Robotic Pole Inspection Collar

Team 505

“Team Southern Pine”

FPL

Department of Computer & Electrical Engineering
Department of Mechanical Engineering

FAMU-FSU Engineering

ME Team Introductions

Mathew Crespo
Mechanical Systems Engineer

John Flournoy
Design & Material Engineer

Carey Tarkinson
Mechatronics & Programming Engineer

Angelo Mainolfi
Project Engineer

Angelo Mainolfi

EE Team Introductions

Corie Cates
Project Engineer

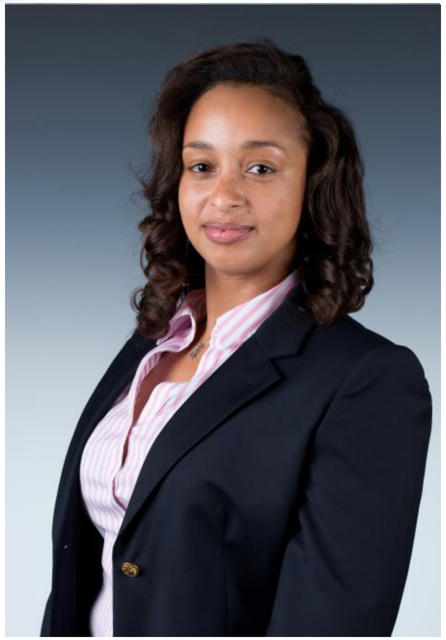
Alonzo Russell
Hardware Engineer

Leonardo Vazquez
Software Engineer

Thomas Williams
Hardware Engineer

Angelo Mainolfi

Sponsors and Advisors



<u>Engineering Sponsor</u>
Genese Augustin
Lead Project Manager
Smart Grid & Innovation
Florida Power & Light

<u>Engineering Sponsor</u>
Troy Lewis
Engineer II
Smart Grid & Innovation
Florida Power & Light

<u>Academic Advisor</u>
Jonathan Clark, Ph.D.
Associate Professor

<u>Engineering Professor</u>
Shayne McConomy, Ph.D.
Teaching Faculty

Angelo Mainolfi

Objective

The objective is to design a mechanism that can climb a wooden utility pole and check its structural integrity

Angelo Mainolfi

Project Background

- FPL is Florida’s largest utility company serving over 5 million customer accounts
- FPL’s linemen interact with wooden utility poles daily to maintain reliability
- Checking the structural integrity is crucial to keeping linemen safe

Angelo Mainolfi

Problem

- Over the summer of 2020 a lineman suffered serious injuries after a rotten utility pole cracked
- This mechanism is being created to replace outdated testing measures
- Currently a hammer is used to check for rotten wood
- This test is certified by OSHA

Angelo Mainolfi

Project Guidelines

Key Goals

- Ascend and descend a wooden utility pole
- Detect rot within the pole
- Interface the readings to the linemen

Targets & Metrics

- Climb a minimum of 15 feet
- Scan a minimum depth of 8 inches
- Interface readings within 60 seconds

Angelo Mainolfi

Rapid Prototypes

Prototype 1

Prototype 1 used a bicycle frame structure

Prototype 2 used a simpler geometric frame

Prototype 2

Angelo Mainolfi

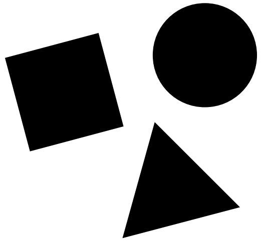
Pole Samples

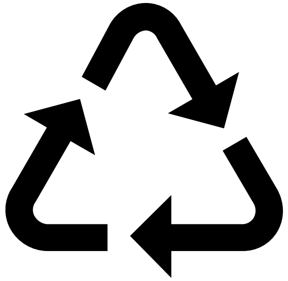
- FPL provided us with three pole samples
- This keeps our team safe from active powerlines
- The unhealthy sections are used by the Electrical Engineering team

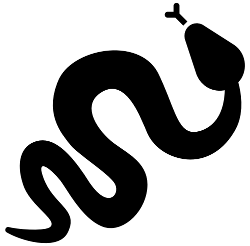
Angelo Mainolfi

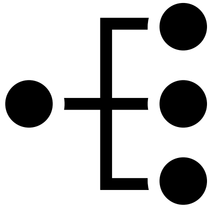
Concept Generation

- Crapshoot
- SCAMPER
- Biomimicry
- Morphological Chart



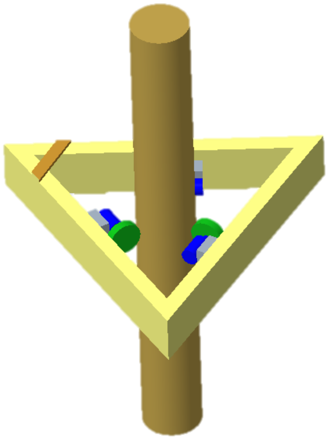


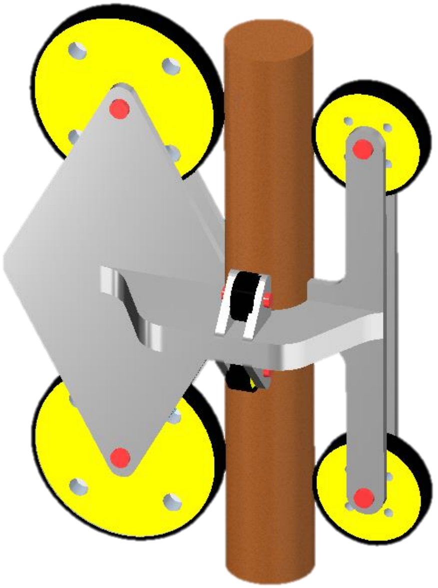


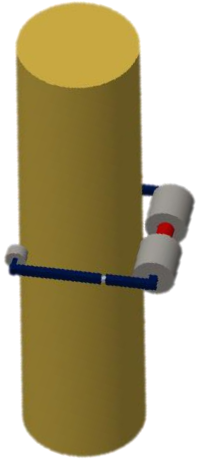


Mathew Crespo

High Fidelity Concepts







Mathew Crespo

Concept Selection

Binary Pairwise

Evaluation Criteria Hierarchy

1. Rot Detection
2. Ability to Climb
3. OSHA Test Standards
4. Data Interface
5. Portability
6. Modularity

House of Quality

Engineering Characteristics

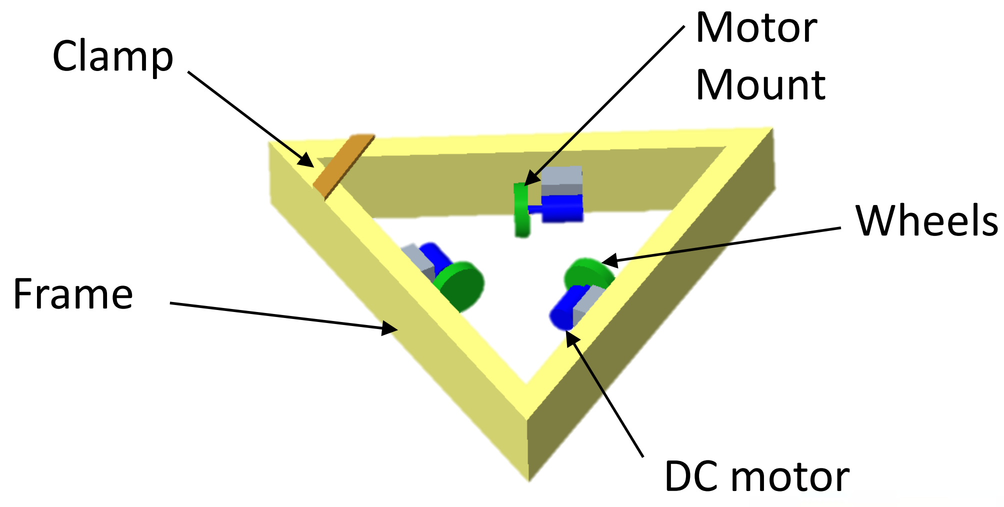
- ❖Stability
- ❖Safety
- ❖Maneuverability
- ❖Speed

Mathew Crespo

Winning Concept

Triangle Climber

- Modularity
- Stability
- Easy to use
- Variable climbing



Mathew Crespo

Prototype Three

Motorized Triangle Climber

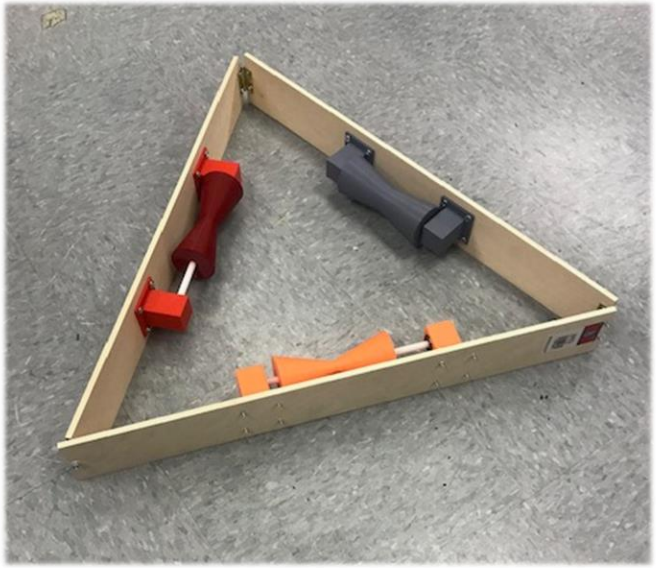
Revelations found:

- Pinching caused by poor wheel mounting
- Motors were grossly underpowered
- Wheels struggled to maintain contact to pole

Mathew Crespo

Prototype Four

- 3D printed hourglass wheels to increase contact area
- 3D printed bearing mounts that attach to the inside of the frame
- Skateboard bearings allow smooth rotation of acetal wheel shafts
- Long passive wheel shaft for diameter compliance



Mathew Crespo

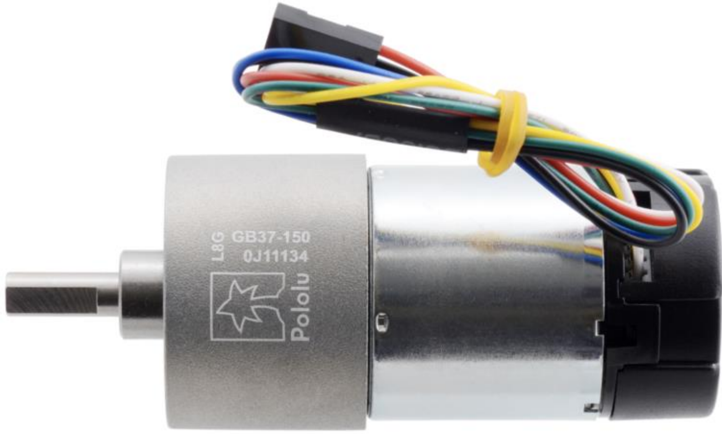
Prototype Five

- Utilized prototype four and incorporated a lower unit for extra stability
- Designed to eliminate pinching caused by motor torque
- Provides more area for ground penetrating sensor

Mathew Crespo

Motor Specification

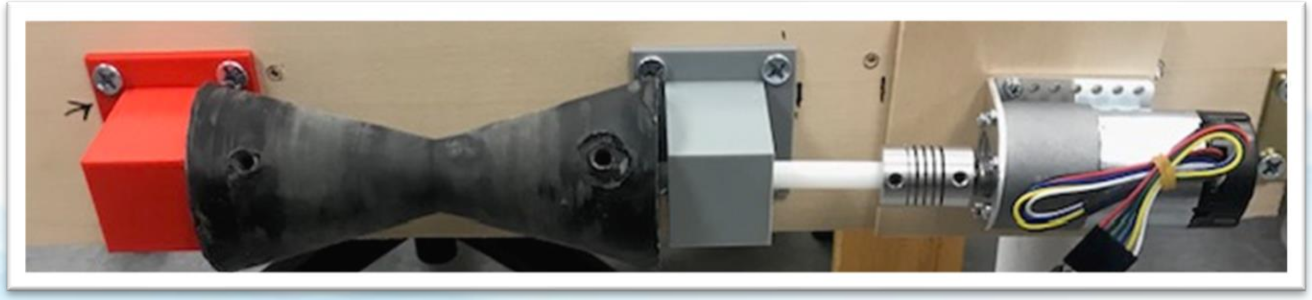
- To spec a motor, we needed to determine minimum torque necessary to overcome gravity
- The radius of the wheel was taken as an average of the major and minor diameters of the hourglass wheel
- The torque was calculated with a weight of 40 lbs and a moment arm of 25 mm



Carey Tarkinson

Shaft Mounting

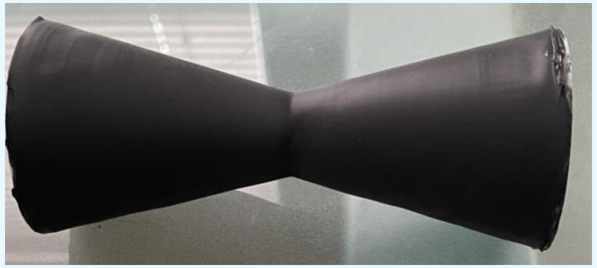
- The hourglass wheel's unconventional design poses a problem with easily mounting to a motor shaft
- To remedy this, holes were created on each side of the hourglass wheel where setscrews will be installed to keep the hourglass wheel mounted to the shaft



John Flournoy

Wheel Friction Method

- The more friction the driver wheel produces, the less tension will be needed to support the robot
- The coefficient of friction must be increased as high as possible so the robot will not neutralize on the pole
- A rubber coating was applied to the 3D printed driver wheel
- Coefficient of rubber on wood is 0.95



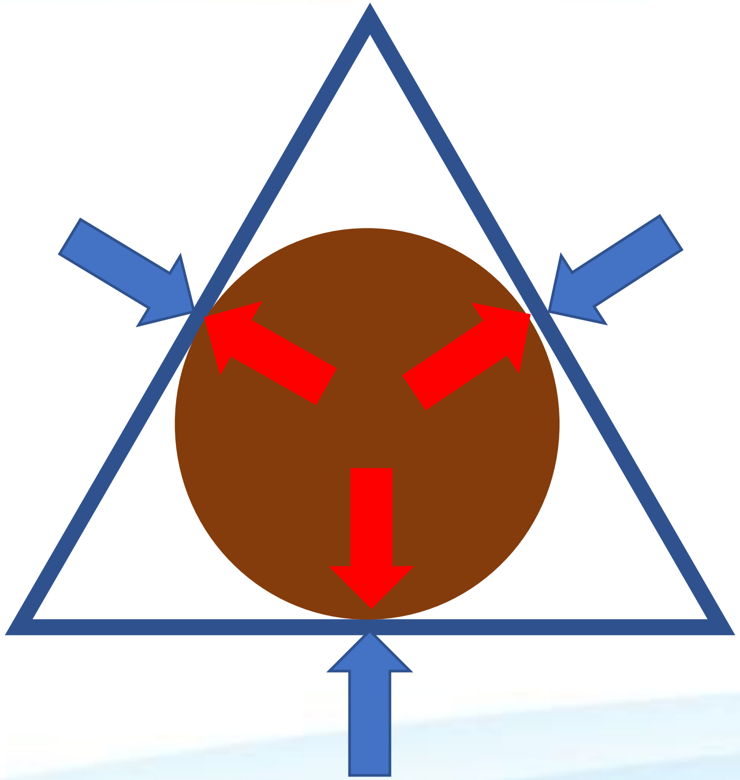
John Flournoy

Prototype Five

Carey Tarkinson

Strap Positioning Ideas

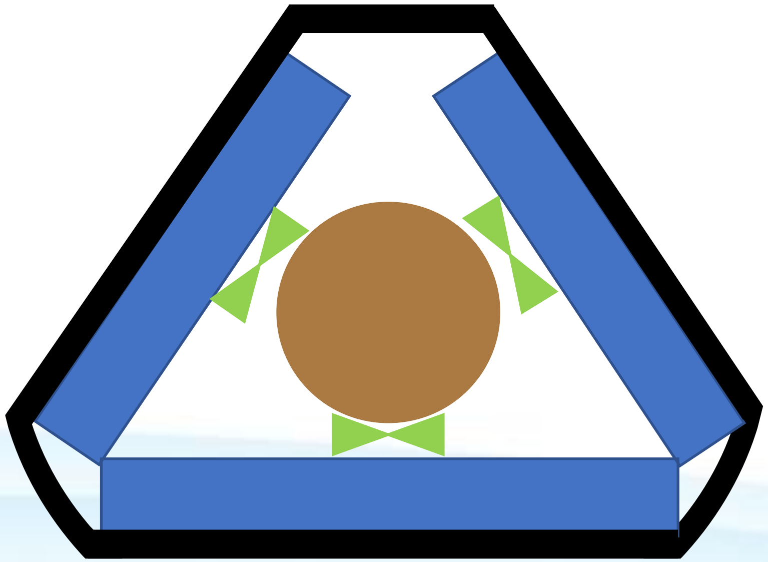
- Tension around the robot increases the friction on the driven wheel
- This friction is needed to translate the collar up
- A ratcheting strap provides the tension needed to push the wheel into the pole



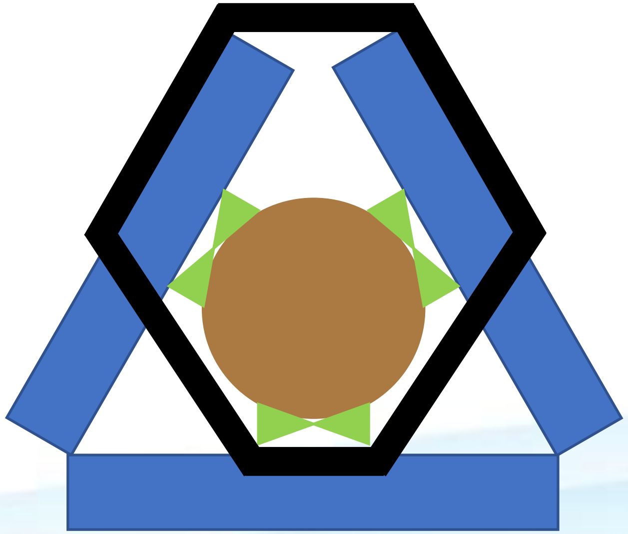
Carey Tarkinson

Tension Strap Path Ideas

Perimeter wrap



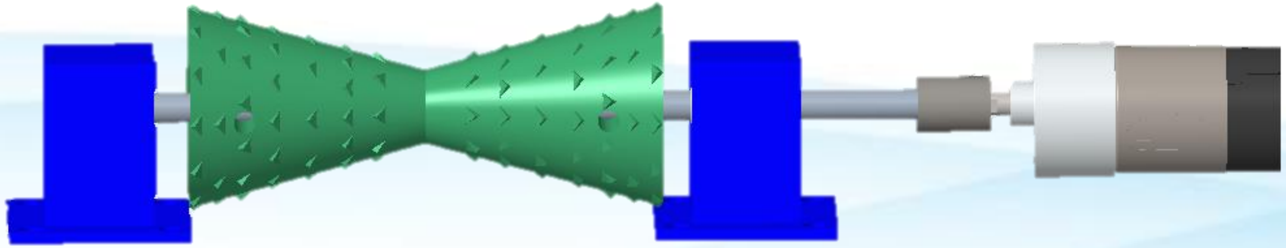
Weave wrap



Carey Tarkinson

Wheel Design Modifications

- Ridges and a rubber coating were added to the hourglass wheel to provide better grip
- A spiked wheel design was also considered in the case that the traction wheel failed



Carey Tarkinson

Spike Wheel Design

- To produce the most traction, ¼ inch track spikes were imbedded into the hourglass wheel
- The spikes are minimally invasive and allow the robot to traverse with ease

John Flournoy

Prototype Six

- This robot utilized the weaved strap design, spiked wheel, and a ratchet strap
- The ratchet strap supplied the tension needed to create contact between the pole and the driving wheel
- The robot successfully climbed without additional help

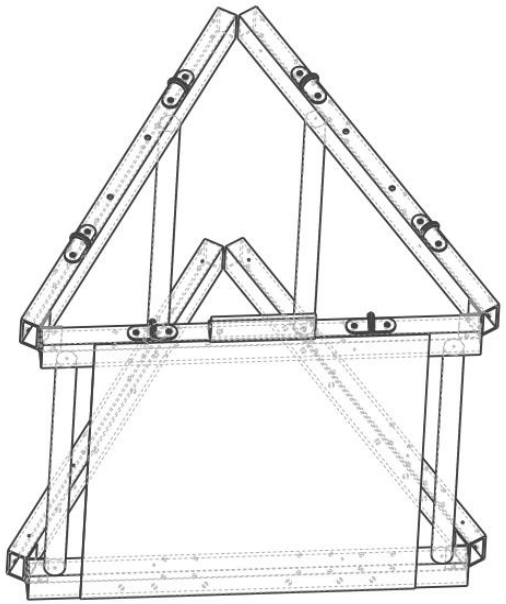
John Flournoy

Climbing Action

John Flournoy

New Strap Method

- The strap-slot method was revised, and the strap was repositioned to the top of the frame
- A Ratchet strap was selected because of their high-tension capability



John Flournoy

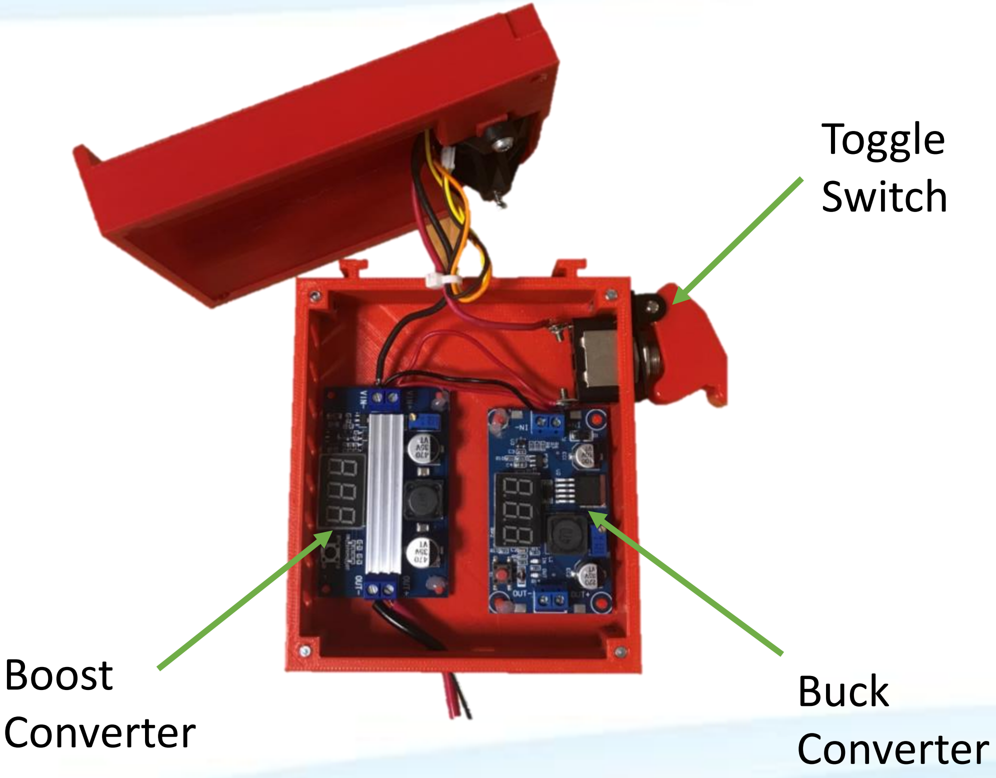
Power Supply

- To best accommodate FPL lineman, the battery powering the robot is an FPL issued drill battery
- The battery can deliver 21.6 V at 5.2 Ah
- The battery adapter and cargo box is modeled similarly to a commercial grade battery charger

John Flournoy

Power Supply

- Within the cargo box are the DC-to-DC converters necessary to distribute power accordingly
- The buck converter is used to downgrade the output battery voltage for the microcontroller
- The boost converter increase the battery voltage to 24 Volts to supply the rated voltage to the motor

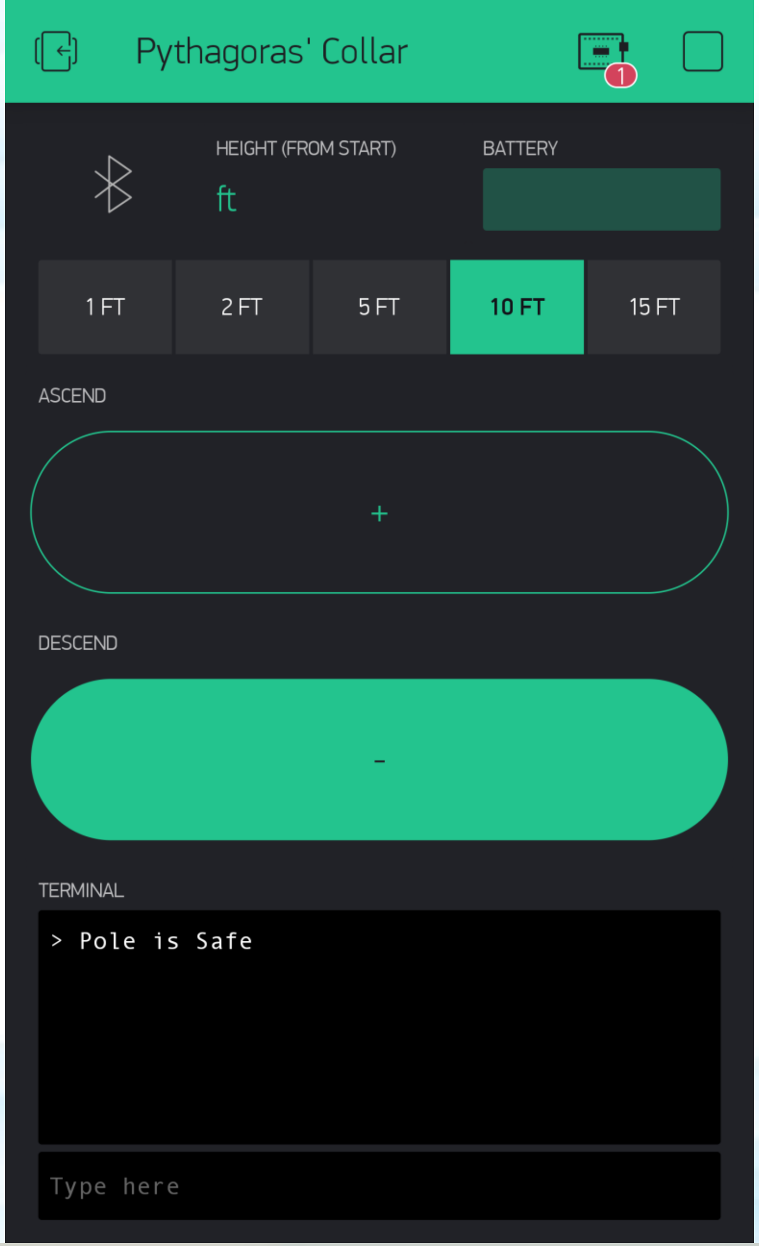


John Flournoy

Controls and Interface

- Blynk will be used to wirelessly control robot with a smart phone via Bluetooth
- The user interface will display various measures to the operator
- Buttons will be used to control the ascent and descent of robot

Carey Tarkinson



Carey Tarkinson

Incomplete Work

- GPR sensor is currently not fully assembled
- Microcontroller need to be programmed
- Waiting arrival on the bluetooth module
- ABS components need to be printed and integrated
- The final robot frame is awaiting assembly

John Flournoy

Lessons Learned

- Rapid prototyping is extremely helpful
- Testing the prototypes early is crucial for success
- Our two teams should have started integration earlier in the semester
- Always follow up on a parts order
- Reworking the dynamics of a system can provide improved characteristics

Angelo Mainolfi

Summary

- The robotic pole inspection collar is a beneficial device that provides additional safety for linemen
- Simple geometry allows for strength and ease of assembly
- There is always room for improvement
- This inspection collar has the potential to replace the OSHA standard tests

Angelo Mainolfi

Appendix

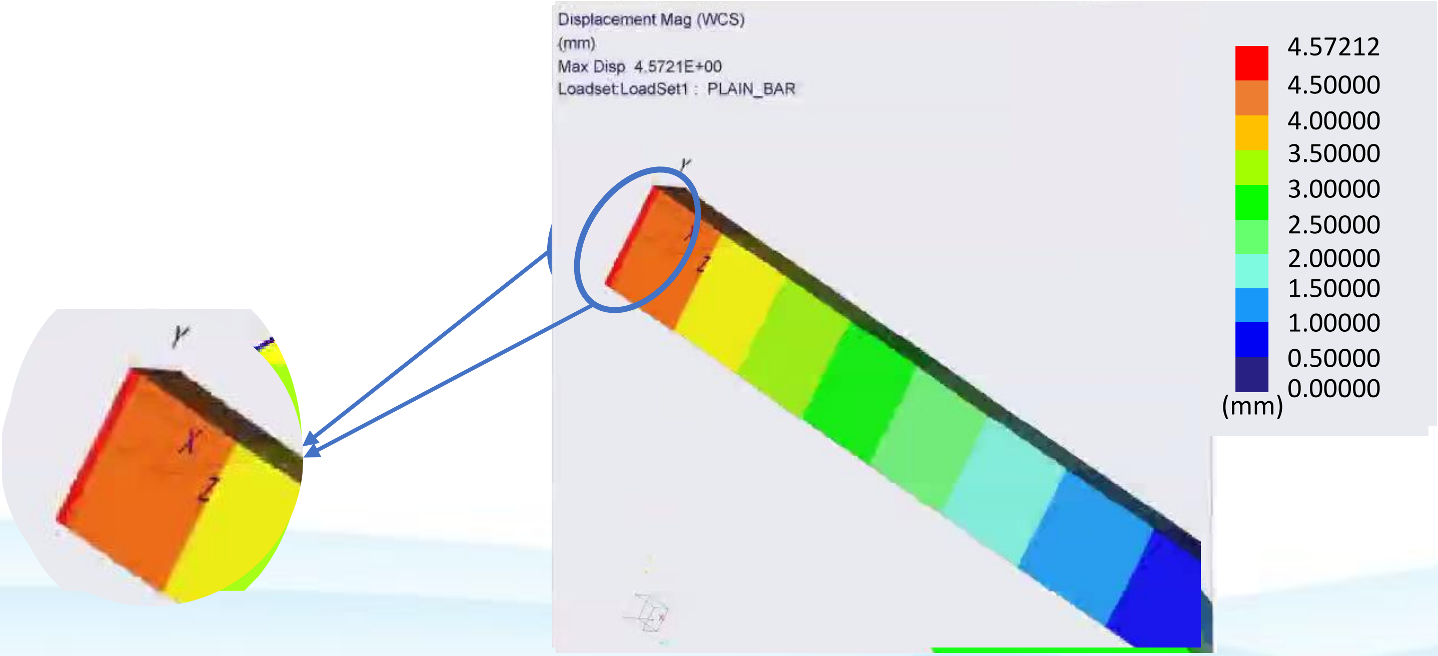
- The following slides have supporting information

Sources

- https://www.slunglow.org/event/new-show-cap-pie/
- https://journalnow.com/archive/so-metal-the-world-of-metal-detecting-is-changing-and-north-carolina-is-home-to/article_7bb241c8-ecac-11e6-a1f4-7f1a74729de1.html
- https://www.onlinewebfonts.com/icon/546768
- https://www.flaticon.com
- https://devmesh.intel.com/projects/blynk

Perimeter Wrap FEA

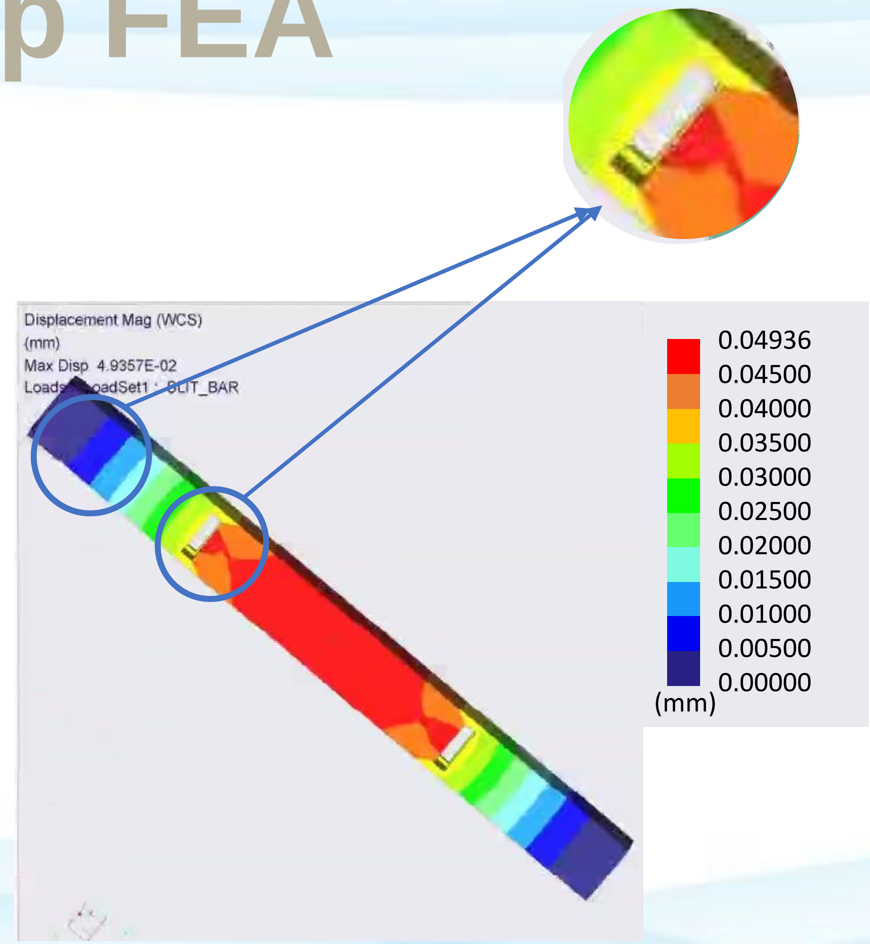
60lbs tension



Carey Tarkinson

Weave Wrap FEA

60lbs tension



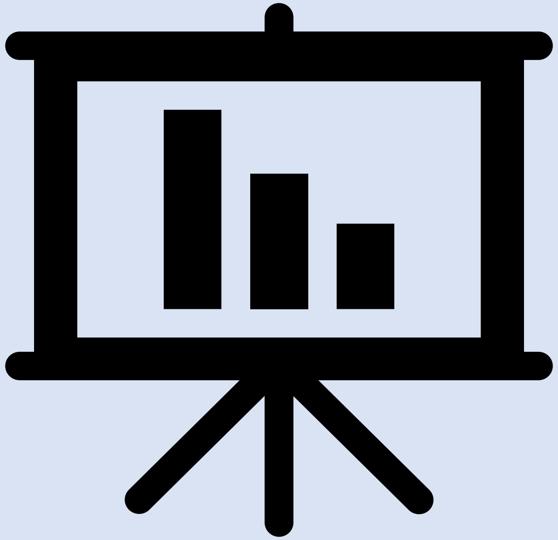
Carey Tarkinson

Material properties

Mechanical Properties			
Hardness, Brinell	95	95	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	120	120	Converted from Brinell Hardness Value
Hardness, Rockwell A	40	40	Converted from Brinell Hardness Value
Hardness, Rockwell B	60	60	Converted from Brinell Hardness Value
Hardness, Vickers	107	107	Converted from Brinell Hardness Value
Ultimate Tensile Strength	310 MPa	45000 psi	AA; Typical
Tensile Yield Strength	276 MPa	40000 psi	AA; Typical
Elongation at Break	12 %	12 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Elongation at Break	17 %	17 %	AA; Typical; 1/2 in. (12.7 mm) Diameter
Modulus of Elasticity	68.9 GPa	10000 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Notched Tensile Strength	324 MPa	47000 psi	2.5 cm width x 0.16 cm thick side-notched specimen, K_t = 17.
Ultimate Bearing Strength	607 MPa	88000 psi	Edge distance/pin diameter = 2.0
Bearing Yield Strength	386 MPa	56000 psi	Edge distance/pin diameter = 2.0
Poisson's Ratio	0.33	0.33	Estimated from trends in similar Al alloys.
Fatigue Strength	96.5 MPa	14000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen
Fracture Toughness	29 MPa-m½	26.4 ksi-in½	K_{IC}; TL orientation.
Machinability	50 %	50 %	0-100 Scale of Aluminum Alloys
Shear Modulus	26 GPa	3770 ksi	Estimated from similar Al alloys.
Shear Strength	207 MPa	30000 psi	AA; Typical

Analytical Hierarchy Process - AHP

- Pairwise Matrix
- Normalized Pairwise Matrix
- Criteria Weights
- Weighed Sum Vector
- Consistency Vector



AHP Chart

Table 1: Analytical Hierarchy Process

Pairwise Comparison							
Customer Needs	Ability to Climb	Rot Detection	Data Interface	Portability	OSHA Test Standards	Modularity	**Total**
Ability to Climb	-	0	1	1	1	1	**4**
Rot Detection	1	-	1	1	1	1	**5**
Data Interface	0	0	-	1	0	1	**2**
Portability	0	0	0	-	0	1	**1**
OSHA Test Standards	0	0	1	1	-	1	**3**
Modularity	0	0	0	0	0	-	**0**
Total	1	0	3	4	2	5	

AHP 2

Table 2: Normalized Analytical Hierarchy Process

Normalized Pairwise Comparison							
Customer Needs	Ability to Climb	Rot Detection	Data Interface	Portability	OSHA Test Standards	Modularity	**Weight**
Ability to Climb	-	0	0.33	0.25	0.5	0.2	**1.28**
Rot Detection	1	-	0.33	0.25	0.5	0.2	**2.28**
Data Interface	0	0	-	0.25	0	0.2	**0.45**
Portability	0	0	0	-	0	0.2	**0.20**
OSHA Test Standards	0	0	0.33	0.25	-	0.2	**0.78**
Modularity	0	0	0	0	0	-	**0**
Total	1	0	1	1	1	1	

HOC

Table 3: House of Quality Relationship Matrix

Relationship Matrix between Engineering Characteristics and Customer Needs							
		Engineering Characteristics					
Improvement Direction		↓	↑	↑	↑	↓	↑
Units		lb.	ft/s	N/A	N/A	s	N/A
Customer Needs	**Importance Weight Factor**	Weight	Speed	Stability	Safety	Ease of Mounting	Maneuverability
Ability to climb	**5**	9	7	9	8	5	7
Rot Detection	**5**	4	5	8	9	4	8
Data Interface	**4**	2	9	9	8	3	5
Portability	**3**	9	3	5	3	9	8
OSHA Test Standards	**5**	3	2	7	8	5	5
Modularity	**2**	4	1	2	4	6	4
Raw Score (887)		123	142	175	174	121	152
Relative Weight %		13.9	16.0	19.7	19.6	13.6	17.1
Rank Order		5	4	1	2	6	3

Pugh Chart 1

Table 4: Initial Pugh Chart

Selection Criteria	**Datum**	Variable Arm Climber	Rollercoaster Gripper	Counter-Weight Triangle Hybrid	Serpent Robot	Hybrid Bike Design	Triangle Climber	Batmobile Climber
Vertical Traversal Speed	**Bike Climber**	-	+	-	-	-	-	+
Stability		S	+	S	+	+	+	-
Weight		-	-	-	-	-	+	+
Ease of Mounting		-	-	-	-	-	-	+
Portability		S	-	-	-	-	+	+
Modularity		S	+	+	-	S	+	-
Simplicity		-	-	-	-	-	-	-
Number of Pluses		0	3	1	1	1	4	4
Number Minuses		4	4	5	6	5	3	3
Number of S's		3	0	1	0	1	0	0

Pugh Chart 2

Table 5: Second Pugh Chart

Selection Criteria	Datum	Triangle Climber	Batmobile Climber	Variable Arm Climber
Vertical Traversal Speed	**Roller Coaster Gripper**	+	+	-
Stability		+	-	S
Weight		+	+	+
Ease of Mounting		+	+	+
Portability		S	+	-
Modularity		+	-	S
Simplicity		+	+	-
Number of Pluses		6	5	2
Number Minuses		0	2	3
Number of S's		1	0	2

Project Management

Most Important Points

1. The quick brown fox jumps over the lazy dog.
2. The quick brown fox jumps over the lazy dog.
3. The quick brown fox jumps over the lazy dog.
4. The quick brown fox jumps over the lazy dog.
5. The quick brown fox jumps over the lazy dog.
6. The quick brown fox jumps over the lazy dog.

Lessons Learned

Reference

Questions (be sure to design your own)

Backup Slides