College of Engineering
Department of Mechanical & Industrial Engineering

College of Engineering
School of Electrical Engineering & Computer Science

To Predict ▶ To Design ▶ To Perform

ME, ECE Capstone Design Programs

Team #30: University Student Design and Applied Solutions Competition

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NACE INTERNATIONAL

Jack Rettig ExxonMobil

Objective

The team will design and build a system to remotely detect and quantify corrosion-related defects inside of a 6.3′ length of coated A36 steel pipe. The system cannot damage the structure. The goal is to place first in the NACE International University Student Design and Applied Solutions Competition (USDASC).

Inspection Capabilities

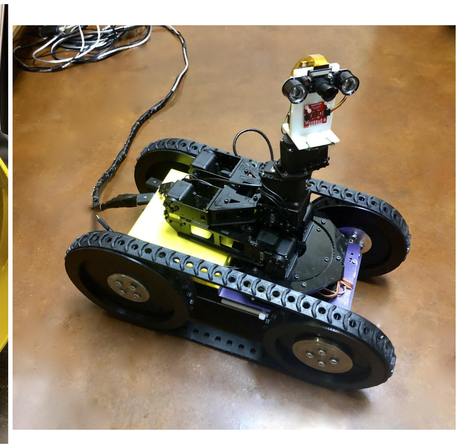
Specification:	Value:
Navigation and Image Collection	Camera Module
Determining Type of Damage	Visual Inspection
Area Measurement	Software processing of collected images
Depth Measurement	Time of flight distance sensor
Location , within 1 in^2	Inverse kinematics and rangefinder
Diameter Measurement of Pits/Pinholes, within 1mm	Software processing

Design Specifications

Specification:	Value:
Weight (lbs)	12.5 lbs
Average Speed (feet per second)	0.3 ft/sec
Dimensions (in)	8.75 x 17.56 inches
Motors and Electronics Battery Duration (hour)	1 hour
Vertical Clearance (in)	3 inches

Power System

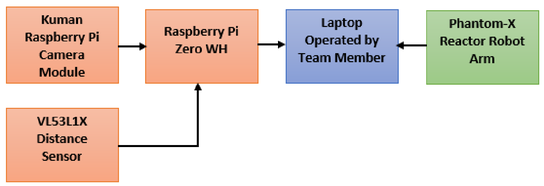
Specification:	Value:
Motor Voltage	12V
Motor Battery	Max Amps Lithium Polymer Battery Pack
Capacity and Discharge	2800mAh; 100C
Operating Voltage	9.6-12.6V
Electronics Battery	Mi Power-Bank
Capacity	5000mAh
Operating Voltage	3.75-5.1V
Power Switch	Baomain Toggle Switch SPST 12V 25A
Fuse	7.5A ATC Blade Fuse w/ 14 AWG Fuse Holder
Motor Controller (ESC)	12A Continuous Current; 25A Max Current



Manufacturing and Chassis

The chassis is constructed from two aluminum panels connected by column supports in the front and bracketed side panels in the rear. The front axles are connected to the wheel hubs with epoxy and attached to the chassis by a combination of ball bearings and pillow mounts. The rear axle is supported by a ball bearing press fit into the rear side panel; it is connected to the wheel hub by internal threading and a countersink, and is hollow at the end to allow an attached shaft collar and set screw to connect with the motor shaft for torque transmission. The wheels, back component housing, and receiver housing located beneath the robotic arm were created using additive manufacturing.

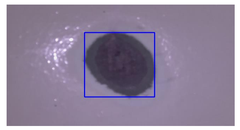
Communications System



Method of Transmission and Reception:	Value:
Operating System (Raspberry Pi) to Operator Laptop:	Ethernet over USB
Distance Sensor to Operating System:	I2C Qwiic Cable
Camera Module to Operating System:	Raspberry Pi Camera Ribbon Cable
Robotic Arm Controller to Operator Laptop:	Serial over USB through a UART Sbee
Sabertooth Motor Controller to Operator Controller:	R12DS Radio Controller Transceiver

Analysis

Analysis for each instance of coating damage and corrosion was done using OpenCV and implemented through Python software. The area calculation for a sample of damage was calculated by first allowing the user to outline the instance in a rectangle over software. The dimensions of this rectangle were then individually squared and divided by a polynomial ratio that corresponds the pixel count of a selection of damage to the distance from the system's camera to the damage in question. The software then reported the size of corrosion in the judges' preferred format within one square inch. The software also calculated the angle of rotation of the system's robotic arm as well as the system's distance from the front of the testing structure.



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12 o'clock + 32 min.
25.667654 in. into pipe (50.730346 in. raw)
1.0625109154726373 x 0.8192855251837203 dimensions (in.)
47.85414790375223 total area (in.^2)
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Figs. Example Image of Corrosion (Left)
Corresponding Processing Output (Above).

Testing and Validation

Fig. Acceptance Testing

Acceptance testing was successfully performed on the mobility and communications systems in an aluminum foil wrapped PVC structure created by the team. Competition regulated obstacles were made with additive manufacturing and adhered in the pipe with epoxy. Corrosion was simulated with checkerboard patterns of known areas. Test data was transmitted to the operator.

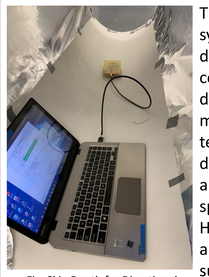
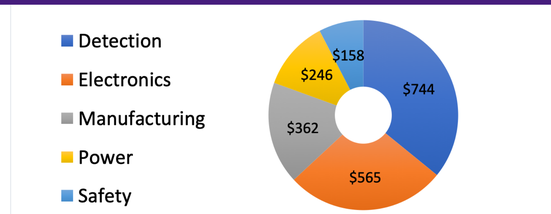


Fig. Skin Depth for Directional Antenna Test.

The communications system was originally designed to be completely wireless. A directional antenna was manufactured and tested to have a gain of 6 dB, a range of over 30ft, and a transmission speed of 150 mbps. However, the directional antenna was unable to successfully integrate with the Raspberry Pi operating system. Also, the independent radio frequency XBee device for the robotic arm failed repeatedly under Faraday cage effects. This caused the team to switch to a wired approach.

Budget



Total System Cost Including Donated Equipment: $2075

Concept Generation	Concept Selection	Component Selection	Engineering Analysis & Simulation	Purchase Parts	Assembly & Manufacturing	Testing and Competition Simulation	Competition
September 13	October 16	October 29	November 5	January 14	February 22	March 25	April 16

Sponsors: NACE International, Mr. Jack Rettig, Exxon Mobil, LSU Robotics

Adviser: Dr. Hsiao-Chun Wu