CISCOR

CENTER FOR INTELLIGENT SYSTEMS, CONTROL, AND ROBOTICS

Team 10
GOLIATH Autonomous ATV

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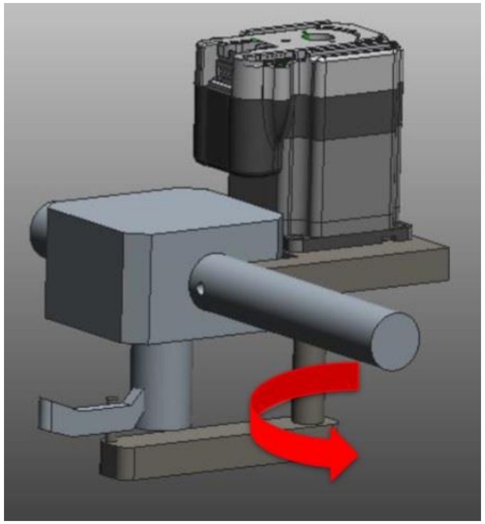
Background/Needs

- CISCOR focuses on mobile robotic path-planning
- Requires a more robust autonomous off-road platform
  - All Terrain Vehicle
- Previous work included remote control of the ATV
  - Actuators installed
    - Gear shift
    - Throttle
    - Brake
    - Steering



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Objectives

- Integrate a sensory system that will scan the surrounding environment to perform simple autonomous navigation
  - Road following
  - Waypoint-to-waypoint
  - Low speed testing, no obstacle avoidance
  - Proof of Concept
- Will be used as a future research platform for CISCOR
- Requirements
  - Budget of 1500.00 USD
  - Project completion by end of April 2014
  - Retain human operation

Overall Function

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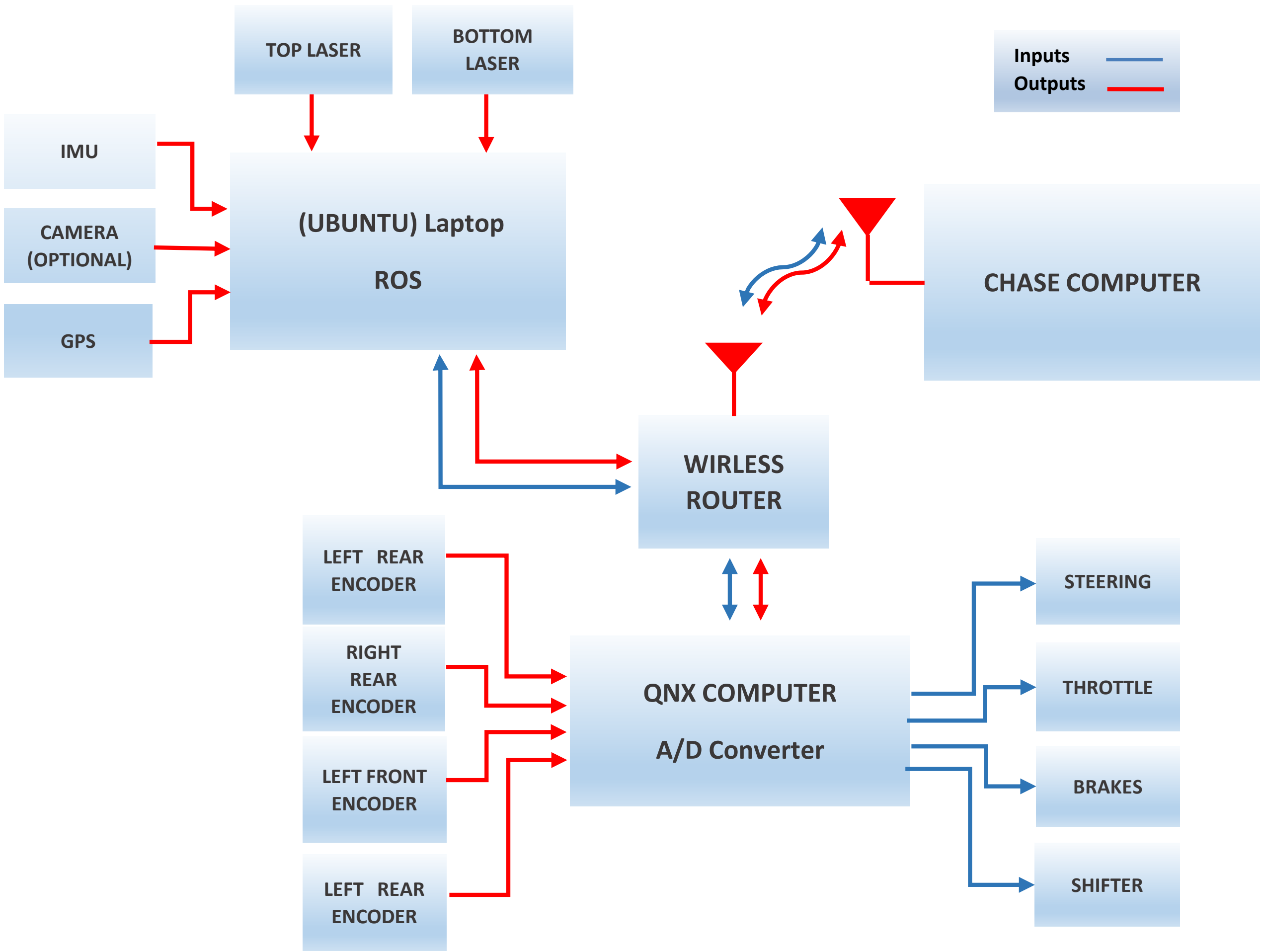
Overall Function

- Created a system for communication
- Sensory inputs used for decision making
- Output commands to actuators



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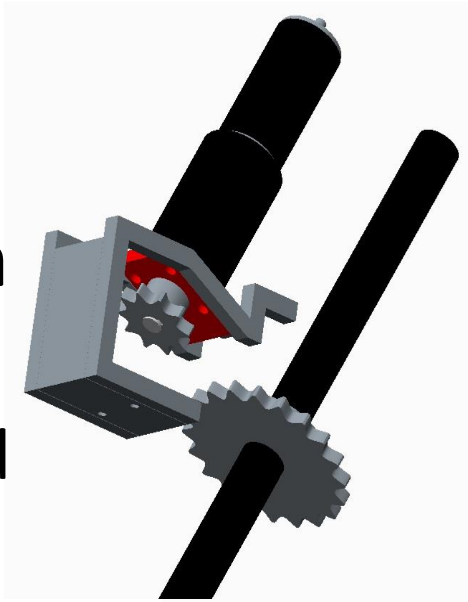
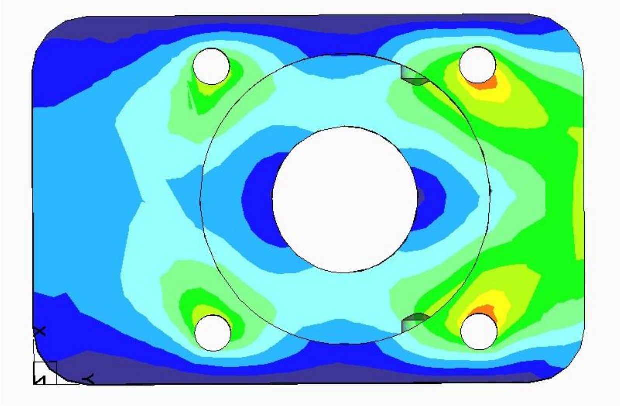
Concept Selection

- Decision matrix design parameters
  - Functionality
  - Simplicity (# of parts)
  - Ease of manufacture
  - Low cost
  - Low time to manufacture
  - Small amount of interference (parts/human)
  - Low susceptibility to damage (environment, impact, rust etc..)
  - Ease of data calculation
  - Ease of adjustment
  - Low energy consumption
  - Lightweight

Steering Motor

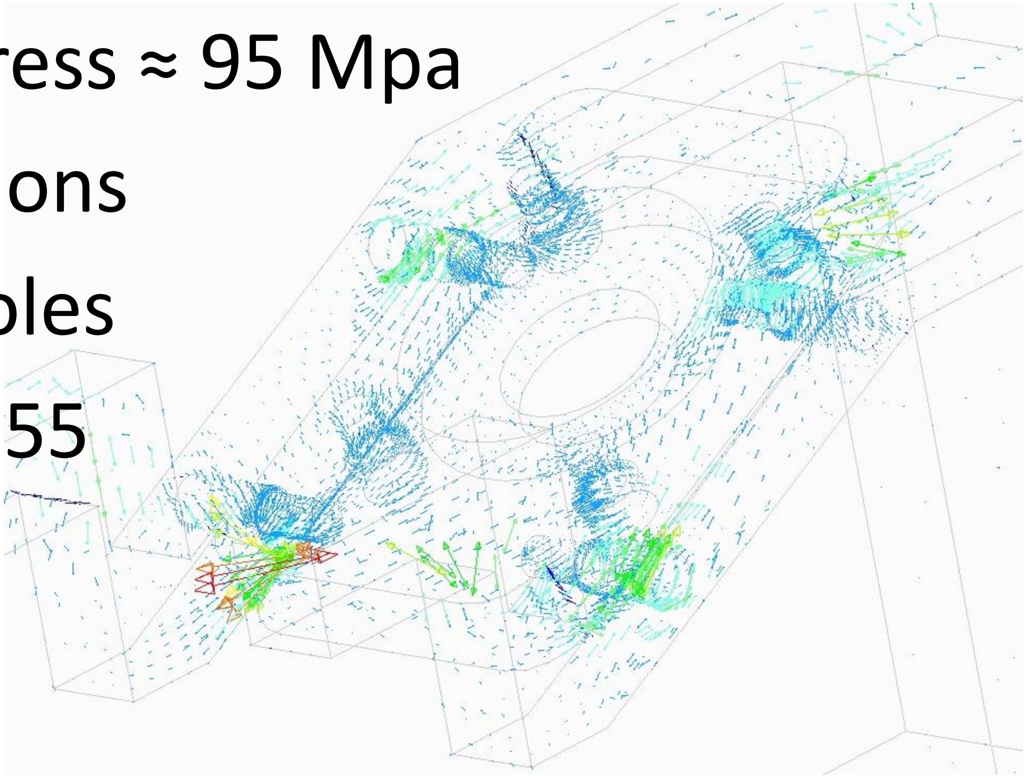
- Previous motor was underpowered
- New motor mounted in same location
  - Only one design needed
- Max motor torque 892 Nm
  - Stall torque (worst case scenario)
  - Value used in FEA





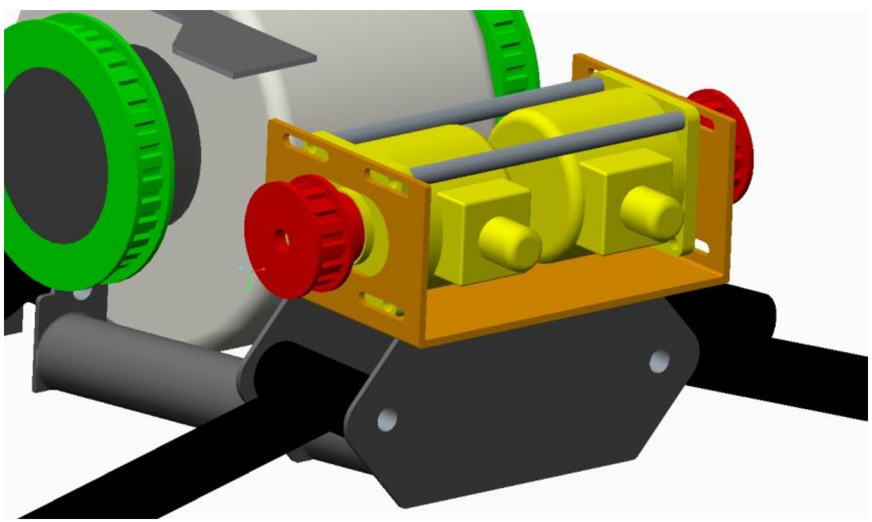
Steering Motor Mount

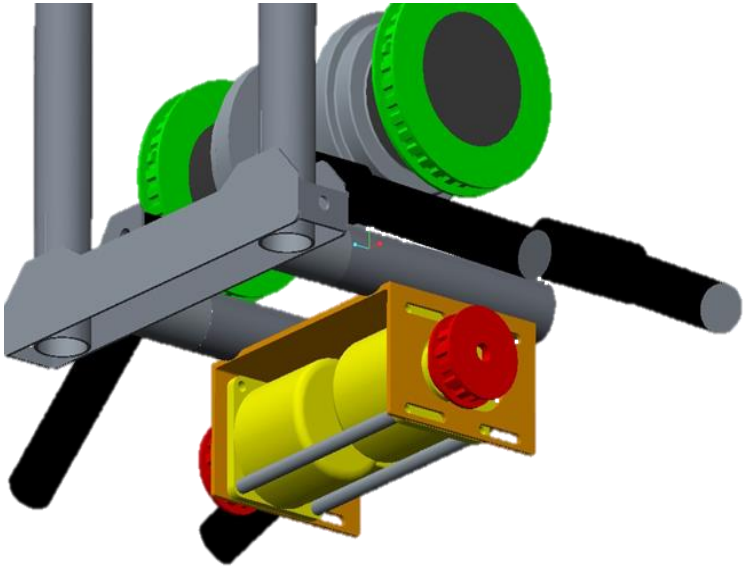
- 6061-T6 aluminum yield strength ≈ 240 Mpa
  - Previous frame and new mount
- Max von mises stress ≈ 95 Mpa
- Stress concentrations located at bolt holes
- Factor of safety 2.55



Encoders

- Encoders output rotational position of wheels
  - Four mounted on ATV sub frame
- Three separate mounting designs for front
- One possible location for the rear





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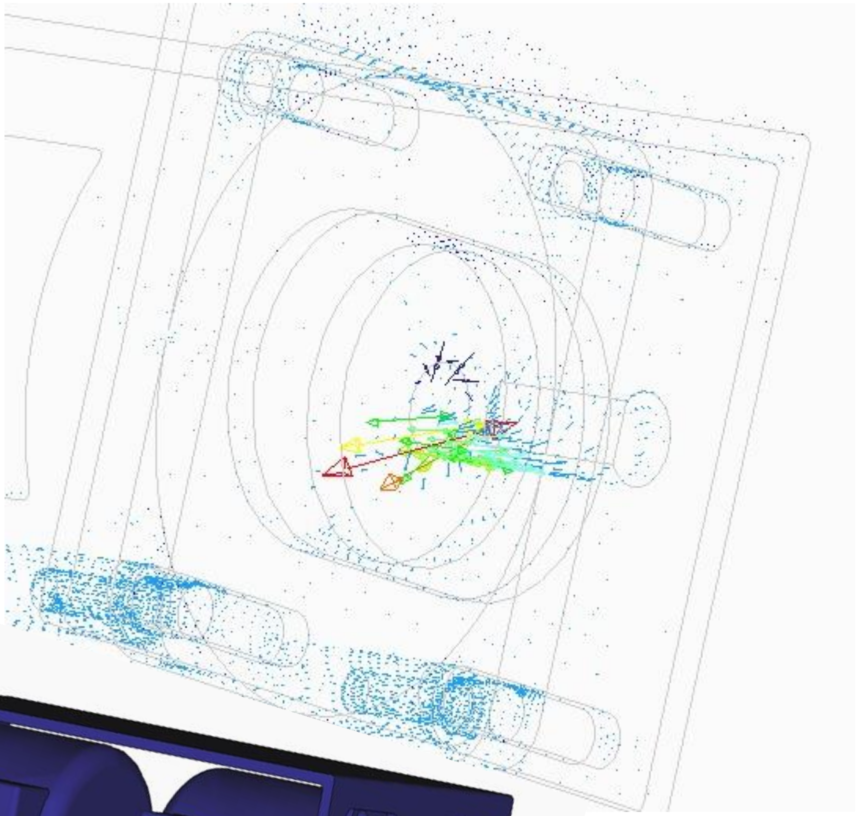
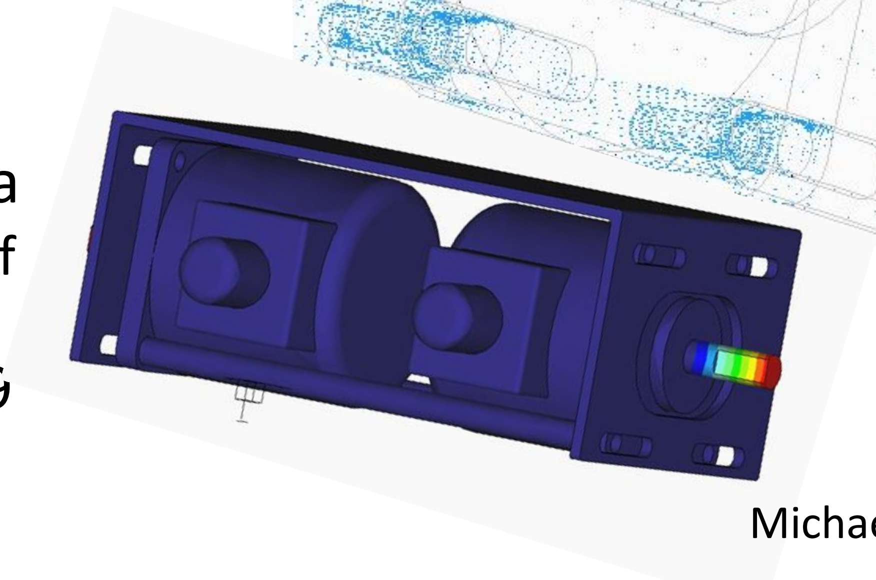
Encoder Mounts

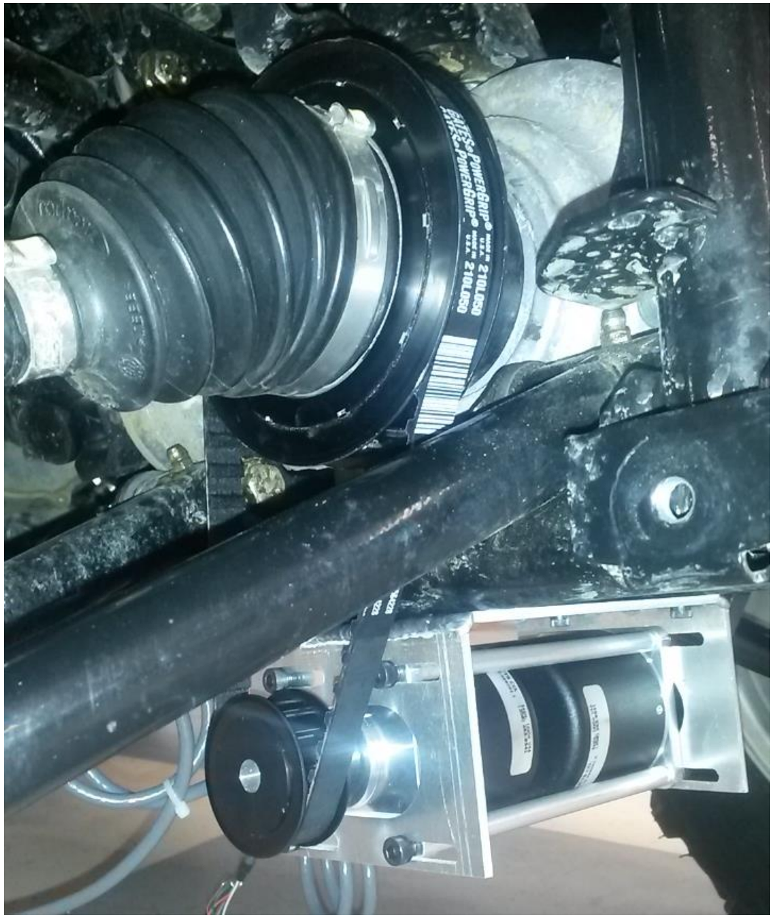
- Applied 80 lbf radially to encoder shafts for FEA
  - Maximum allowable load rating
  - Shafts made from 303 stainless steel
  - Support structure made from 6061-T6 aluminum
- Stainless steel yield strength ≈ 200 Mpa
- Max stress ≈ 80 Mpa
  - Located at base of encoder shafts
- Factor of safety 2.49





Encoder Mounts

- Manufactured with waterjet
  - Parts cut out flat
  - Bent along perforations
  - Welded along the bends to repair stress cracks
- Encoder mount holes cut oblong
  - Belt tensioning and adjustment
  - Ease of belt removal



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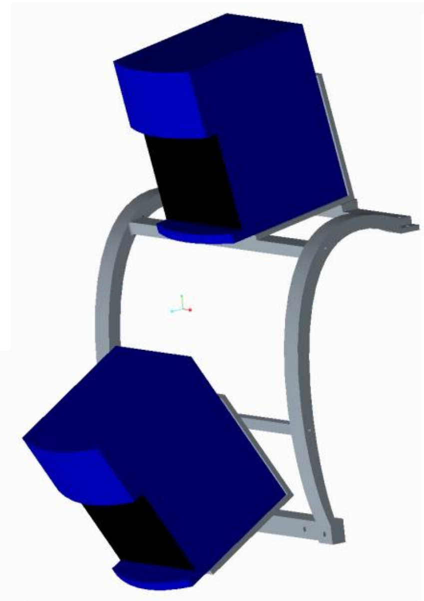
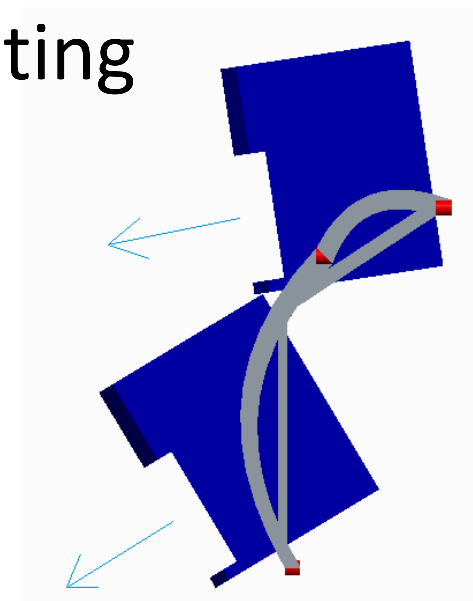
Laser Mounts

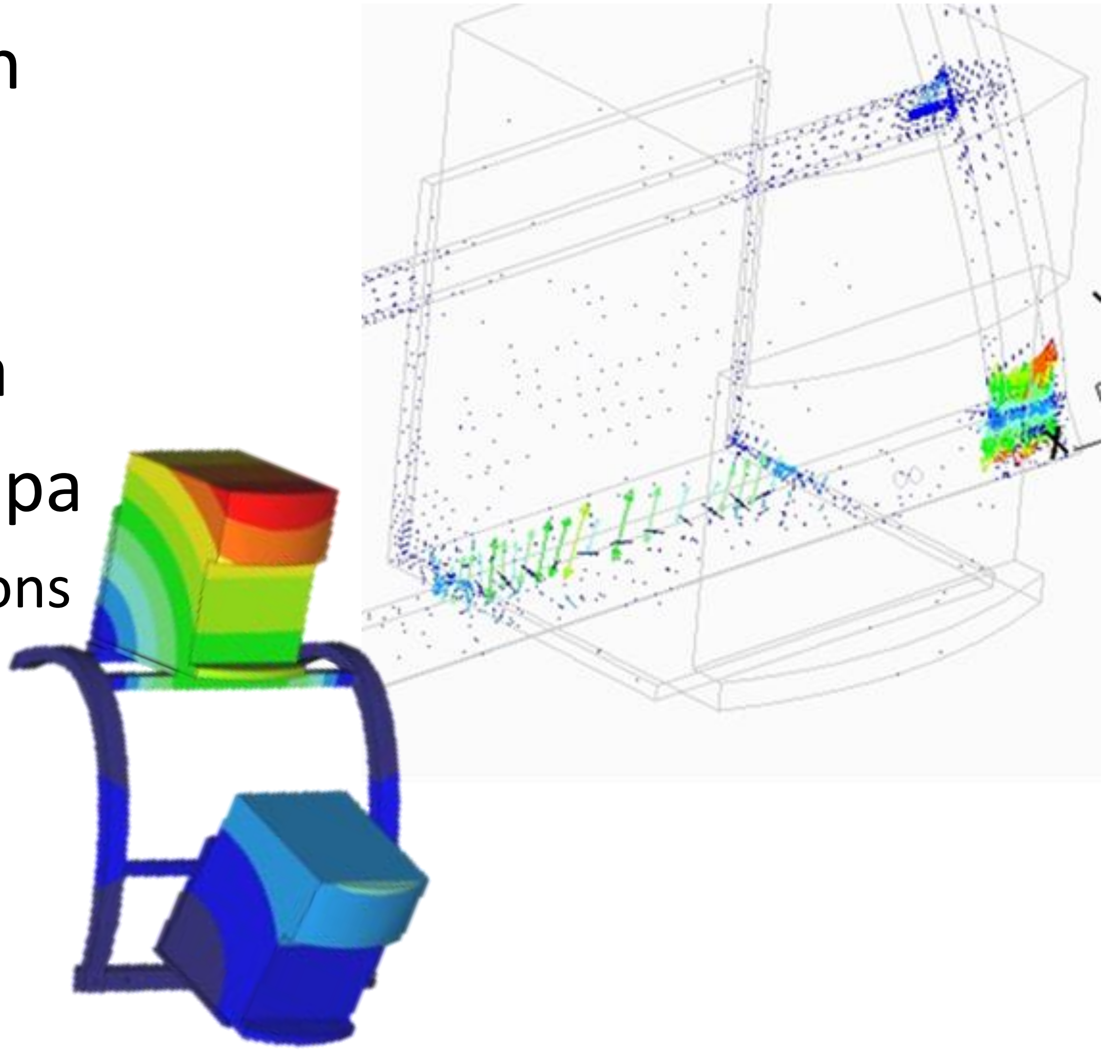
- Two laser measurement devices used for curb and obstacle detection
- Three possible mounting configurations
  - Top of trunk
  - Side-by-side
  - Stacked





Laser Mounts

- Simulated 20 mph collision for FEA
- 6061 AL yield strength 241 Mpa
- Max stress 105 Mpa
  - Stress concentrations located at joints
- Factor of safety 2.303

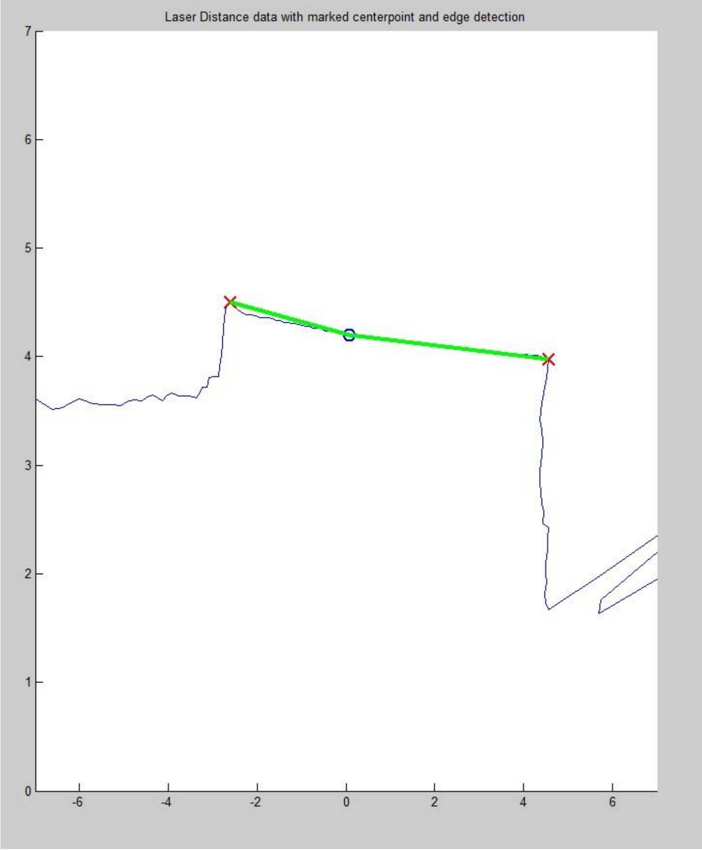


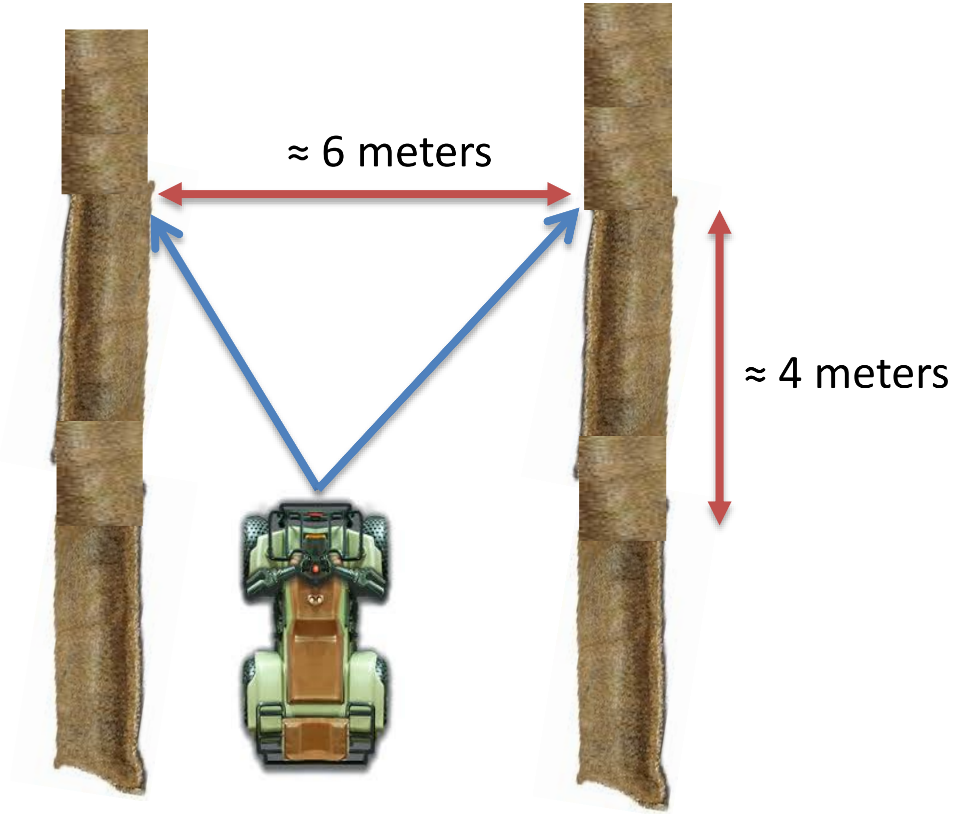
Laser Mounts

- Final design
  - Modified with straight sections
  - Added angle adjustment

Road Following

- Raw laser data





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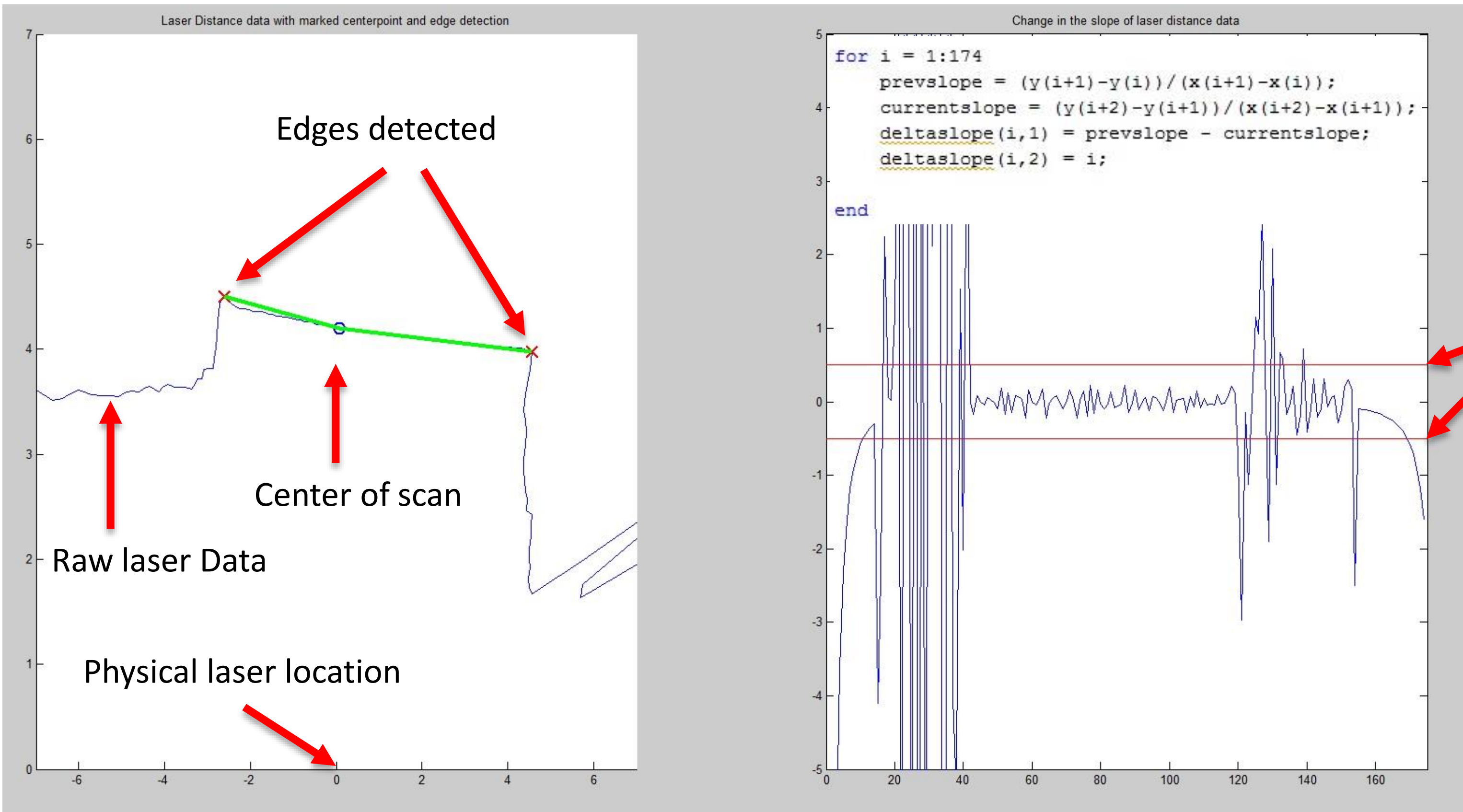
Road Following

- Laser data acquisition and manipulation



Hysteresis Band

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IMU / GPS

- Inertial Measurement Unit
  - Outputs angular velocity and linear acceleration in x, y and z- directions
- Global Positioning System
  - Outputs ATV location in DMS (Degrees Minutes Seconds)
- Three possible mounting locations for each
- Final design included mounting both in trunk
  - Both sensors, router and antenna mounted on one plate inside trunk lid
- GPS and IMU used in waypoint navigation algorithm

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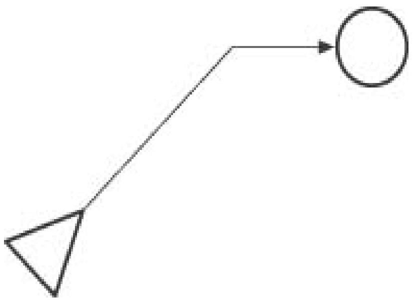
Waypoint Navigation

- Basic Path Finding Algorithm
  - Demonstration of system functionality

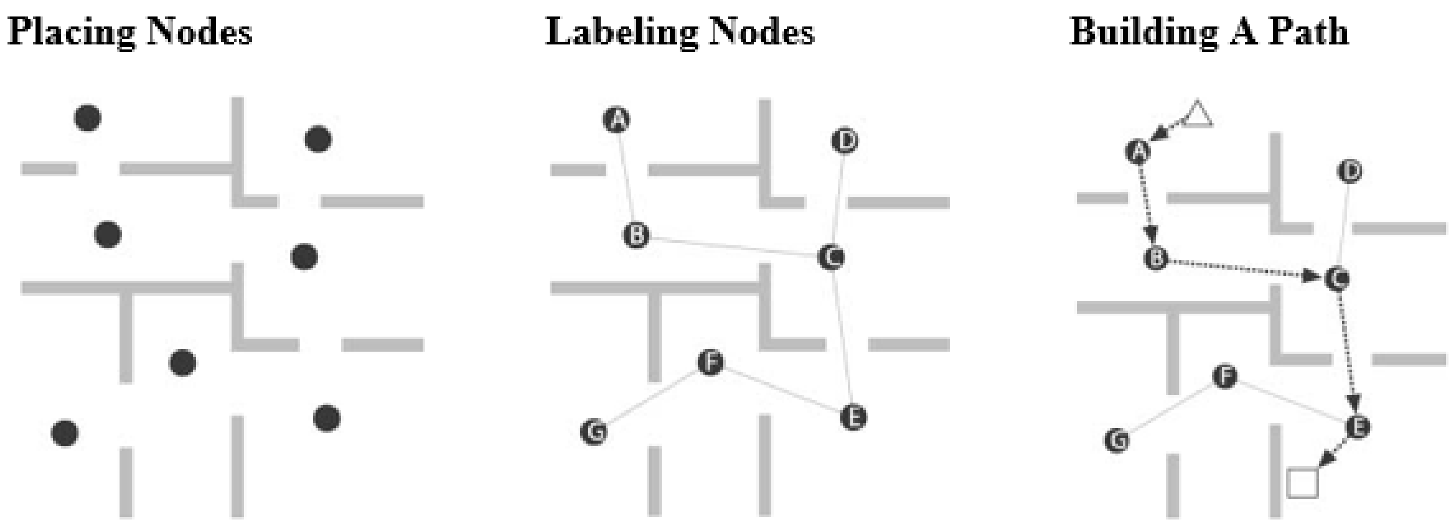
Basic Path Finding Algorithm:

```
Given a destination (x2,y2)
Record current position (x1,y1)
If x2 > x1
    Orient in Eastern direction
Else if x1>x2
    Orient in Western direction
While ( current position != destination)
    If x1 < x2
        x1← x1++    ; using the encoders to determine the necessary trajectory to
    else if  x1 > x2
        x1 ← x1 - -
    If y1 < y2
        y1← y1++
    else if  y1 > y2
        y1 ← y1 - -
```



Waypoint Navigation

- Navigation using multiple waypoints(or nodes)
  - Extension of Basic Path Finding Algorithm
  - Uses node table to determine best path of navigation



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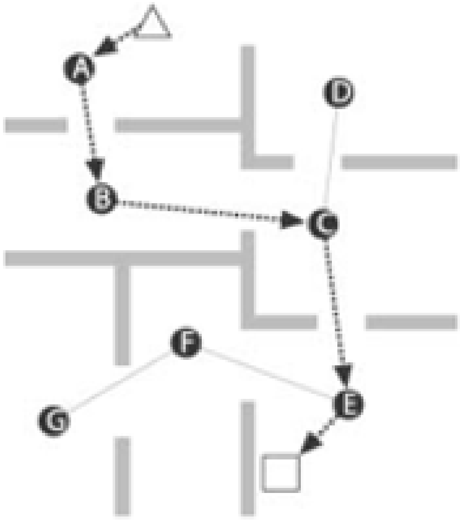
Waypoint Navigation

Functionality

1. User places nodes on a map of the testing terrain
2. Nodes will be labeled in order of nodes that are most accessible
3. Node table is used to determine best path to destination

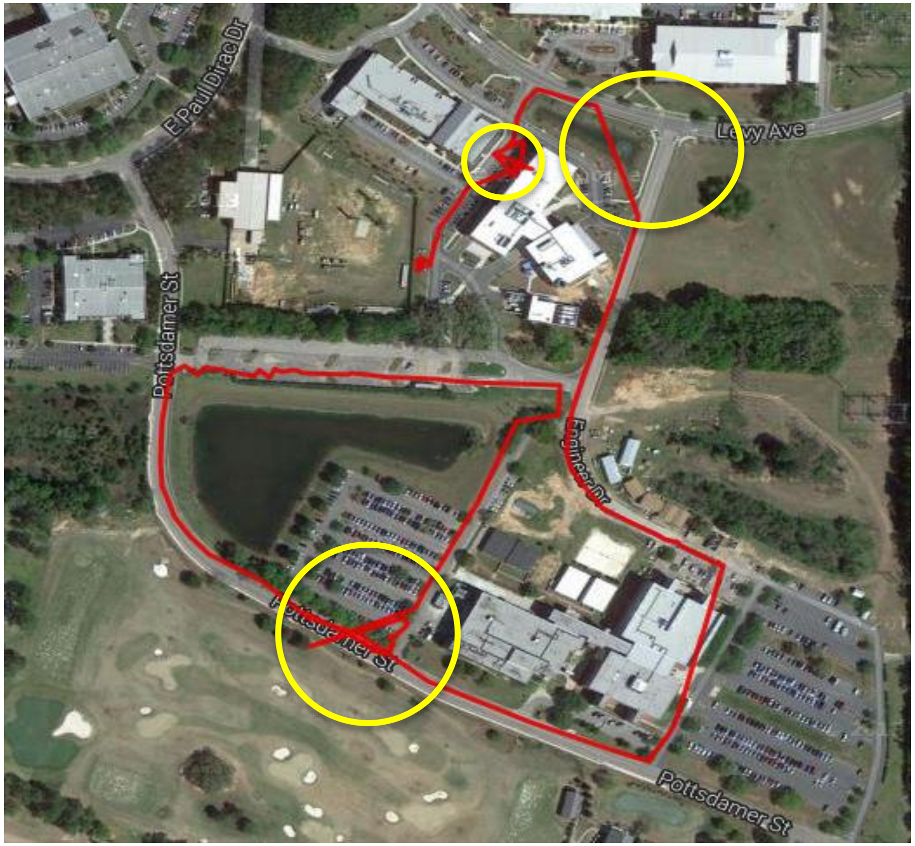
Node Table

Start \ End	A	B	C	D	E	F	G
A	—	B	B	B	B	B	B
B	A	—	C	C	C	C	C
C	B	B	—	D	E	E	E
D	C	C	C	—	C	C	C
E	C	C	C	C	—	F	F
F	E	E	E	E	E	—	G
G	F	F	F	F	F	F	—



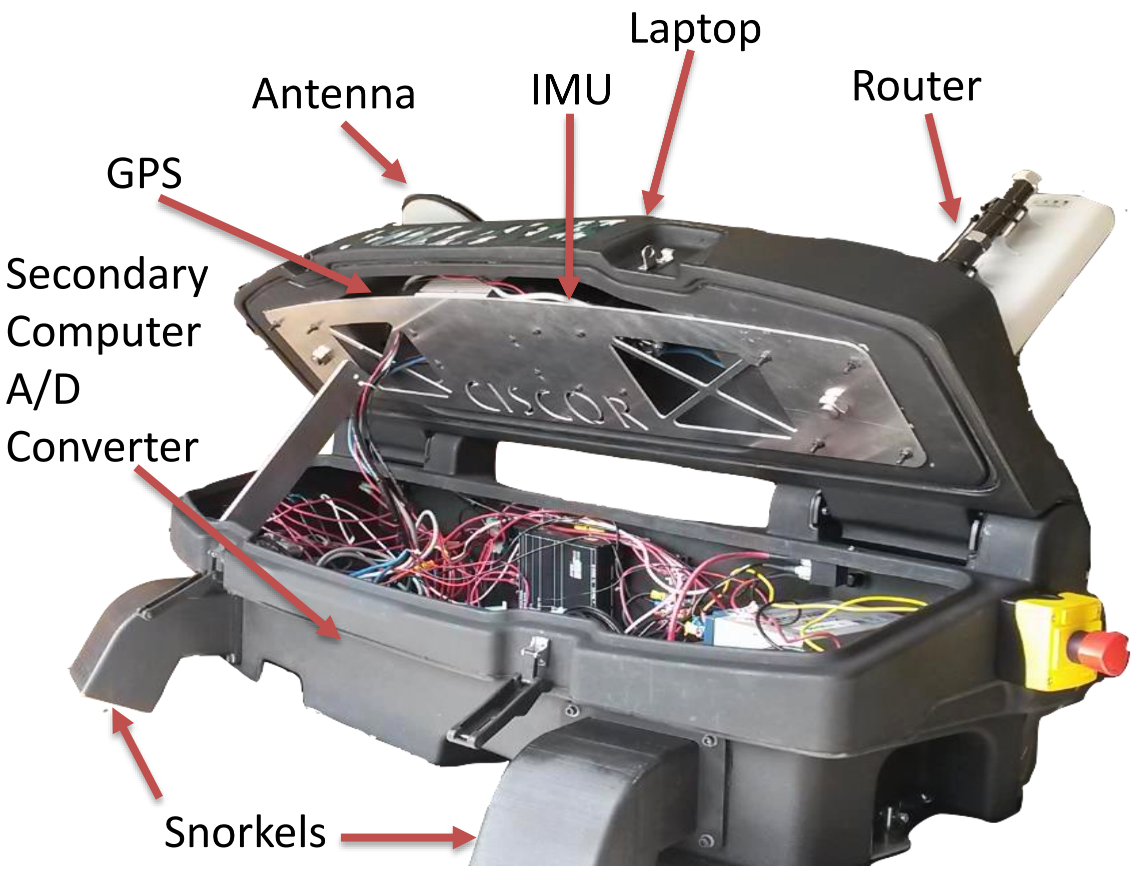
Waypoint Navigation

- GPS data logging / testing
  - Installed in commercial vehicle
- Erroneous/missing data
  - Satellite signal lost
  - GPS updates at 1Hz
  - IMU fills in position data in between GPS signals



Trunk Contents

- Contents also include:
  - Batteries
  - Motor driver
  - Relays/switches
  - USB hub
  - Serial-to-USB converter



Computers

- Toughbook running Ubuntu OS mounted above trunk
  - ROS (Robot Operating System)
  - Sensor inputs
- Single Board Computer mounted inside trunk
  - Sensoray A/D Converter
  - Logs encoder outputs
- Electronic components inside trunk created heating issue

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Cooling System

- Previous issue with electronic components in the trunk overheating
- Three possible solutions
  - Natural Convection
  - Forced convection
  - Liquid Cooling
- Forced convection selected
- Weatherproofing needs to be maintained
  - 3D printed snorkels

Cooling System

- Power dissipation needs ≈64.4W
- Analysis assumptions (worst case scenario)
  - Modeled as forced convection over flat plate
  - Outside air temp 90 ^{o}F
  - Isothermal internal surfaces 130 ^{o}F
- Two 250 ft^3/min fans

Safety Considerations

- 4 safety cut-off switches located on all corners of vehicle
- Coded safety precautions
  - Top speed governor
  - Obstacle detection
  - Minimum turn radius
- Closed course testing
- Cooling fan blades exposed inside trunk
  - Avoid running fans with trunk open
- Refer to operational manual for further safety procedures

Cost Analysis

- Cost analysis
  - Budget: 1500.00 USD
    - Raw materials: 617.99
    - Fasteners: 62.22
    - Misc. Electrical: 146.69
    - 3D printing: 300.00
    - Total: 1126.90
    - Remaining: 373.10

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Conclusion

- All sensors mounted and wired
- Steering motor mounted and tested
- Heating issue resolved
- Lasers, GPS, and IMU communicating
  - Accurate data requisition
- Finished V 1.0 of waypoint navigation and road following code
  - Needs further testing
- Set up of single board computer and A/D converter required
- Within budget

Future Recommendations

- Purchase and install RF cutoff switch for increased safety
- Create ROS packages for IMU, GPS, and encoders
- Install stereoscopic camera
- Replace both lasers with one vertically actuated laser
- Install skid plate to protect front encoders
- Revise autonomous algorithms

Testing

Fin

Questions?

Comments?

Special thanks to Nahush Kulkarni and Ryan David-Reyes

Gantt Chart

Team 10 Autonomous ATV (GOLIATH)

ACTIVITY	Start date	End date	Percent complete
Part Ordering			95%
Updated Plan/Specs			100%
Finalize Mechanical Designs			100%
GPS Communication/Testing			100%
Laser Communication/Testing			100%
Webpage Update			100%
Part Manufacturing			100%
Initial Installation			100%
Initial Part Testing			100%
IMU communication/Testing			75%
ROS/QNX Communication			75%
Midterm 1			100%
Midterm 1 Presentation			100%
Finalize Part Installation			100%
Final Part Testing			95%
Autonomous Code			100%
Autonomous Code Testing			25%
Midterm 2			100%
Midterm 2 Presentation			100%
Operational Manual			100%
Finalize Algorithms			20%
Final Testing			30%
Manu/Reliab Report			100%
Walkthrough			100%
Open House			100%