
UCSB HYPERLOOP
Design Review
Feb. 23, 2018

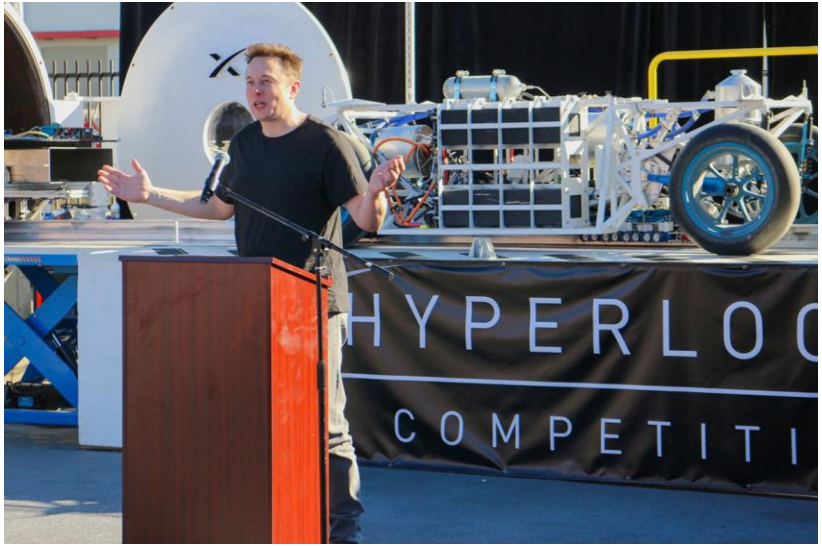
What is Hyperloop?

By: Rachel, Raymond

Levitation Competition Rules

By: Rachel

- **There-and-back race** on **outdoor** test track
- Pod must **levitate** for entire duration of run
- 5 foot minimum pod length
- **Fastest pod wins!**



Levitate at Start — **Translate forward** → **Stop at 75 feet**

Stop at Finish ← **Translate in reverse**

Updated Key Specs

By: Raymond

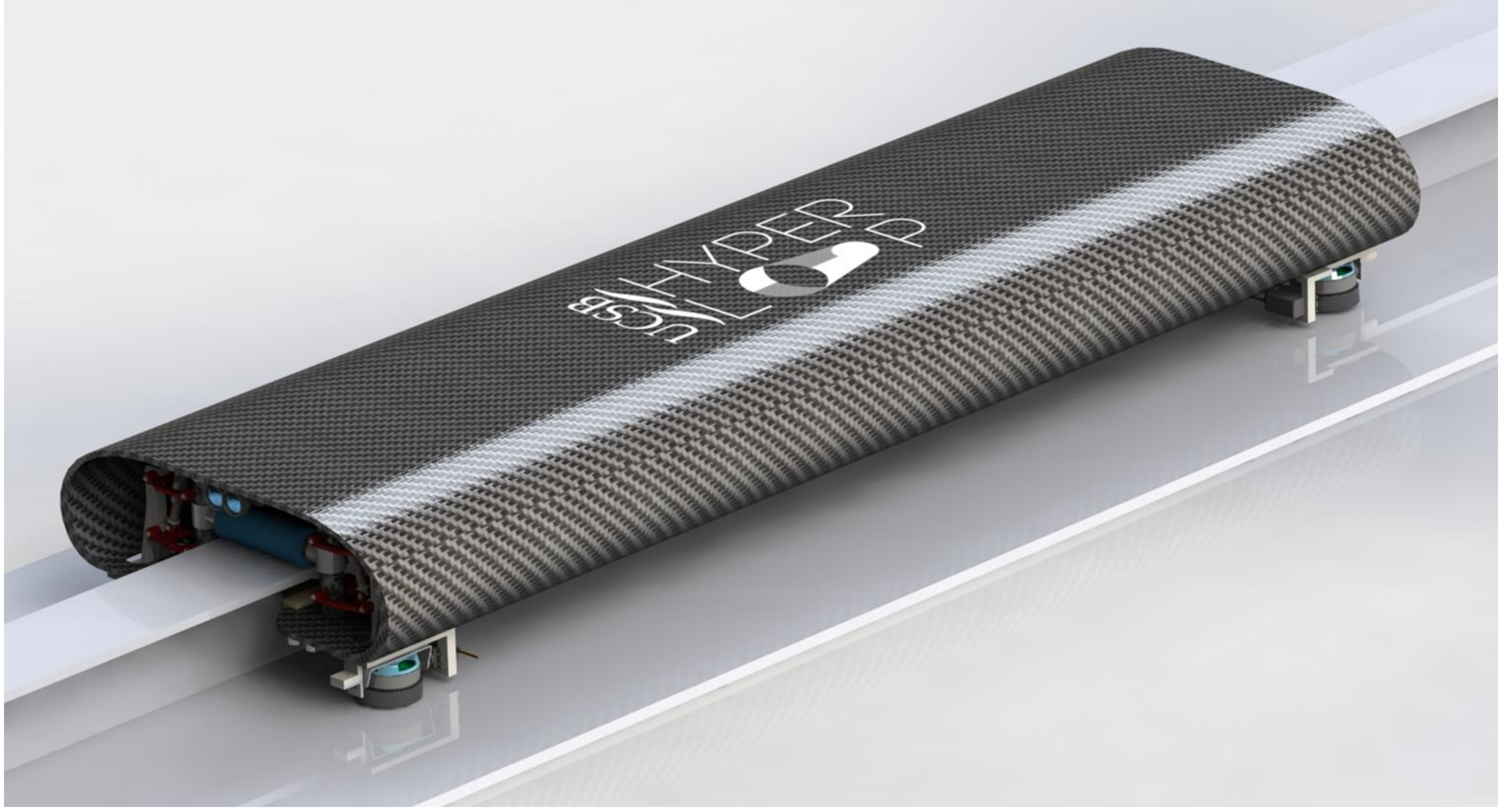
- Accepted into final competition in July at SpaceX
  - Competing directly against San Jose State University in Levitation Competition

Team Name	University
UCSB Hyperloop	University of California, Santa Barbara
Spartan Hyperloop	San Jose State University

- Our target pod:
  - **Total weight**: 8.8 lbs
  - **Acceleration**: 0.2g
  - **Lap time**: 13.6 seconds

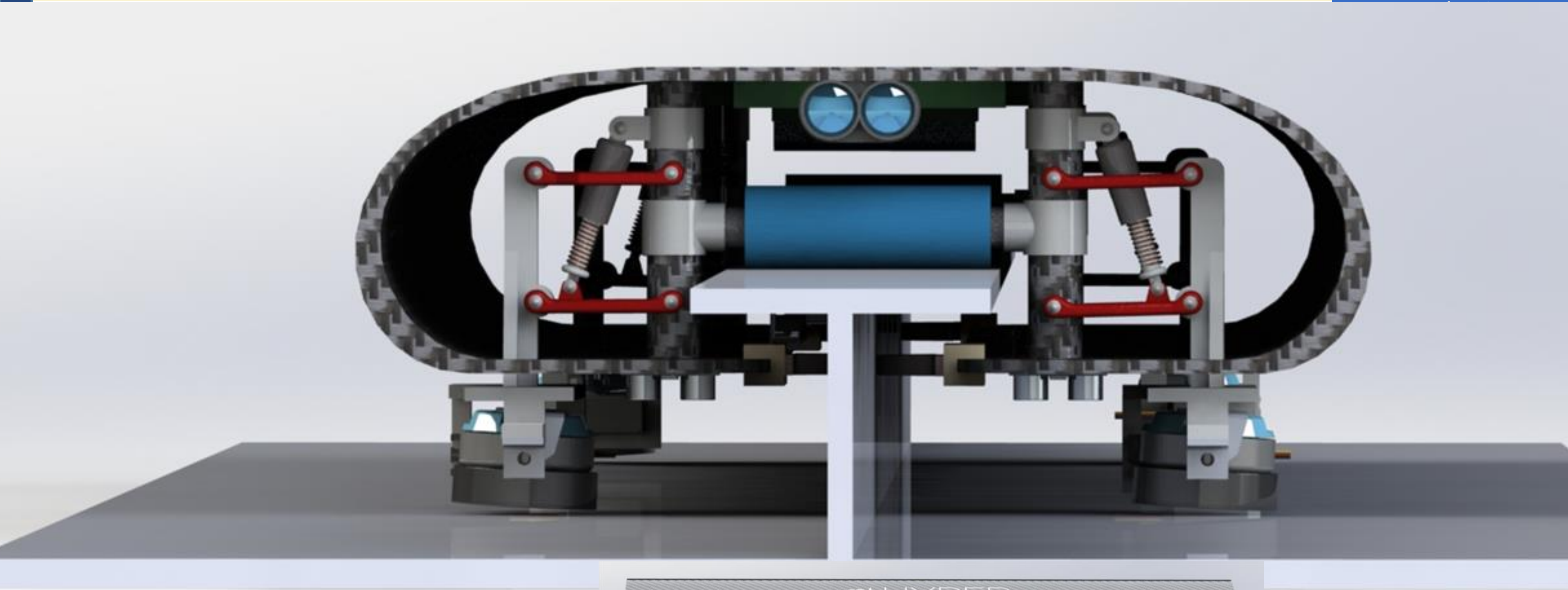
UCSB Hyperloop III

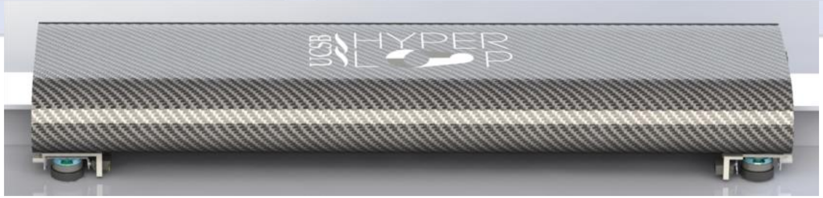
By: Nate



Pod Overview

By: Nate





Our Sponsors

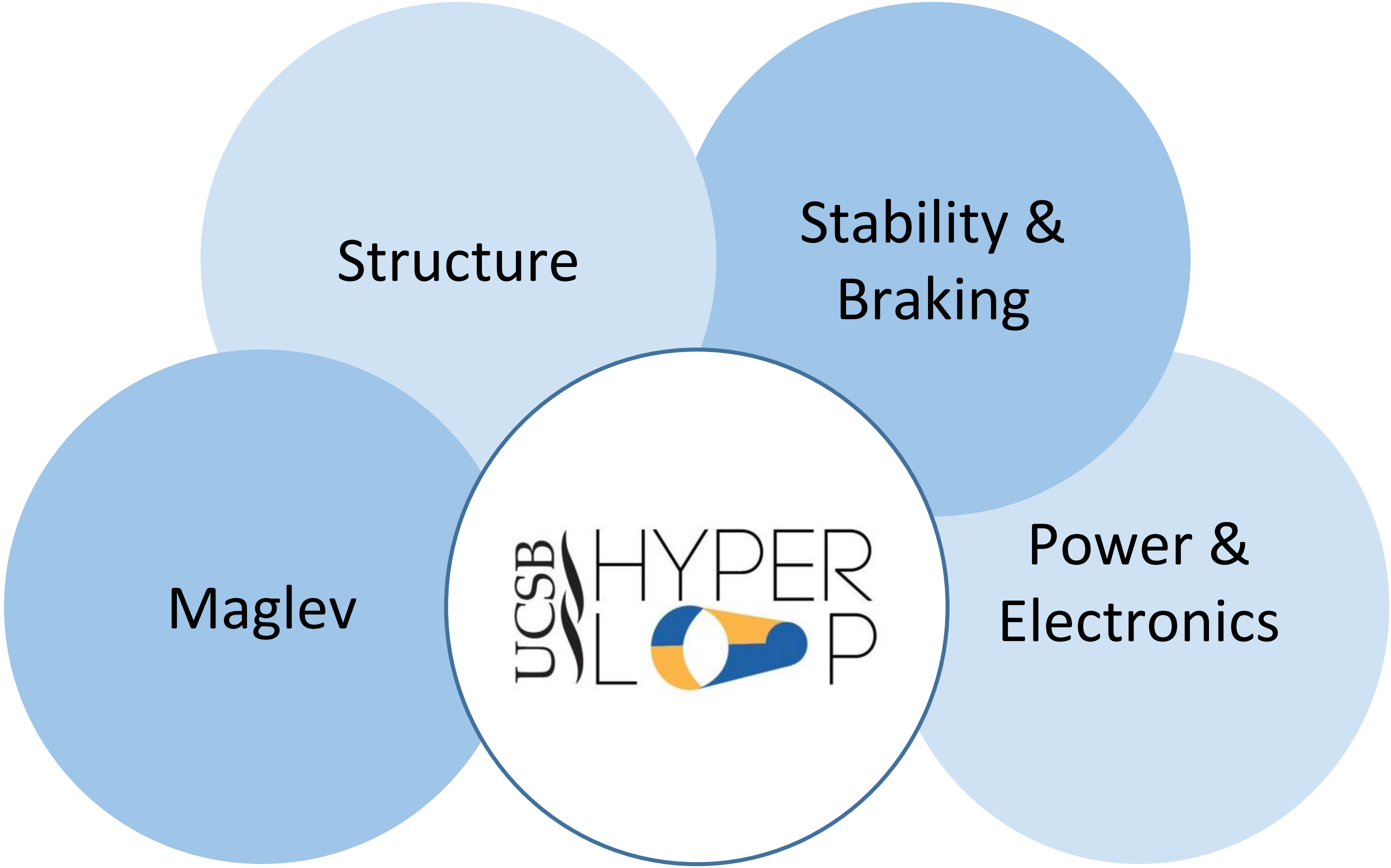
Subsystem Weight Allocation

By: Nate

Subsystem	Mass (kg)	Weight (lb)
Maglev	1.52	3.35
Structure	1.07	2.5
Stability/Braking	0.81	1.78
Electronics	0.62	1.14
Total	**3.98 kg**	**8.77 lb**

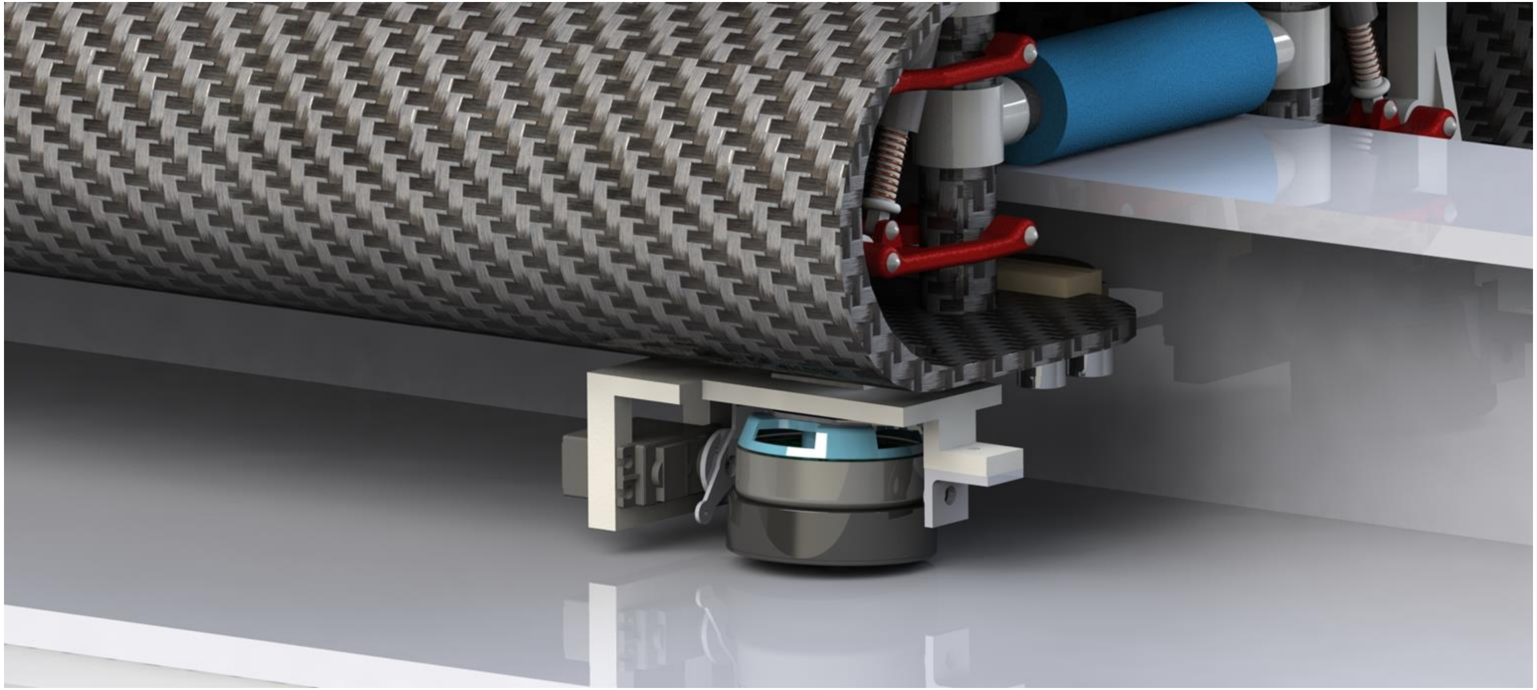
System Design

By: Nate



Maglev

By: Andrew



MagLev Propulsion

By: Andrew

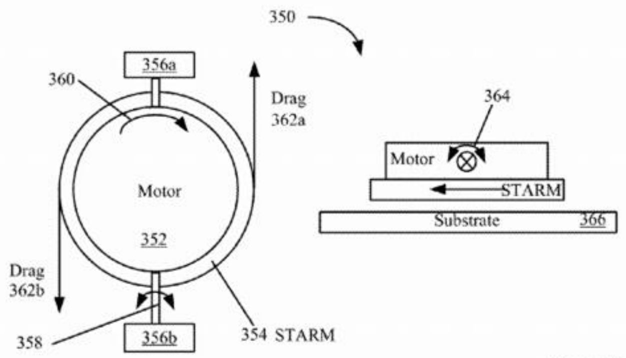


Figure 30A

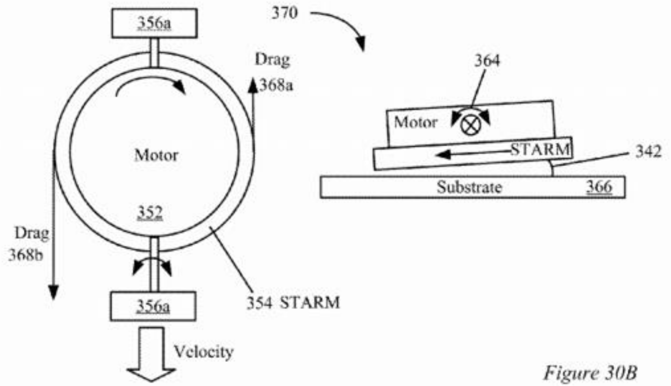
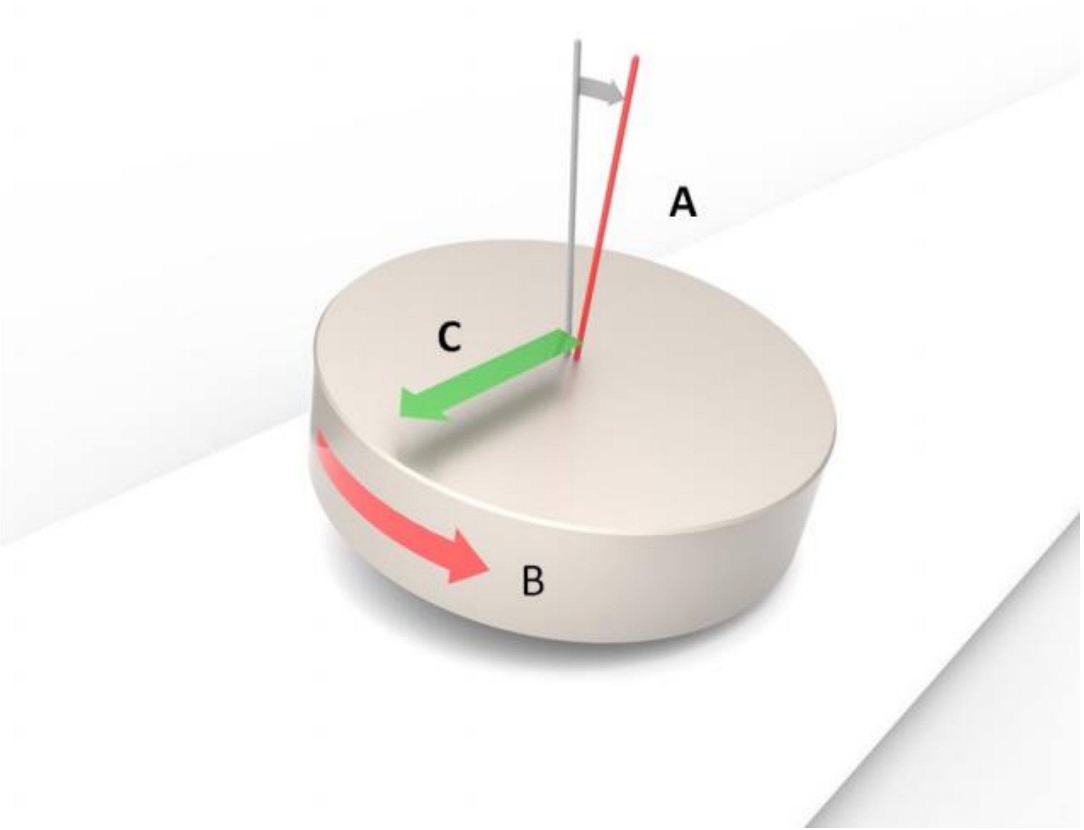


Figure 30B

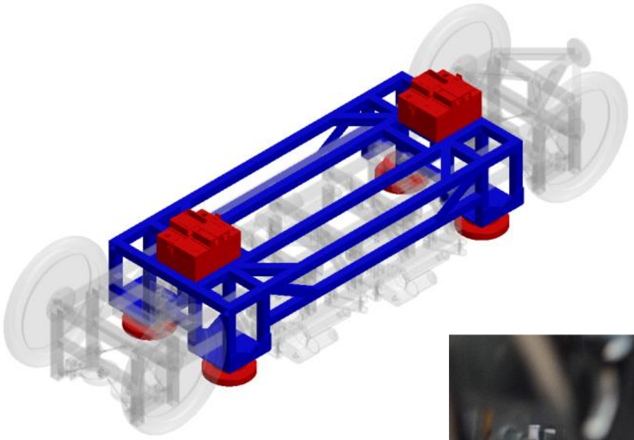
MagLev Propulsion

By: Andrew

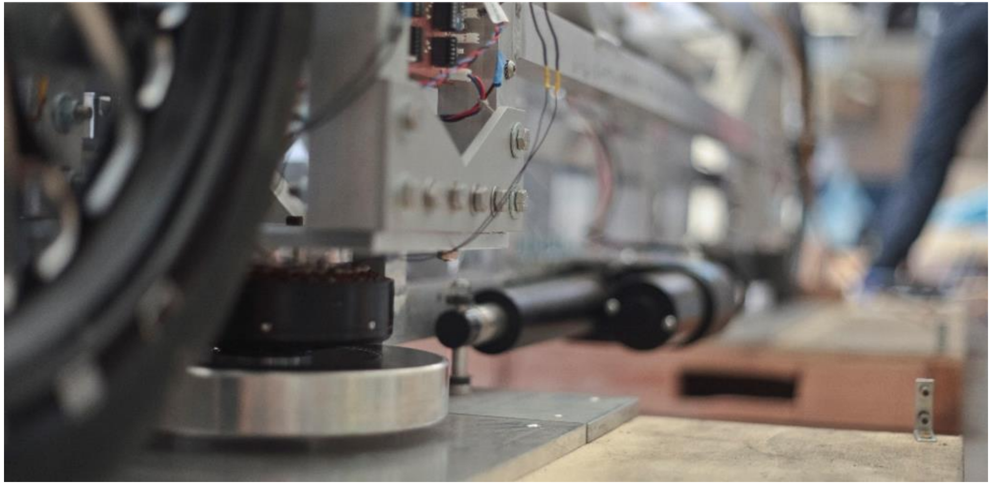


Last Year: MagLev

By: Nate



- Hybrid Payload System
- Large Arx Pax HE3.0 Maglev engines
- Heavy and power hungry
- Lacked suspension system to dampen oscillations created by MagLev engines



Levitation Concept Validation

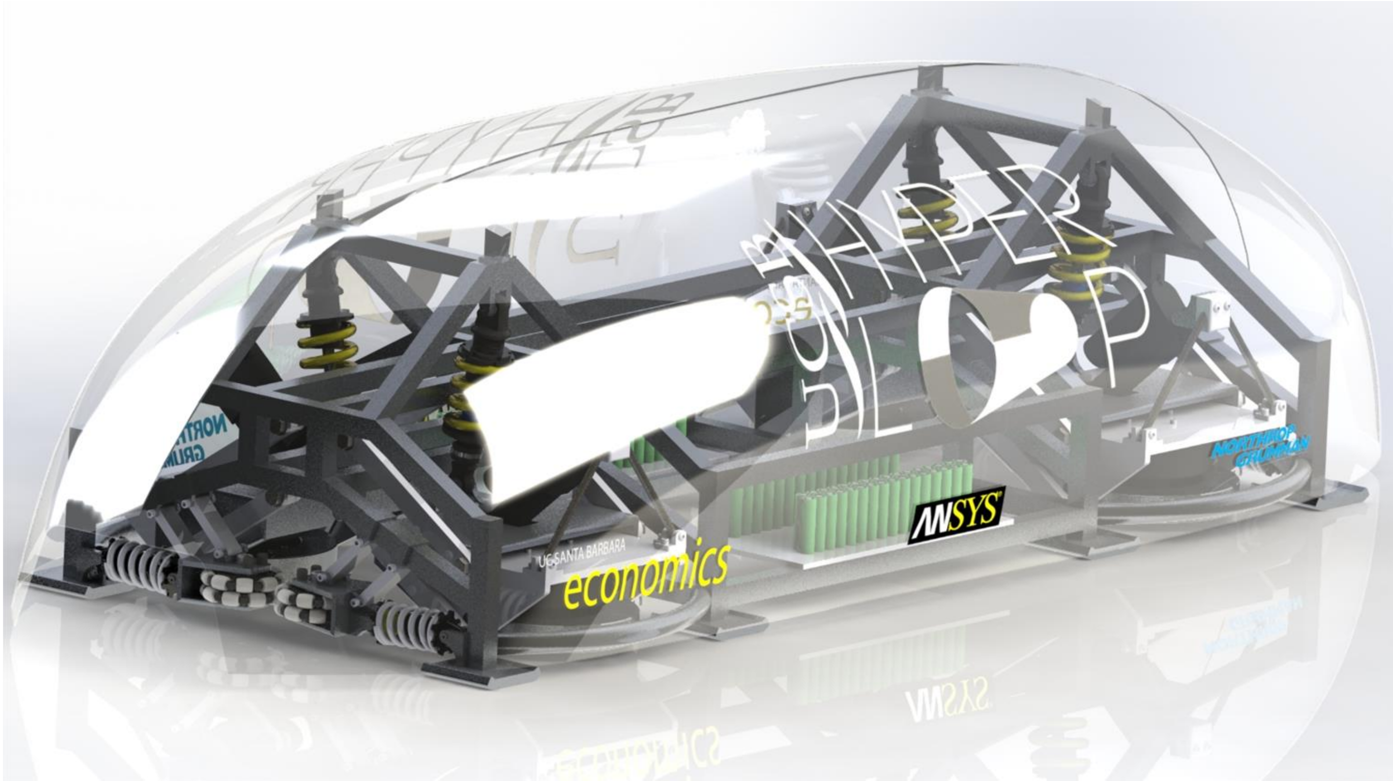
By: Nate

- **Air Bearing** prototype
  - Developed as potential alternative
  - Didn’t achieve full levitation
  - Requires separate propulsion system

- **Maglev** prototype
  - Scaled down using **HDK** motors
  - Proved viability of tilt propulsion
  - Showed promising acceleration

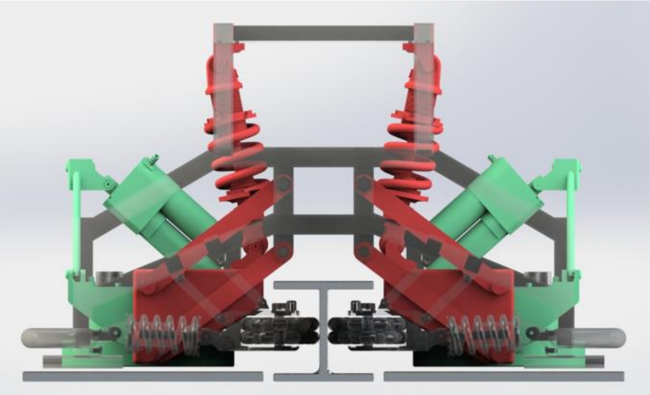
Levitation Concept Development

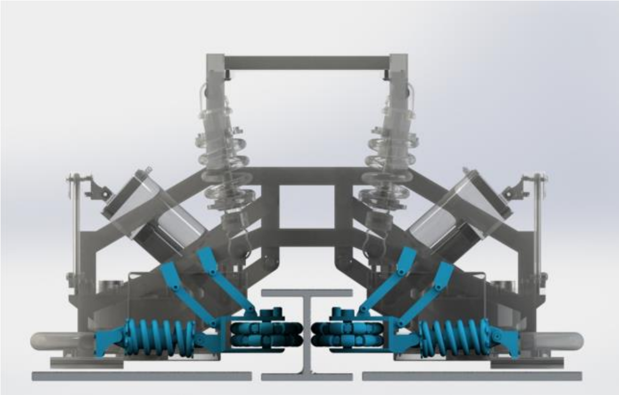
By: Nate

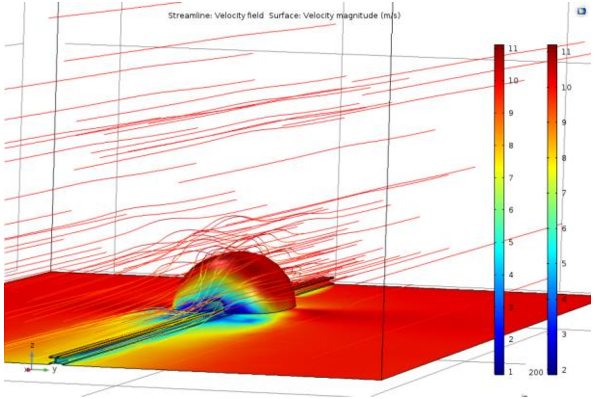


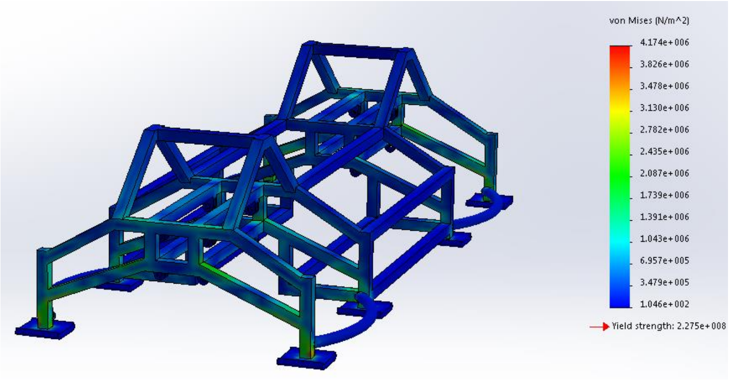
Levitation Concept Development

By: Nate



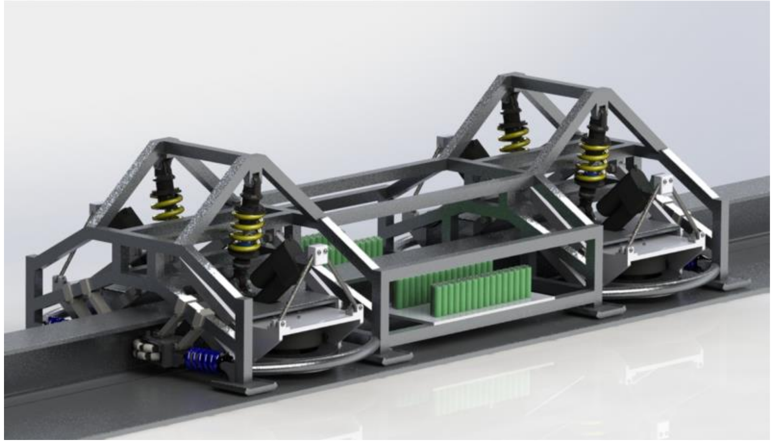


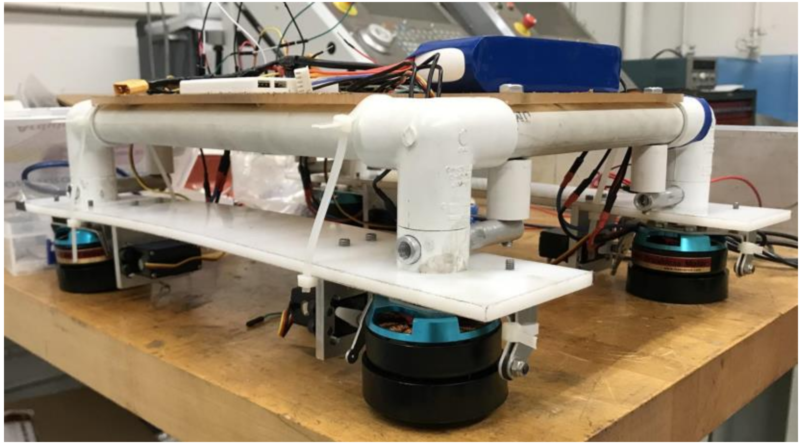




Levitation Concept Development

By: Nate





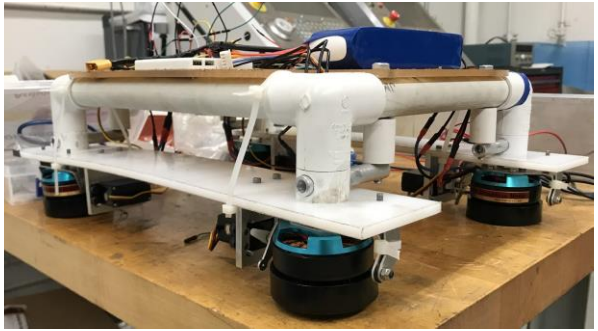
Levitation Concept Assessment

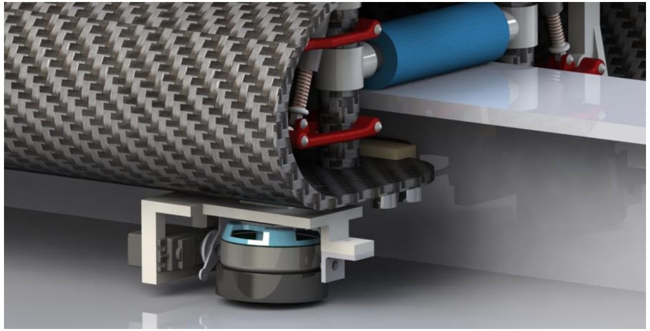
By: Nate

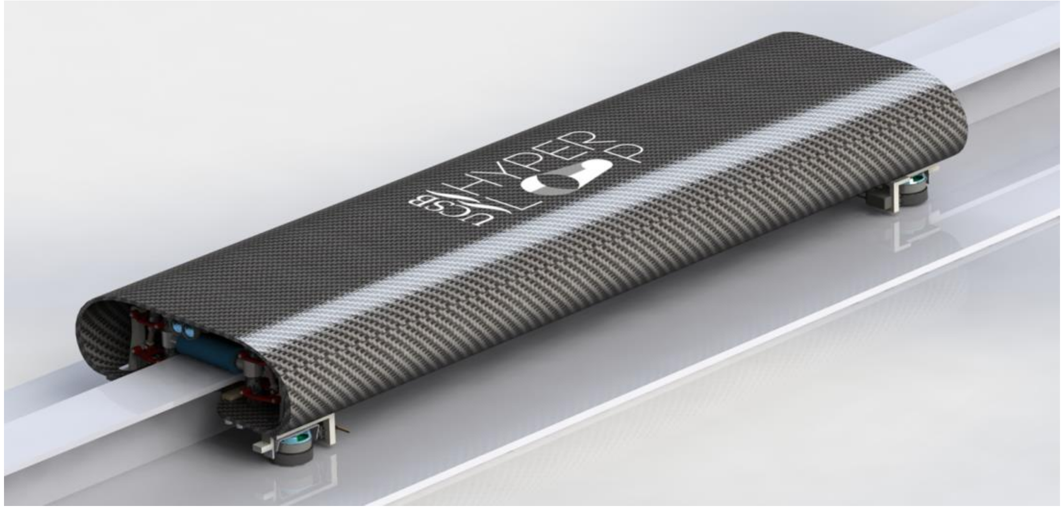
Design Criteria	HDK (small maglev) Pod	HE3.0 (large maglev) Pod
Proven Concept (0-15)	10.8	5.2
Simplicity of Design (0-10)	7.2	3.43
Cost (0-5)	4.4	2.8
Modifiability (0-10)	9	3.6
Timeline (0-20)	18.4	9.4
Weight Limit (0-25)	8.75	19.17
Acceleration (0-25)	10.8	18
Total	**69.35**	**61.60**

Maglev

By: Nate

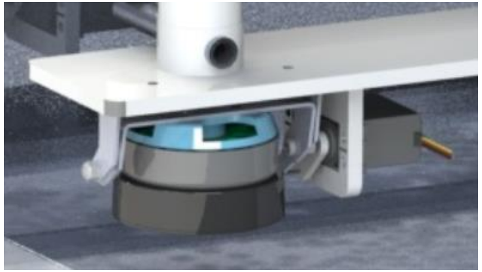






Tilt Mechanism

By: Andrew



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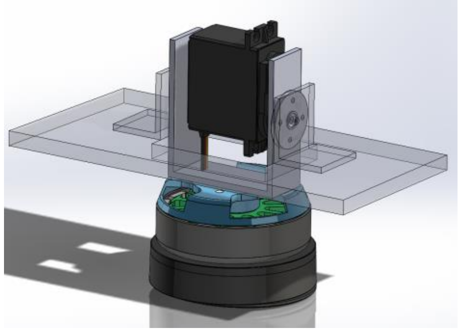

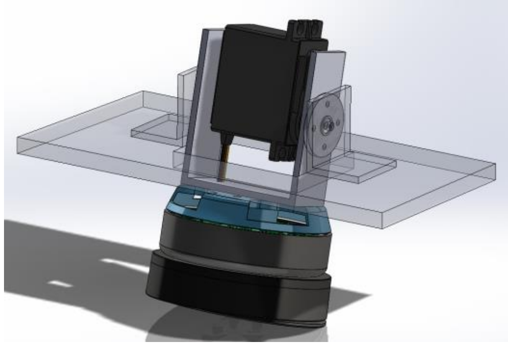

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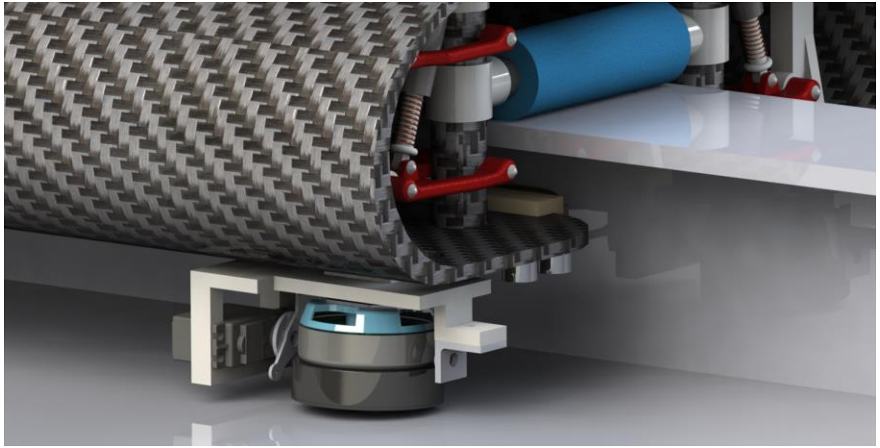
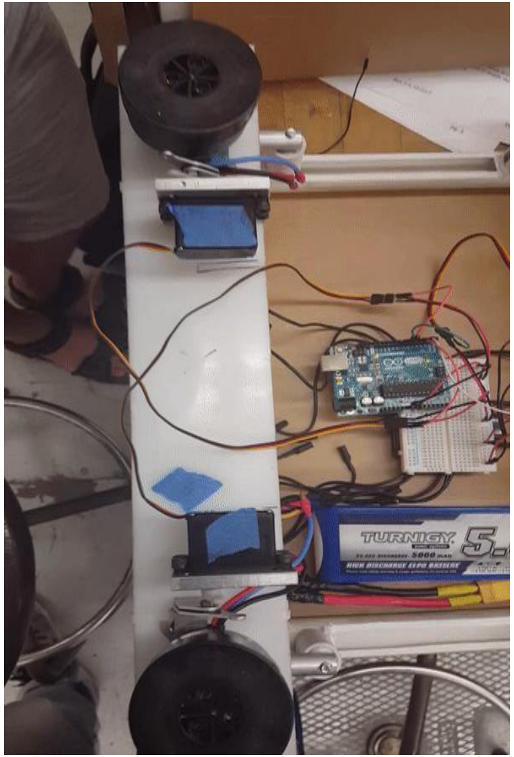


Maglev Prototype Progress

By: David

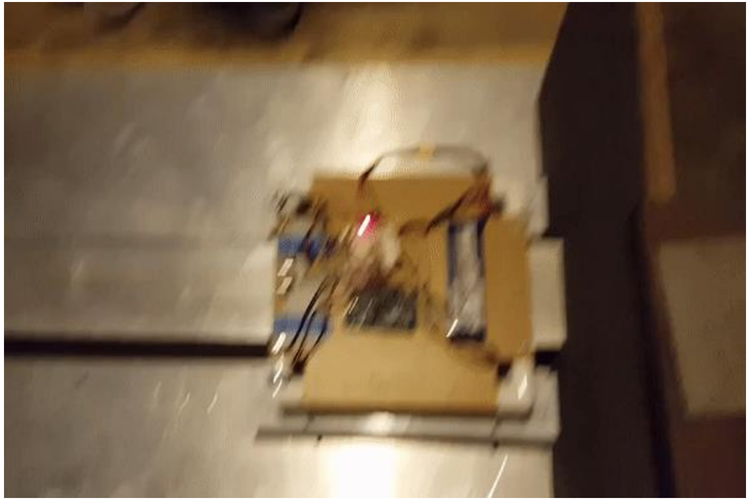
- Scaled down prototype 4 maglev engines and 4 servos
- LiPo battery powers servos and engines
- ESC controls servos and engines using PWM signals from the microcontroller



Maglev Prototype Progress

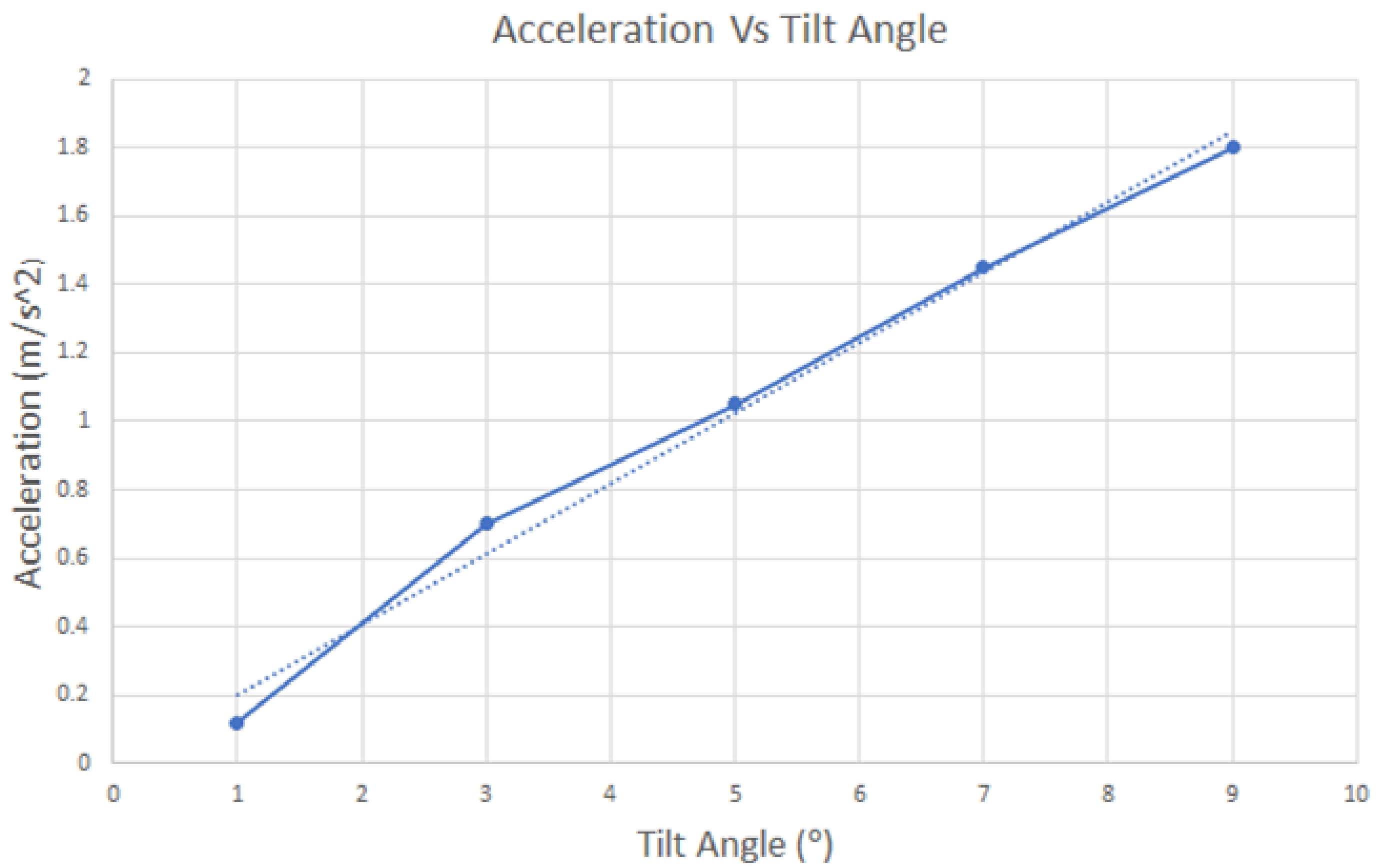
By: Alex

- Used Arduino to test prototype
- Controls Testing
  - Timing profile
  - Sensor feedback using ultrasonic sensor
- Currently integrating PCB to replace the Arduino



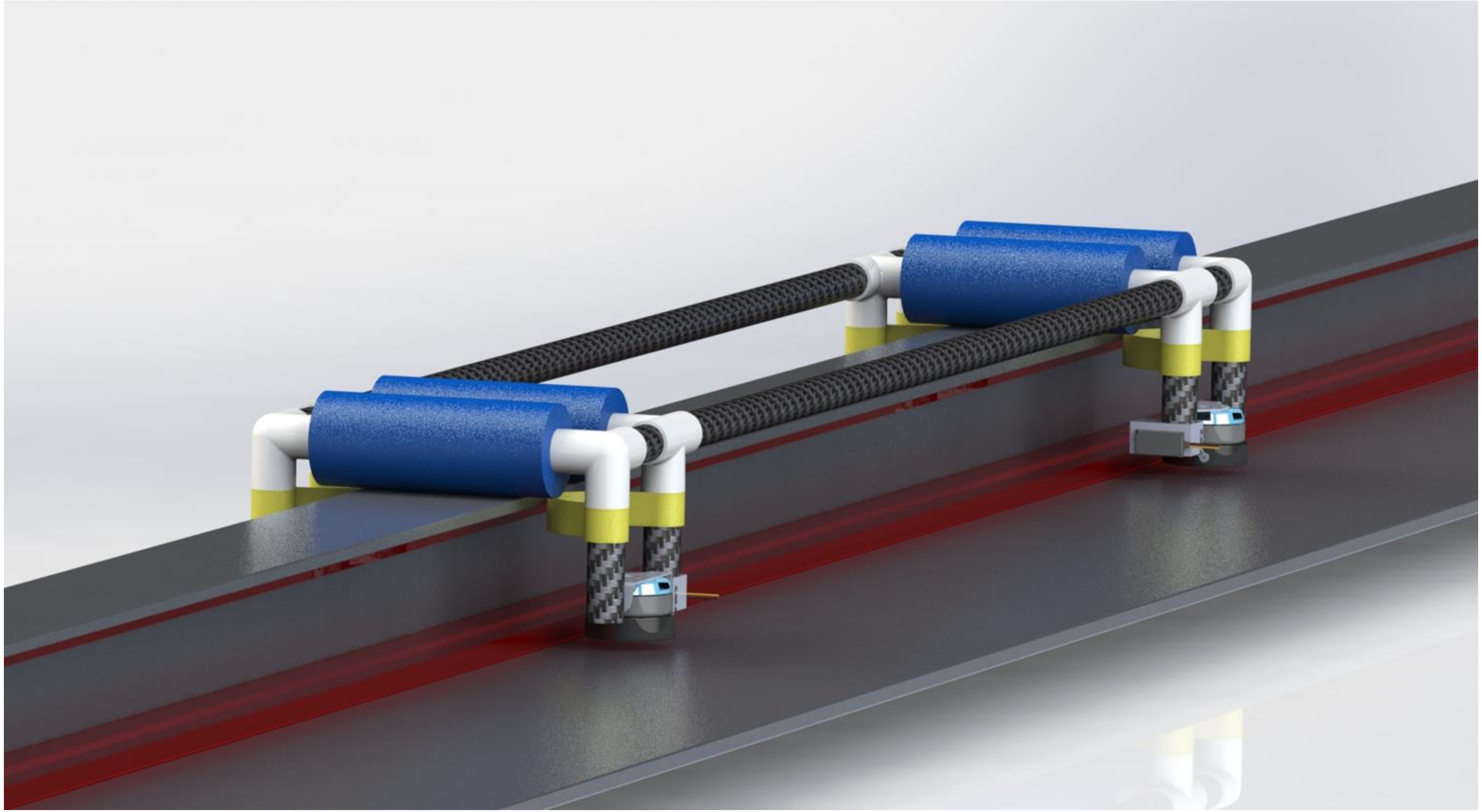
Maglev Motor Testing

By: Alex



Maglev Prototype Progress

By: Edsel



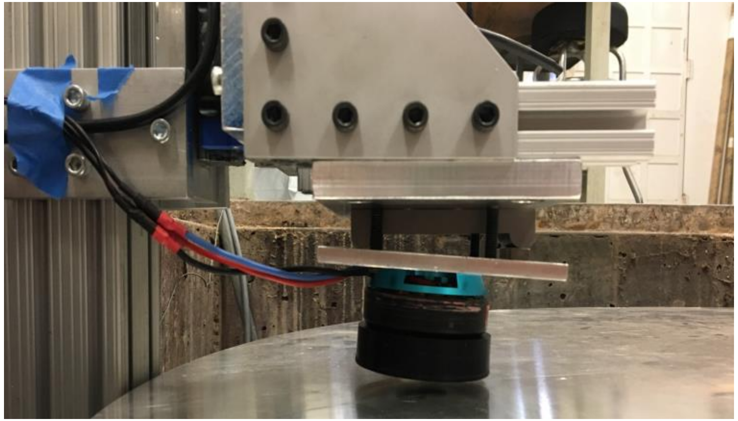
Translational Rig Testing

By: Xingchen, Jack D.

- Aluminum disk simulates translational motion
- Actuator adjusts height
- Sine bar adjusts angle

Updates:

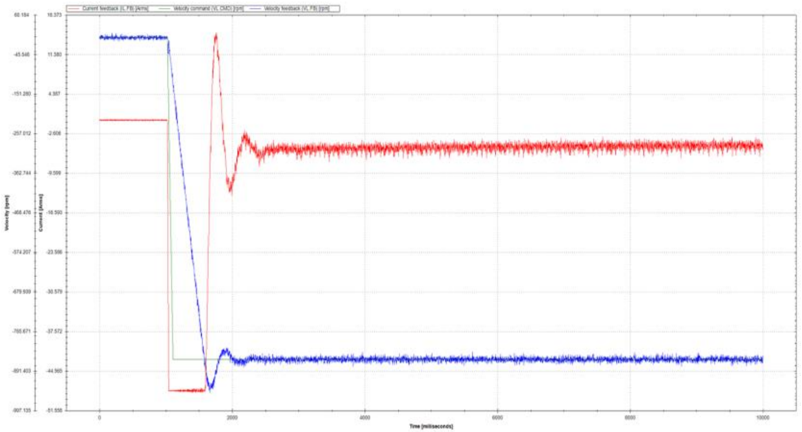
- Translational Test Rig Ready
- Mini-maglev testing in progress
- More extensive testing to come

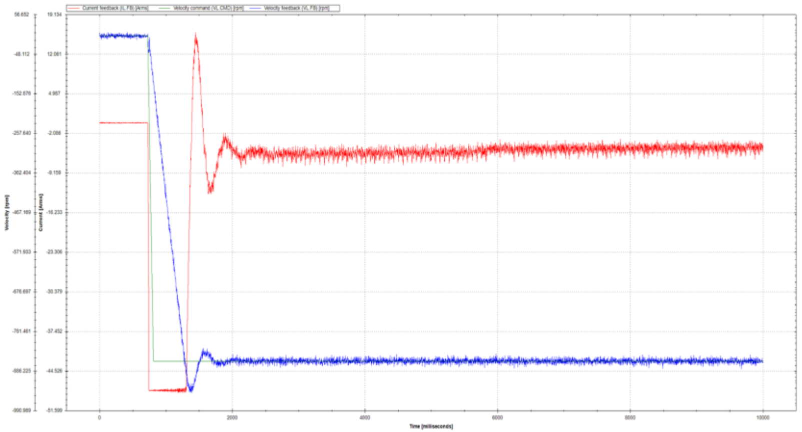


Collecting Data

By: Jack D.

- Vary height, angle, and speed
- Record load cell data to obtain lift force
- Collect motor current feedback to calculate torque exerted on disk by maglev
- MATLAB program to calculate resultant thrust force

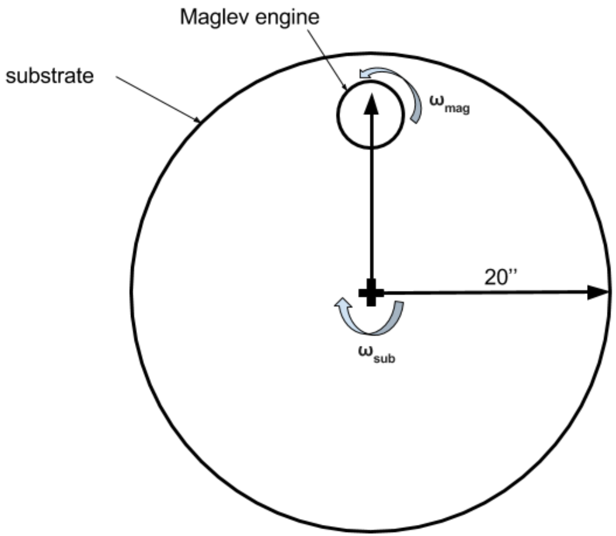


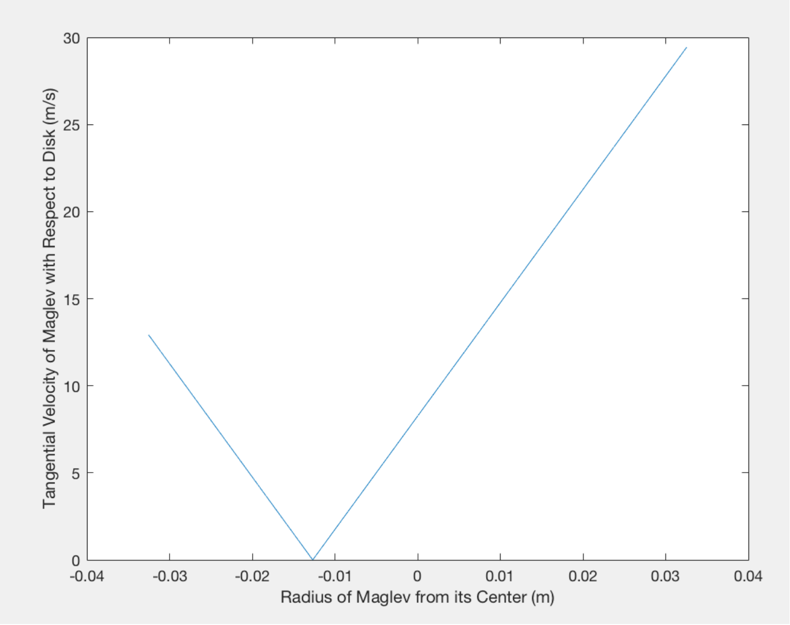


Analyzing Data

By: Pedro

- The velocity analyzed was the velocity of the Maglev engines with respect to the disk. The velocity vectors were treated similar to a "distributed load" to find a resultant and centroid.
- The linear velocity of the disk were subtracted from the Maglev engine's linear velocity.



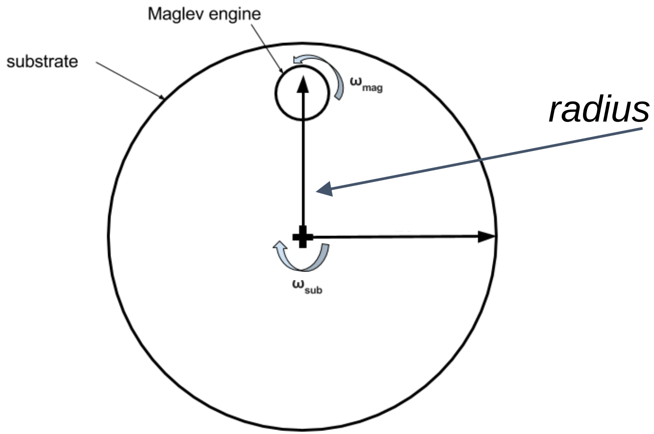


Analyzing Data

By: Pedro

- We can then use the equation to find the centroid of the load which will be the location where we can apply the basic torque equation.

$$x_S = \frac{\int_0^b x\, w(x)\, dx}{\int_0^b w(x)\, dx}$$

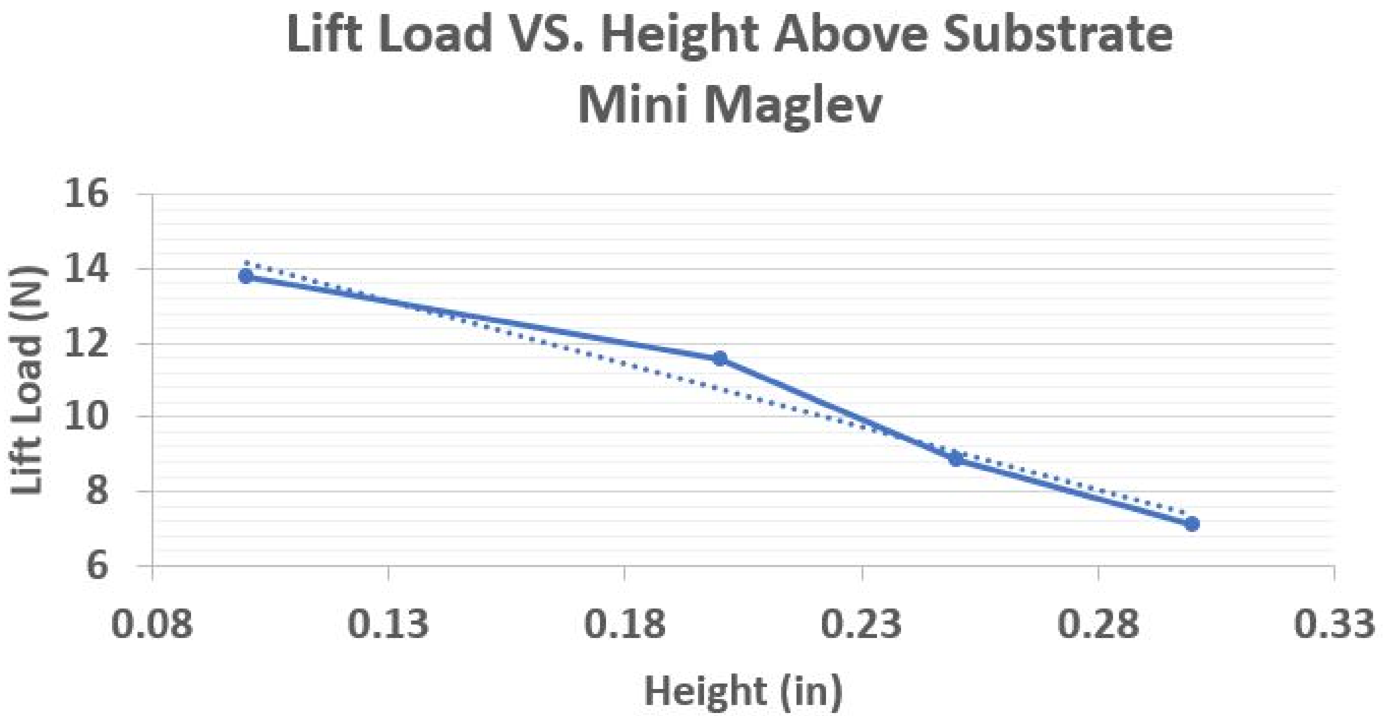


$$\tau_{in} = k_m \times I \qquad F_{drag} = \frac{\tau_{drag}}{radius}$$

τ=torque
k_m= Motor Constant
I= Current

Magnetic Lift Data

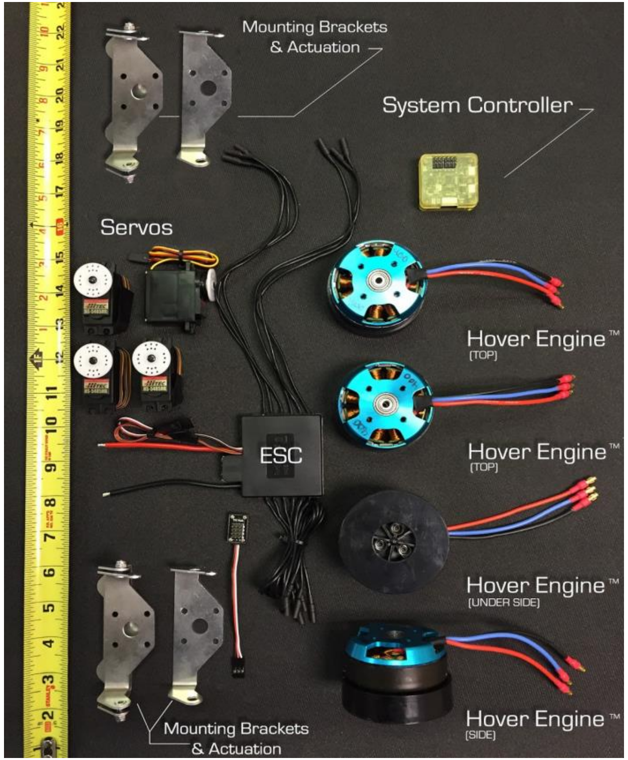
By: Xingchen



Custom Maglev Manufacture

By: Andrew

- Currently there are no backups in case of failure.
- Our solution is to design and manufacture custom maglev engines.
- Goal of 10 total custom engines, 4 for the final pod, 4 for potential addition, and 2 for backups.
- The design of these custom motors are meant to replace the HDK maglev engines, allowing current subsystems to continue prototyping with the HDKs and make minimal changes to accommodate for the custom engines.

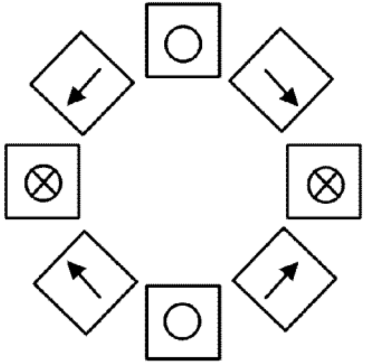


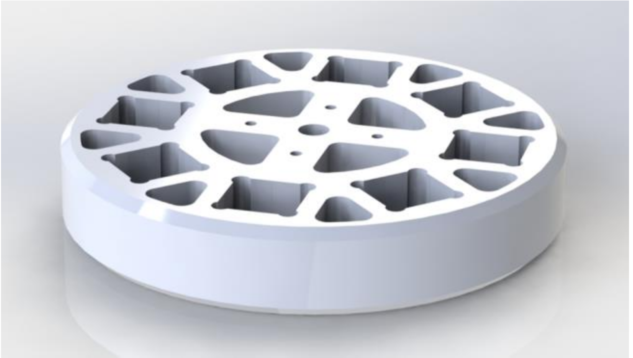
Custom Maglev Manufacture

By: Andrew

Specifications for Custom Engine:

- Max Voltage: 28.8 V
- Max Current: 24 A
- Max Power: 680 W
- 8* ½ inch cubic N52 Neodymium Magnets
- 3-inch diameter Delrin halbach array housing

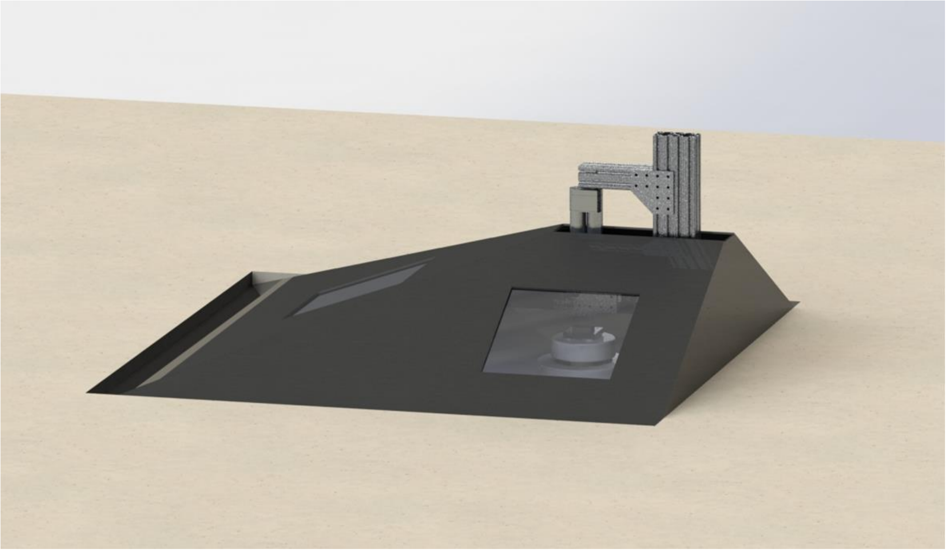




Custom Maglev Testing

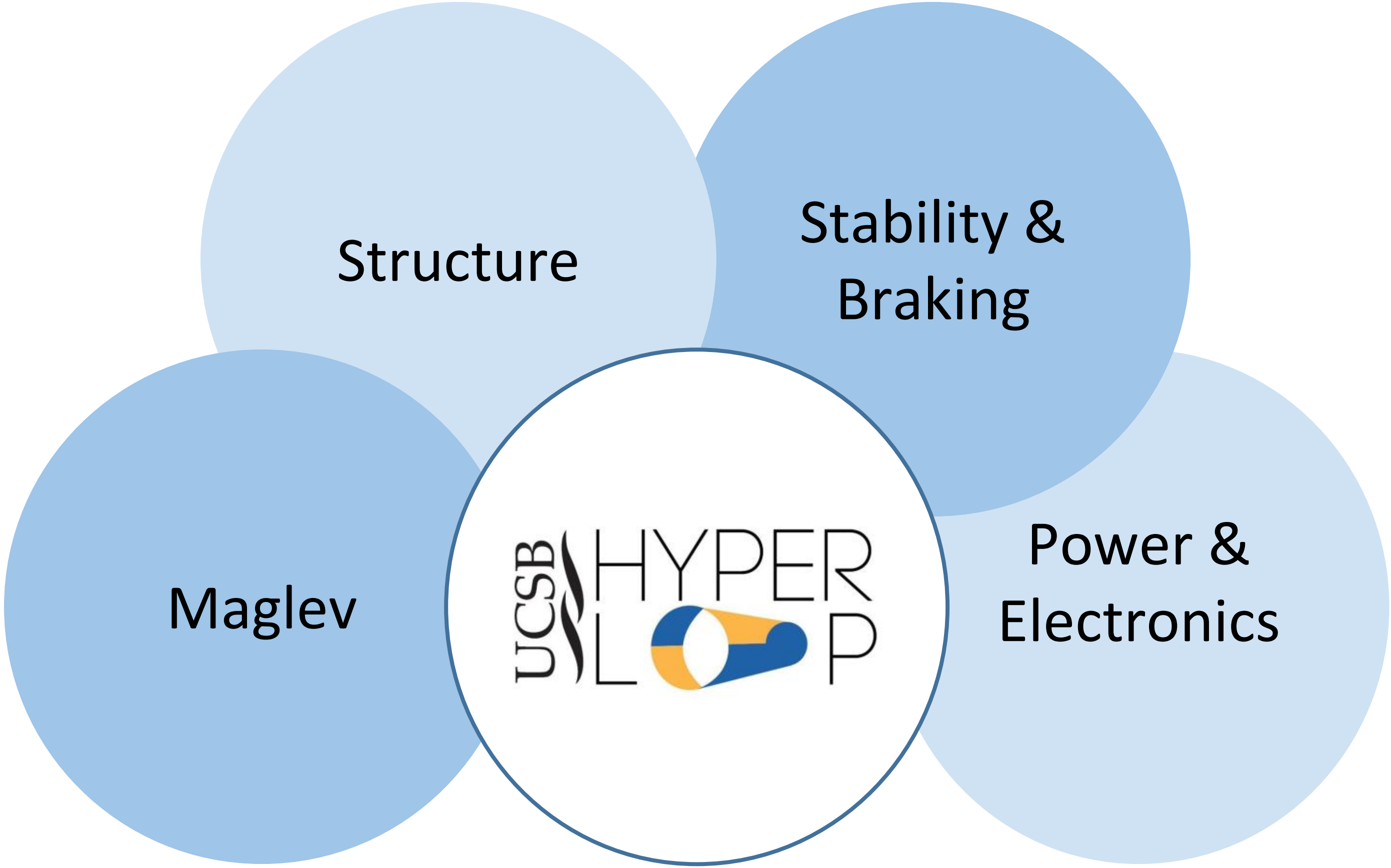
By: Andrew

- Bunker Cover
  - 8 gauge sheet steel
  - Cutouts for acrylic plates
- Spin up custom maglev to 6000 rpm (or failure) in increments of 500 rpm for 1 min.
- Engines are classified safe to use only after 5 successful tests to 6000 rpm.



System Design

By: Nate

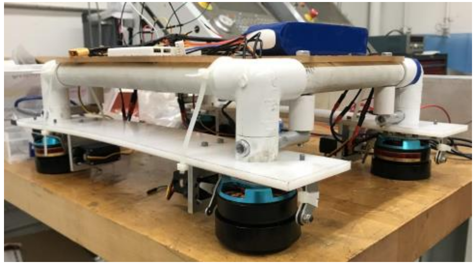


Structure

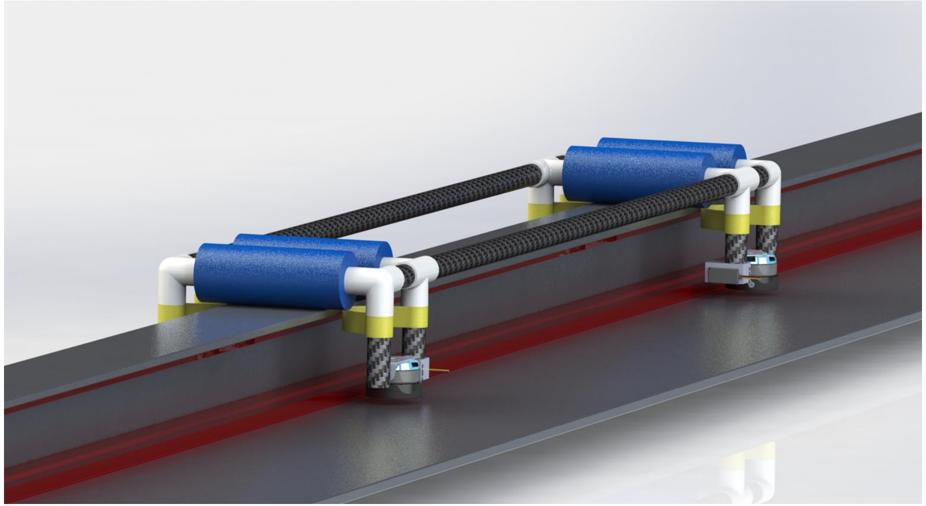
By: Ryan P.

Major Structure Design Requirements now focused around Mini Maglev Motors:

- Very Light (2.5 lb or less)
- Strong
- 5 ft. Minimum length



Mini Maglev Prototype



Full Scale Prototype using Carbon Tubing

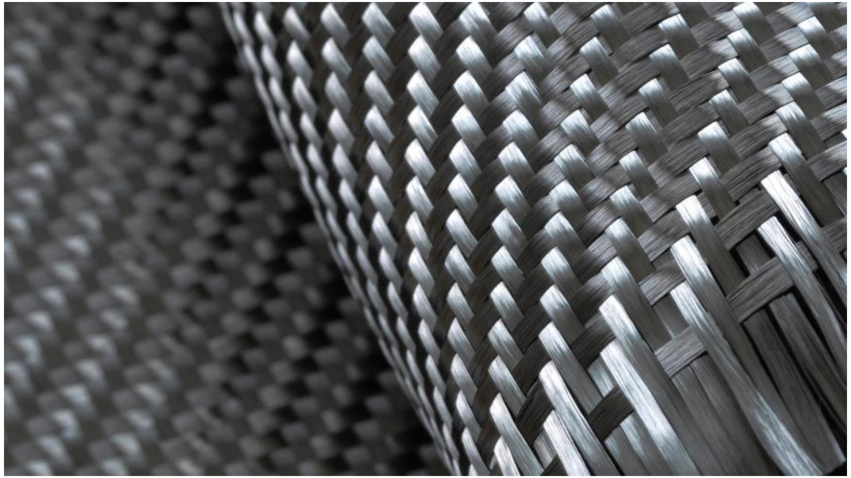
Structure

By: Ryan P.

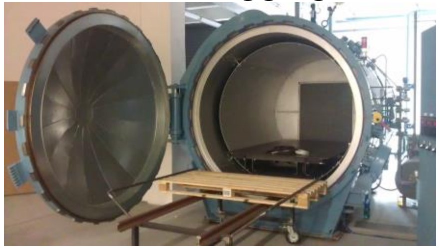
Carbon Fiber:

- Not just limited to Tubing/Truss structures.
- Met with Composites One Rep. to learn about different processes

COMPOSITES ONE®



Vacuum Bagging



Autoclave

Honeycomb

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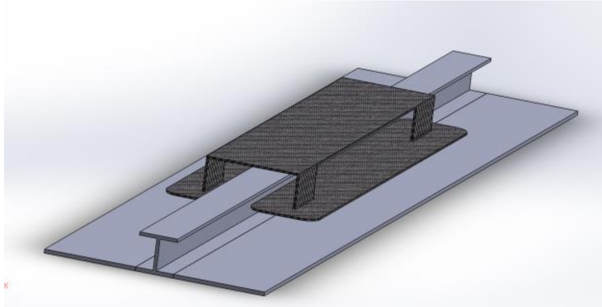
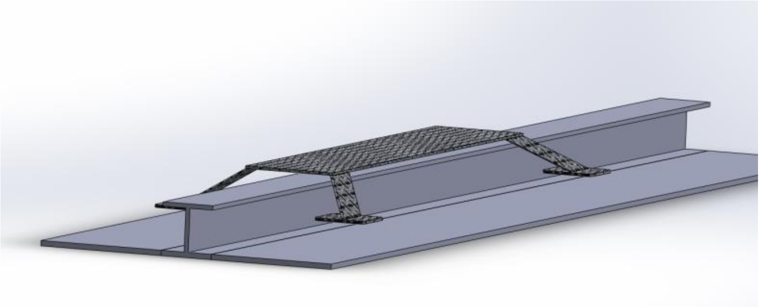
Structure

By: Ryan P.

Design Ideas:

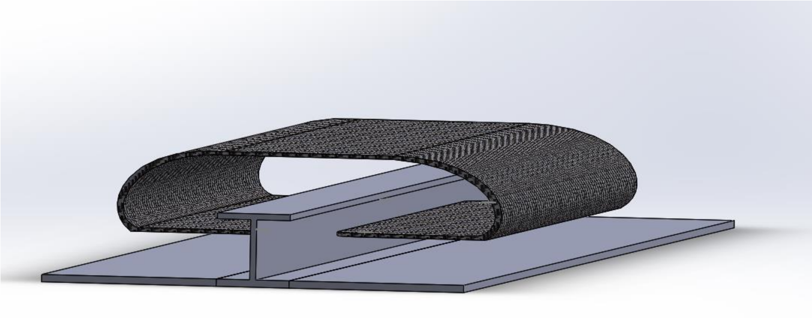


Concept 1



Concept 2

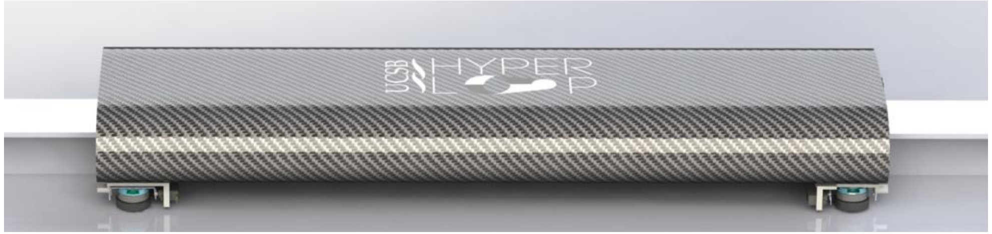
Fall Quarter Design

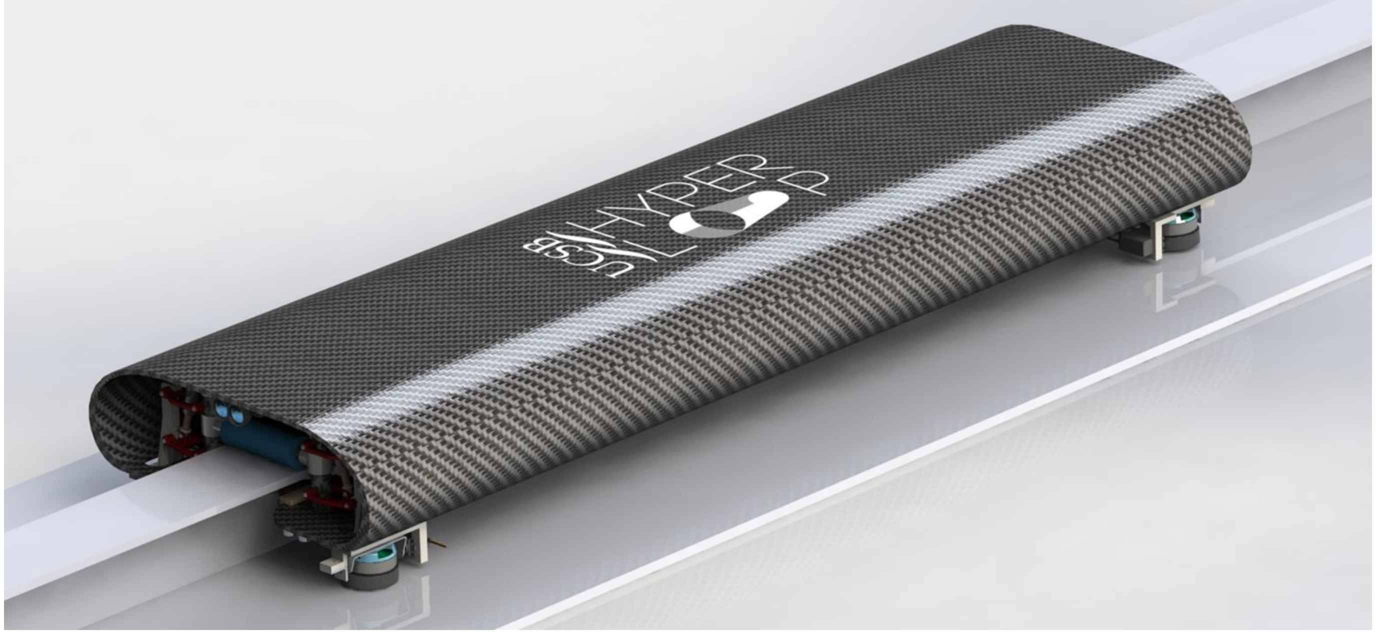


Concept 3

Structure

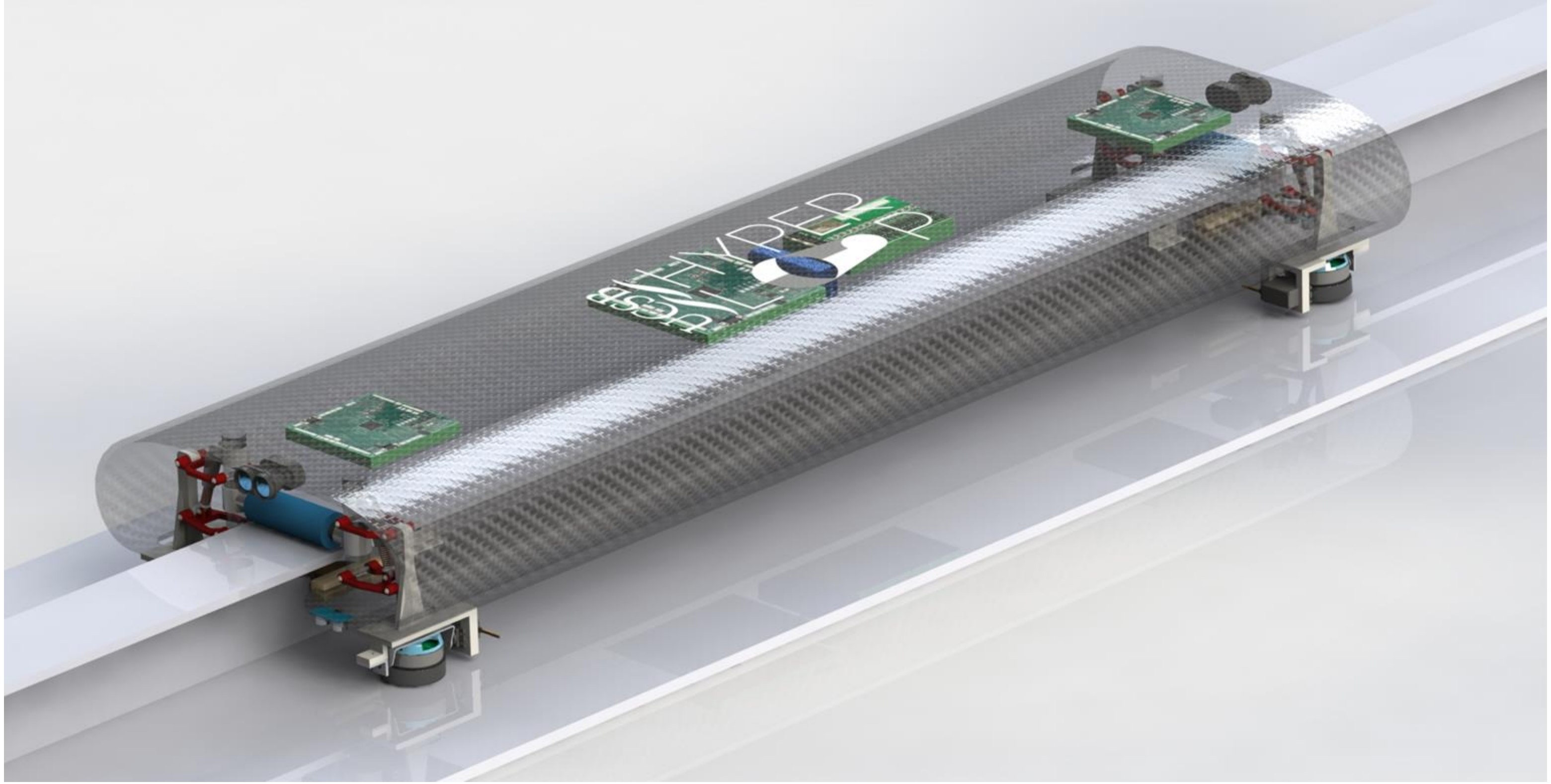
By: Ryan P.





Structure

By: Ryan P.

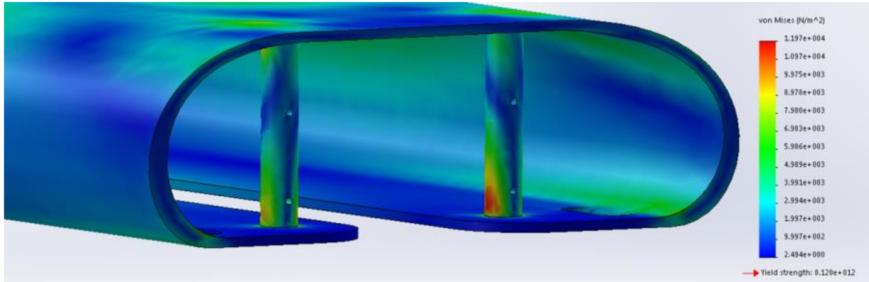


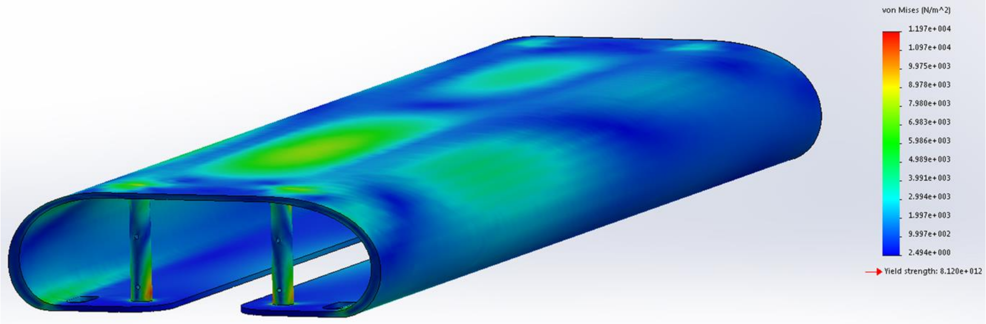
Structure

By: Edsel

FEA Case 1: Acceleration (max tilt)

- Concern: Base of pillars
- Forces: Lift, Drag, Weight, Thrust
- Results are magnitudes below yield strength





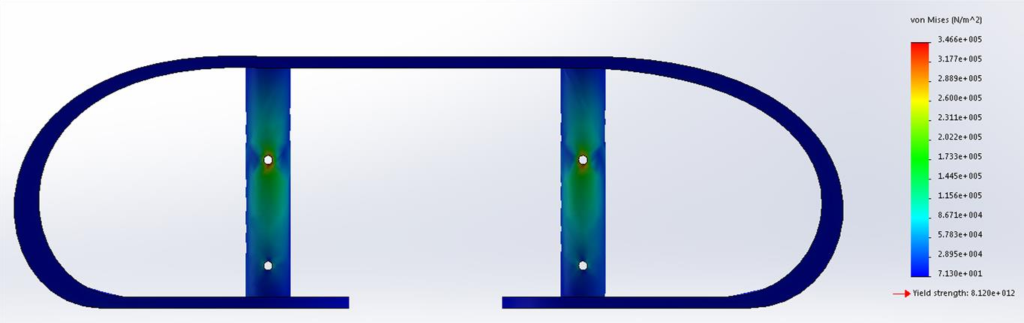
	Hand Calculated Value (KPa)	FEA Value(KPa)
Stress at base of pillar	11.8	12.0

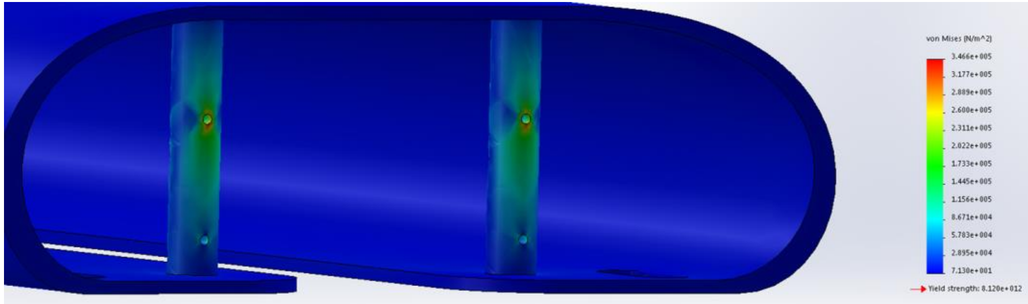
Structure

By: Edsel

FEA Case 2: Braking
(Worst case)

- Concern: Pillar’s brake stress
- Forces: Drag, Weight, Inertia, Braking
- Results magnitudes below yield strength





	Hand Calculated Value(KPa)	**FEA Value(KPa)**
Stress at pillar brakes	31.5	34.7

Structure

By: Ryan P.

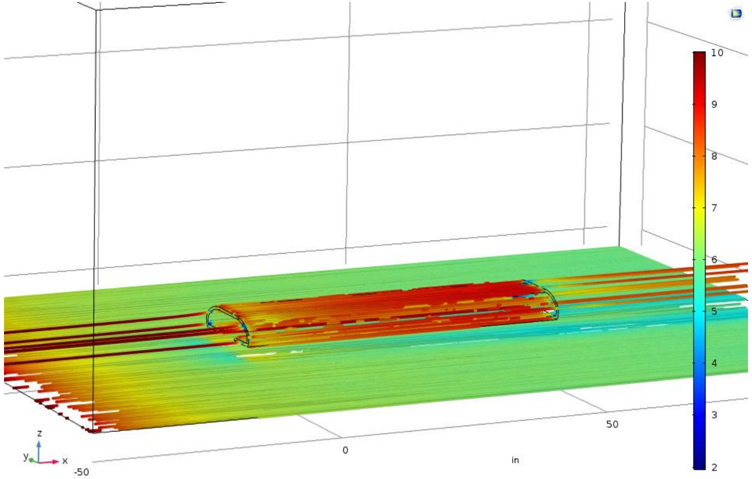
UC SANTA BARBARA engineering

CFD Analysis of Frame with and without Capped Ends at 10m/s:

<u>Open Ends</u>

Drag Force: 0.58 N

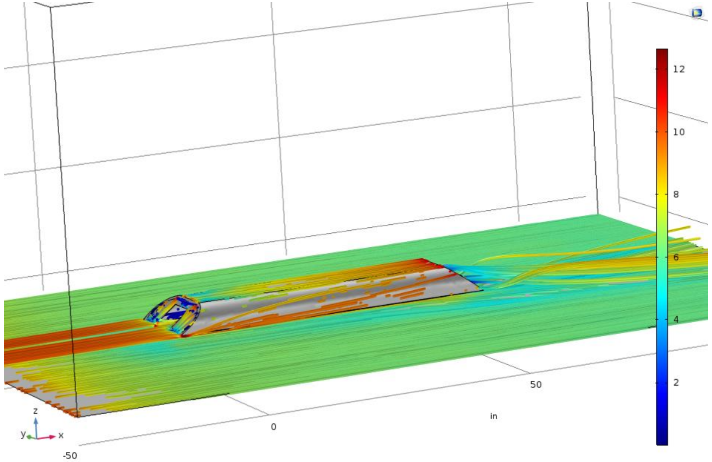
Vertical Force: -0.44 N



<u>Capped Ends</u>

Drag Force: 1.54 N

Vertical Force: -4.64N



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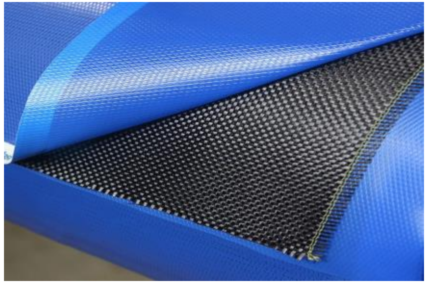
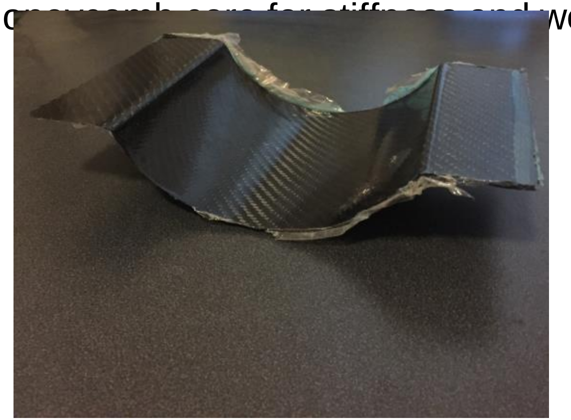
Structure

By: Ryan P.

Construction:
- Looking at using Prepreg Carbon Fiber (pre-impregnated resin)
  - Cured only under heat and pressure, not ambient temperature
  - When uncured can be easily cut and laid
  - Honeycomb core for stiffness and weight


Prepreg Carbon Fiber


Example Piece


Prototype Mold

System Design

By: Nate

Structure

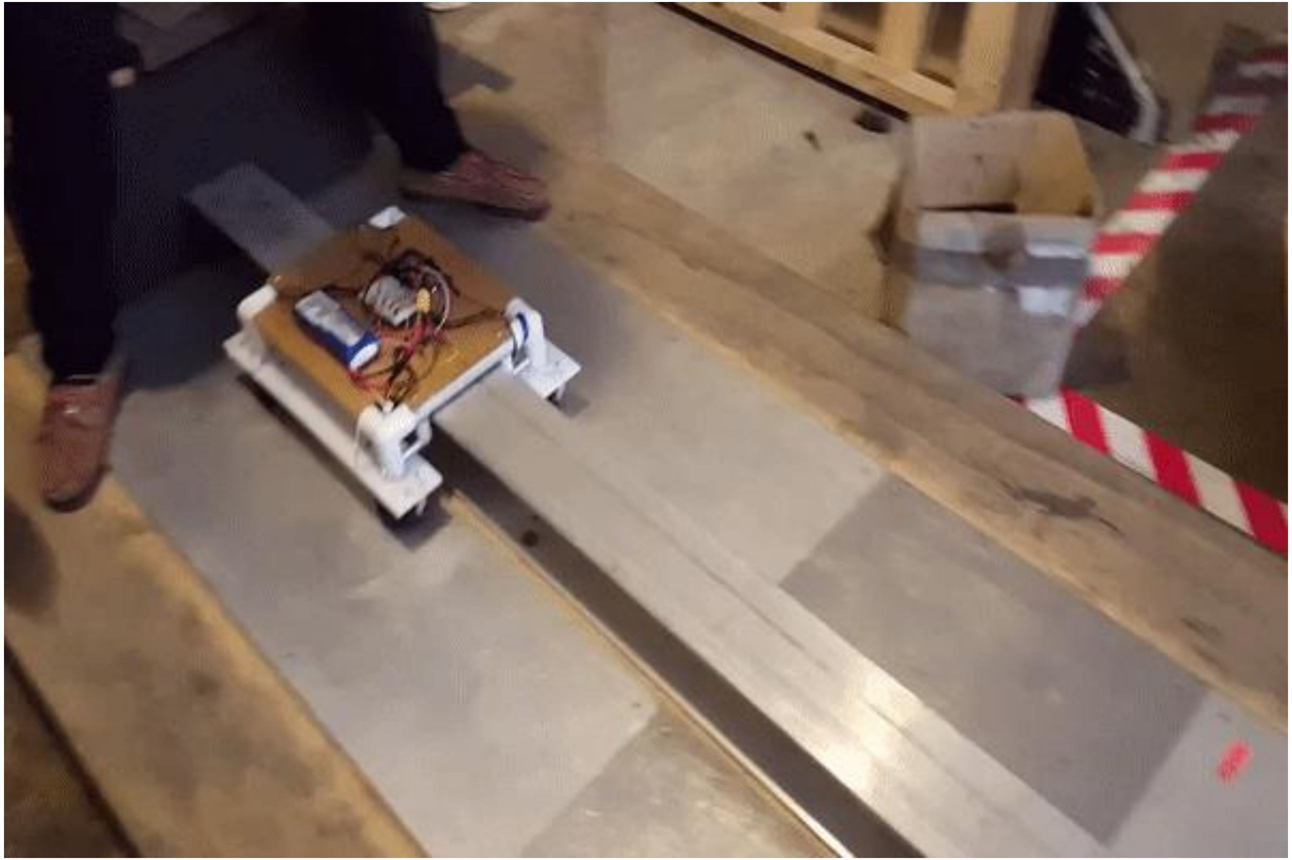
Stability & Braking

Maglev

Power & Electronics

Primary Braking

By: Gavin M.



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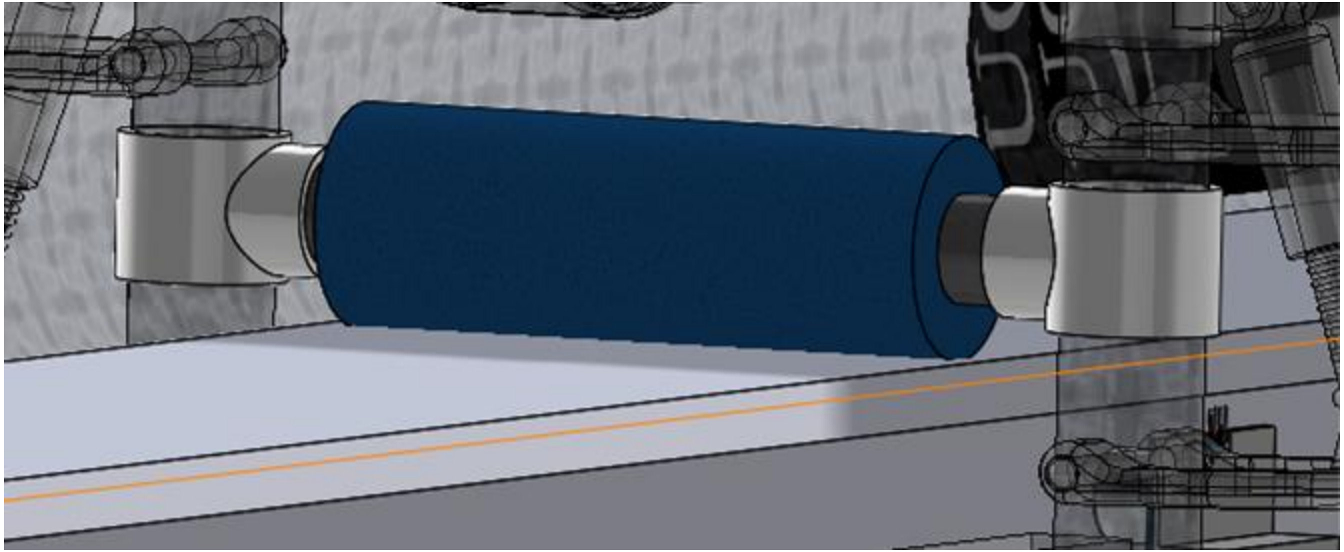
Secondary Braking

By: Gavin M.

- Only being used if the MagLev engines fail
- Rubber pads on pod
  - They cushion the landing as Maglev engines spin down
  - Generate frictional braking force



Secondary Braking Analysis

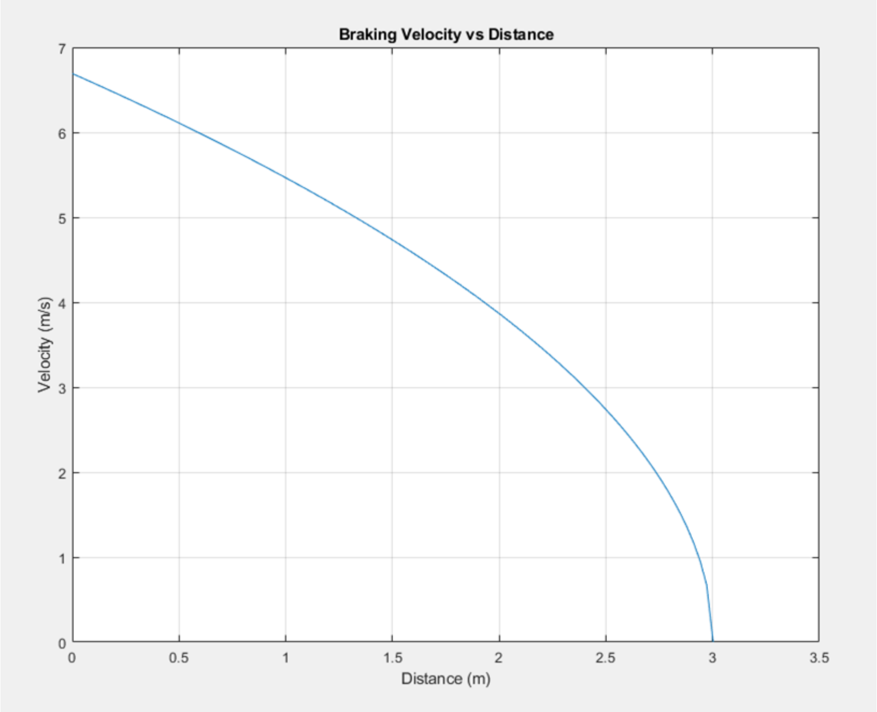
By: Gavin M.

Technical Specifications:

- Coefficient of Friction ~ 0.75
- Max Deflection ~ 2.87 mm
- Thickness of rubber ~ 1 cm
- Weight ~ 560 grams

Deceleration Data:

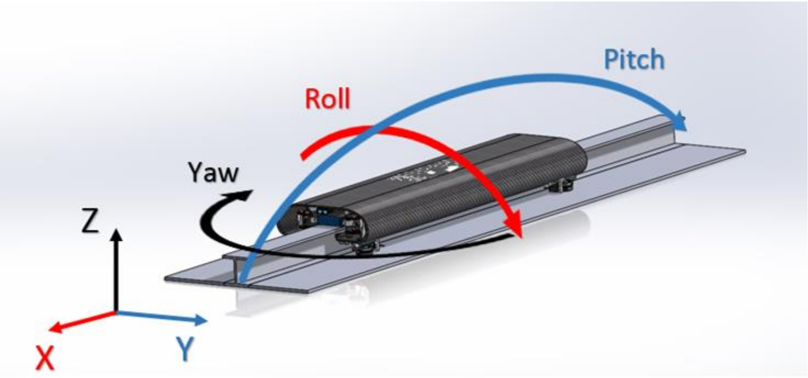
- Comes to a stop in ~ 0.90 s
    - Travels ~ 3 m



Stability

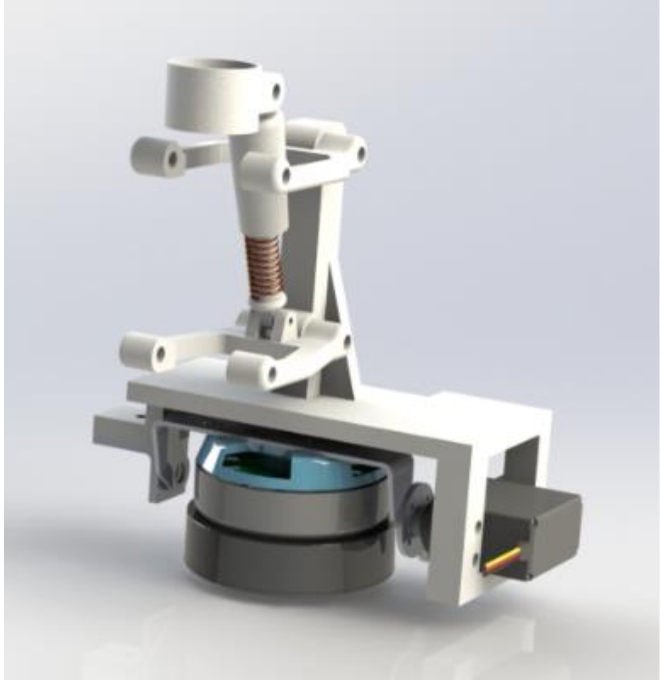
By: Gavin M.

Direction	Constraint
X	Maglev gimbal propulsion Failsafe friction rubber brake
Y	Leaf spring lateral suspension
Z	Double wishbone vertical suspension
Roll	Double wishbone vertical suspension
Pitch	Double wishbone vertical suspension
Yaw	Leaf spring lateral suspension



Vertical Suspension

By: Wesley C.



- Independent double wishbone suspension to maintain pod attitude
- 3D printed Nylon
- Simplified wishbone suspension
- Air piston damper
- Spring constant ~ 2000 N/m
- Weight per suspension ~ 350 grams

Total Weight: ~ 1400 grams

FEA Vertical Suspension

By: Wesley C.

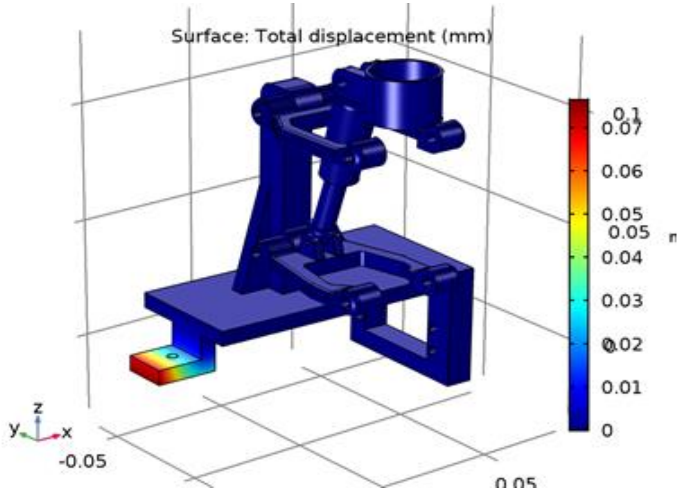


Figure: Maglev Support

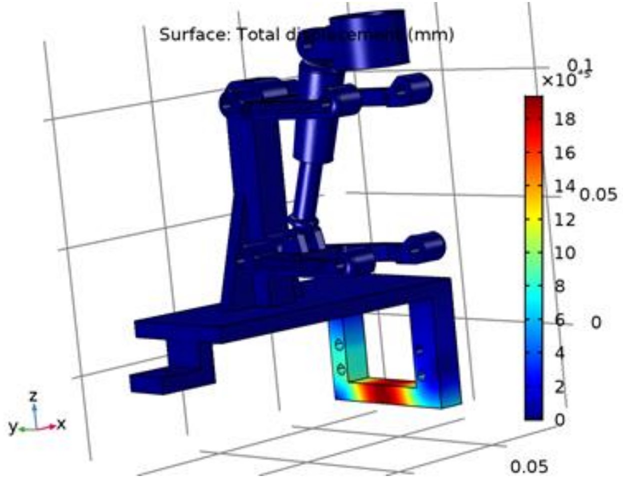


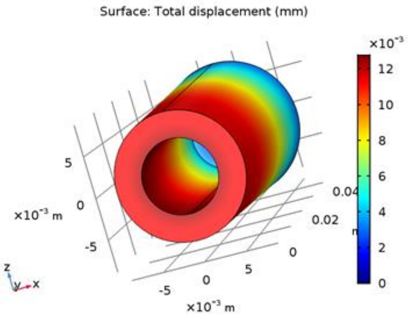
Figure: Servo Support

The displacements of the suspension are very small.

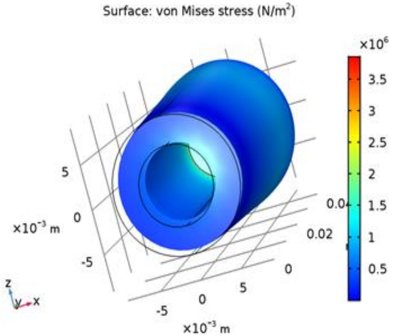
Sy = 2 x 10^9 Pa

FEA Vertical Suspension

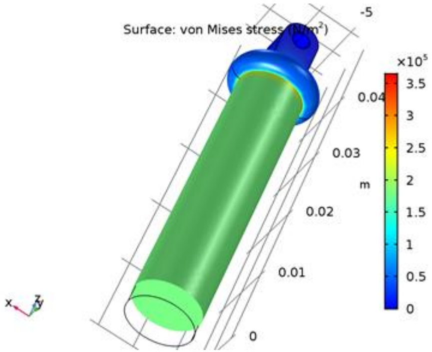
By: Wesley C.



Displacement of Cylinder



Stresses on Cylinder



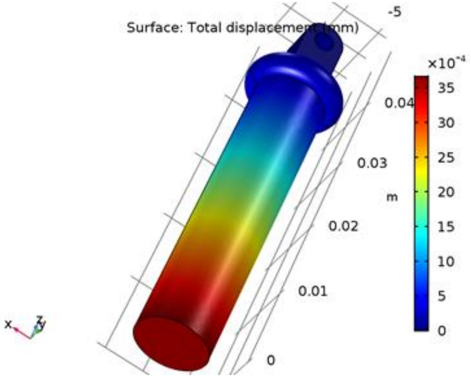
Stresses on Piston

<u>Hand Calculations</u>:

Boyle's Law:

$$P_1V_1 = P_2V_2$$

Stress in a Pressure Vessel: $\sigma = (P_2R\ ) / (2t) = 180$ kPA



Displacement of Piston

Sy = 2 x 10^9 Pa $\sigma < Sy$

∴ Will not yield

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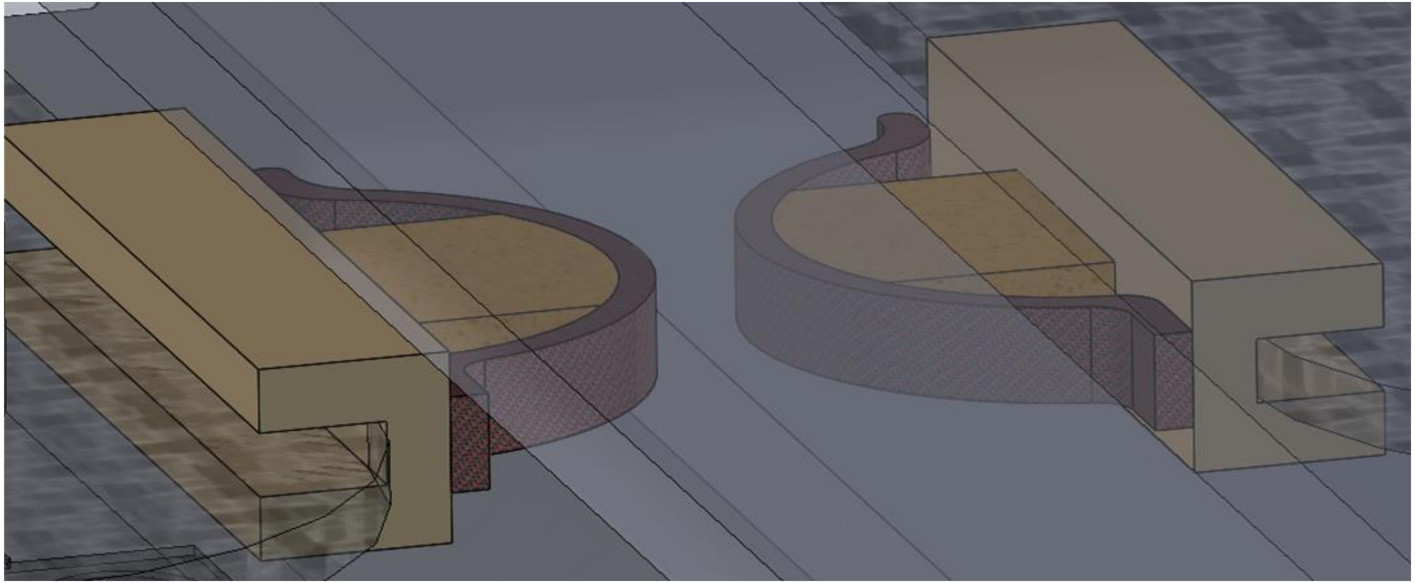
Lateral Suspension

By: Gavin M.

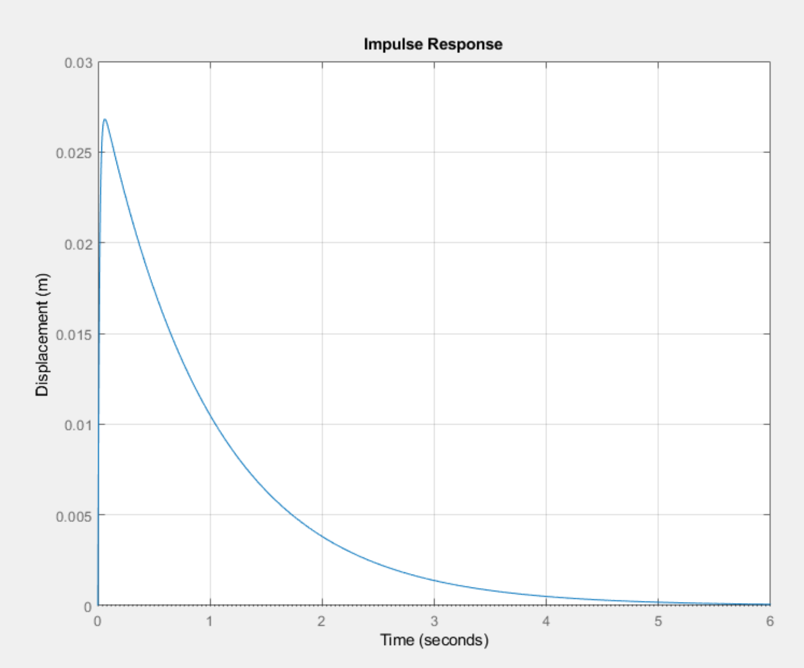
- Composite E-glass leaf spring
- Polyurethane foam block damper
- Teflon tape on the surface to minimize friction between spring and I-beam
- Weight per leaf spring ~ 30 grams

Total Weight: ~ 120 grams



Lateral Suspension

By: Gavin M.

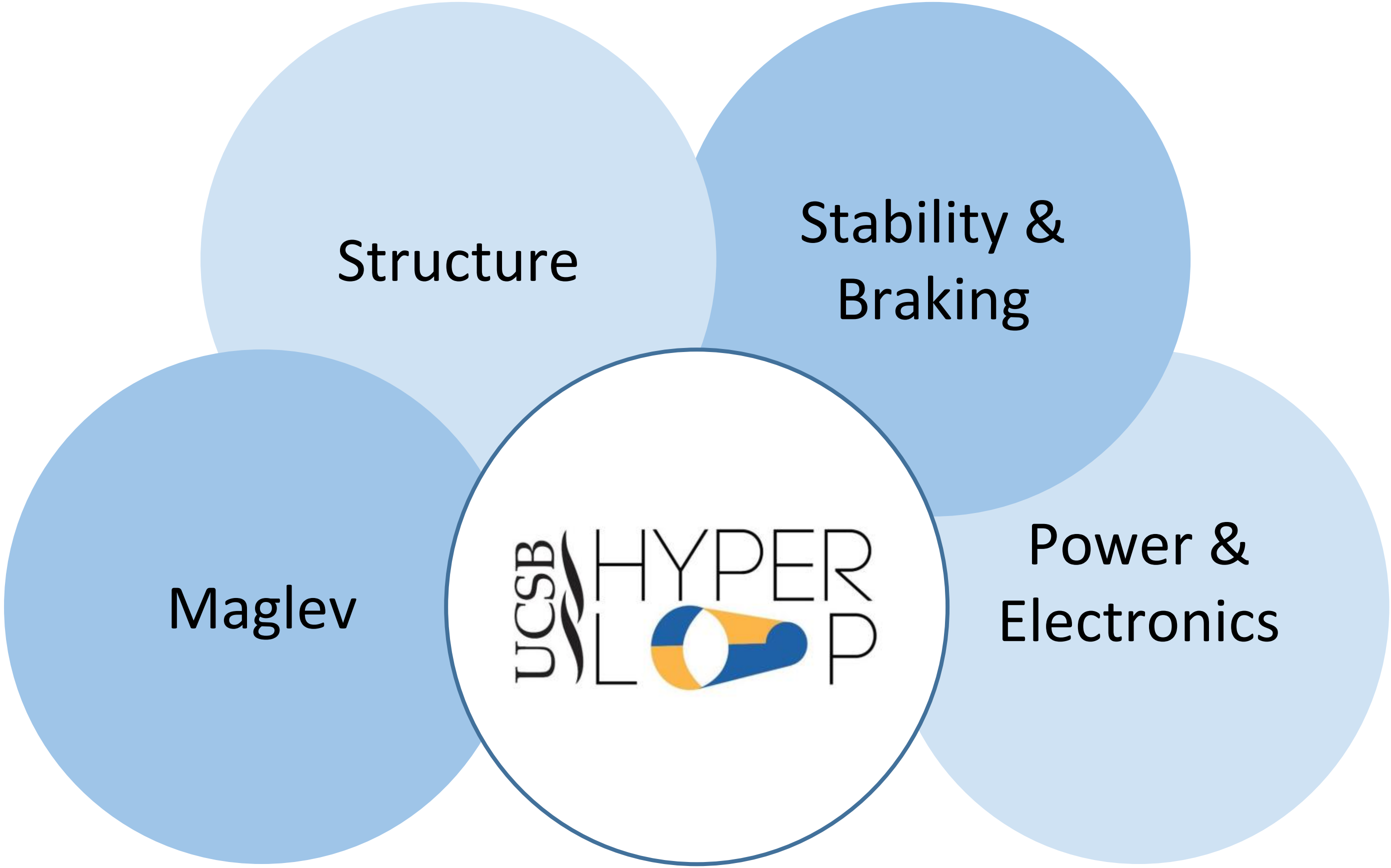


Damping Time ~ 3 s

- Expected forces on leaf spring only require a spring force with k ~ 20 N/m
- Polyurethane foam has a damping coefficient up to
  b ~ 40 Ns/m

System Design

By: Himangshu



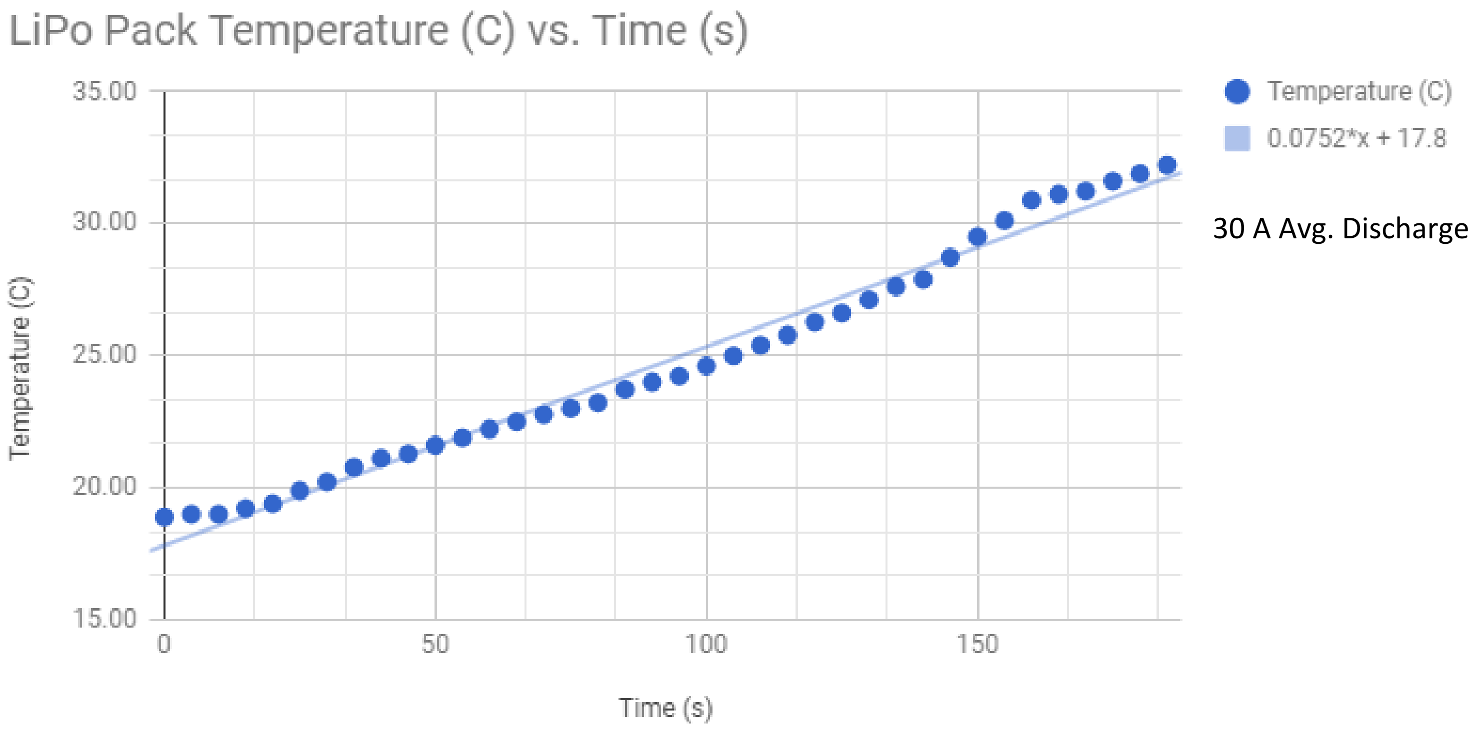
Battery Chemistry Decision

By: Himangshu

	Lithium Ion (NMC)	Lithium Polymer (CO)
Cells in Series	4	4
Cells in Parallel	4	1
Total Nominal Voltage (V)	14.8	14.8
Total Cont. Current (A)	120	99
Total Capacity (mAh)	6000	2200
Total Weight (g)	725	245
Power/Weight Ratio (W/g)	2.45	5.98
Total Cost per Pack ($)	65	30
Safe Temperature (°C)	0-70	0-60(external)

LiPo Temperature Test

By: Mihir

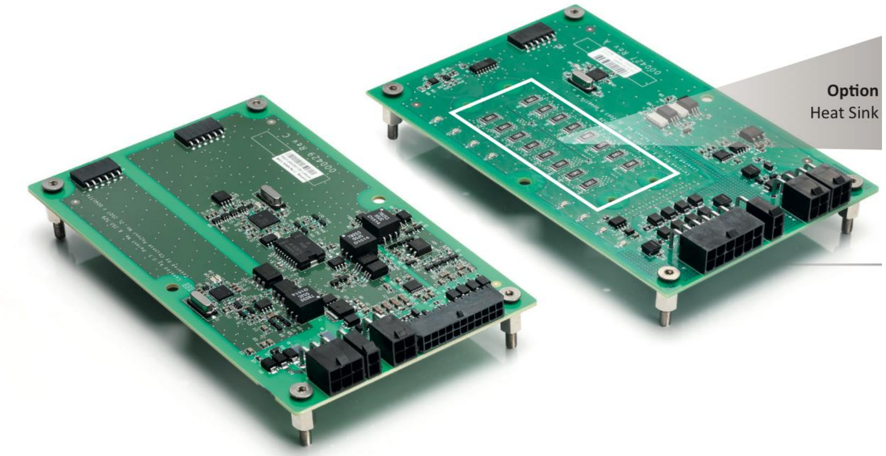


30 A Avg. Discharge

Battery Management System

By: Mihir

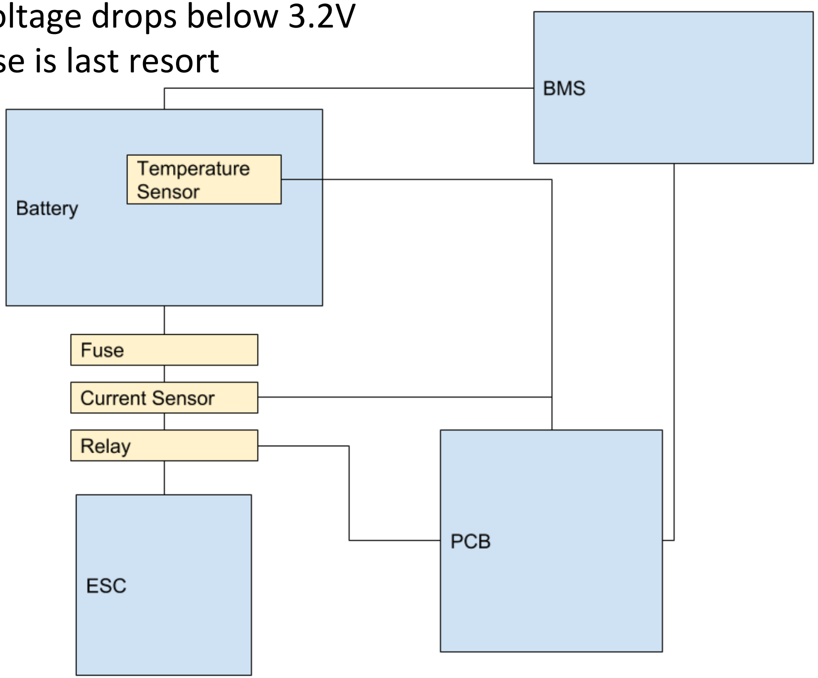
- **BMCU** (Battery Management Control Unit):
  - monitors performance parameters (pack voltage, shunt current, resistance, SoC, SoH)
  - RS232 for communication with PCB
  - inputs & outputs for event notification, connects to peripherals
- **LMU** (Local Monitoring Unit):
  - monitor and balance individual cells at up to 0.84A
  - monitor self temp(shunt temp during bleeding) and pack temp using onboard/external sensors



Safety Protocols

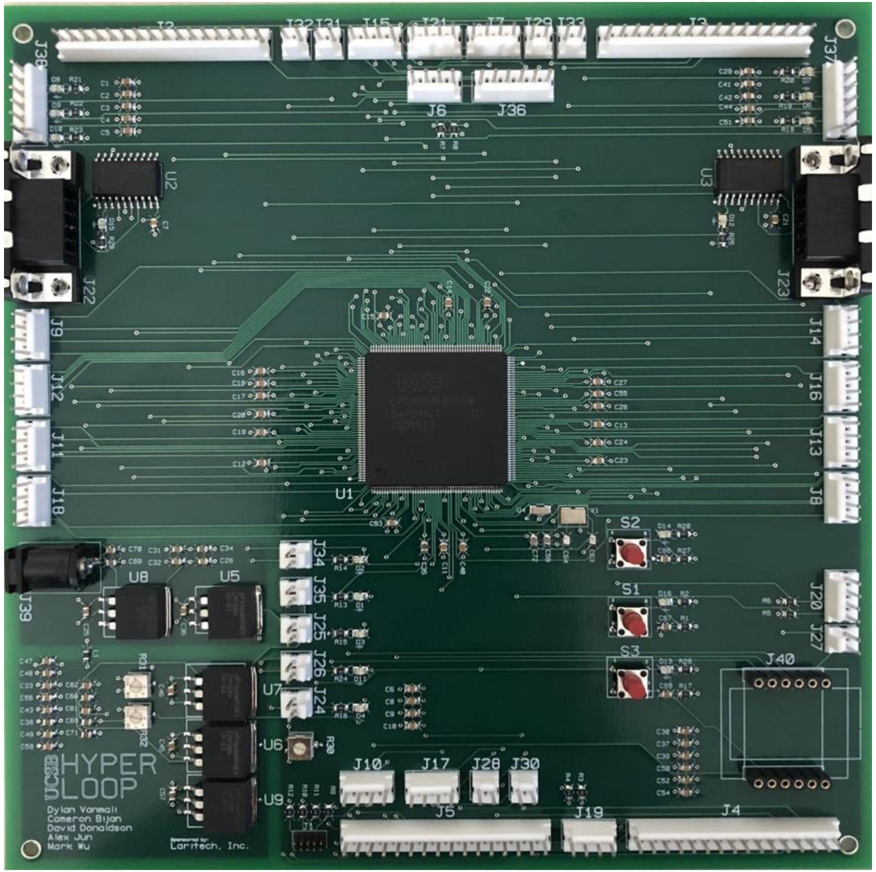
By: Himangshu

- **Relay**: PCB switches relay to physically connect/disconnect battery under normal operation
  - If current rises too far above 100A
  - If temperature of battery rises above 60C
  - If cell voltage drops below 3.2V
- **Fuse**: 130A fuse is last resort



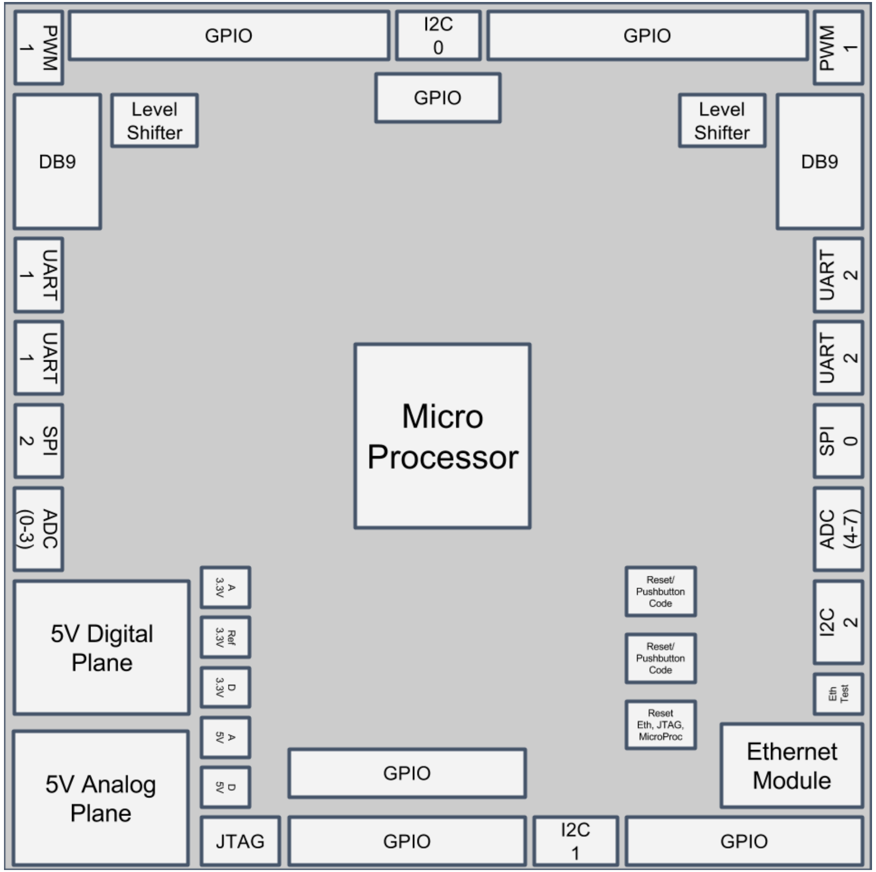
Main PCB

By: Dylan



Main PCB

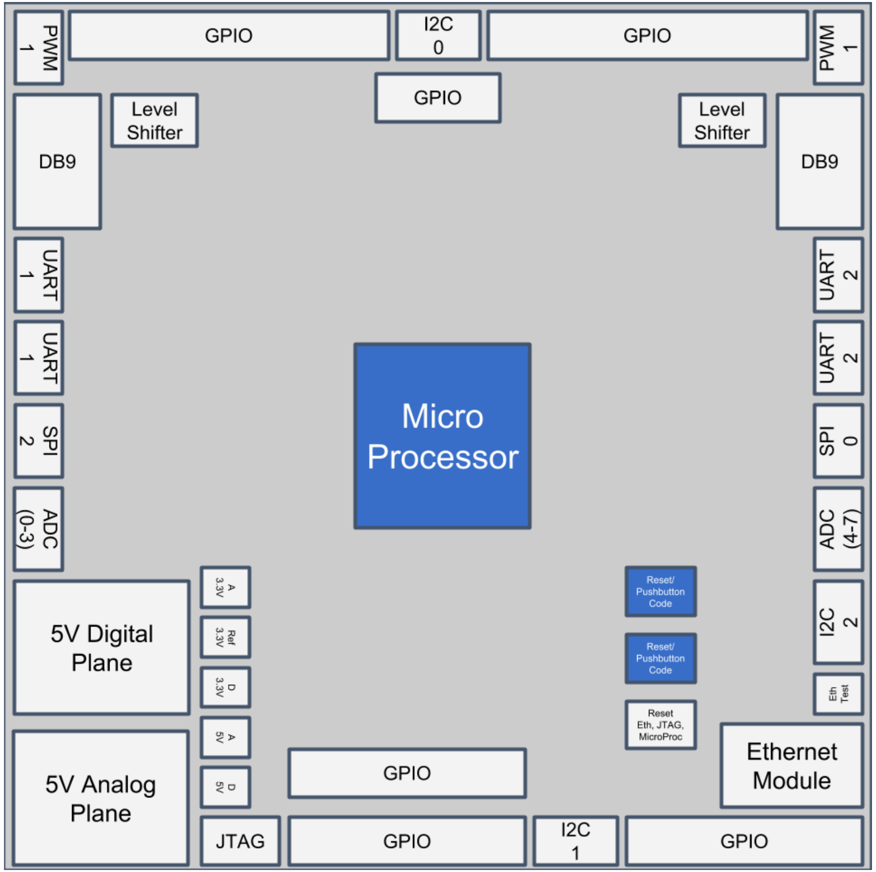
By: Dylan



UC SANTA BARBARA engineering

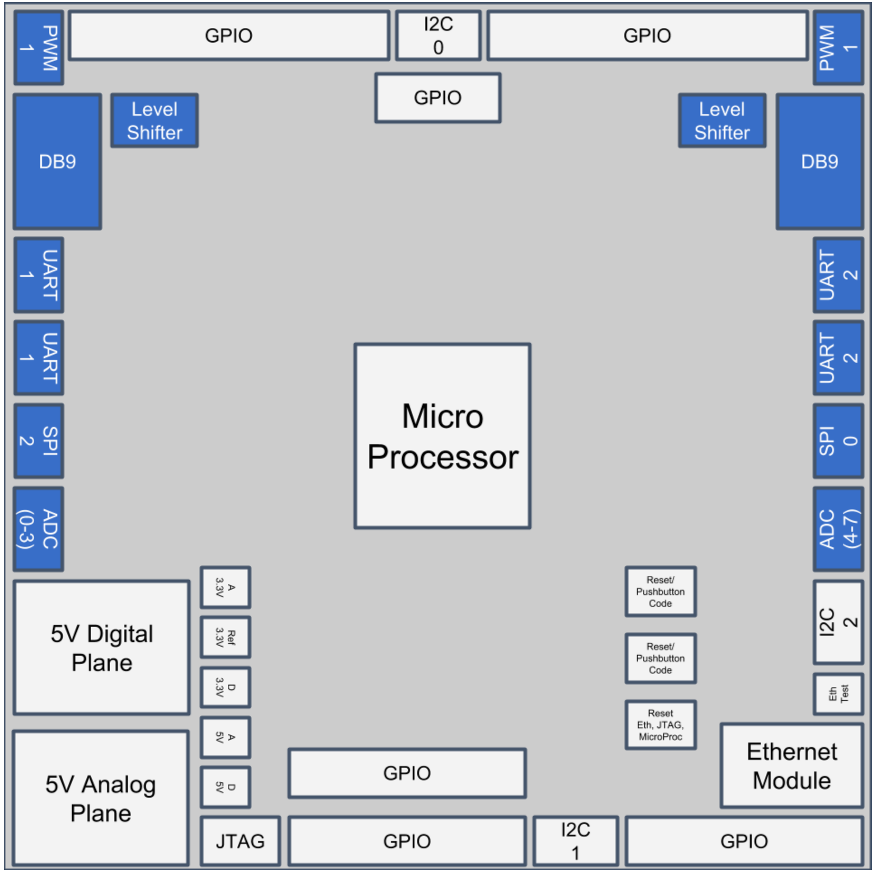
Computing

By: Dylan



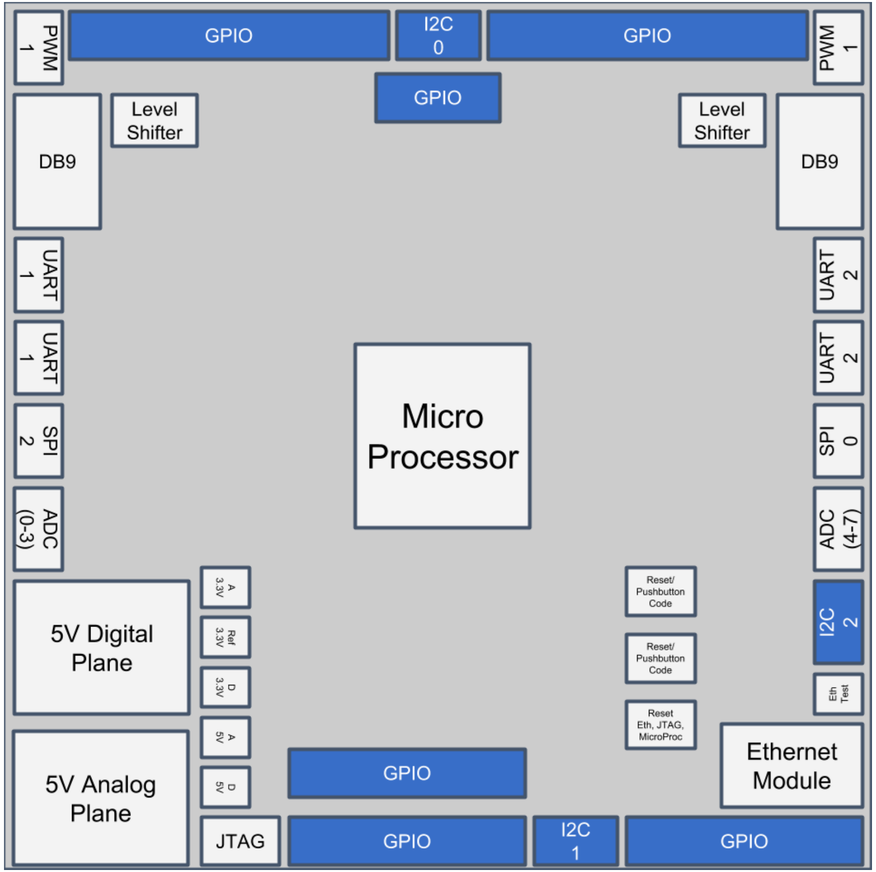
Communication Ports

By: Dylan



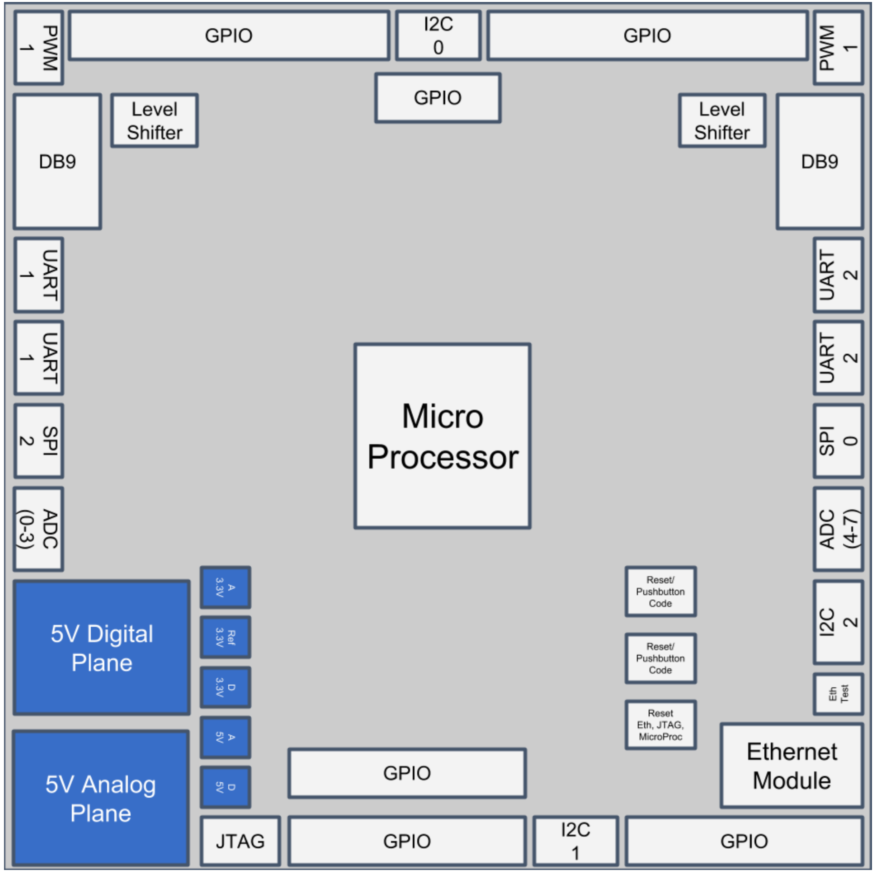
Local Ports

By: Dylan



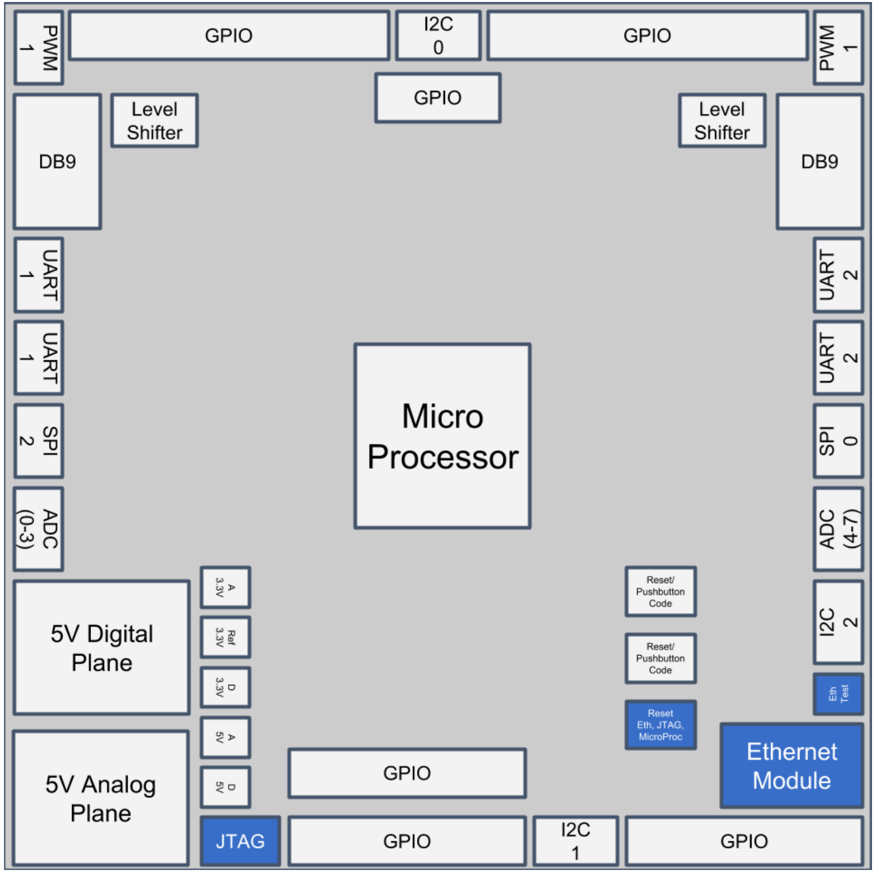
Power

By: Dylan



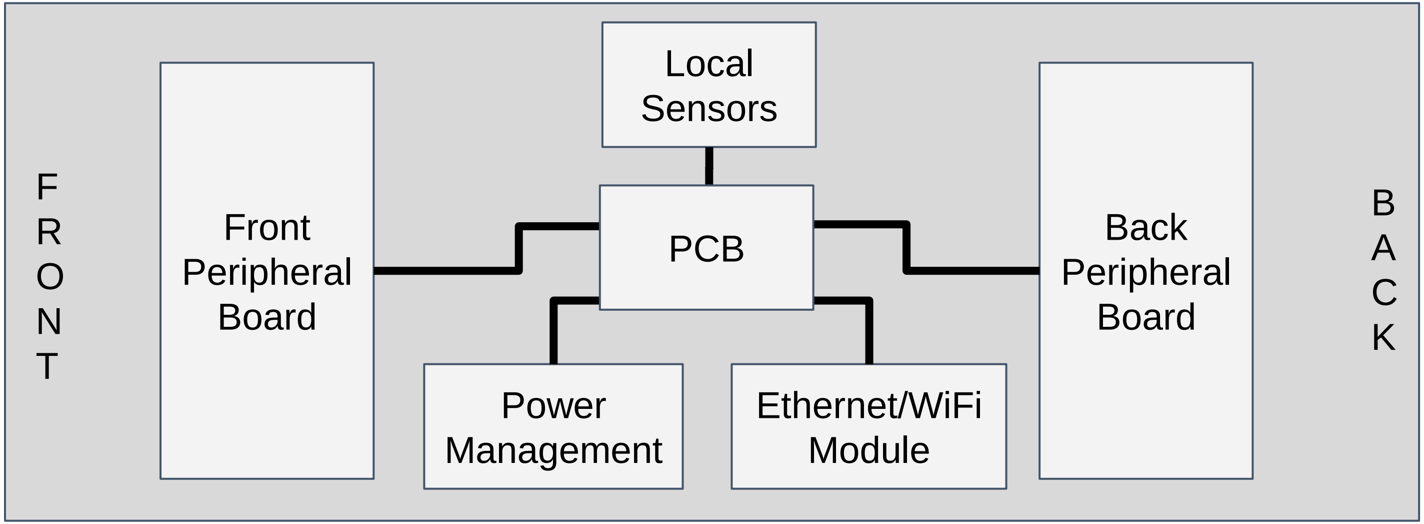
Programming and Wireless Links

By: Dylan



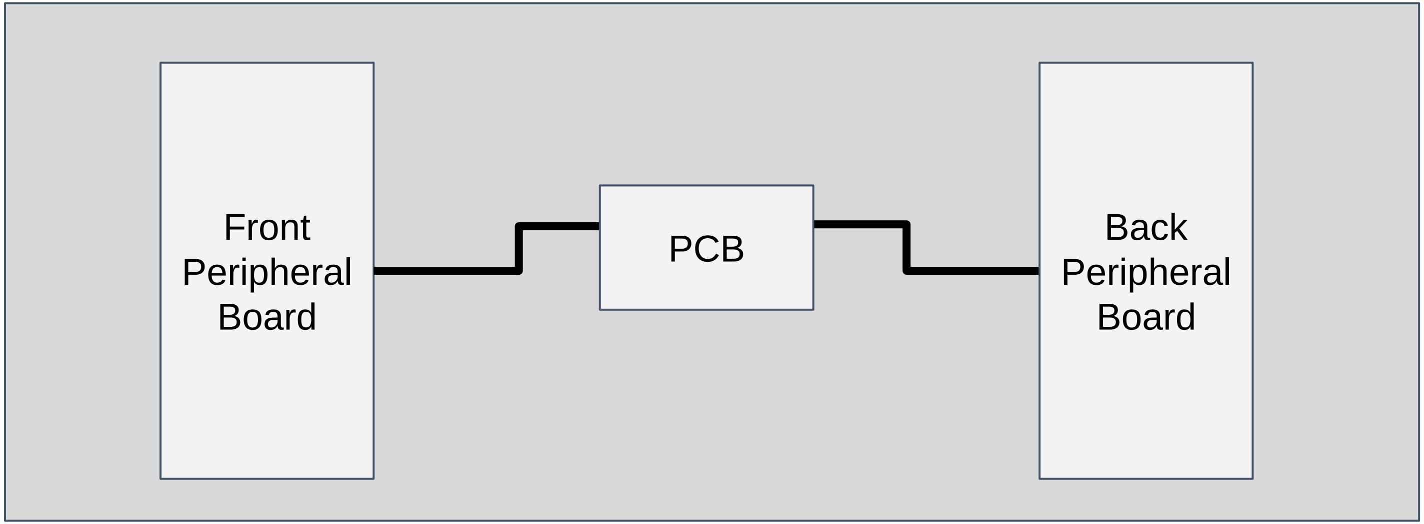
High-Level Electronic Scheme

By: Xiaochang



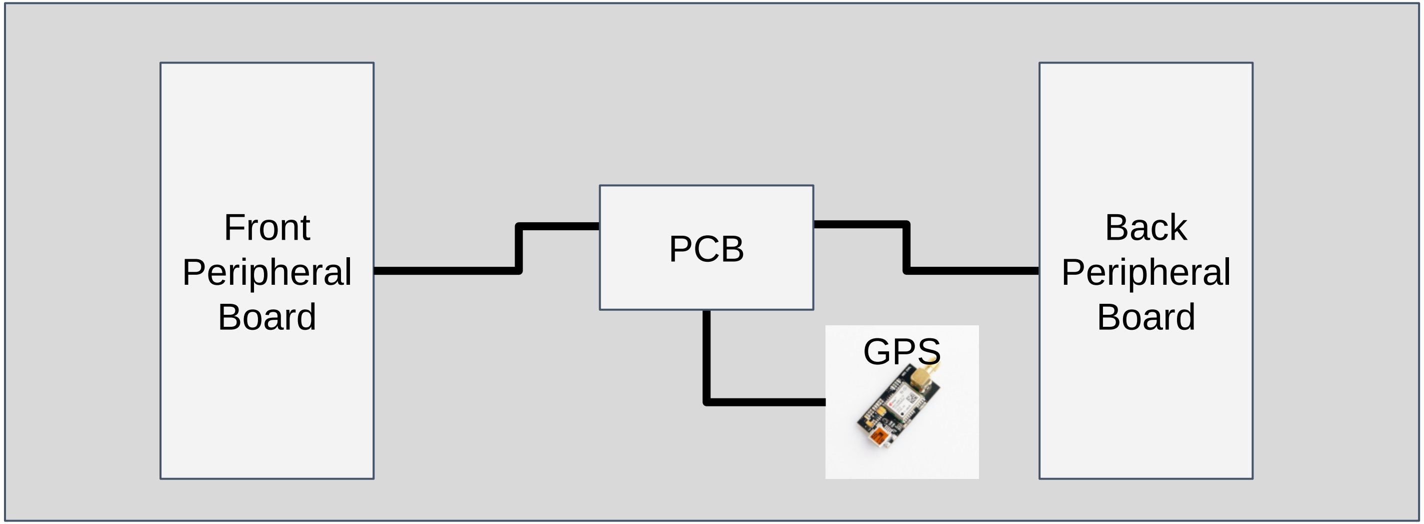
Sensor Locations

By: Cameron



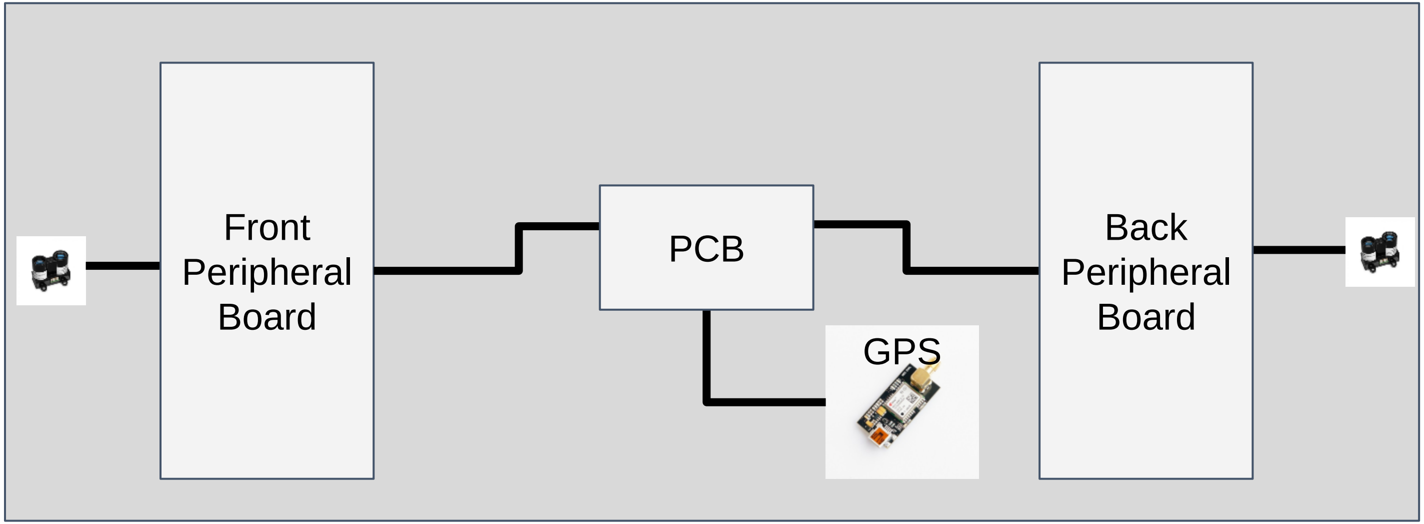
Sensor Locations

By: Cameron



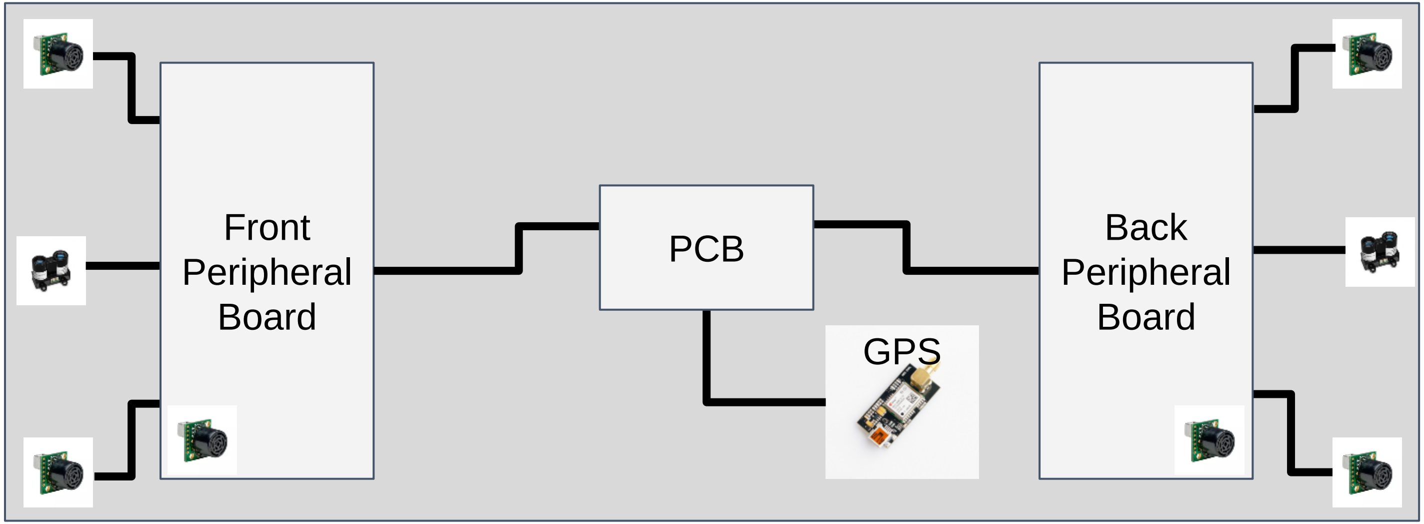
Sensor Locations

By: Cameron



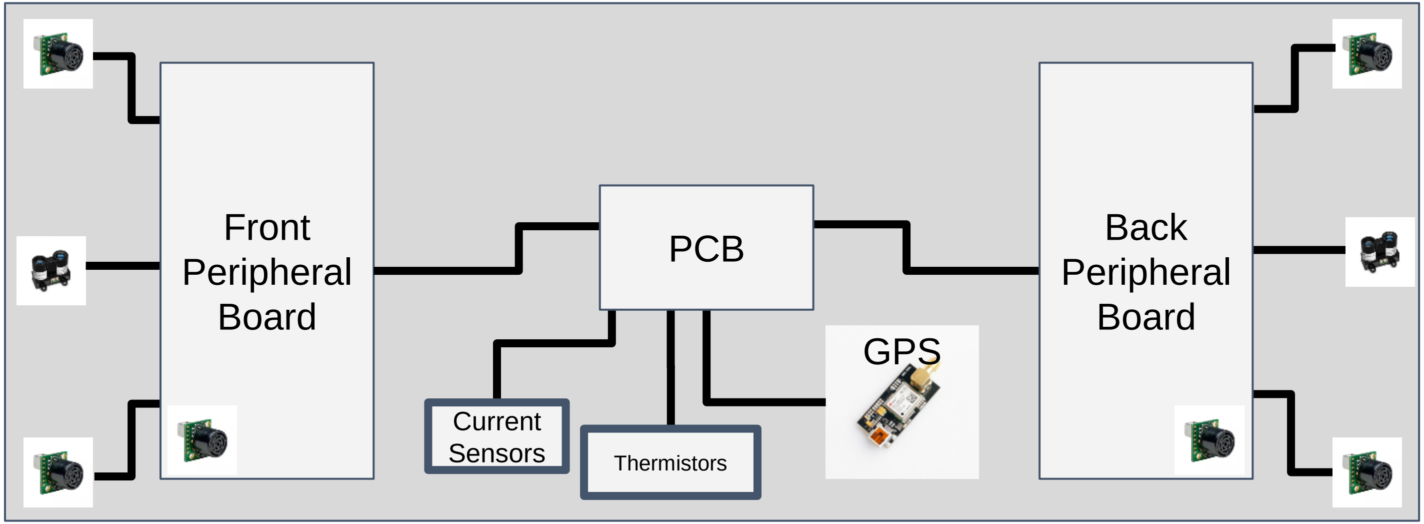
Sensor Locations

By: Cameron



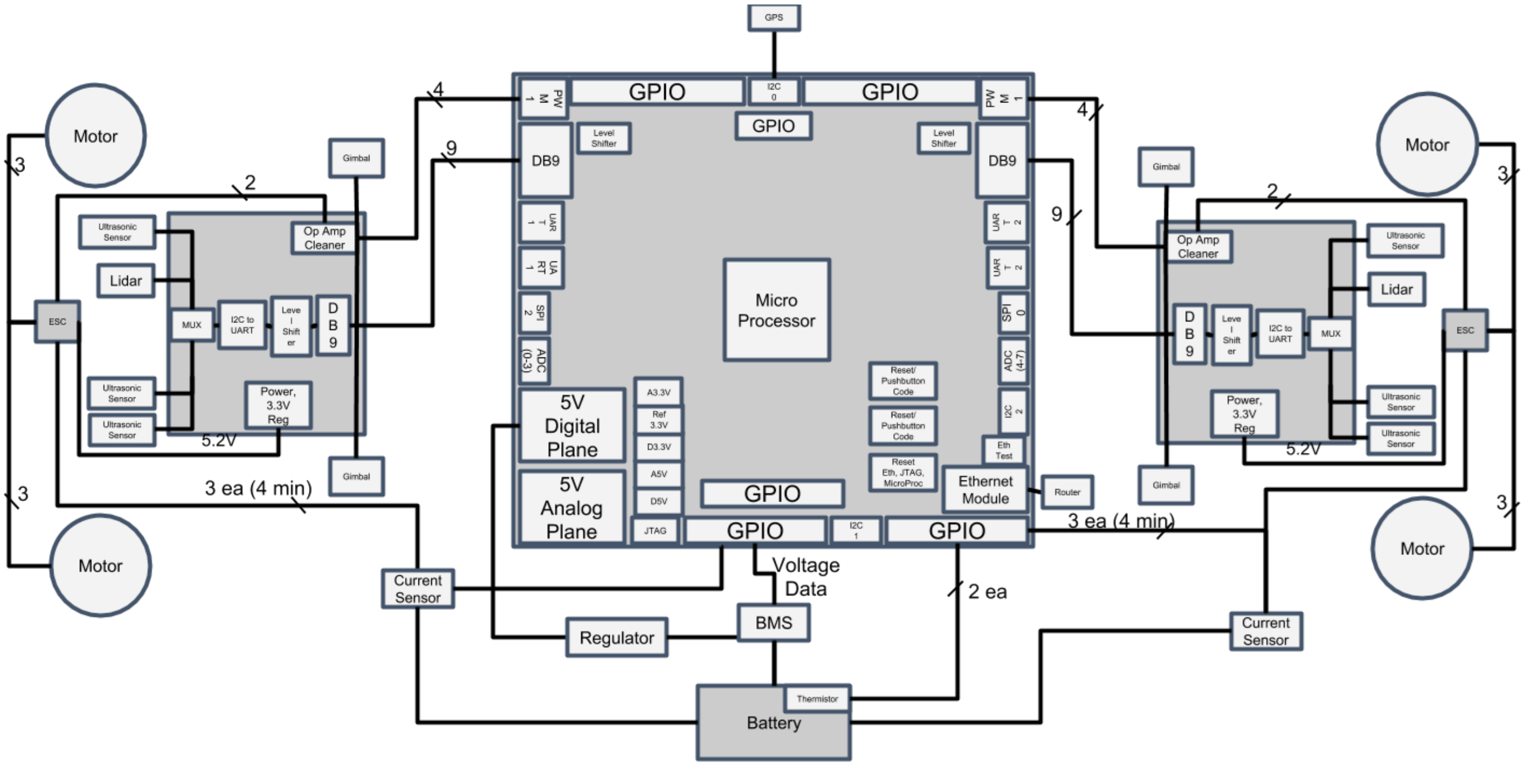
Sensor Locations

By: Cameron



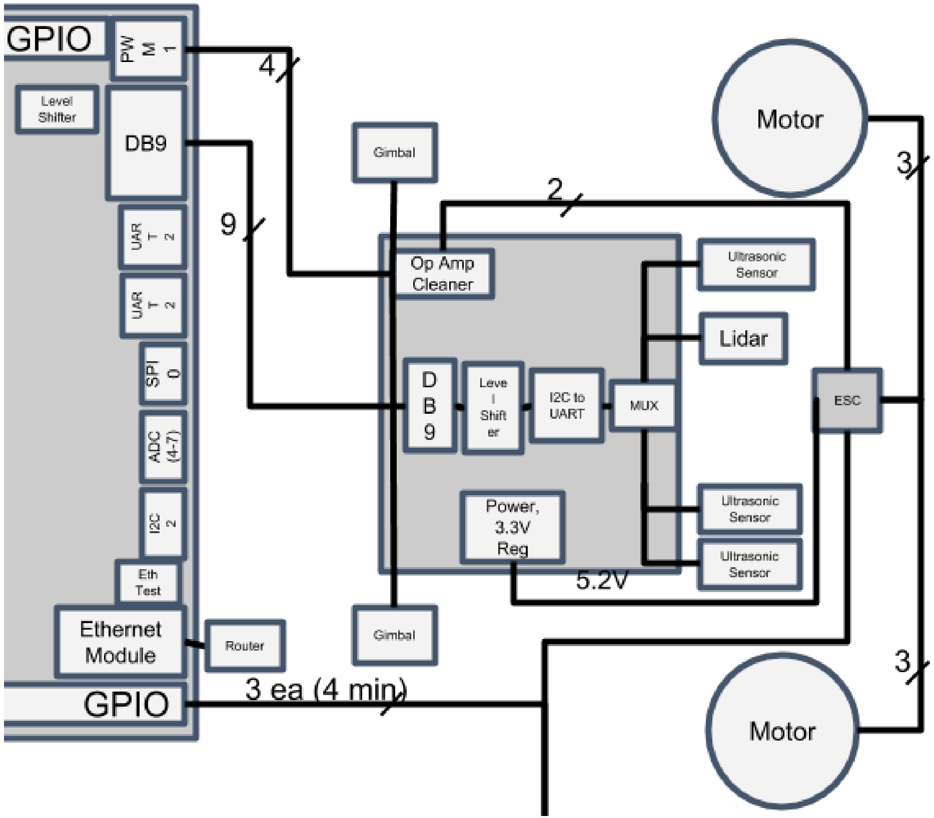
Detailed Electronic Scheme

By: Cameron



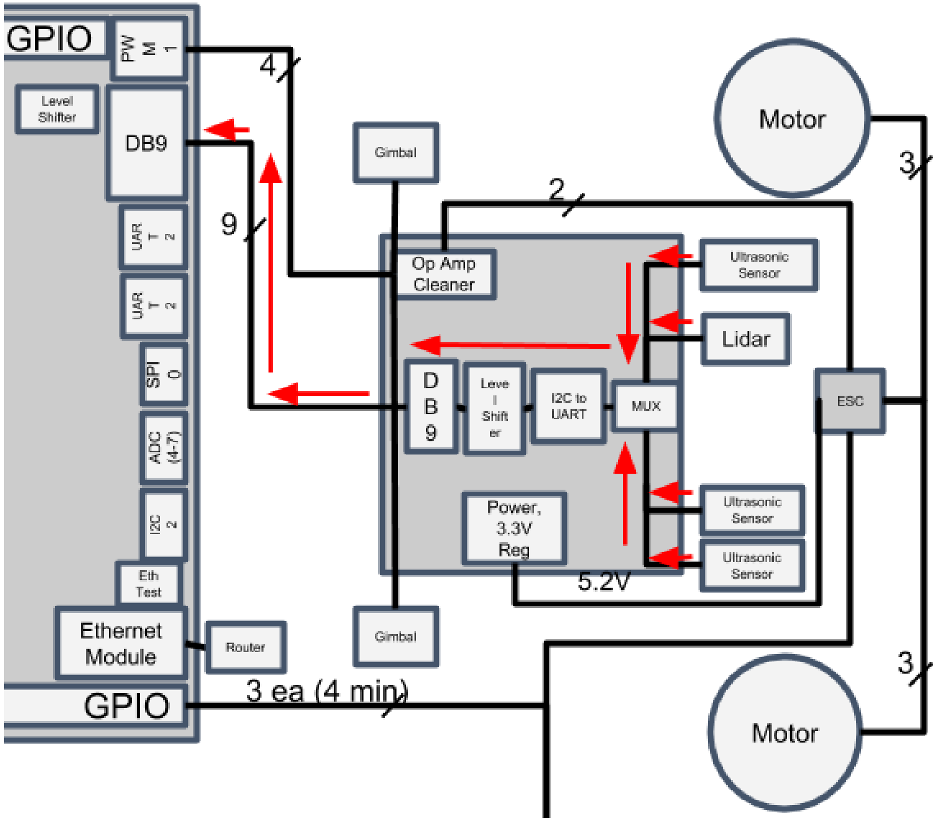
Peripheral Board

By: Cameron



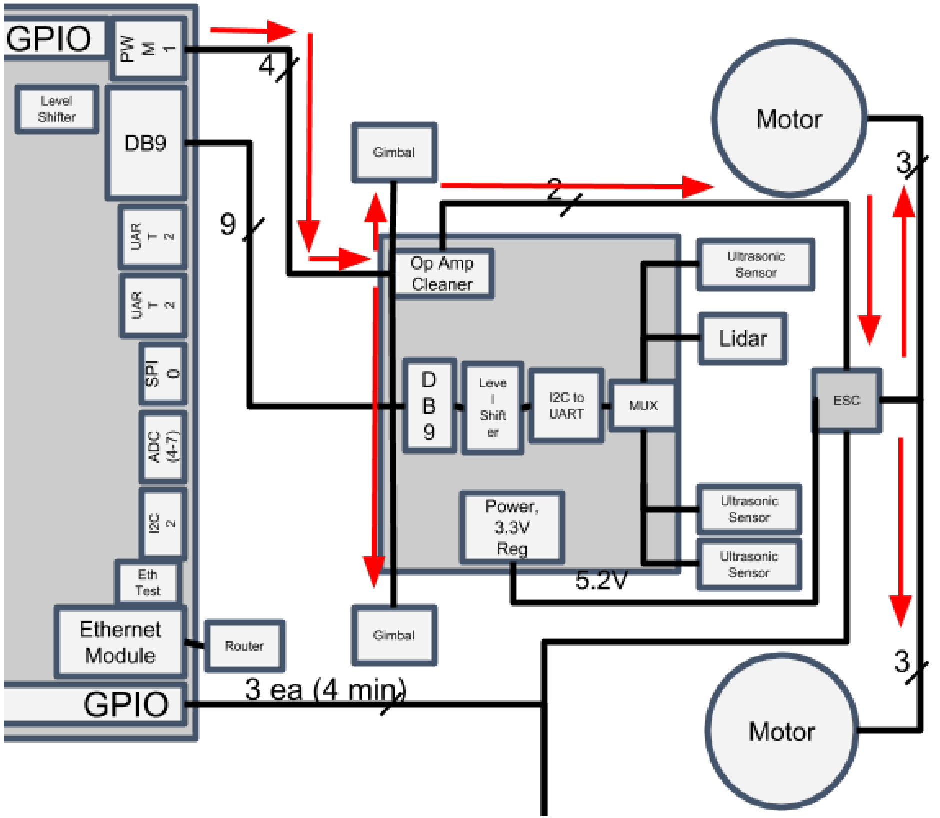
Collecting Data

By: Cameron



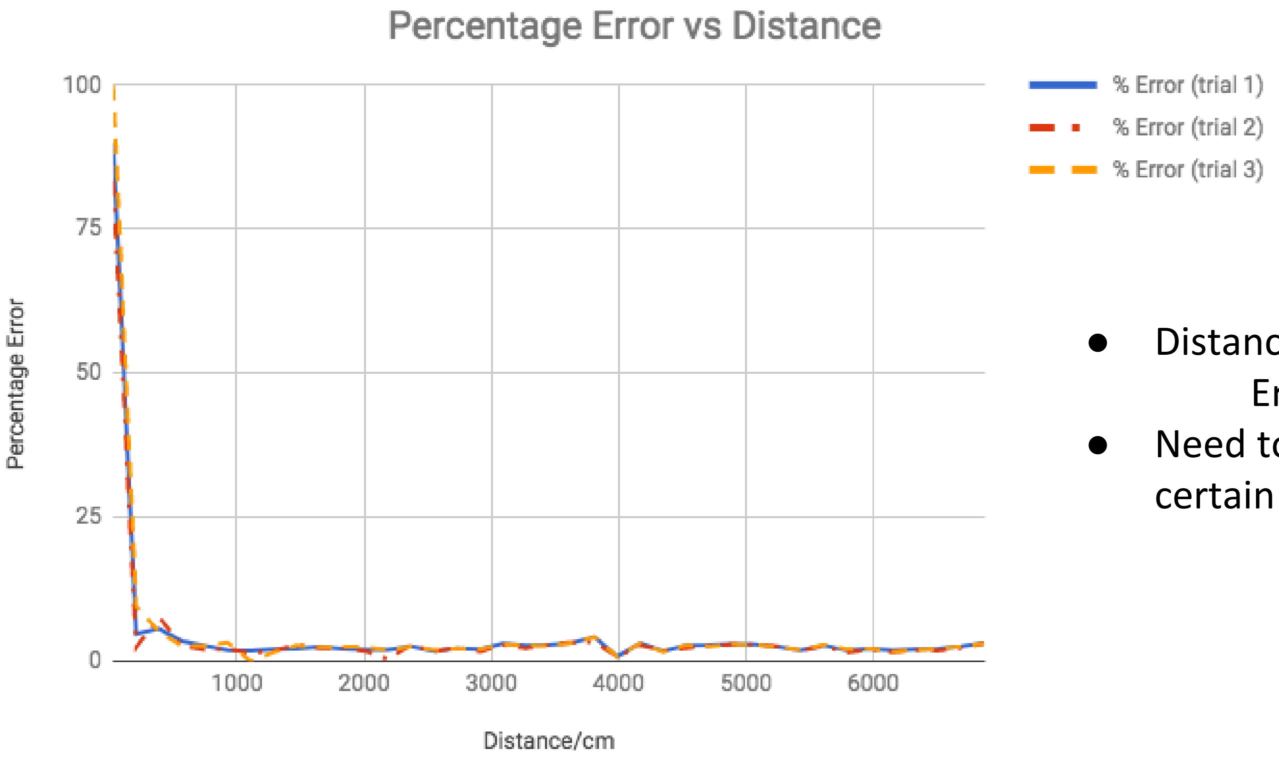
Instructing Motors/Gimbals

By: Cameron



Lidar Sensor Testing

By: Huishan



- Distance > 50cm
  Error < 4%
- Need to test with certain speed

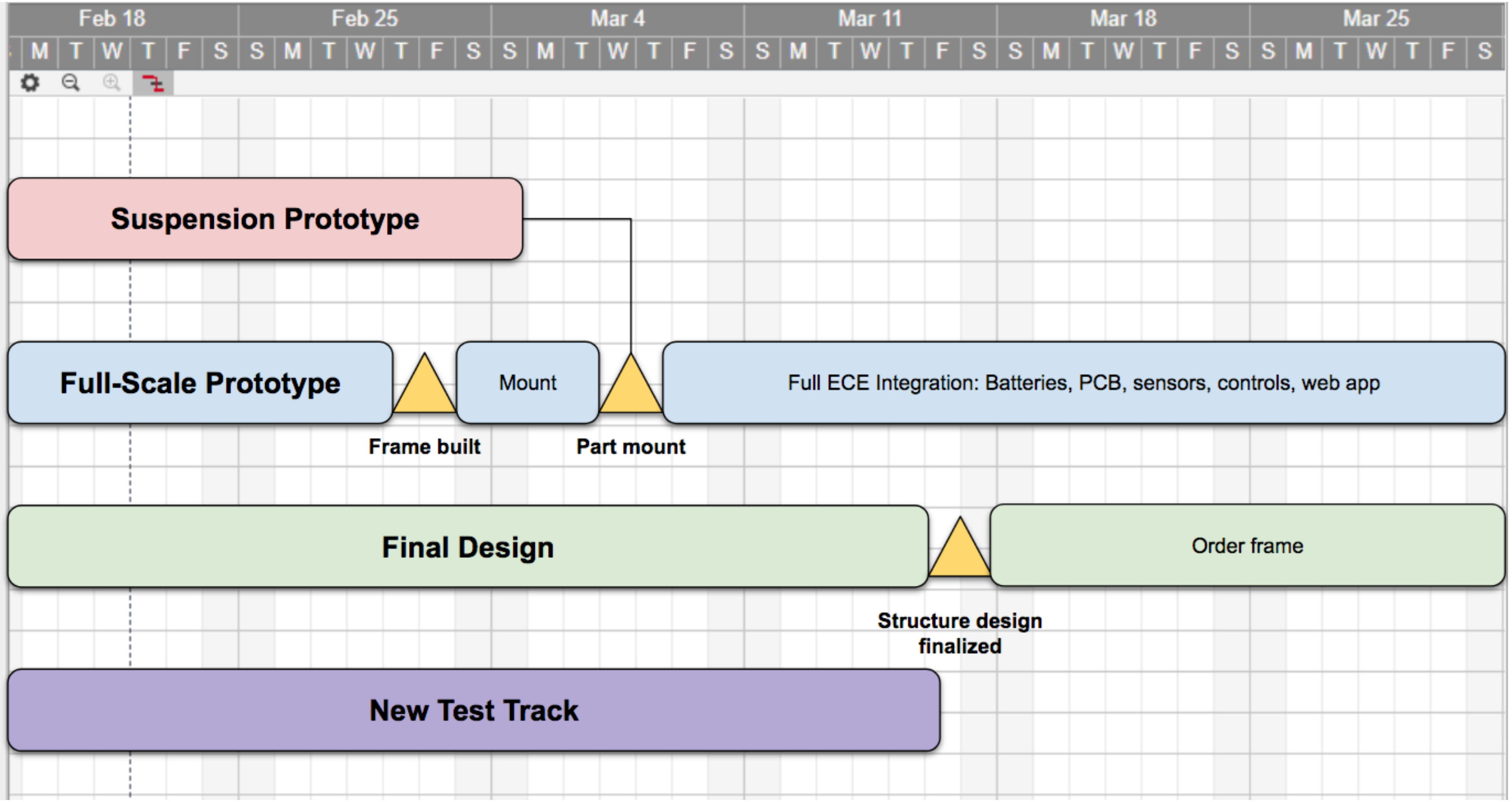
Web App

By: Mark

- Wirelessly monitors sensor data and event logs from the pod every second
- Sends signal to the pod for debugging and production purposes

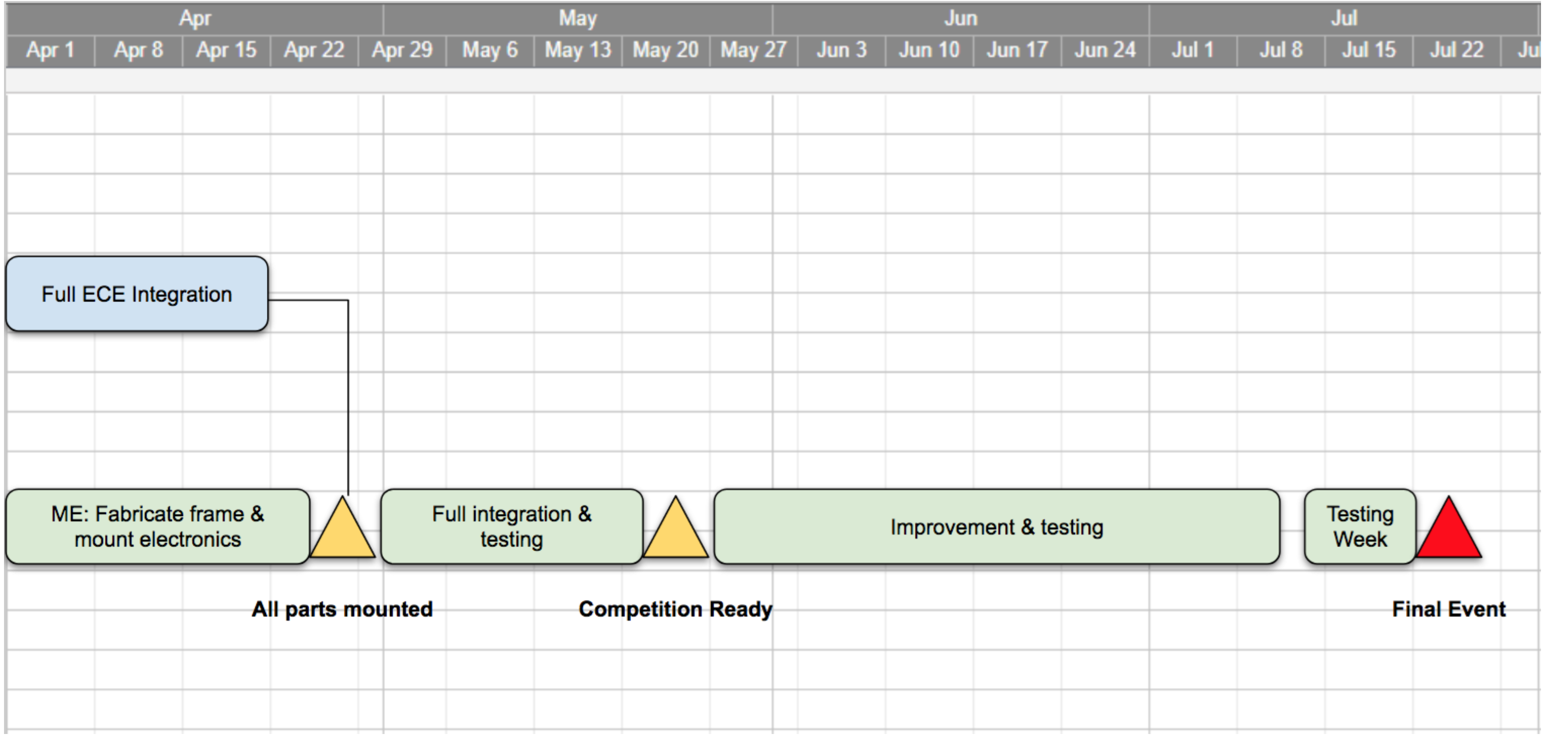
Winter Quarter Schedule

By: Raymond



Spring Quarter Schedule

By: Raymond



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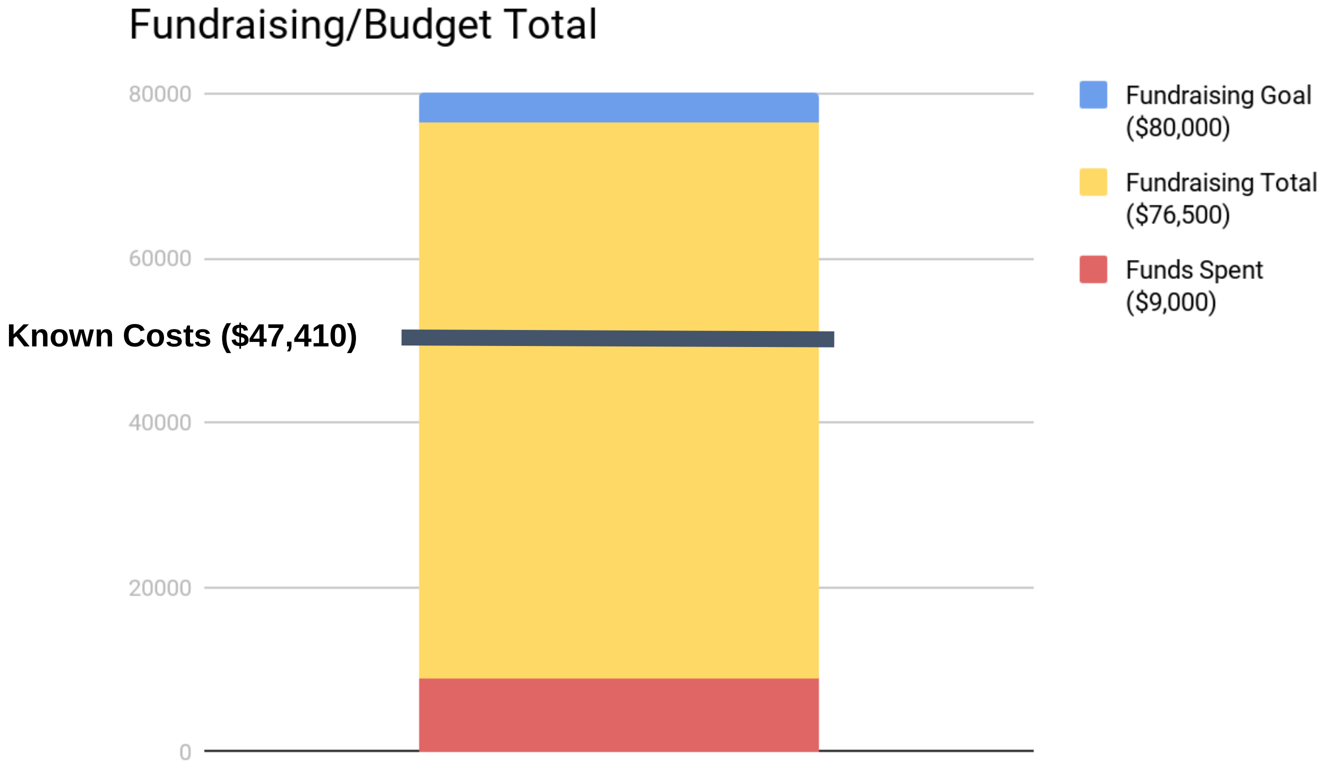
Pod Cost Breakdown

By: Jack B.

Subteam	Item	Price
Structures **Subsystems Cost: $8,000**	I-Beam Test Track	$3,000
	Shell	$5,000
Power and Electronics **Subsystems Cost: $11,160**	Battery Packs + BMS	$600
	Sensors	$560
	PCB (Manufactured by Laritech)	$10,000 (Sponsored By Laritech)
Stability and Braking **Subsystems Cost: $2050**	Secondary Brakes	$50
	Stability System	$2000
Maglev **Subsystems Cost: $13,200**	Servos (MagLev Gimbaling)	$1,200
	Maglev Engines	$12,000
	Total Cost:	**$34,410**

Funds Overview

By: Jack B.



Thank You!

By: Jack B.

Jonathan Siegel

Peter Carter

Burrous Family

Rob 89' & Tracie Jupille

Ken and Nancy Goldsholl

John Jacobs

Paul Hoff


UCSB HYPERLOOP
Design Review
Feb. 23, 2018

Levitation Concept Assessment

By: Nate

	HDK Module (small)	Arx Pax Module (large)
Motor Controller	0.03kg	1kg
Motor and Starm	0.38kg	6.8kg
Batteries	0.065kg	2.25kg
Thrust/Mass	3.53 N/kg	5.97 N/kg