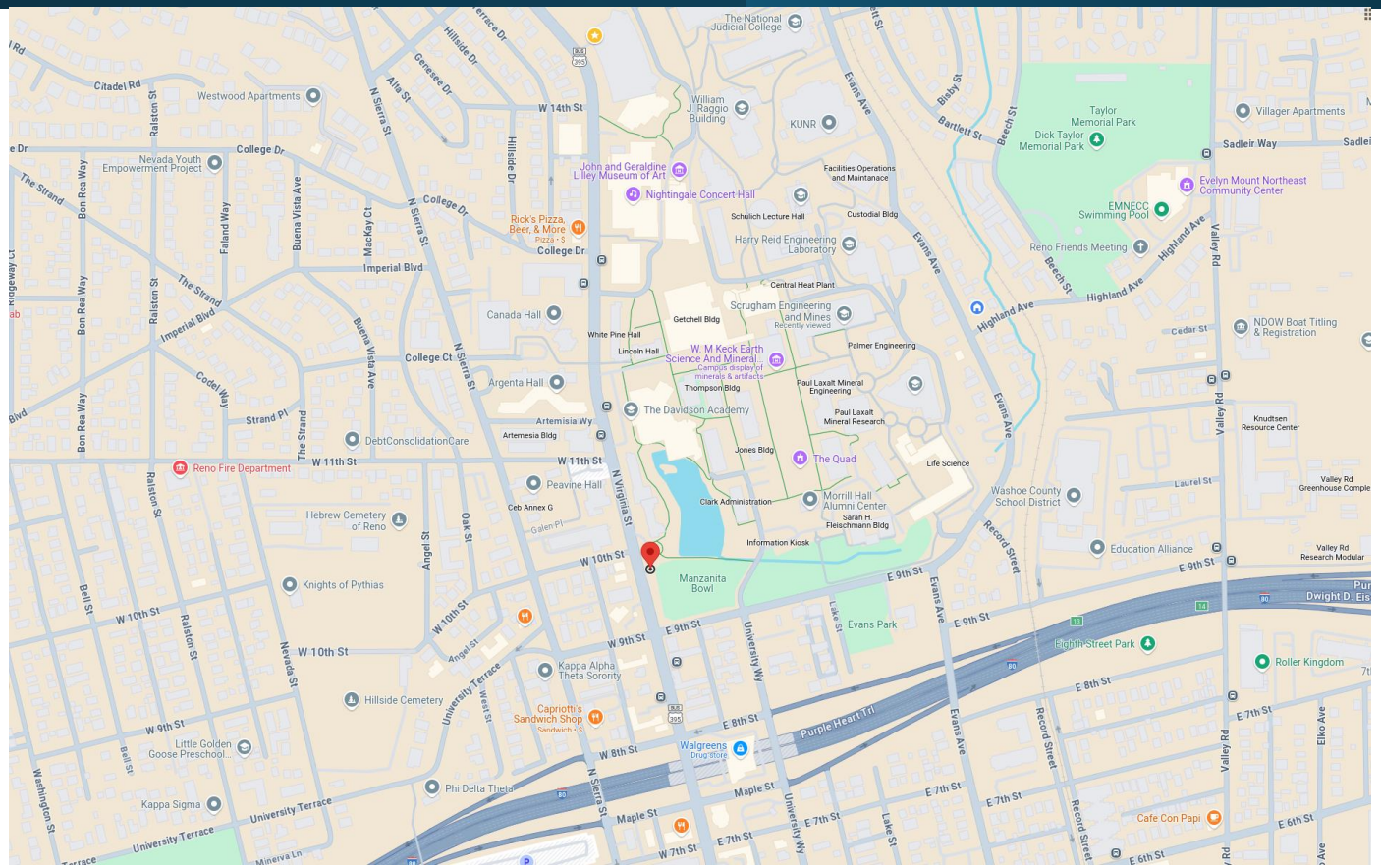
CAIS v1: Outdoor Location: N. Virginia St., Reno

(39.53694, -119.8163)



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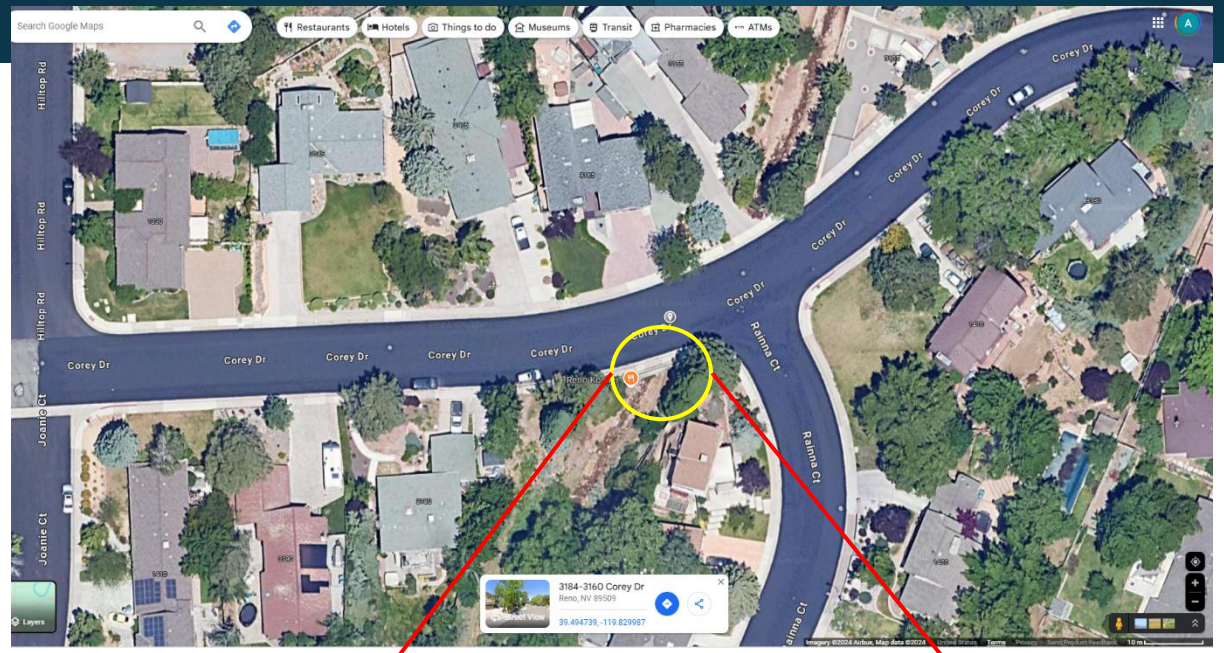
CAIS v1: Outdoor Location: Corey Dr., Reno



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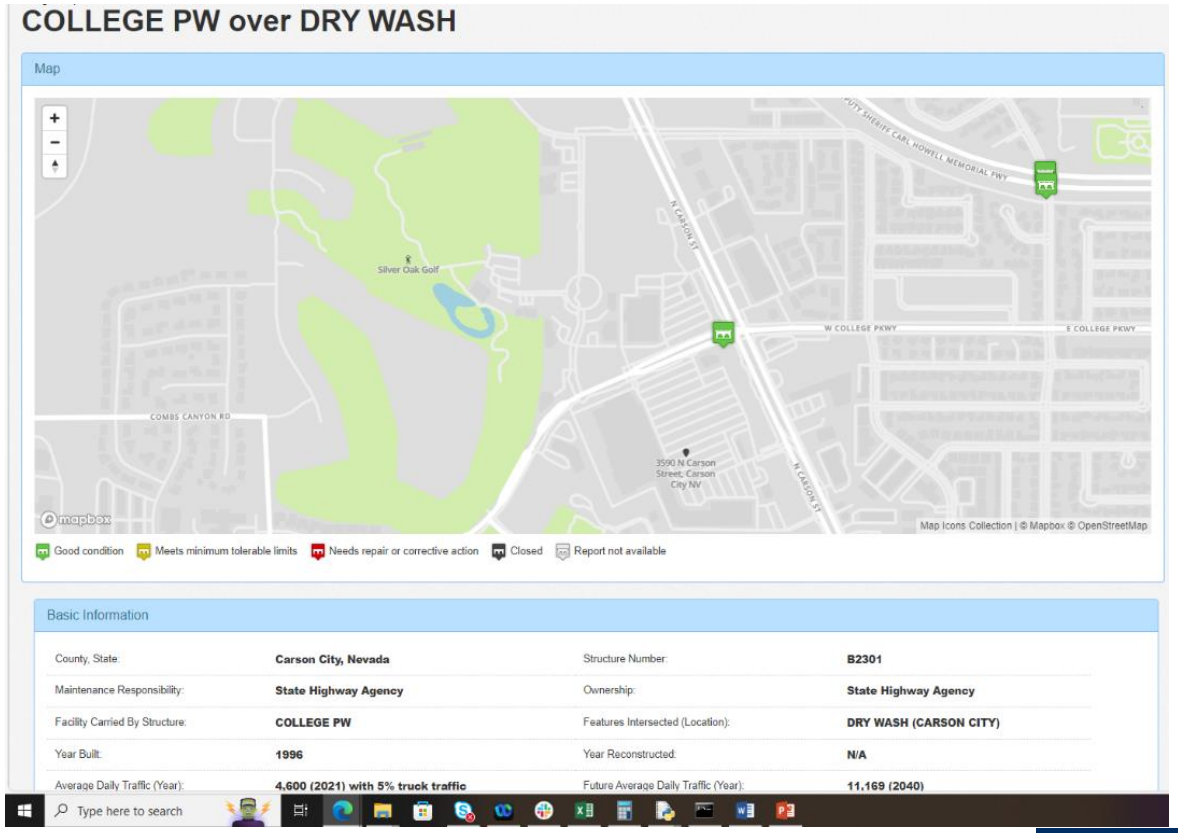
CAIS v1: Outdoor Location: College Pkwy, Carson

In collaboration with NDOT:
Michael Premo
Brandon Henning



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CAIS v1: Outdoor Location: College Pkwy, Carson

In collaboration with NDOT:
Michael Premo
Brandon Henning

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CAIS v1: Outdoor Location: College Pkwy, Carson

Crack and Spalling Detection

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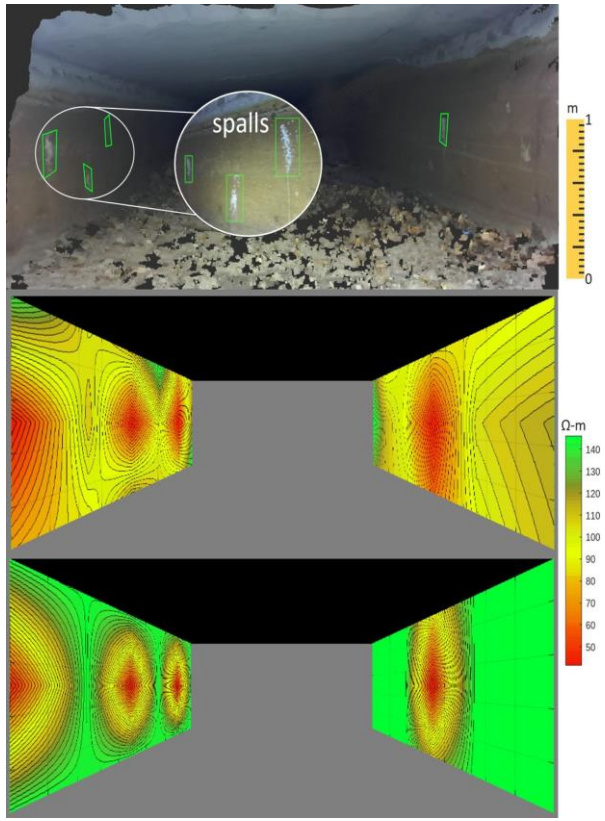
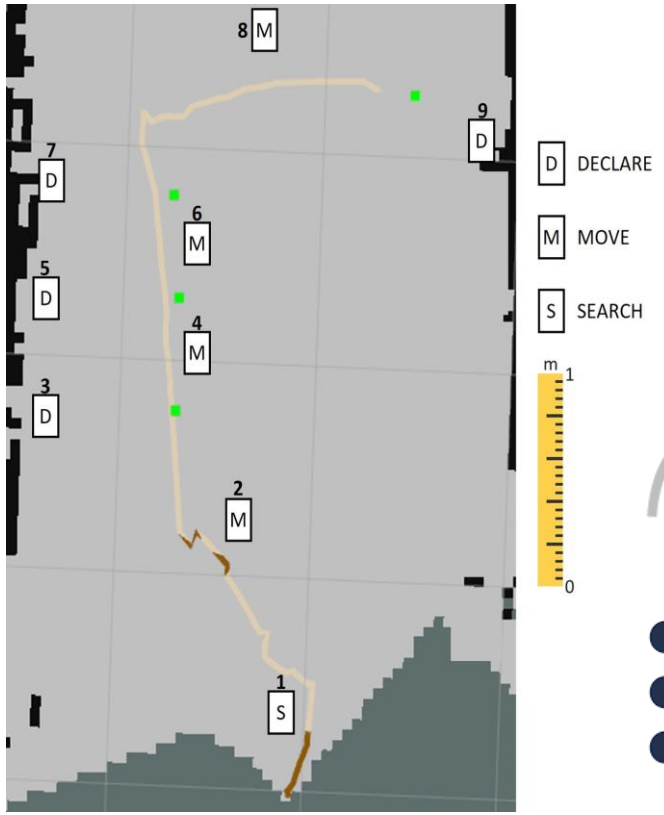
CAIS v1: Outdoor Results

Outdoor Culvert



Trajectory



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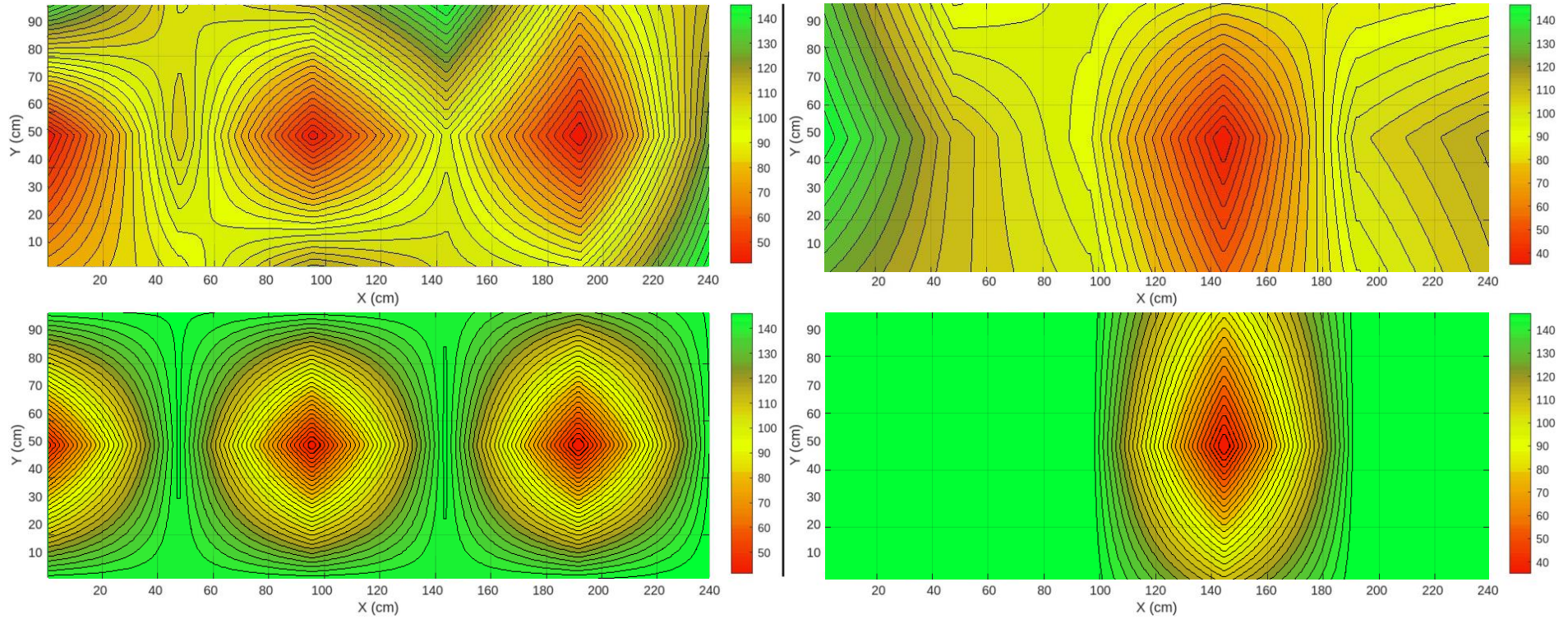
CAIS v1: ER Map Outdoor



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CAIS v1: Video Results

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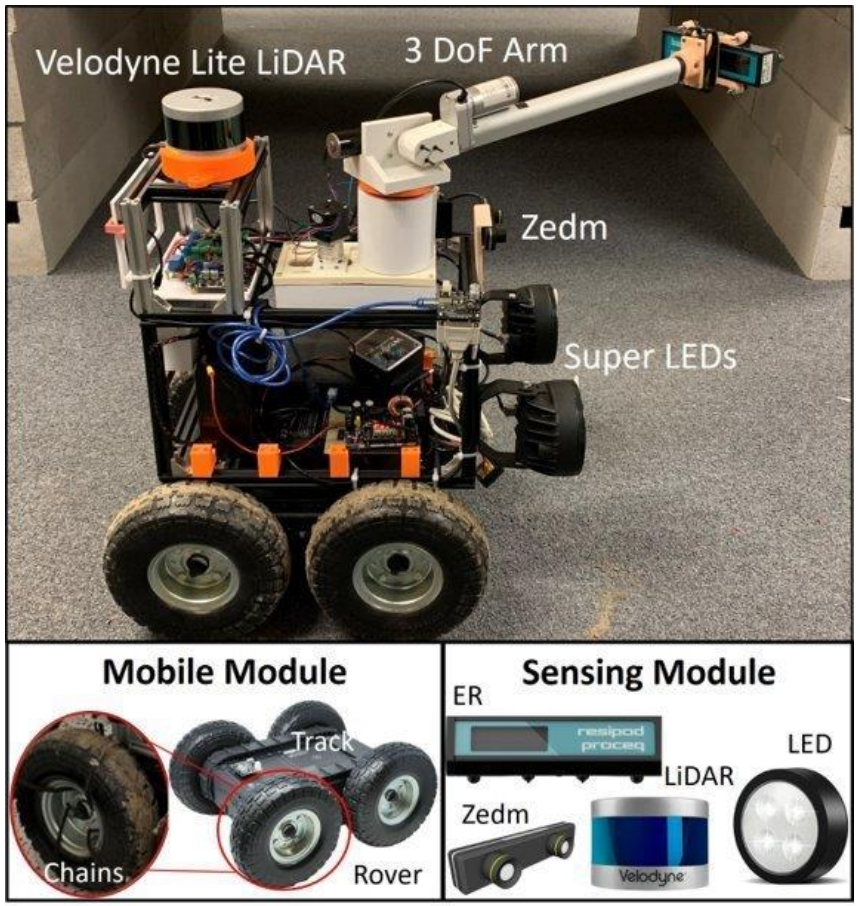
CAIS v1: Drawbacks

Pros

- Detect & assess defects
- Decent 3D map

Cons

- Struggles on rough terrain
- Limited FOV
- Manual Arm



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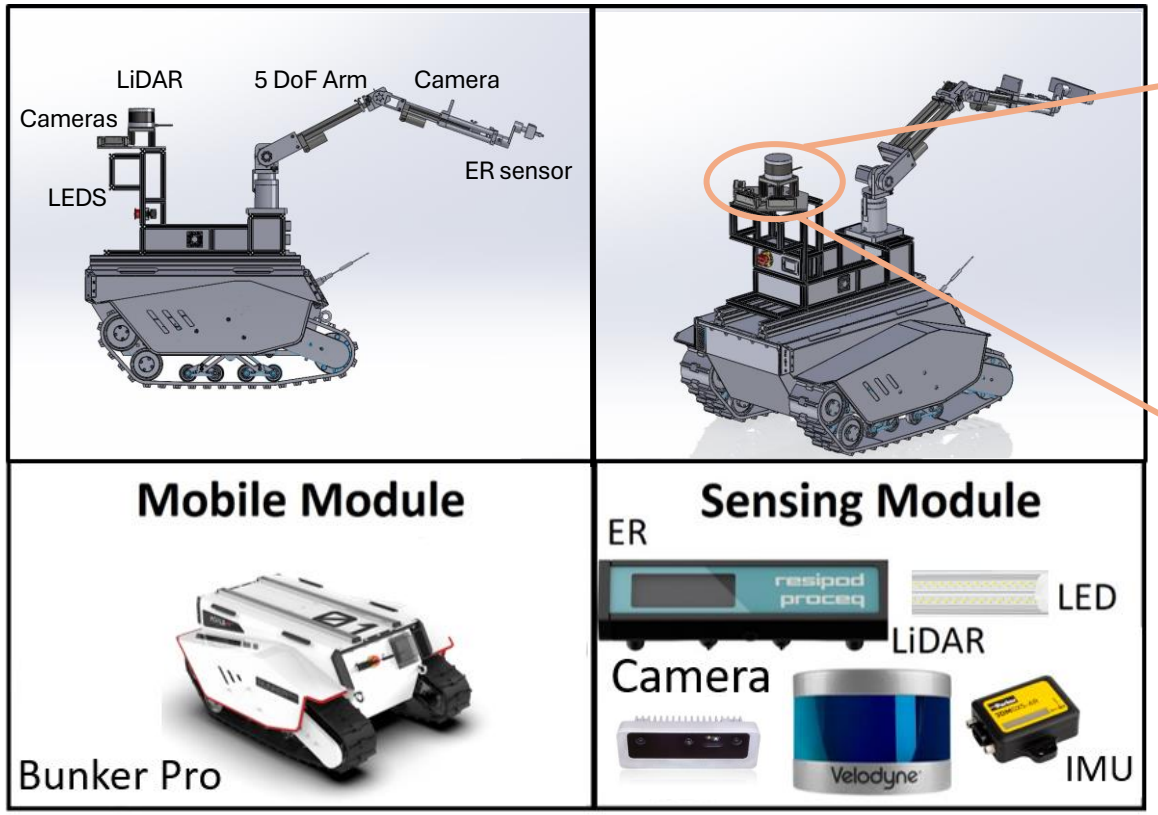
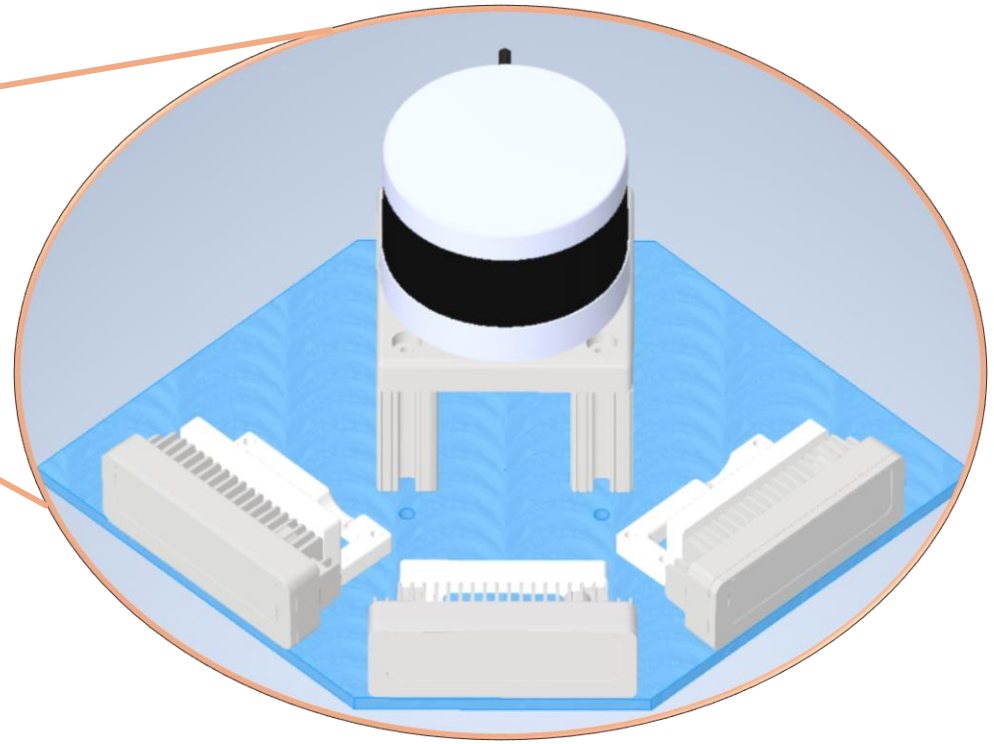
Upgrade: CAIS v2





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CAIS v2: Maneuverability

Bunker Pro:

- Precise maneuvers
- Obstacle crossing and climbing
- High payload of 120kg
- Accurate Positioning

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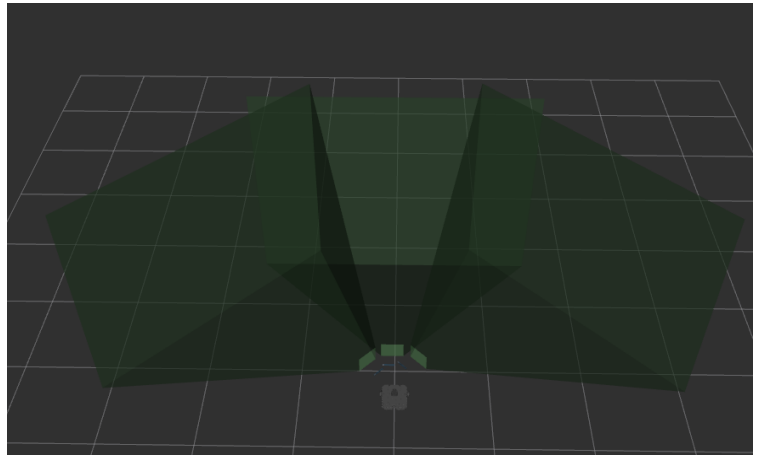
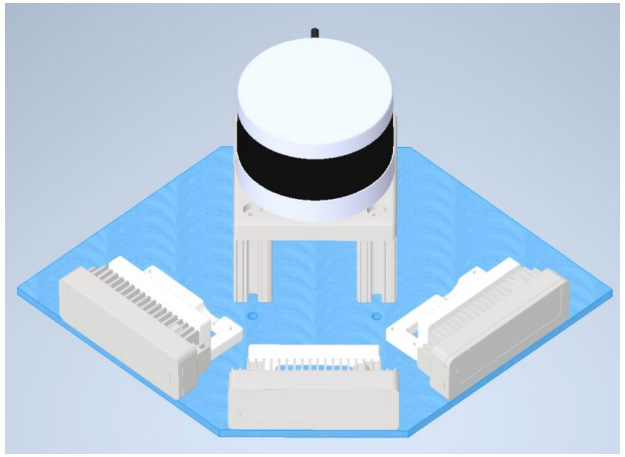
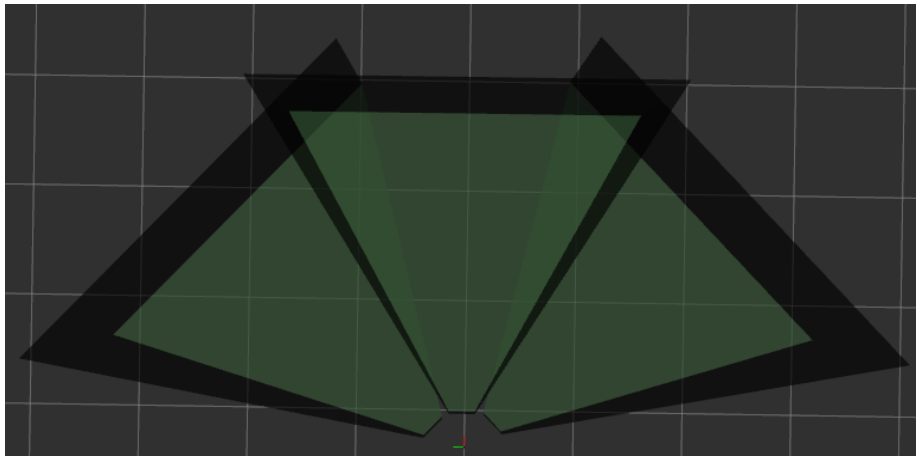
CAIS v2: Multi-sensor

Mult-sensor setup:

- Velodyne LiDAR & 3 Oak-D Pro
- Wide horizontal FOV of about 180°







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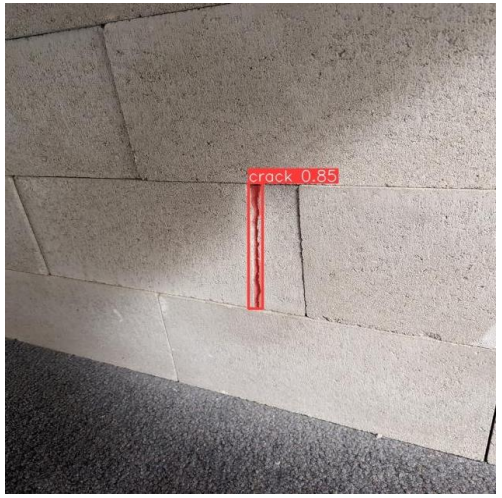
CAIS v2: Instance Segmentation

Advantages

- Provides a pixel-wise mask
- Precise object boundaries



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CAIS v2: Instance Segmentation

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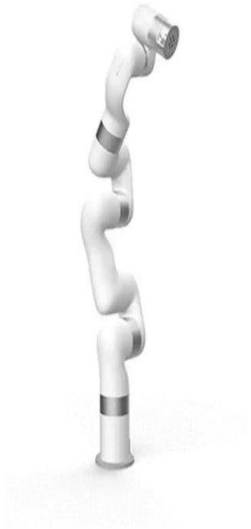
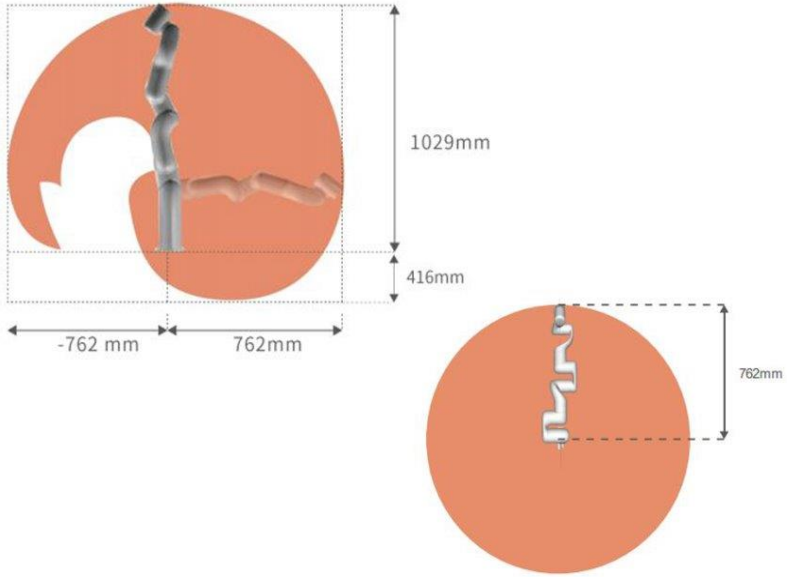
CAIS v2: Autonomous Arm

xArm 5 DoF Lite Robotic Arm

- 700 mm
- 3 kg payload
- 15 kg weight
- ROS platform





ROS

MoveIt

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Other Projects

AUTOMATED INSPECTION ROBOTICS

Solution: InfraGuard Software

Infra-Scan

Depth perceiving camera system detects surface irregularities and fractures.

A.I. Processing Engine

A.I. Trained on 10 Years worth of structural data, compiles sensor information.

LiDAR

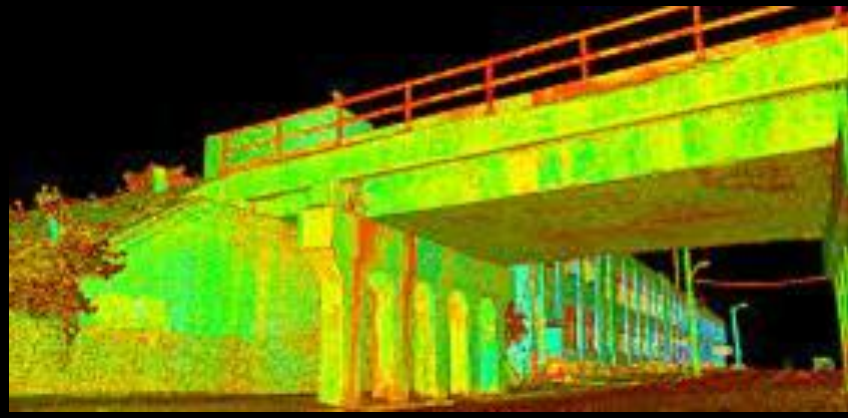
Creates a 3D point cloud map of the structure being inspected.

Infra-See

Smart-fusion hardware sensor detects cracks in steel surfaces with 99% accuracy.

Structural Report

Software generates a comprehensive 3D report for structural inspectors.



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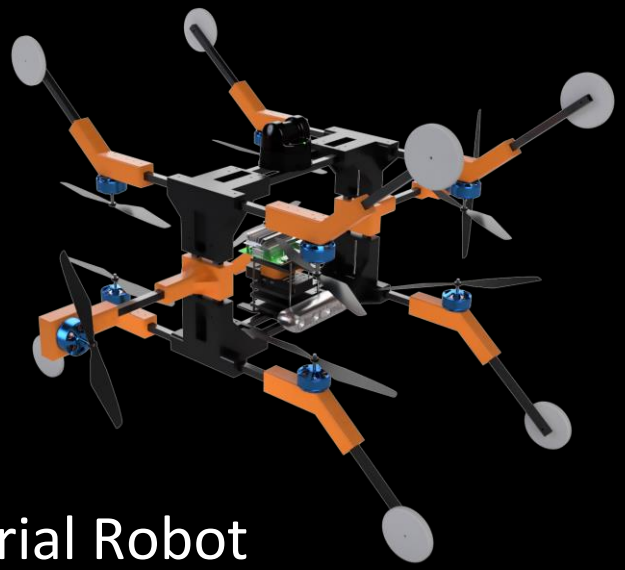
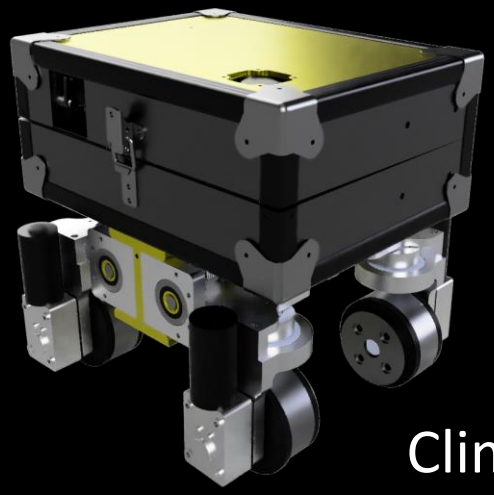
Solution: InfraGuard Hardware



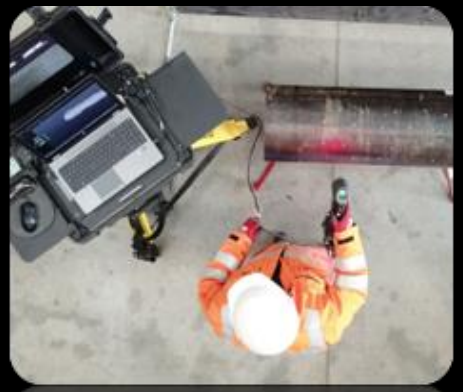
Aerial Robot

(Patent Pending)



Climbing Robot

- 99% More Accurate
- 100% Safer Than Human Operato
- No Traffic Closure



Manual Scanner

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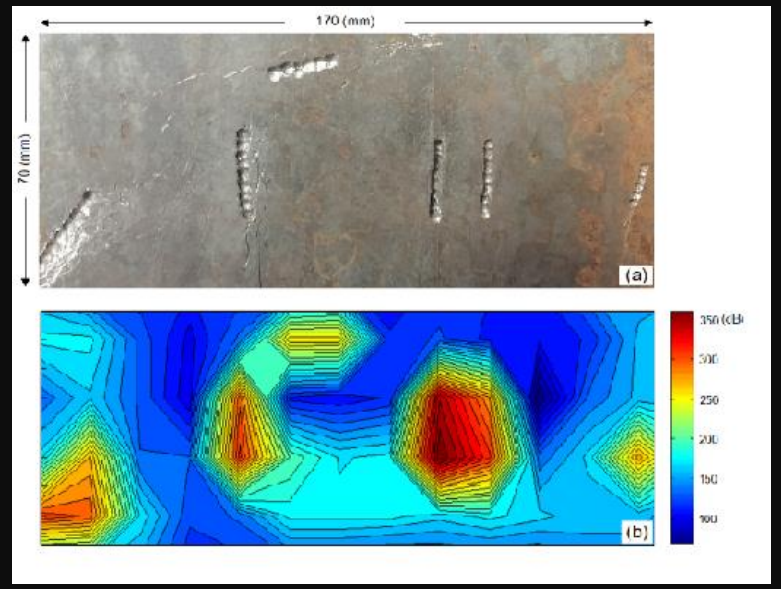
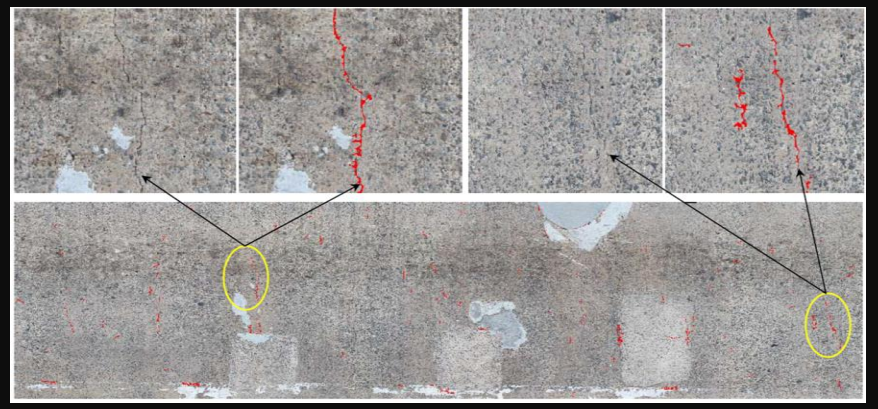
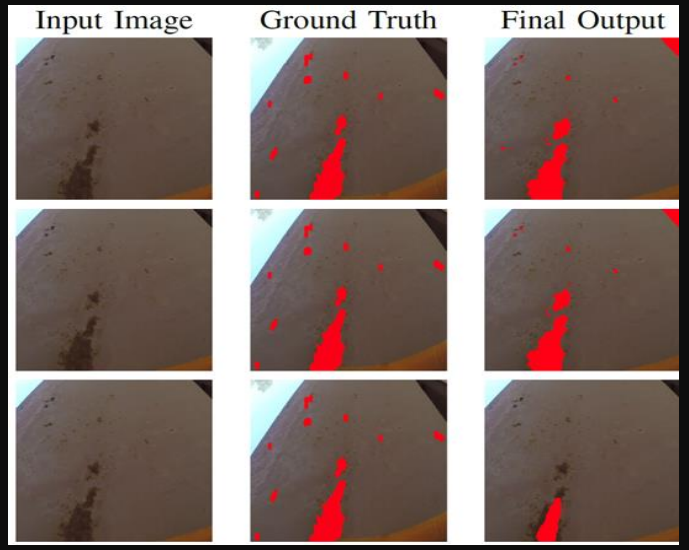
Infra-scan

- AI Computer Vision software
- Solves the toughest problems of visual infrastructure inspection
- Providing easy results
- Fast processing: 100 images/s
- 99% accuracy.







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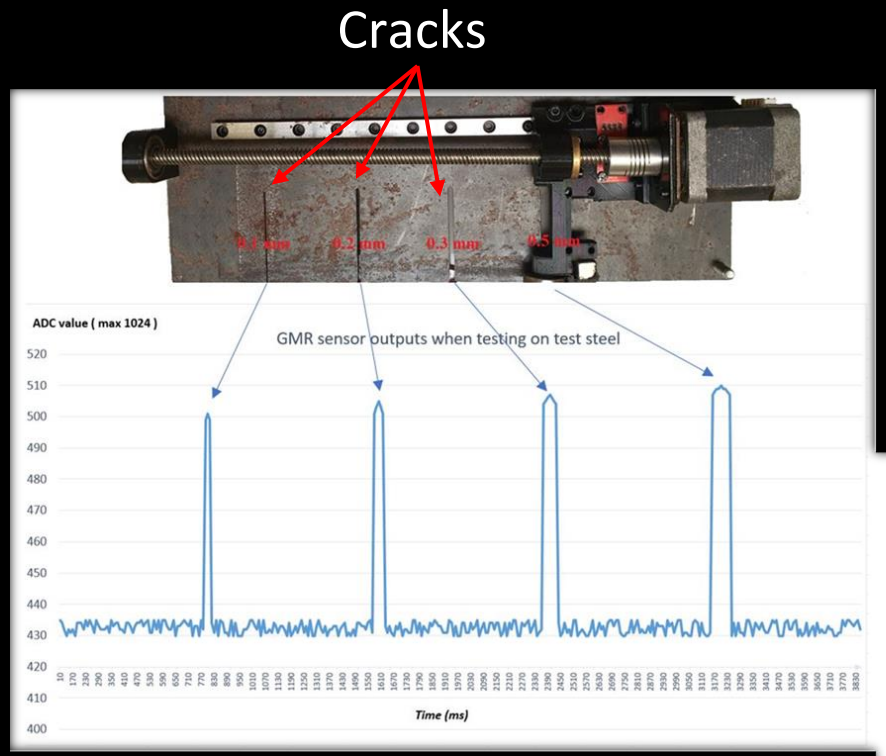
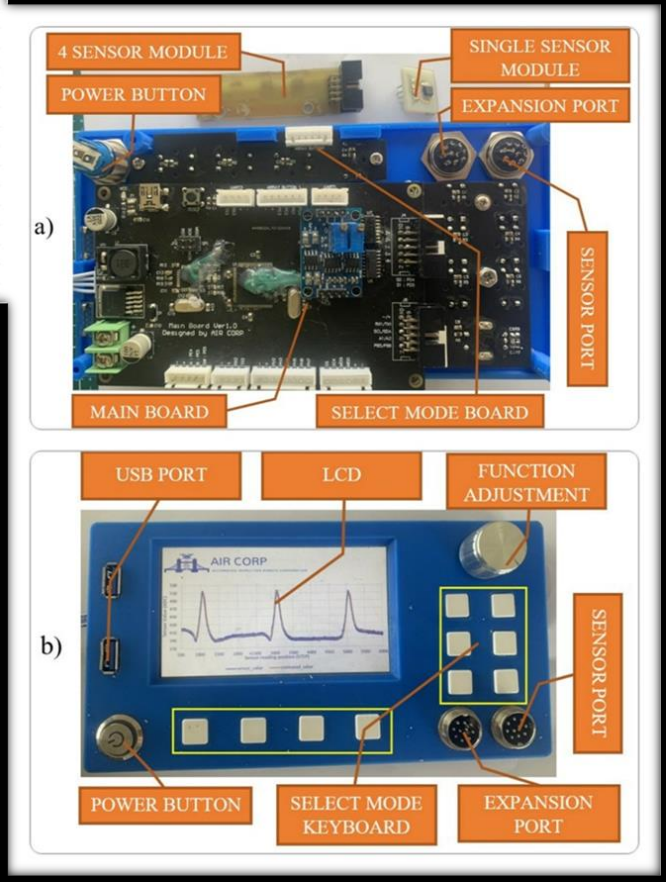
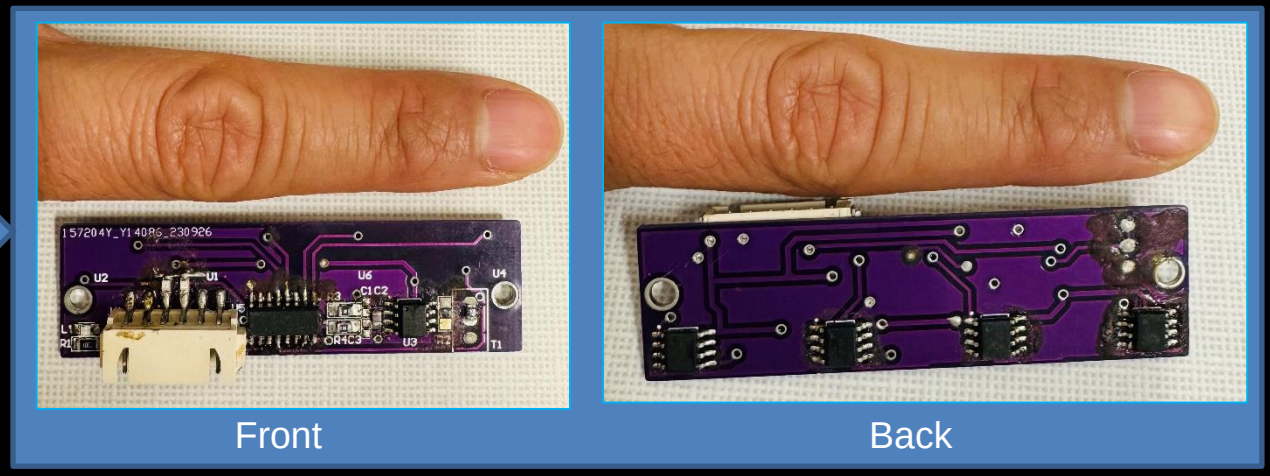
Infra-see

- Smart-fusion hardware
- Detect cracks on or hidden in steel structures
- Small (1-finger size), easy to integrate on drones, robots, hand-held devices
- 99% accuracy.





For drone integration version



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Update: Handheld Device

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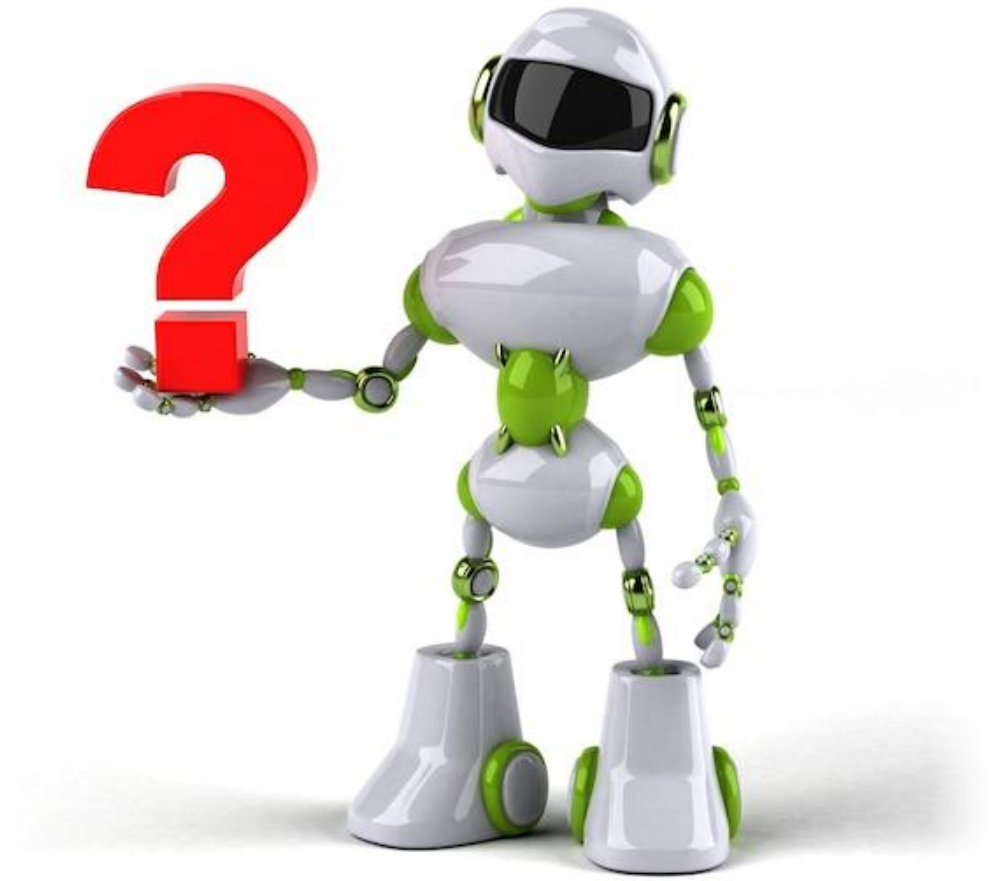
Update: Handheld Device

3D Mapping for
Structure
Inspection

AIR Corp.

Q & A



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