Robotic Pole Inspection Collar

Team 505

“Team Southern Pine”

FPL

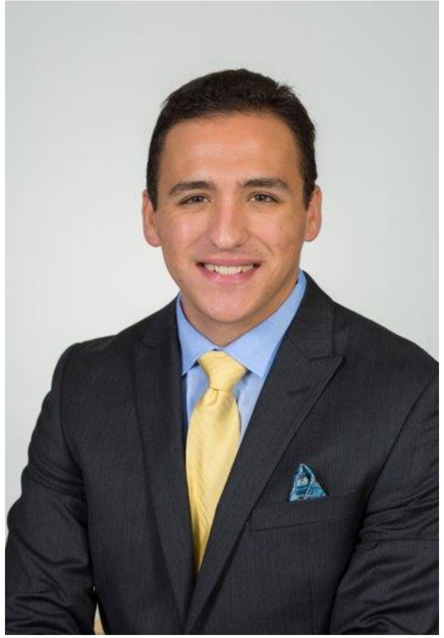
Department of Computer & Electrical Engineering
Department of Mechanical Engineering

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

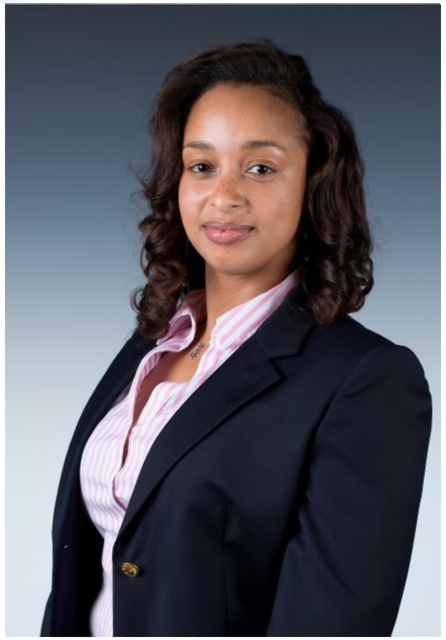
Alonzo Russell
Hardware Engineer

Leonardo Vazquez
Software Engineer

Thomas Williams
Hardware Engineer

Angelo Mainolfi

Sponsors and Advisors



Engineering Sponsor
Genese Augustin
Lead Project Manager
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Florida Power & Light

Engineering Sponsor
Troy Lewis
Engineer II
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Academic Advisor
Jonathan Clark, Ph.D.
Associate Professor

Engineering Professor
Shayne McConomy, Ph.D.
Teaching Faculty

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Objective

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

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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
- A safety incident motivated the development of this project

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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

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Rapid Prototypes

Prototype 1

Prototype 1 used a bicycle frame structure

Prototype 2 used a simpler geometric frame

Prototype 2

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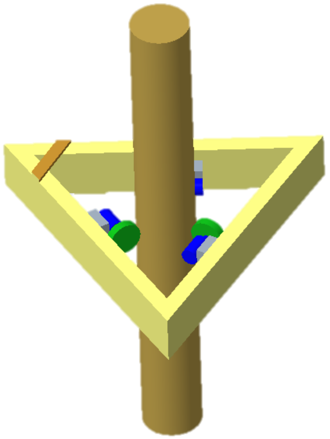
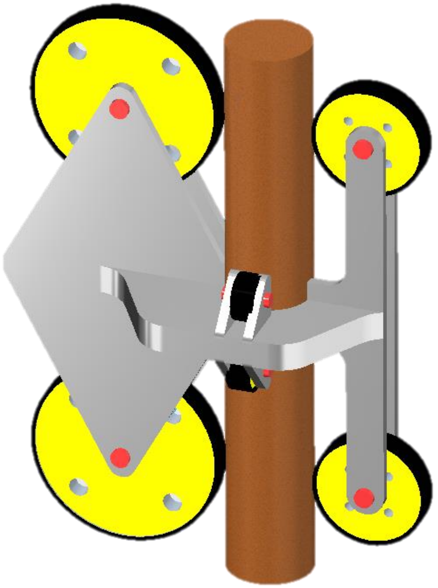
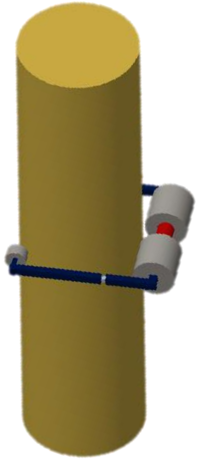
High Fidelity Concepts







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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

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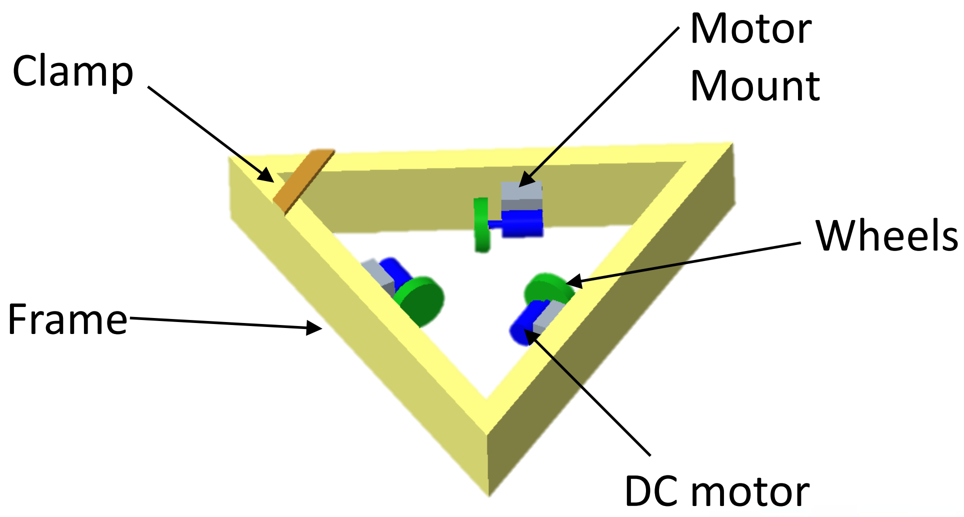
Winning Concept

Triangle Climber

- Modularity
- Stability
- Easy to use
- Variable climbing



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Prototype Three

Motorized Triangle Climber

Revelations found:

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

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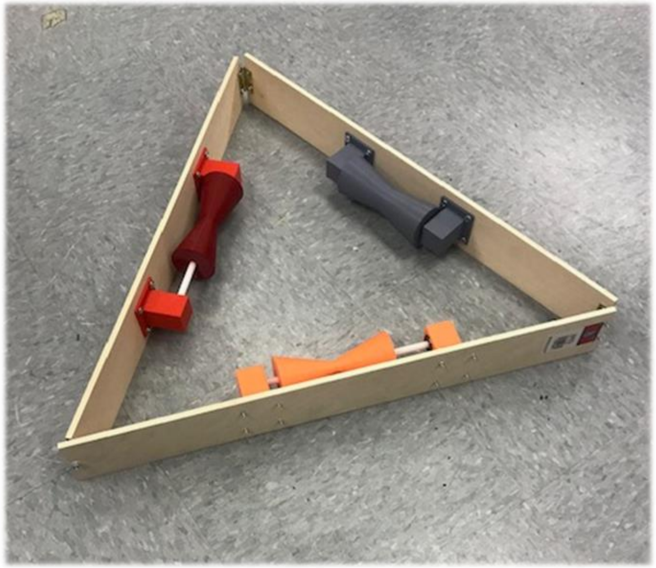
Prototype Four

- 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



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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

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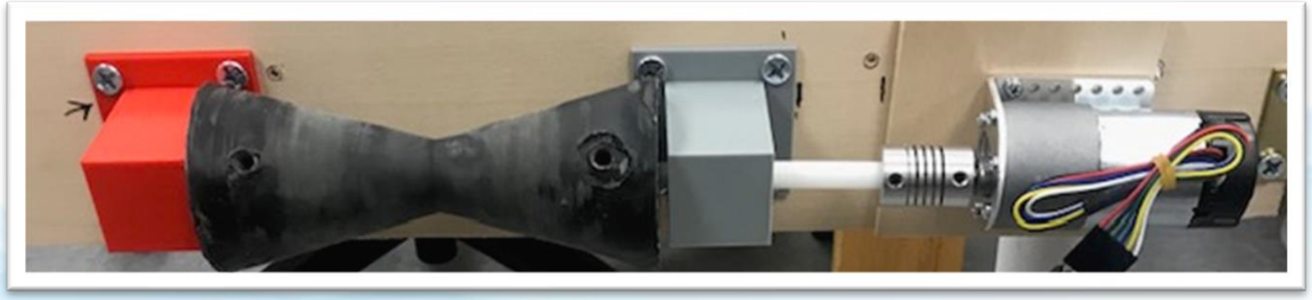
Shaft Mounting Method

- The hourglass wheel's unconventional design proposes 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



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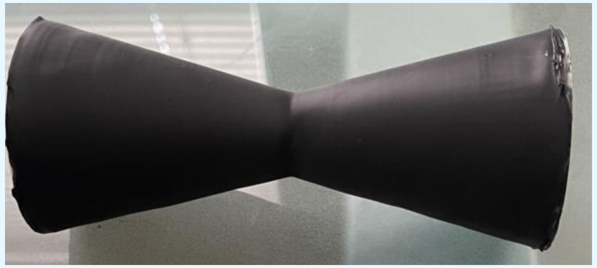
Wheel Friction Method

- 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



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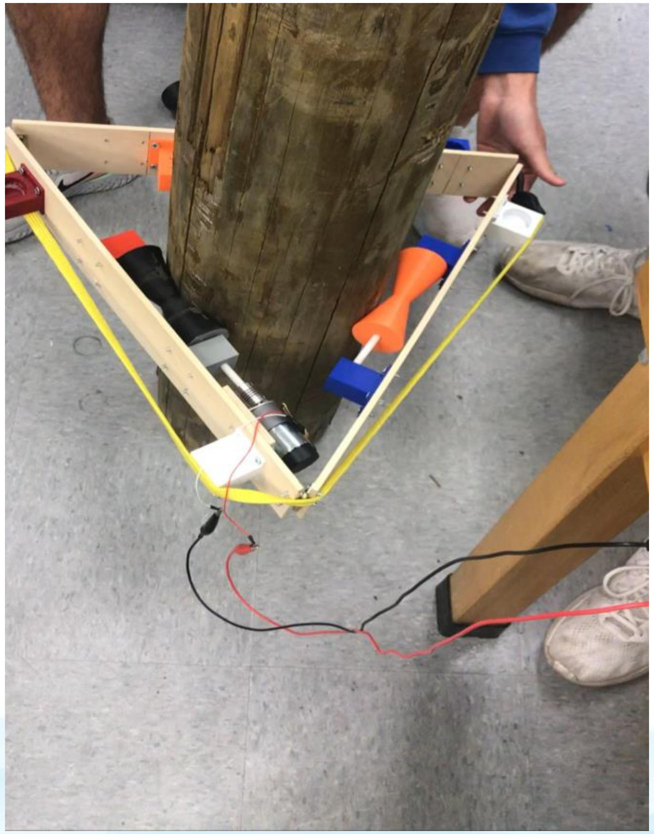
Prototype Five



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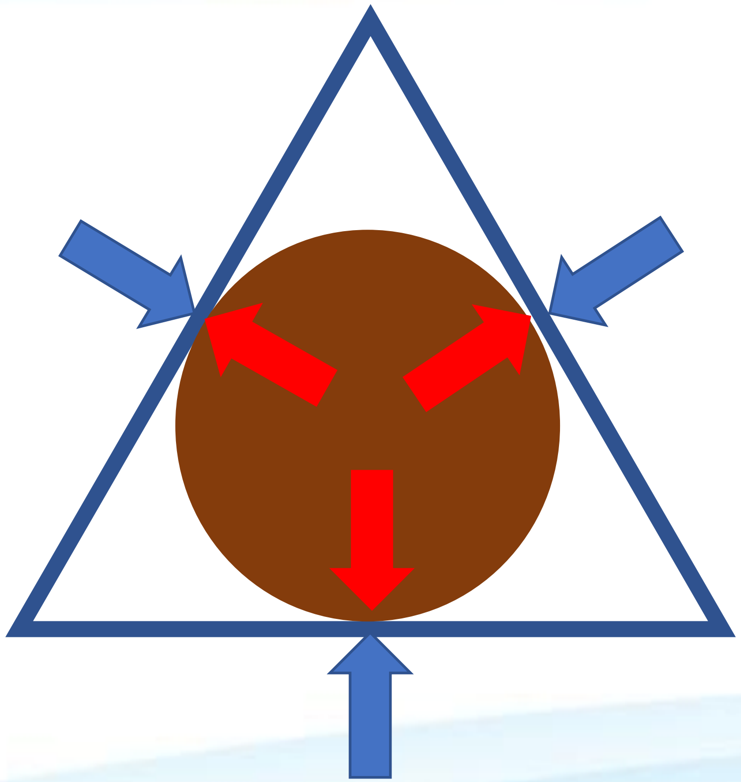
Strap Positioning Ideas

- Tension around the robot increases the friction on the wheels
- This friction is needed to translate the whole weight up
- An elastic strap provides tension around the robot



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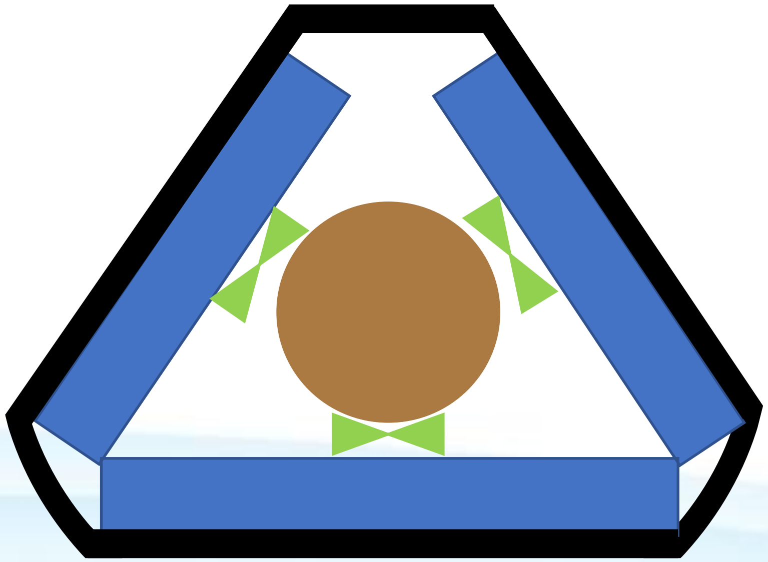
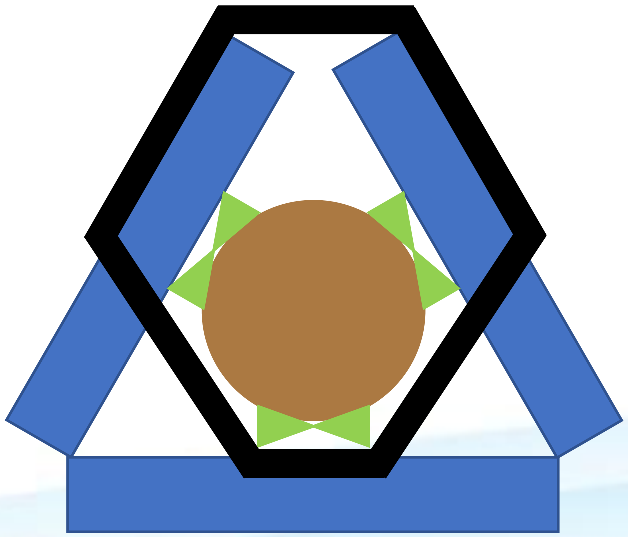
Tension Strap Path Ideas

Perimeter wrap



Weave wrap



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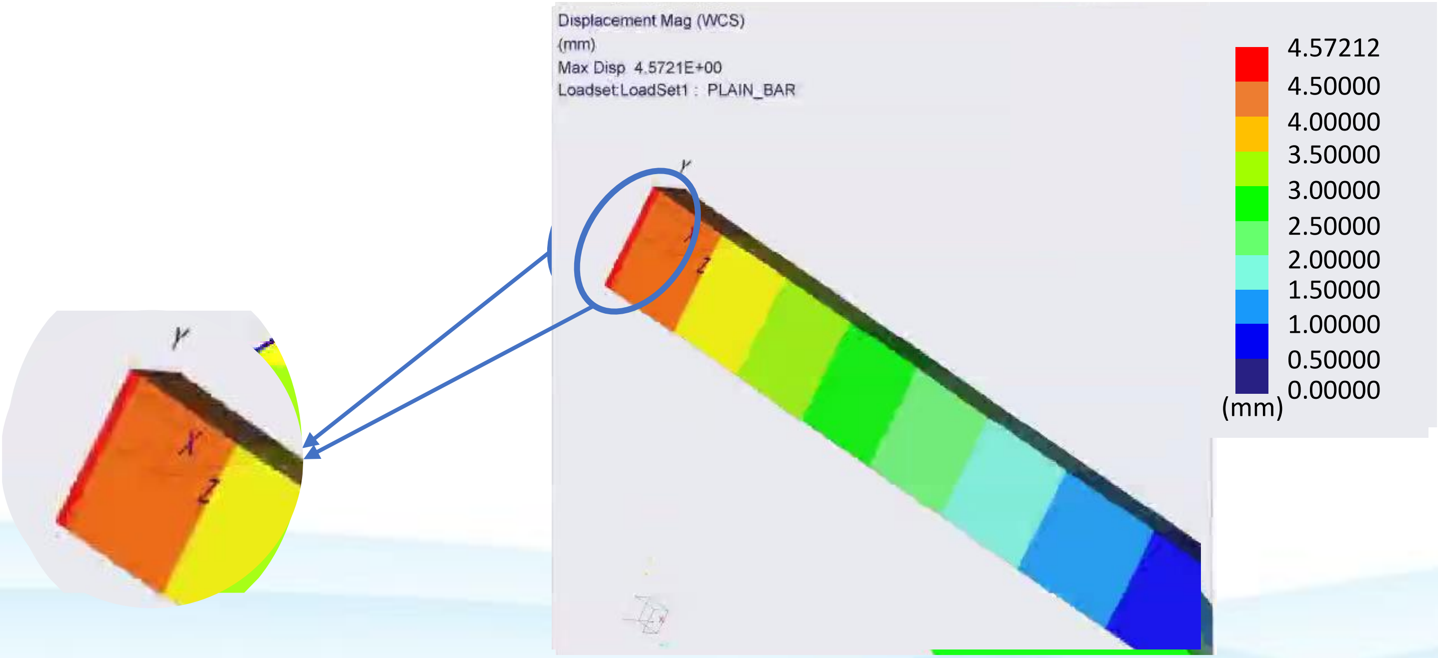
Frame Analysis One

Perimeter Wrap (60lbs tension)



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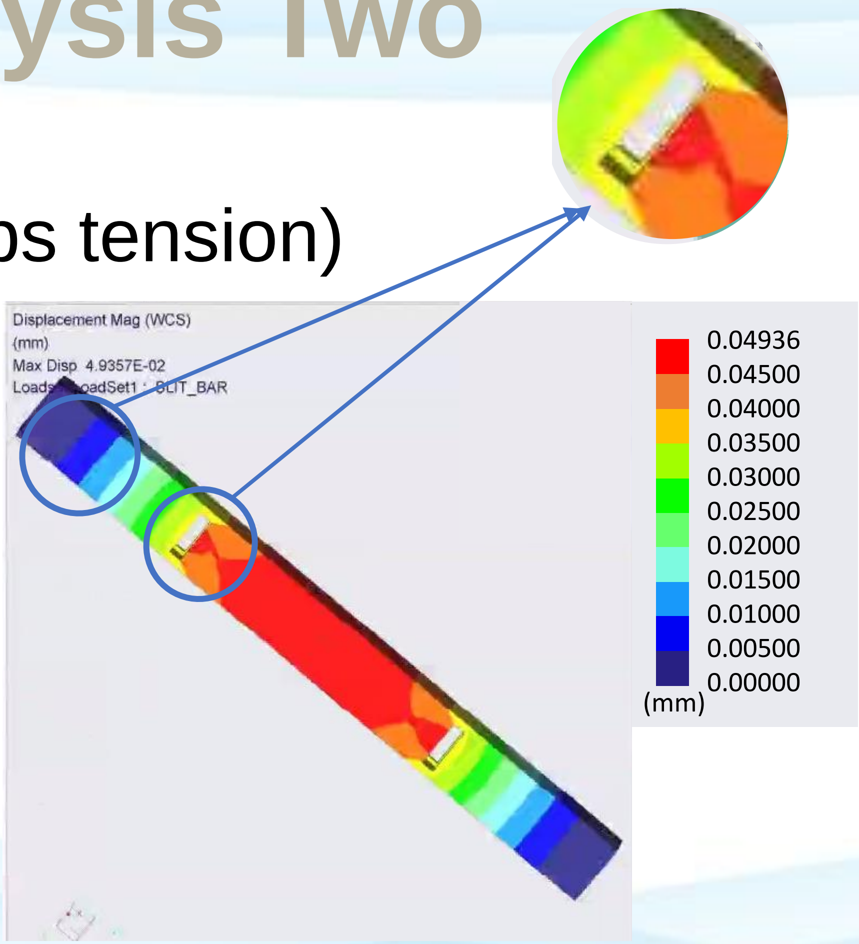
Frame Analysis Two

Weaved Wrap (60lbs tension)



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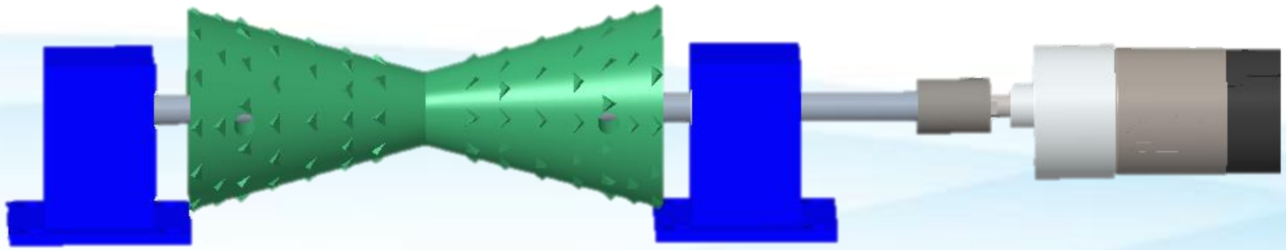
Wheel Design Modifications

- To enhance the friction of the wheel, traction will be added to the current rubber coated wheel design
- If the traction method proves to be unsuccessful, spikes will be imbedded into the hourglass wheel



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Future Work

Purchase an elastic strap

Reprint new wheels in ABS material

Purchase final motor

Order final materials

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Sources

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- 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

Appendix

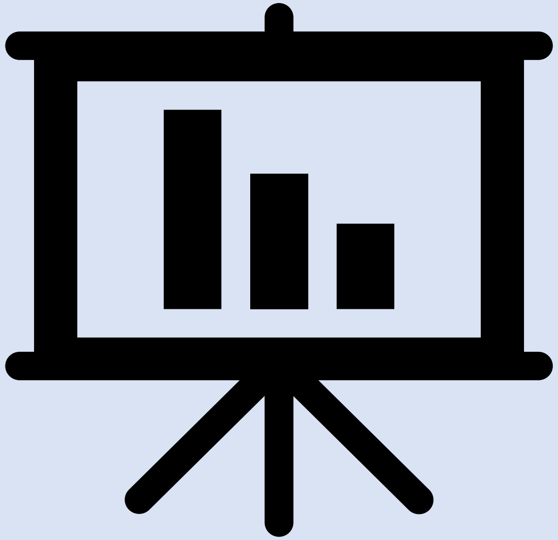
- The following slides have supporting information

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