IGVC
Intelligent Ground Vehicle Competition

Team Members

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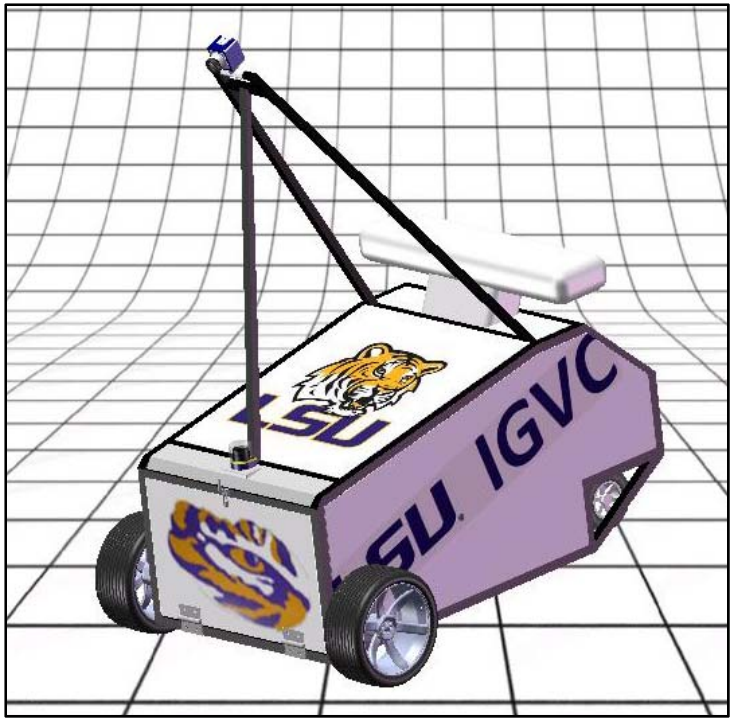
Overview

- Introductory Video
- Prototype Design
  - Obstacle/Boundary Detection
  - Path Planning
  - Computer Processing
  - Chassis Design
  - Vehicle Integrity
- Safety, Cost, & Future Plans



Competition Overview

Prototype Design

- Obstacle/Boundary Detection
  - Information Acquisition
  - Image Processing
  - World Coordinate Transformation
- Path Planning
- Computer Processing
- Chassis Design
- Vehicle Integrity

Information Acquisition

- Elevated image from camera
- Obstacles detected with laser rangefinder
- Emergency distance sensors

Digital Camera

Laser Rangefinder (LRF)

Image Processing

Photo courtesy of www.igvc.org

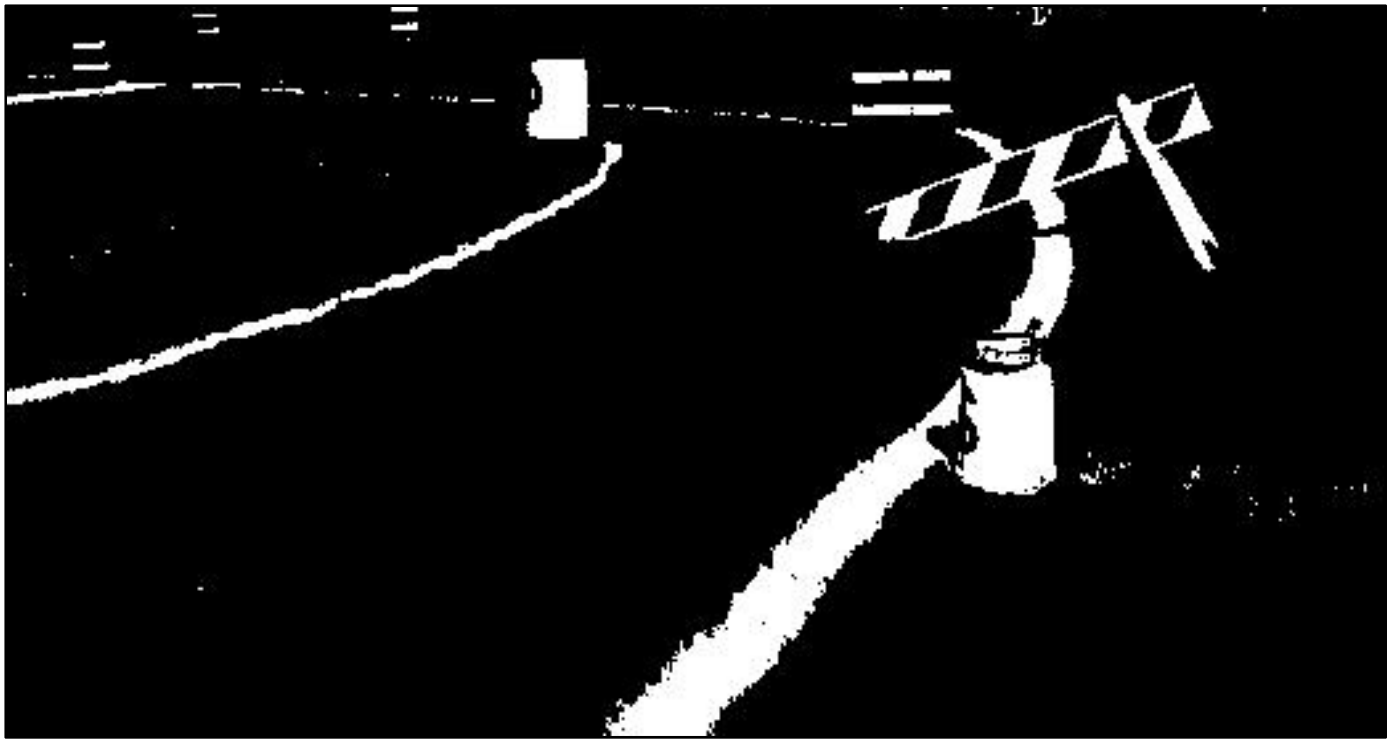
Image Processing

Colors Identified

Image Processing

Green Removed

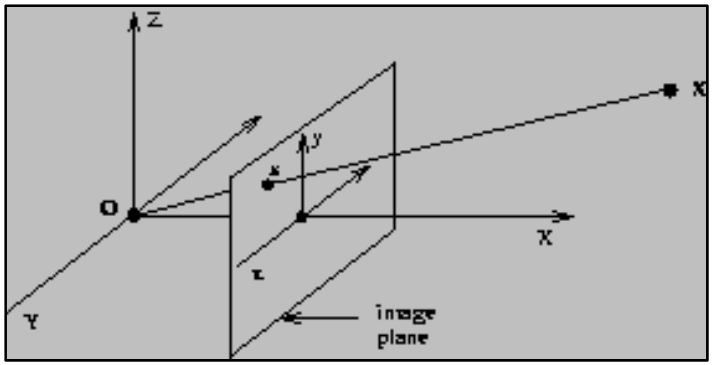
Image Processing

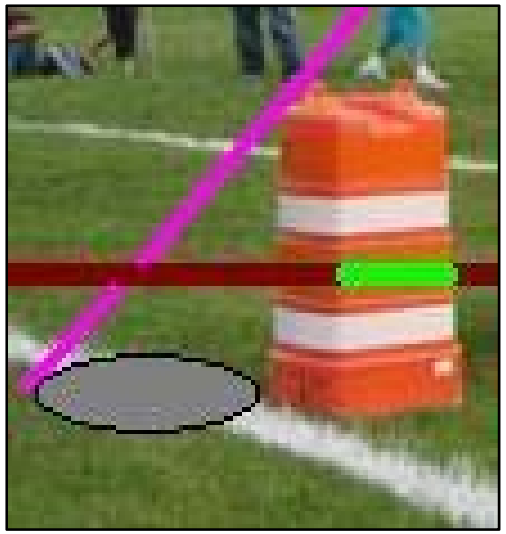


White Only

World Coordinate Transformation

- Pixel↔ line in world coordinates
- LRF pinpoints obstacle
- Estimate obstacle depth
- Separate ground plane
  - Lines & potholes



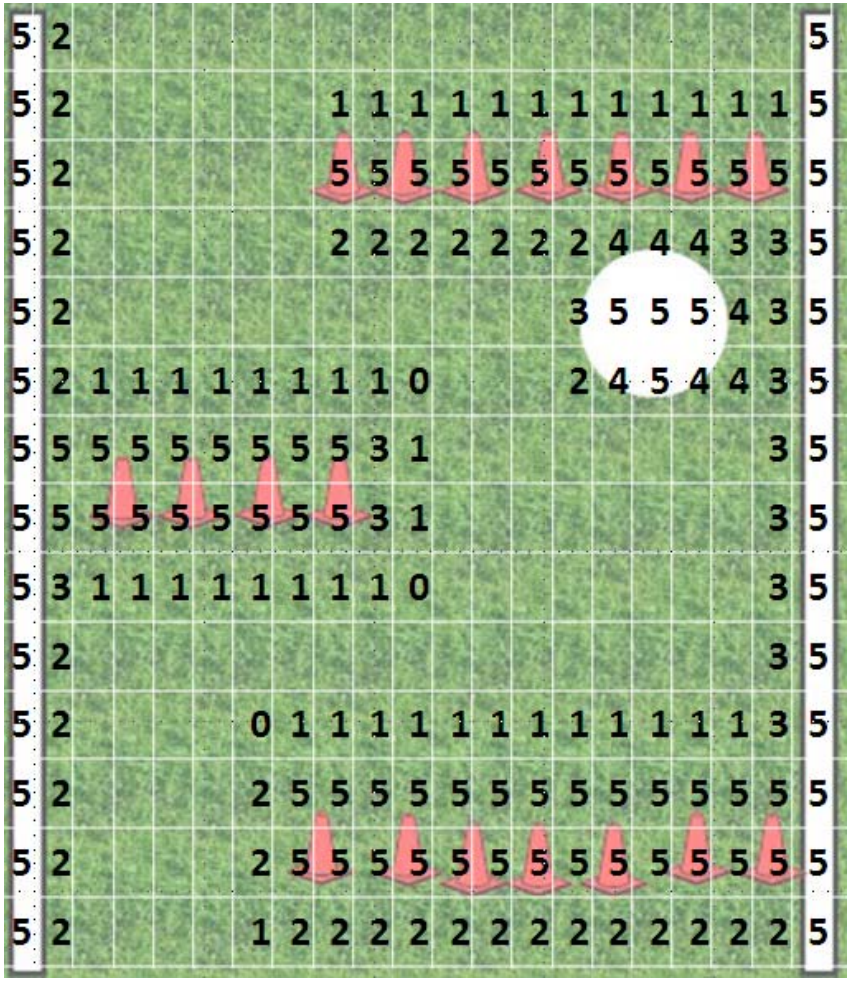


Prototype Design

- Obstacle/Boundary Detection
- Path Planning
  - Avoiding Obstacles
  - Intelligent Navigation
- Computer Processing
- Chassis Design
- Vehicle Integrity

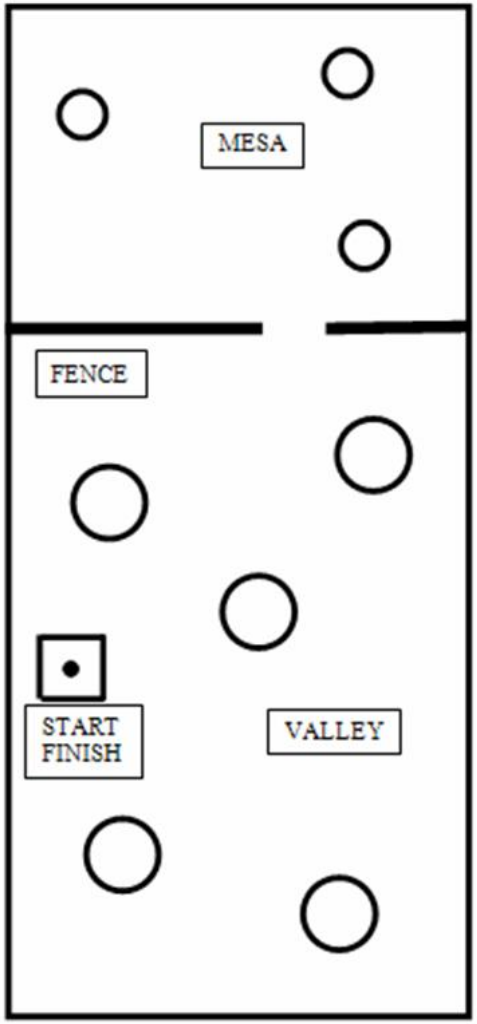
Avoiding Obstacles

- Take 2D Overhead Image
  - Translate into obstacle map
  - Process into weighted grid
- Use A-Star Algorithm
  - Find lowest weight path
  - Option to add panorama
    - Multiple grids
- Two Modes
  - Planning & Following



Intelligent Navigation

- Visit Waypoints in Preplanned Order
  - Brute Force Algorithm
- Map Path to Center of Course
  - Find fence
  - Mark fence coordinates
  - Recalculate path



Prototype Design

- Obstacle/Boundary Detection
- Path Planning
- Computer Processing
  - Software Platform
  - Hardware Platform
  - Hardware/Software Flowchart
- Chassis Design
- Vehicle Integrity

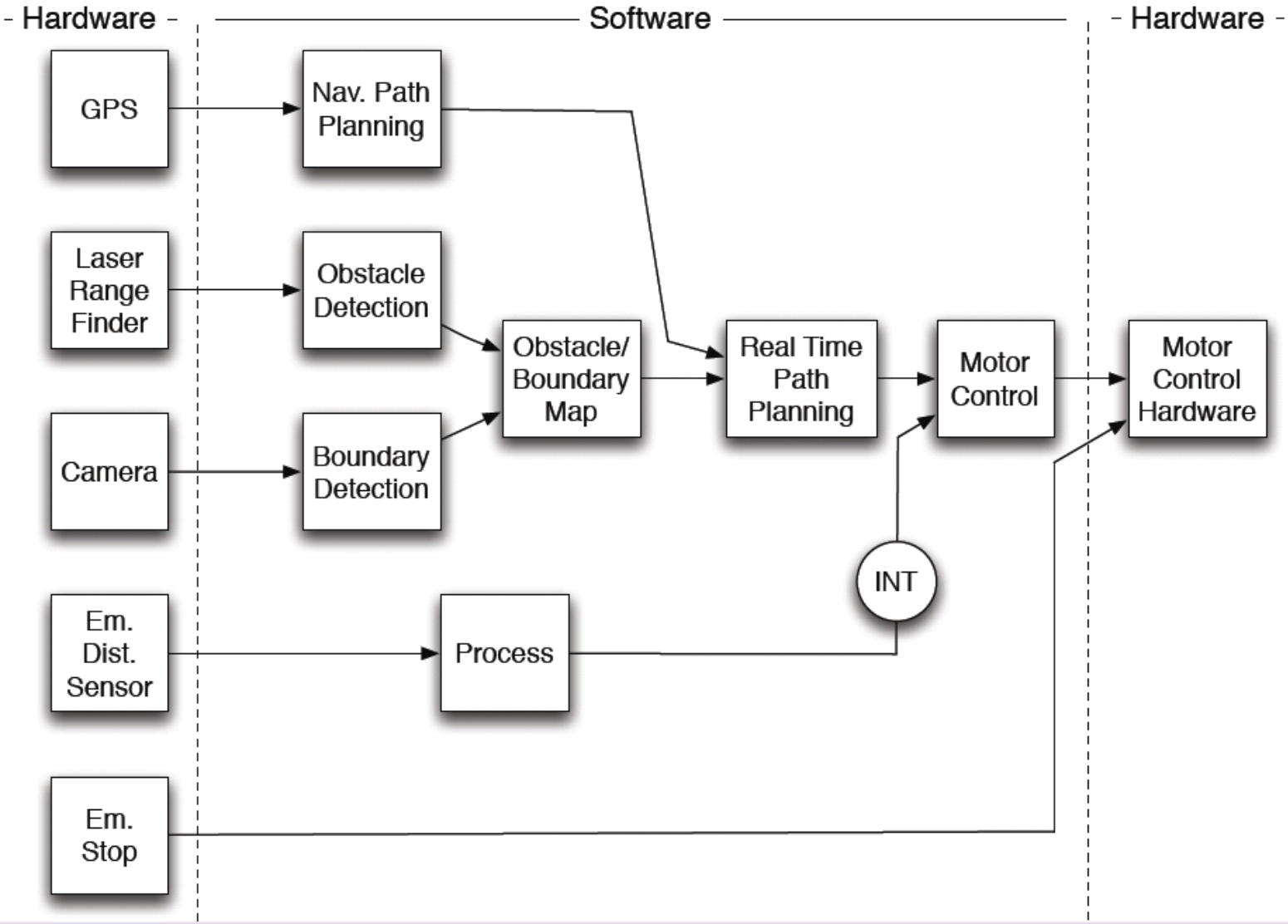
Software Platform

- Linux OS
  - Customizable
    - Kernel features
    - Hardware access
  - Large open source code base
  - System, documentation & support are free

Hardware Platform

- Hardware Platform
  - Mini – ITX Motherboard
    - 6.75 in x 6.75 in
  - Video card nVidia 8800GT 512MB PCIe
    - GPU off loading using OpenVidia library
    - Fast & efficient
  - Core 2 Duo 1.66 – 1.8 GHz
    - True simultaneous multithreading

Hardware/Software Flowchart

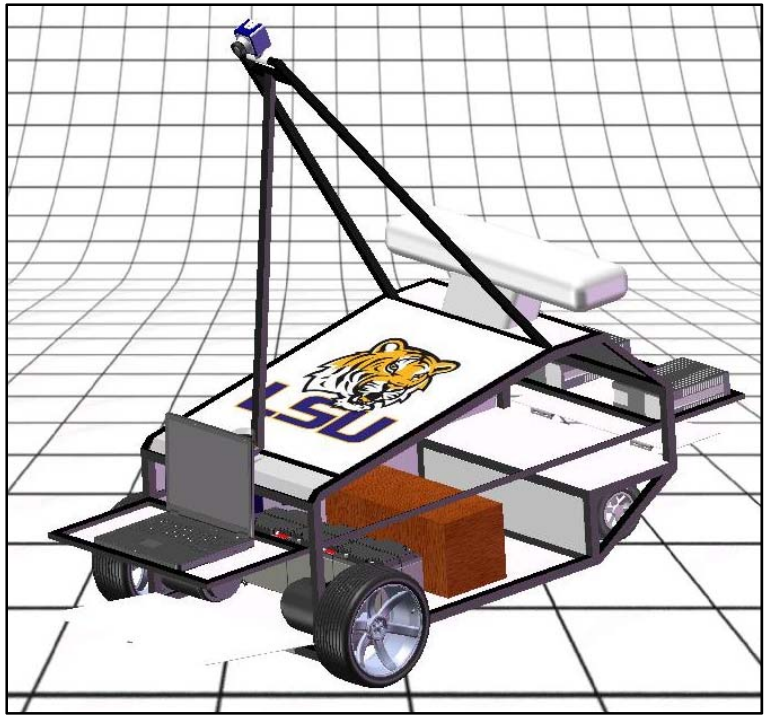


Prototype Design

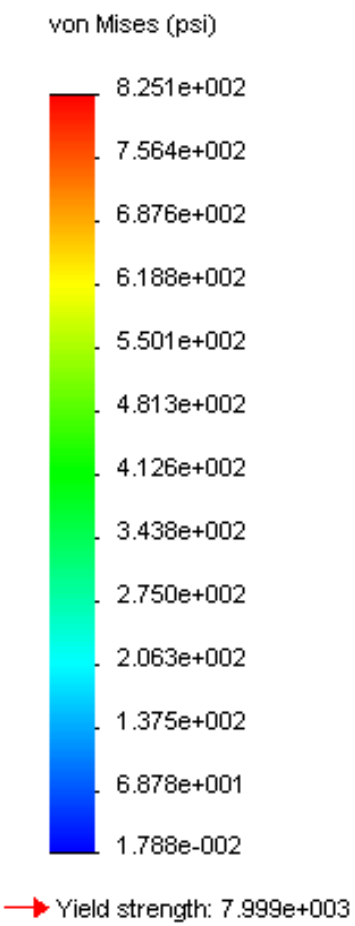
- Obstacle/Boundary Detection
- Path Planning
- Computer Processing
- Chassis Design
  - Weight & Functionality
  - FEA Stress Analysis
  - Camera Mount
- Vehicle Integrity

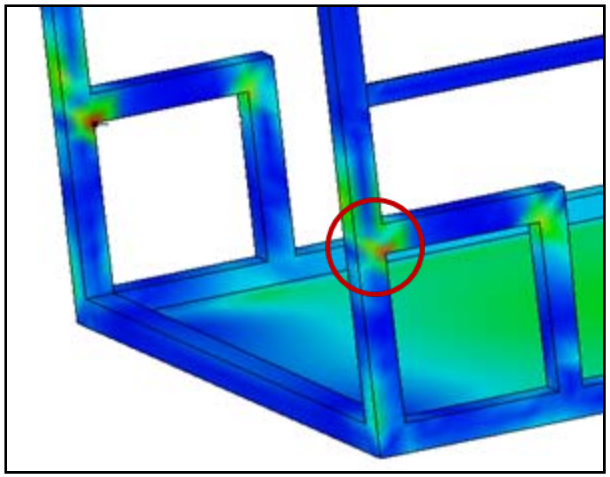
Weight & Functionality

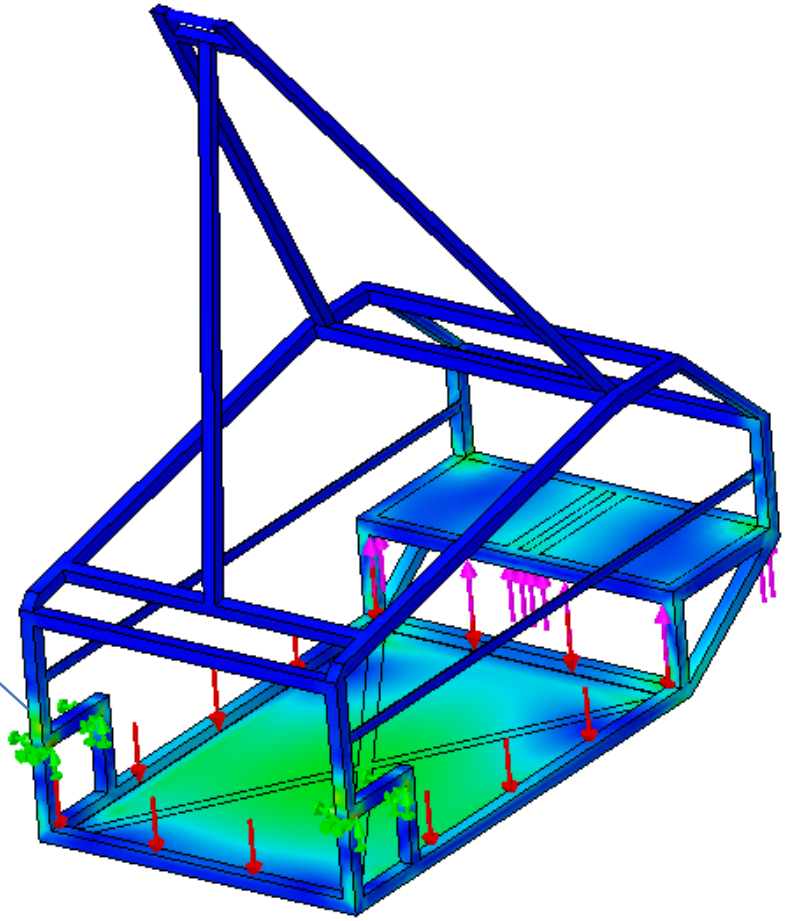
- Al-6061 (1” Square Tube)
  - Total weight=29.18 lbs
  - Previous≈90lbs (304 steel)
  - 67 % weight reduction
- Painted Steel Sheet
  - Weather proofing



FEA Stress Analysis



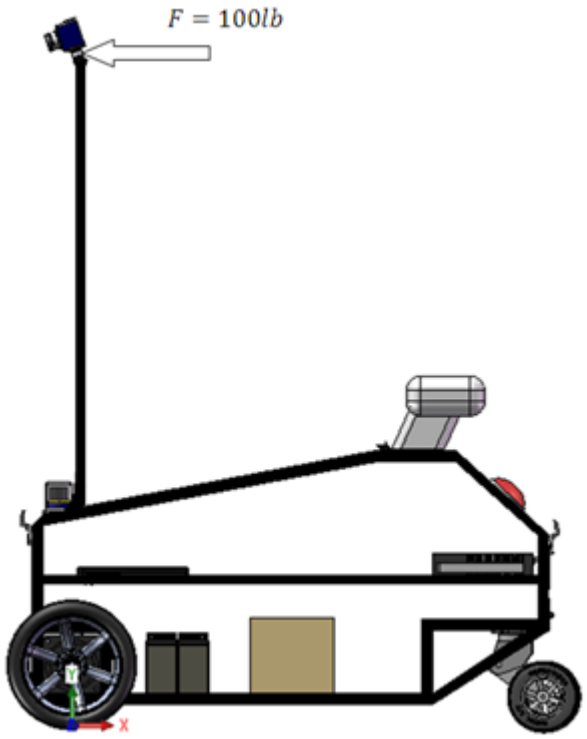




Distributed Load -1000 lbs
Max Stress- 0.83 ksi
Yield Strength- 7.99 ksi
Max Displacement- ~1 mm

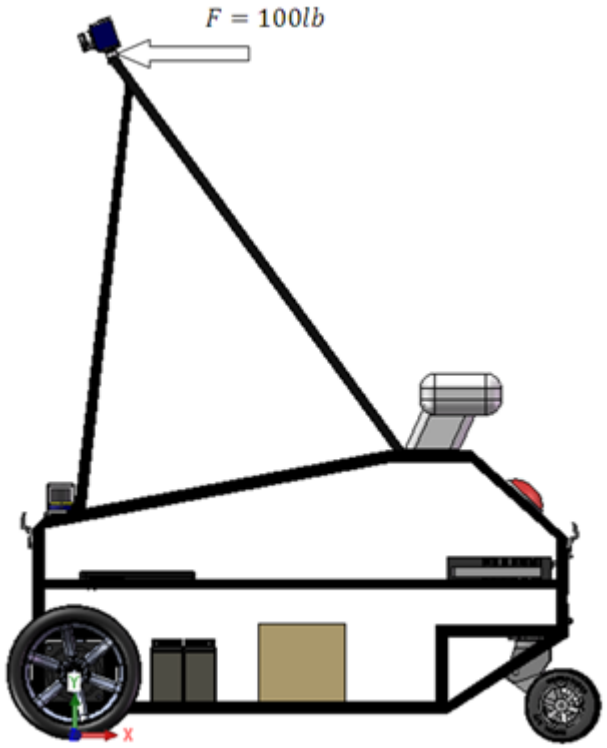
Camera Mount

Option 1



Displacement - 8.21 mm

Option 2



Displacement -3.4 mm

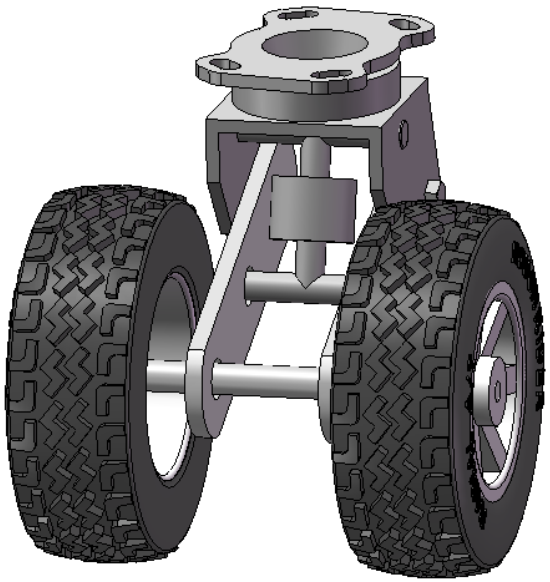
REDUCTION= 58.6%

Prototype Design

- Obstacle/Boundary Detection
- Path Planning
- Computer Processing
- Chassis Design
- Vehicle Integrity
  - Vibrations
  - Dynamic Stability
  - Heat Transfer

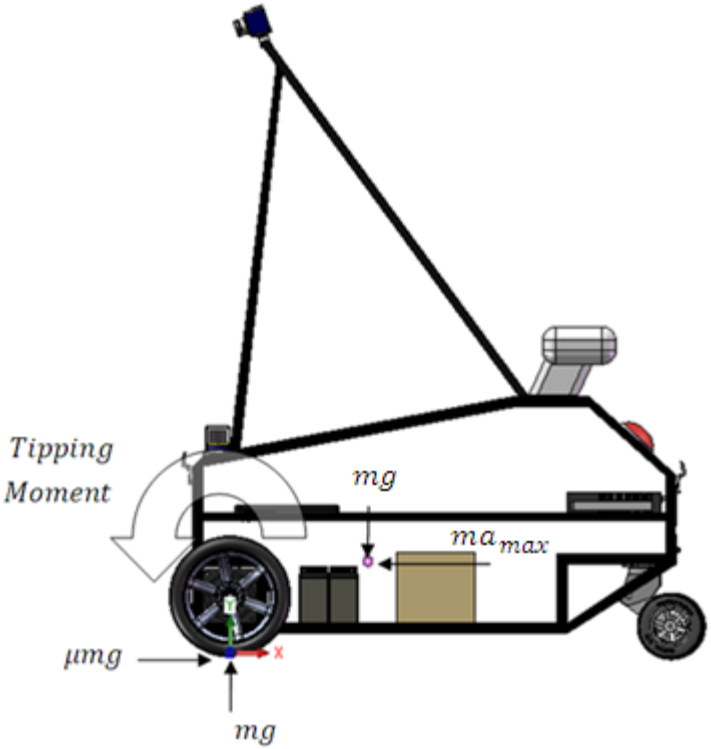
Vibrations

- Acceptable Camera Velocity < 10.6 in/sec
- Preliminary Tests
  - Gravel= 4-6 in/sec
  - Potholes/Bumps= 8-10 in/sec
- Vibration Reduction
  - Low pressure front tires
  - Pneumatic tires
  - Spring suspended caster

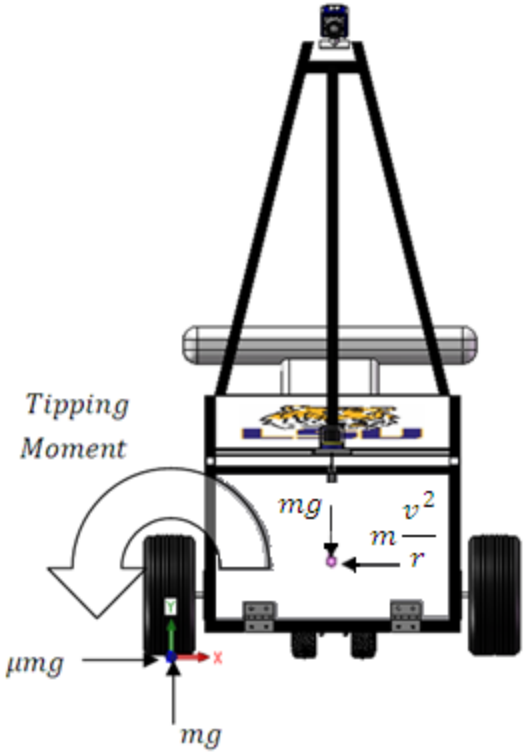


Dynamics

- $= Center\ of\ Mass\ (r_x, r_y, r_z) = (17.7", 7.3", 12.8")$



$Min.Stopping\ Time = 1.18s$



$Min.Turning\ Radius = 10"$

Heat Transfer

- Relative Humidity < 85%
- Heat Decreases Humidity
- T < 122°F
- Fan cfm α Heat load

$$\Delta T = \frac{h_{sens}}{1.08 * cfm}$$

  - 5Watt → 3.16cfm
  - 50Watt → 31.6cfm

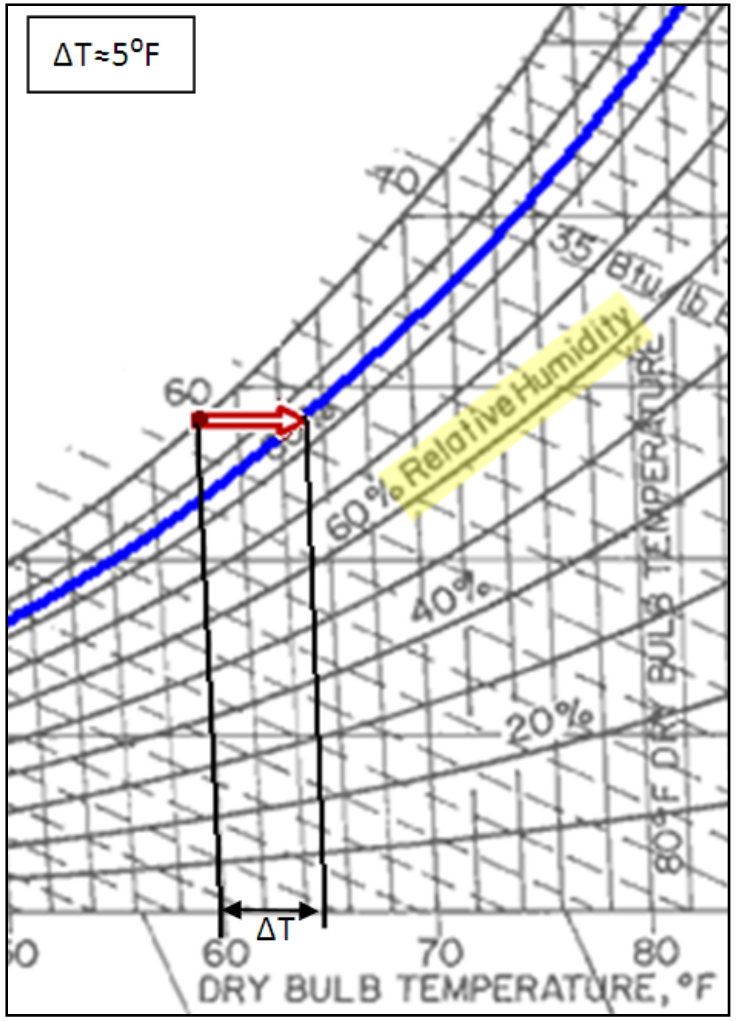


Photo courtesy of www.sp.uconn.edu

Manufacturing

- Lock or Push-in Fasteners on Side Panels
- Bolt-on Motors & Camera Bracing
- TIG-Welded Frame (Al-4043 filler)
  - Pre- and post- weld heat treatment
  - Glass bead peening
  - Grind stress concentrations
  - AWS D1.2 as reference

Safety

- Mechanical Emergency Stop
  - Use “normally closed” button
- Wireless Emergency Stop
- Hardware Limited Speed
- Emergency Distance Sensors

Photo courtesy of www.arcadeshop.de

Cost Breakdown

Description	Estimated Cost
Laser Rangefinder	$2700 (Purchased)
GPS	$3000 (Purchased)
Motors	$600 (Purchased)
Camera	$300 (Purchased)
Batteries & Chargers	$500 (Purchased)
Motor Controllers & Encoders	$700 (Purchased)
Testing Equipment	$1000 (Donated)
Computer	$1000
Frame Material, Wheels, Casters, Tires	$550
Miscellaneous Supplies	$100
TOTAL:	**$10450 (Remaining costs=$1650)**

Future Plans

- Continue testing on images & vibration
- Complete fabrication of chassis & casters (Feb.)
- Complete incremental implementation (April)
  - Self awareness
  - Obstacle & line detection
  - Intelligent path planning
- 2008 IGVC Competition (May 30)

Semester Achievements

- Method for detection and mapping of obstacles
- Unique path planning algorithm
- Image processing load from CPU to GPU
- Modeled chassis (stress levels acceptable)
- Reduced chassis weight & maintained integrity

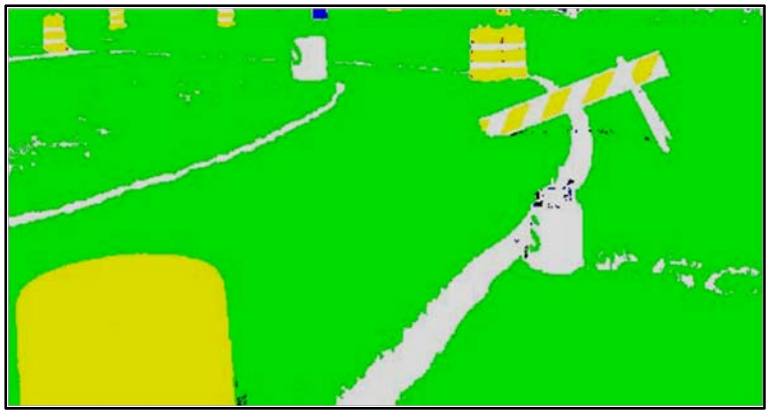
More Information

- Condensed Vision
- GPS and Compass Data
- Motor Controller Data
- Power Distribution
- Motors and Power
- FEA Natural Frequencies
- FEA Displacement
- Vibration Dampening Plots
- Dynamics

Image Processing

1.

2.



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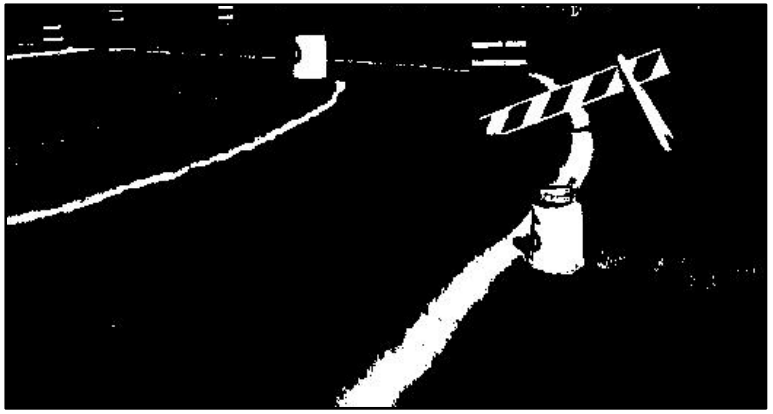


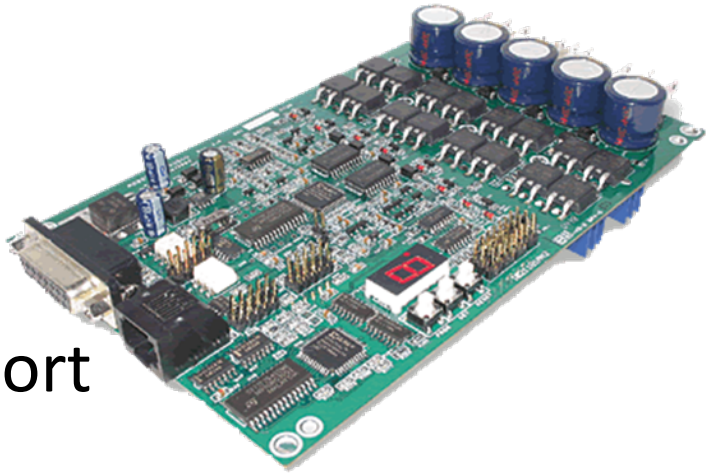
More Information

GPS and Compass

- CSI Wireless Vector GPS Compass
  - Differential correction for <1m position accuracy
  - Heading accuracy of .5 degrees
  - 10 Hz heading updates, 5 Hz position updates
  - NMEA 0183 communications interface over RS-232
  - Low power consumption
  - Waterproof housing

More Information

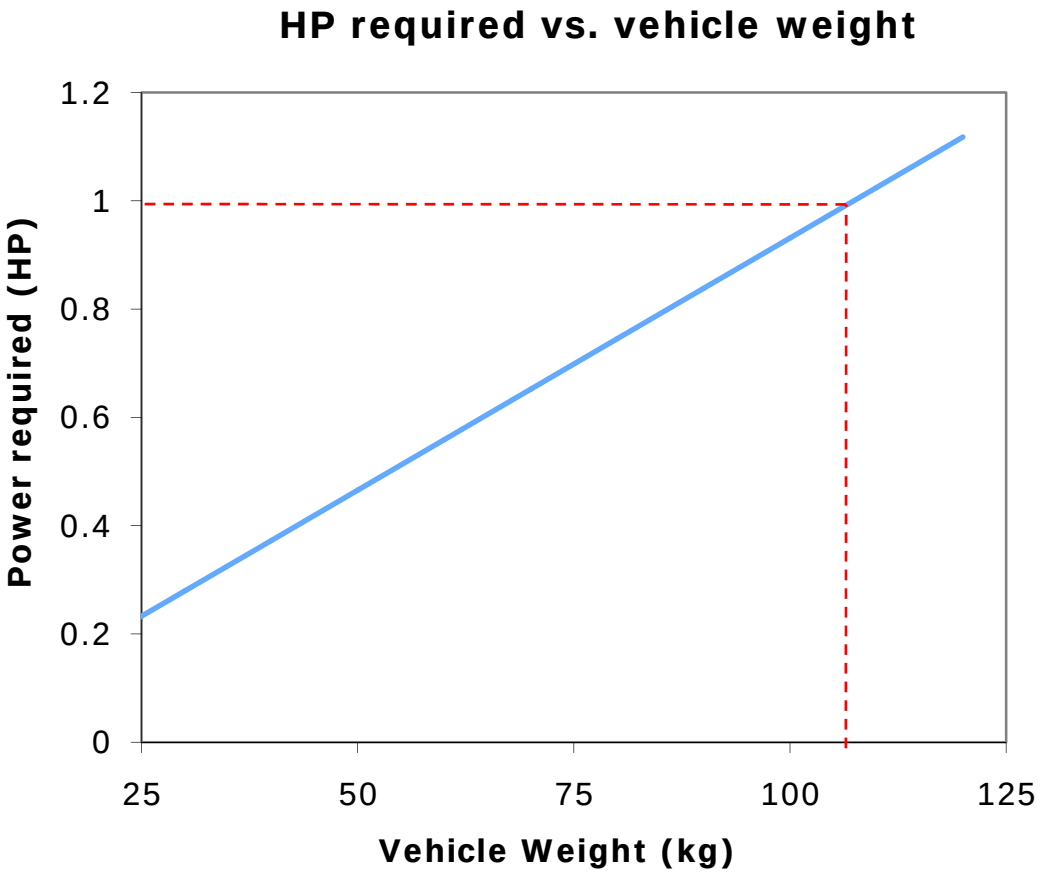
Motor Controller



- Roboteq AX3500
  - 2x60A Continuous output
  - Quadrature encoder support
  - RS-232 Control option
  - Programmable current & speed limitation
  - E-Stop input
  - Transistor temperature monitor
  - Joystick control through PC

More Information

Power Distribution



- Highest required power:
  - 15° incline at 5 mph
  - Friction coefficient (f_r= 0.06)
  - Max req. torque=38.4 ftlb

$$Power = \frac{Energy_{incline} - Energy_{friction}}{time}$$

More Information

Motors and Power

- 2 Motors:
  - NPC-T64
    - 24-36V DC
    - 235 Max RPM
    - 1.6 HP
    - 13 LBs each
    - Stall torque=68.75ftlb

Tire Size	Max Speed
10”	7 MPH
12”	8.4 MPH
14”	9.8 MPH

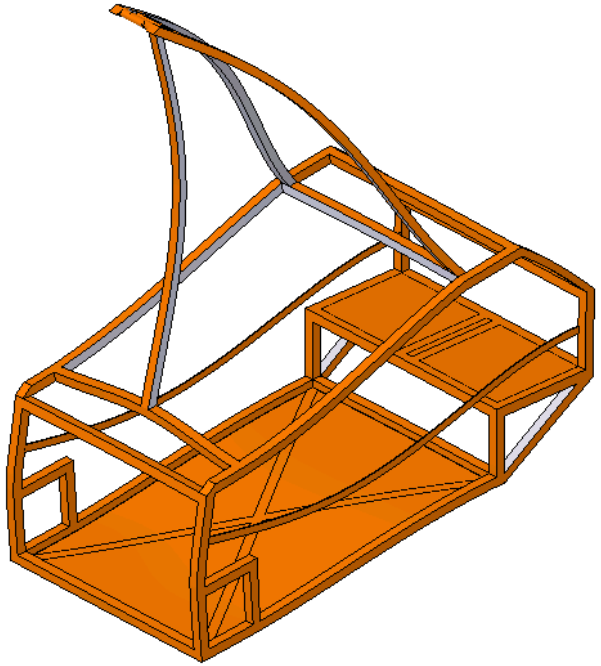
- Battery Bank
  - 6x Sealed Lead Acid Batteries
  - 12V 21.0 Ah/battery
  - 4 – Motor, 1 Computer, 1 Spare
  - Series-Parallel Wiring for 24V 41 AH

More Information

FEA- Natural Frequencies

- Modes→ Different Loads

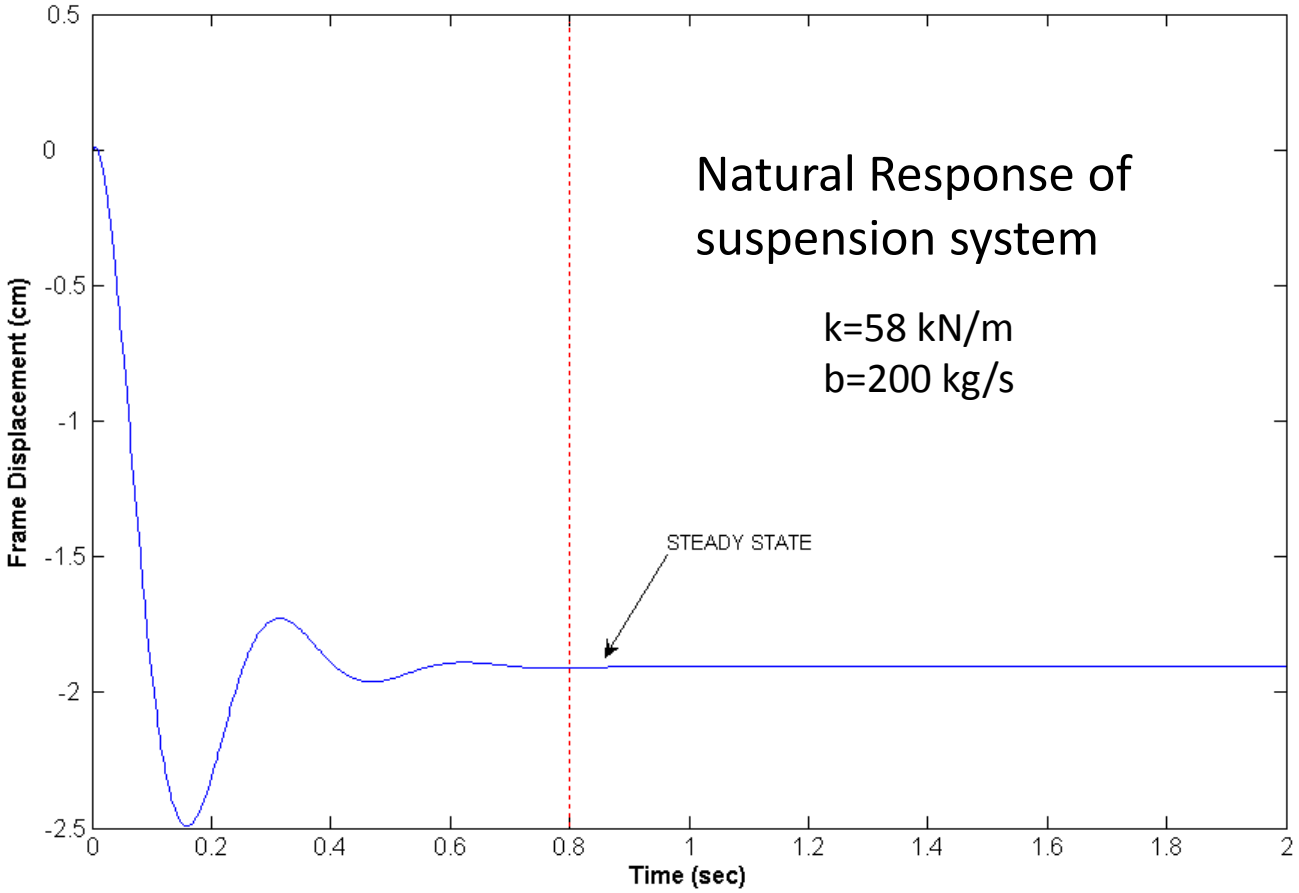
Mode No.	Frequency (Hertz)	
1	20.70	→ LOWEST
2	25.27	
3	64.66	
4	74.91	
5	83.45	→ HIGHEST



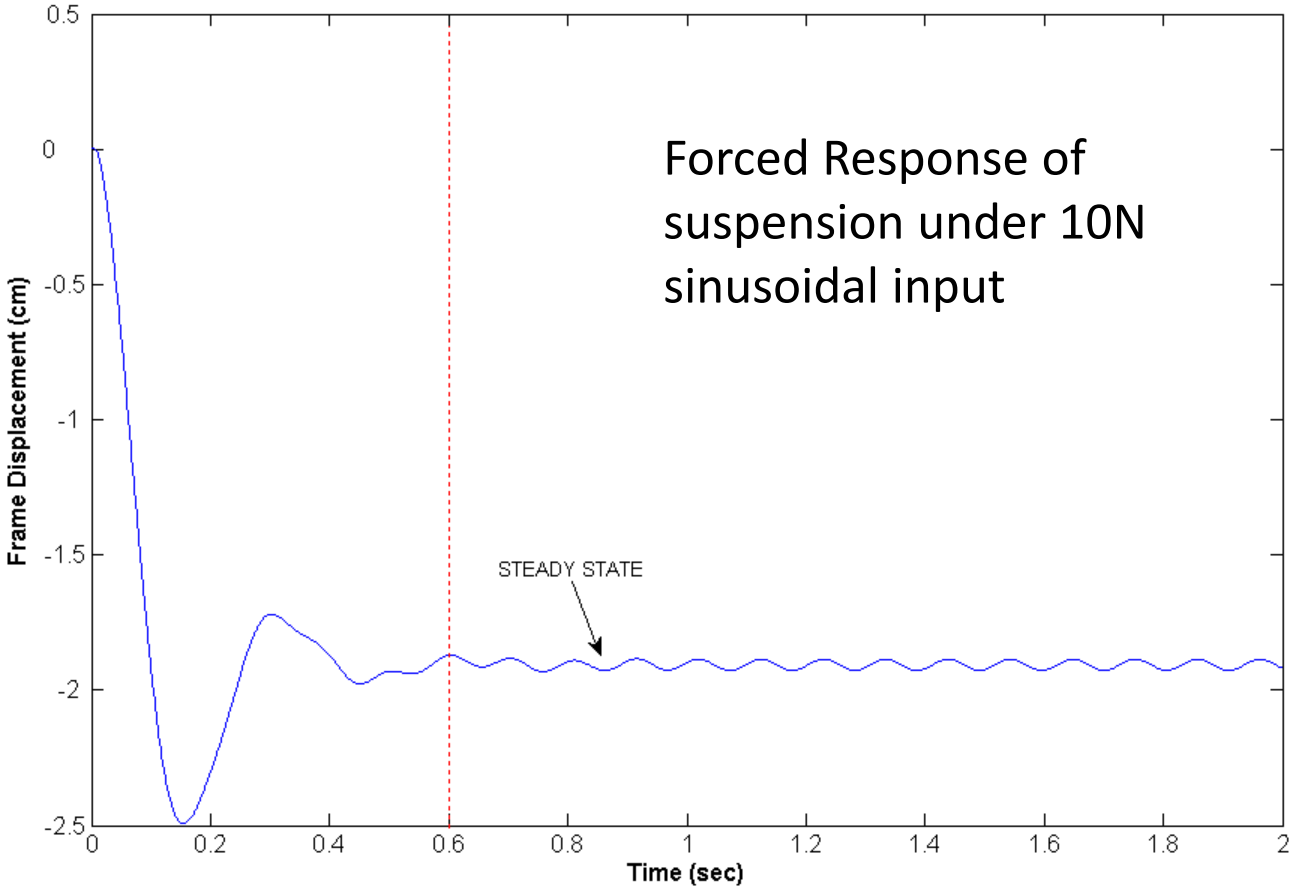
*Tests show highest frequency peaks @17.5 Hz (0.14 in/sec)

More Information

Vibration Dampening



Vibration Dampening



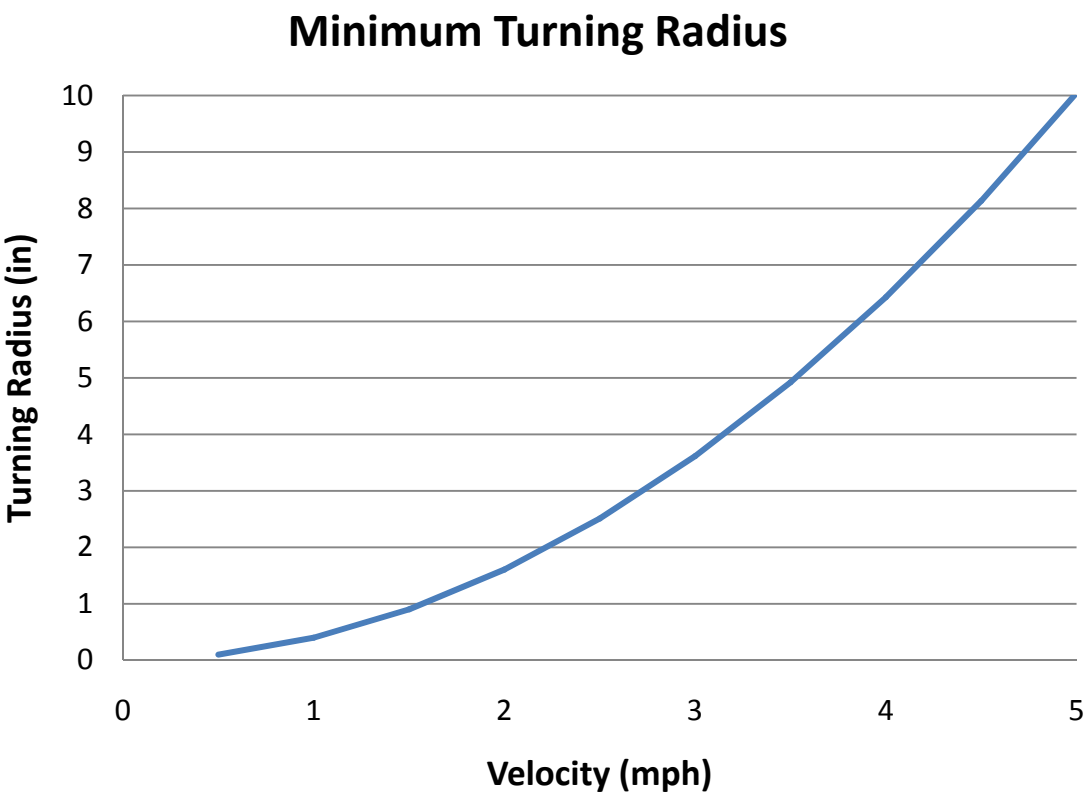
More Information

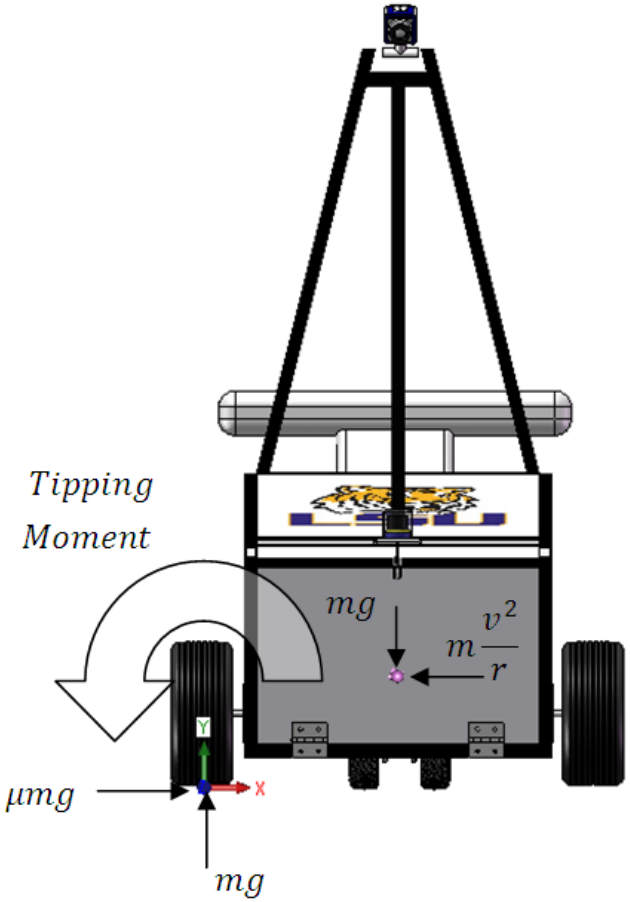
Sponsorship

- Shell
  - DataPAC 1200 Handheld Vibration Monitor
- Metals Depot
  - Discounted 6061-Aluminum Tubing
- Polaris
  - SAE Discount on Polaris Parts

More Information

Dynamics

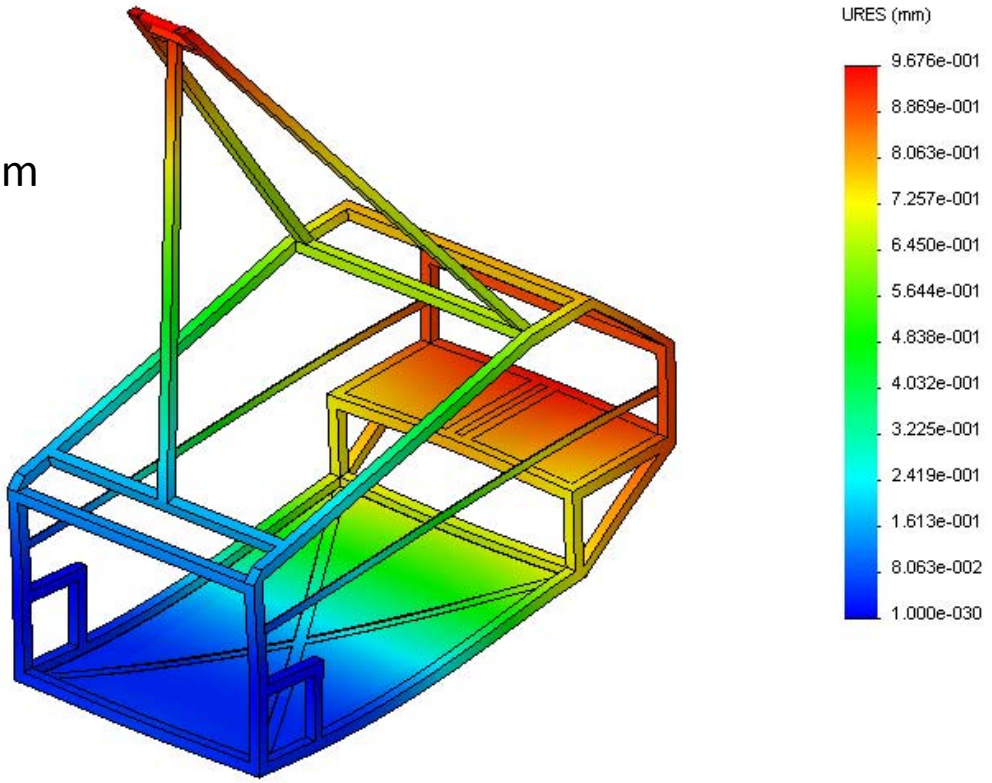




[More Information]

FEA- Displacement

Max Displacement- ~1 mm



More Information