UCSB HYPERLOOP

Critical Design Review

Fall 2016

TEAM

Sensor & Control Systems

- Yang Ren: microcontroller, data storage
- Jesus Diera: web application, ethernet interface
- Asitha Kaduwela: mag lev engine control
- Tristan Seroff: braking control

POD OVERVIEW

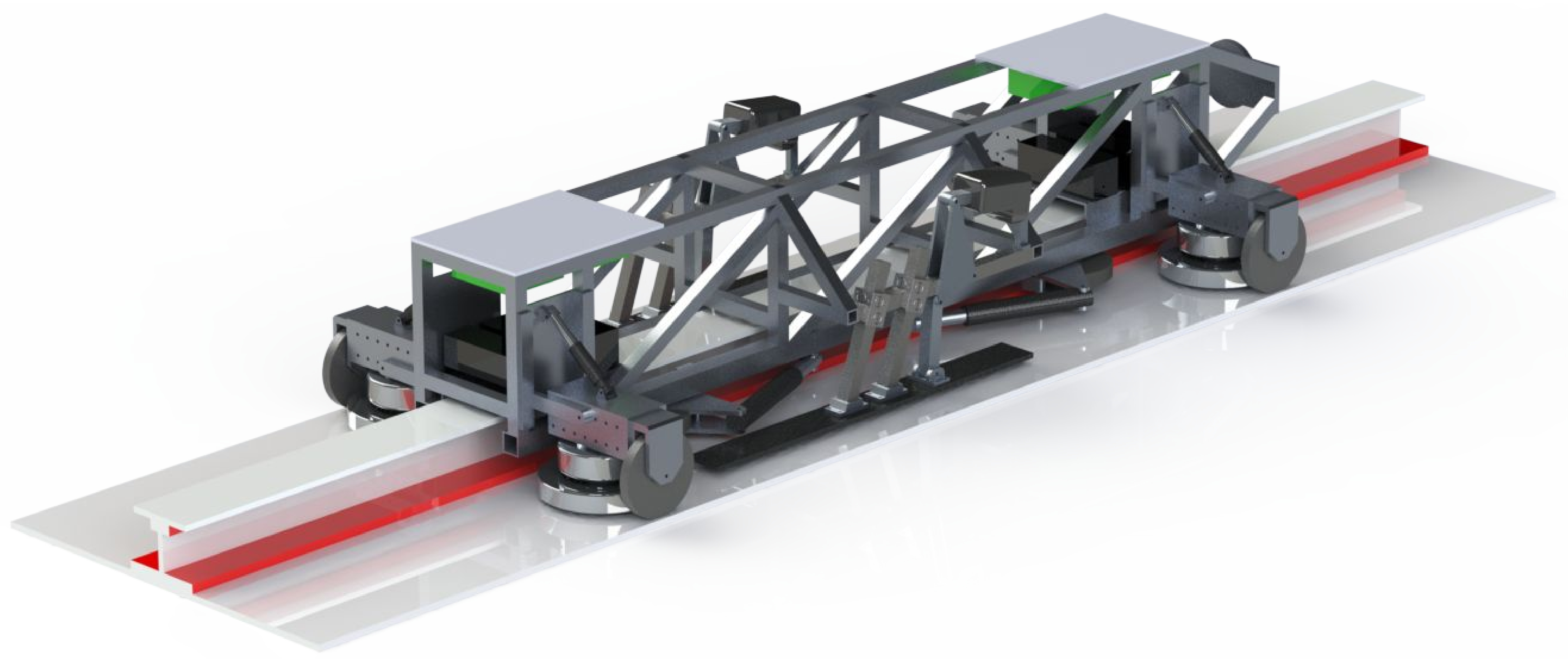

Figure: UCSB Hyperloop proposed design

POD OVERVIEW

Subsystem	Approach
Shell	Synthetic Aircraft Fabric supported by wooden shell frame
Frame/Chassis	Lightweight aluminum frame constructed of hollow square tubing
Levitation	4 ArxPax magnetic levitation motors
Stability	Yaw – spring-damper system around I-Beam Roll/pitch – maglev engine/backup wheel suspension
Backup wheels	6” diameter wheels, oriented outside of the engines
Propulsion	SpaceX Pusher
Brakes	Two friction skid brakes
Electronics	Custom printed circuit board (PCB) with 2 LPC4088 uControllers Various sensor arrays
Power	Distributed lithium polymer batteries
Thermal	Thermal jackets, existing heat sinks, connecting to chassis

LEVITATION

Figure: Arx Pax HE3.0 Hover Engine

LEVITATION

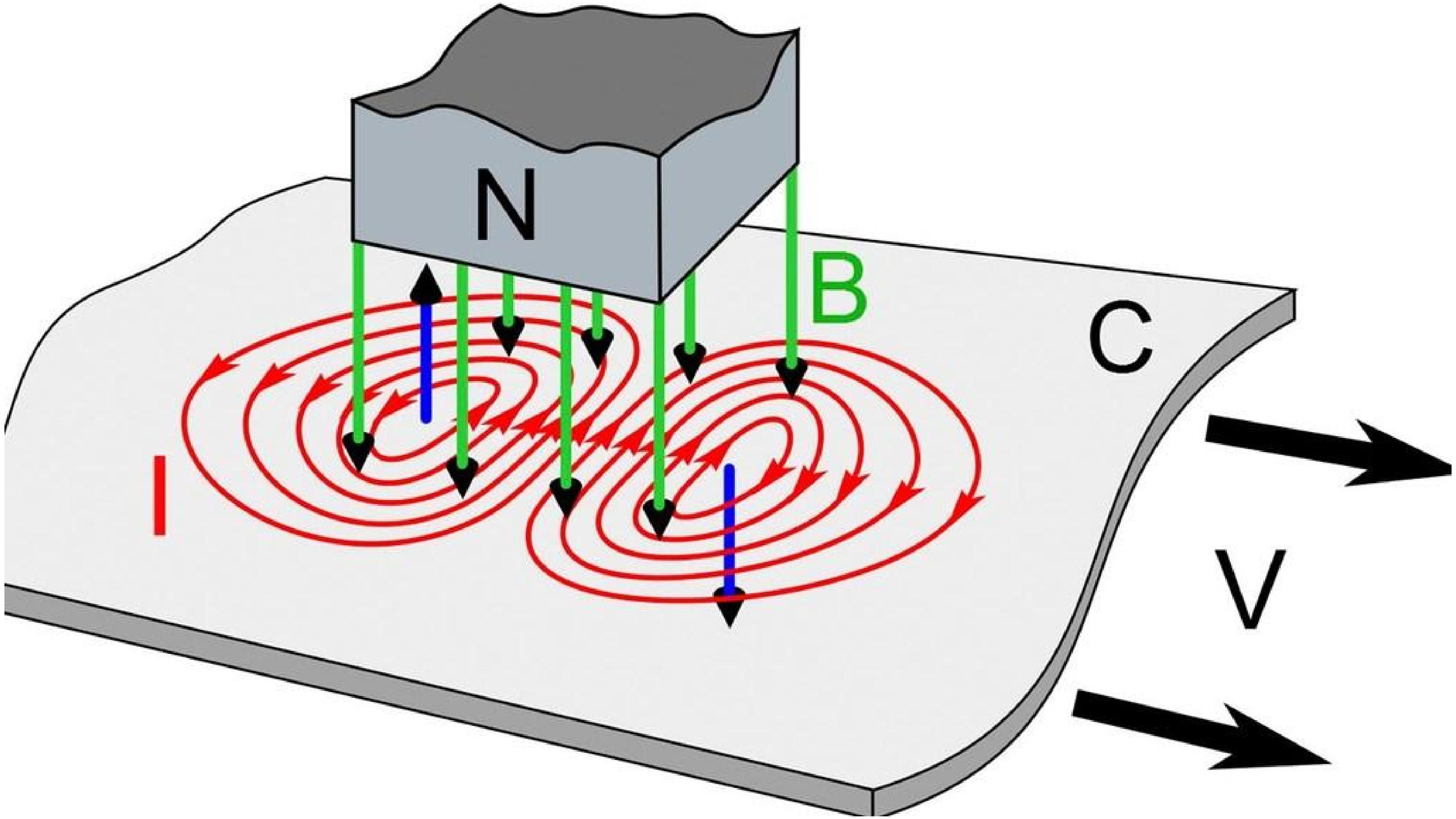

Figure: Diagram illustrating eddy current generation

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Overview
Structure
Levitation
Stabilization
Braking
Electronics
Power
Thermal Considerations
Safety Measures

PROTOTYPE

- First fully hovering prototype
- Gives qualitative information on behavior of hovering pod
- Tests Ranging Sensors, Tachometers, and throttling of motors
- Essential to development of controls scheme

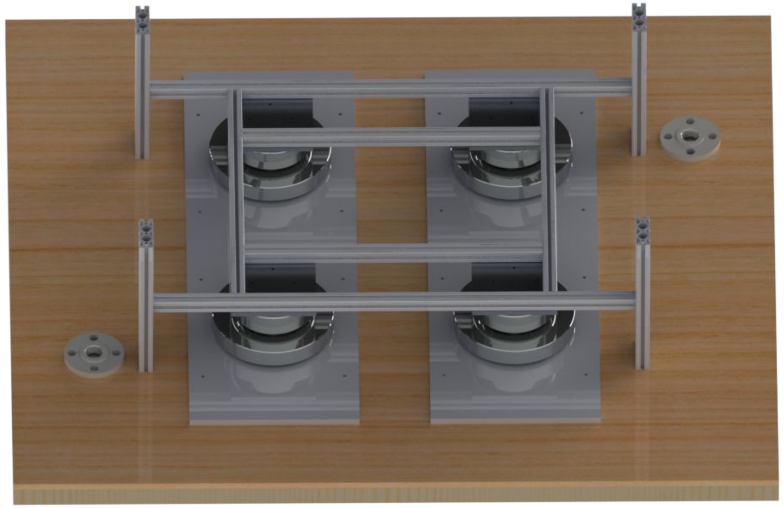


Figure: CAD Rendering of 4-Motor Prototype

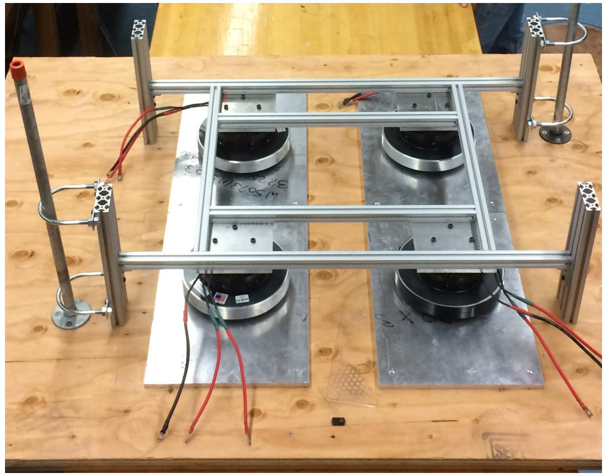
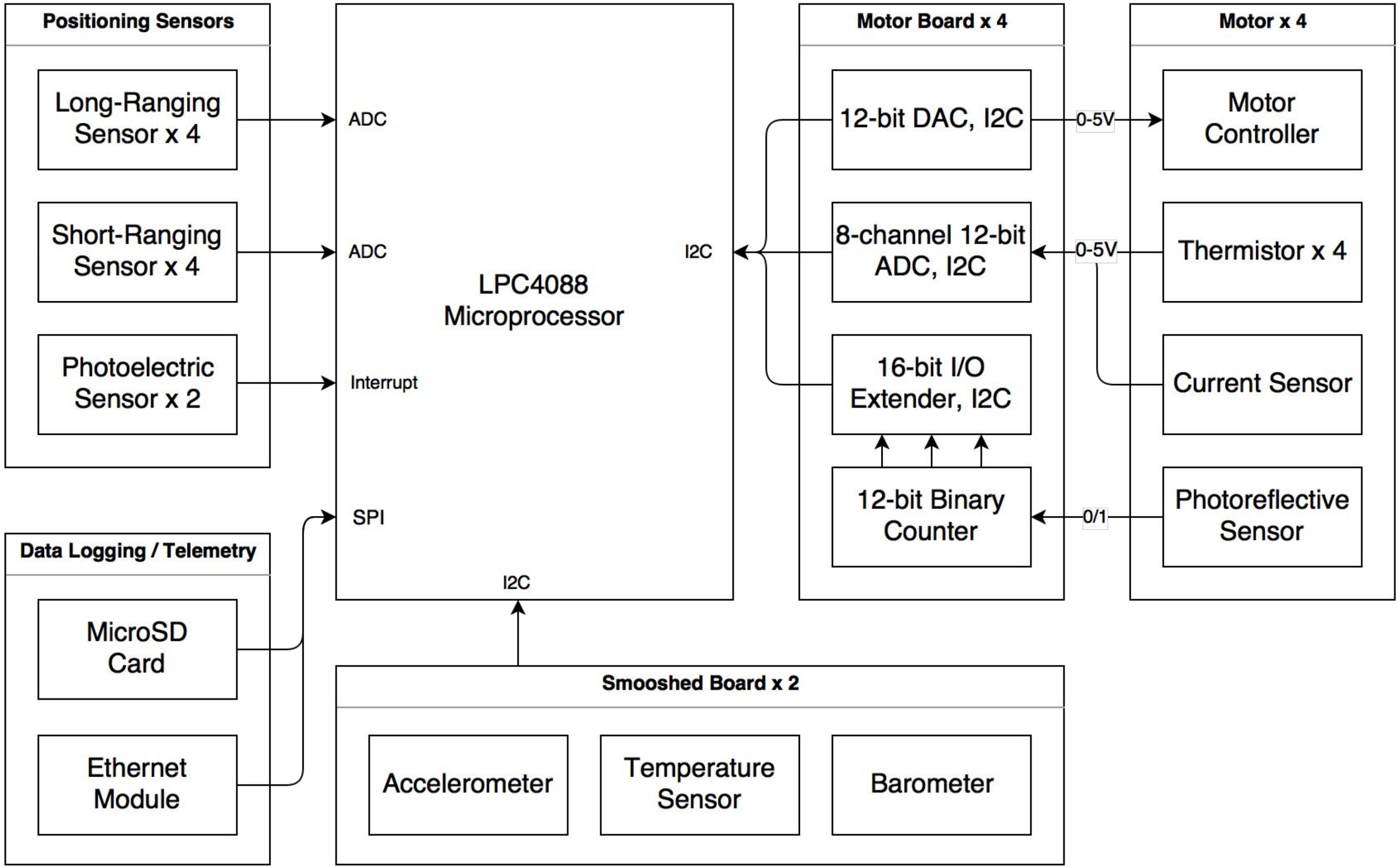


Figure: Working Prototype

BLOCK DIAGRAM



PRINTED CIRCUIT BOARD

- 8.1” x 8.1” printed circuit board
  - (2) ARM Cortex-M4 microcontrollers
  - Actuate brakes, maglev engines, and service propulsion motor
  - Communicate sensor data wirelessly via provided NAP
  - Provide active control system to stabilize maglev engines

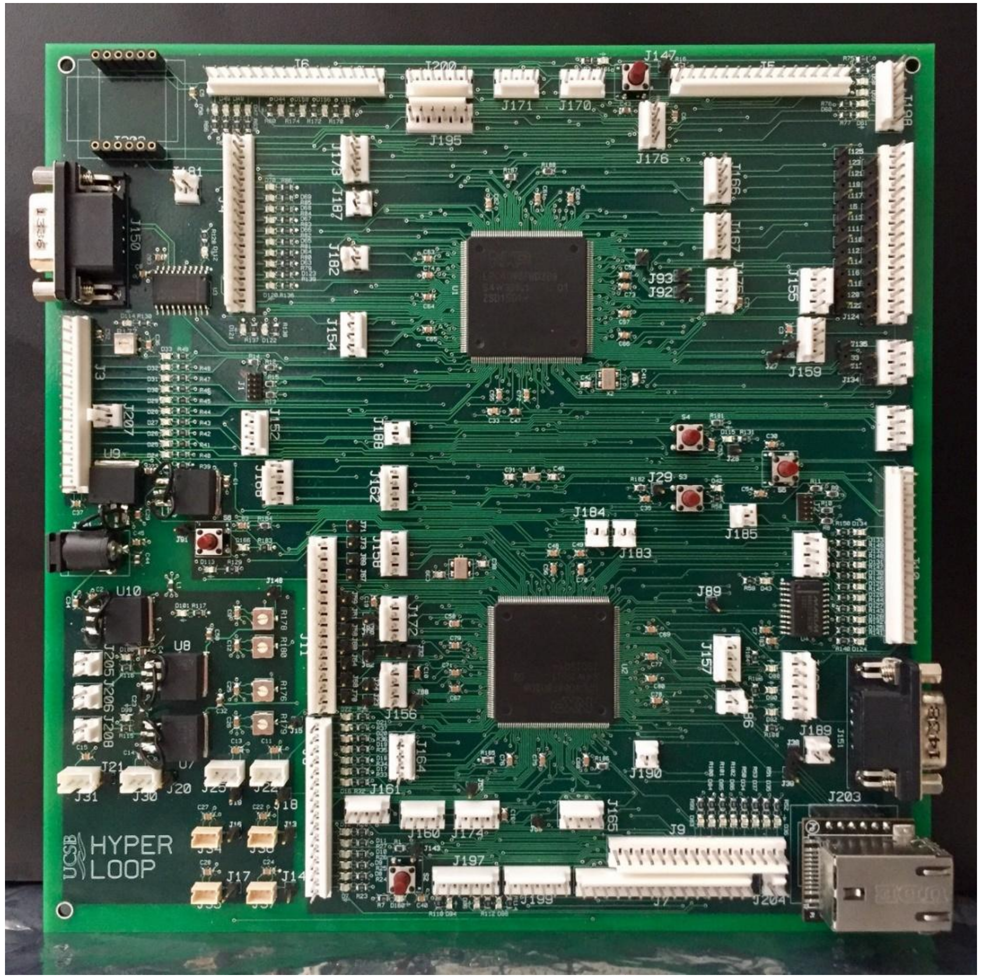


Figure: Printed Circuit Board

NAVIGATION

- **Accelerometer**
  - Dead reckoning via double integration of acceleration to determine distance traveled
  - STMicroelectronics LSM303DLHC
    - Must be accurate enough to avoid dramatic integral drift between strips
    - 16-bit precision = discretizations of 0.0625

- **Diffuse-reflective photoelectric sensor**
  - Absolute measure of position by sensing the reflective strips on the tube wall
  - Omron E3FB-DP13 2M
    - Analog sensor will operate reliably at all speeds

STABILITY CONTROL

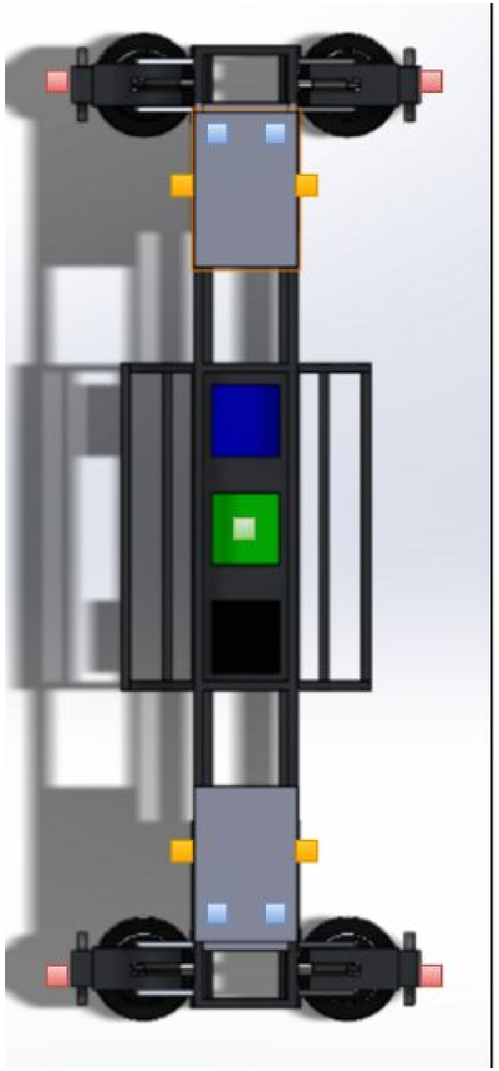
- Testing will determine whether closed loop control is necessary
  - Ideal control scheme is to use tachometers to measure engine speed and keep it constant
  - Active control of the motors' stability is a last resort because of complexity

- Closed feedback loop:
  - 4 tachometers measure engine speed
  - 5 short-ranging sensors under pod determine vertical position
  - 4 separately actuated motors adjust for balance

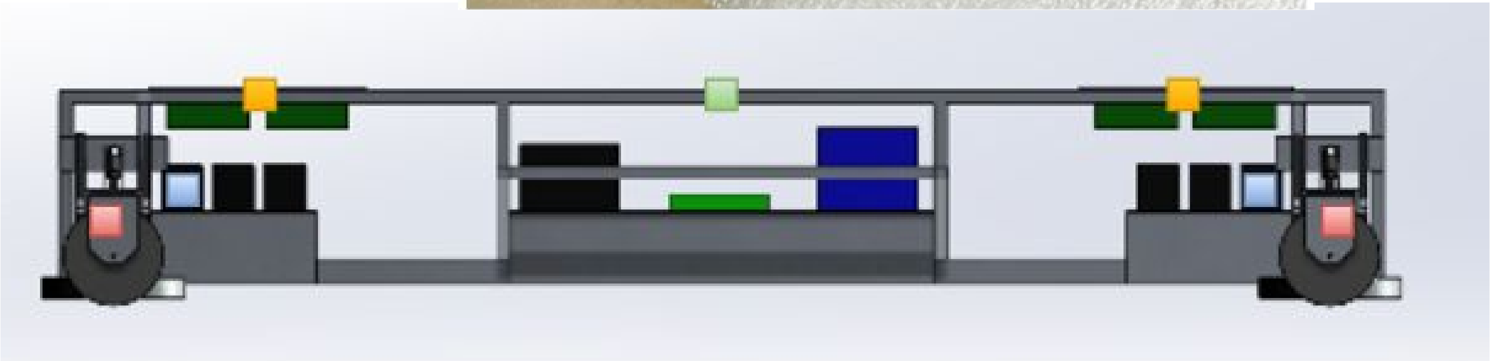
SUBSYSTEM MONITORING

Subsystem	Sensor	Location / Purpose
Magnetic Levitation Engines	Tachometer	1 on each motor / measures motor RPM
	Current	1 on power line connected to each motor / measures current flowing to motor
	Thermistor	4 on each motor / measures motor temperature
Motor Batteries	Thermistor	1 per battery / measures battery temperature
Braking System	Thermistor	1 per brake pad / measures brake temperature

SENSOR LOCATIONS



- Short Range IR
- Long Range IR
- Photoelectric
- Current



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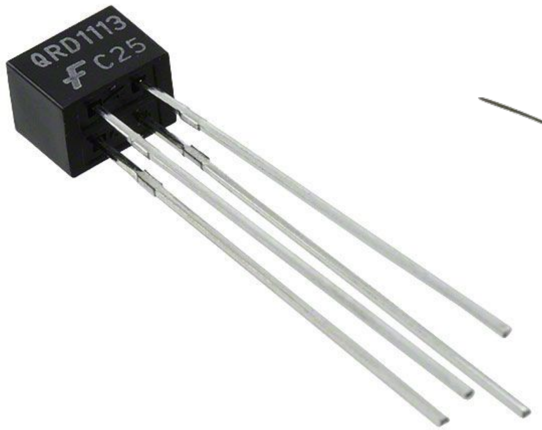
SUBSYSTEM SENSORS

- Current Sensor
  - Hall-effect-based linear current sensor, 150 A range
- Tachometer
  - Photoreflective sensor, detects reflective strips on motor disk
- Thermistor
  - NTC Thermistor 10k Bead, -55 C to 125 C range



MOTOR BOARD

- Collects data from tachometer, current sensor, and thermistors
- Controls motor throttle through DAC
- Communicates w/ PCB via I2C
- Powered by PCB

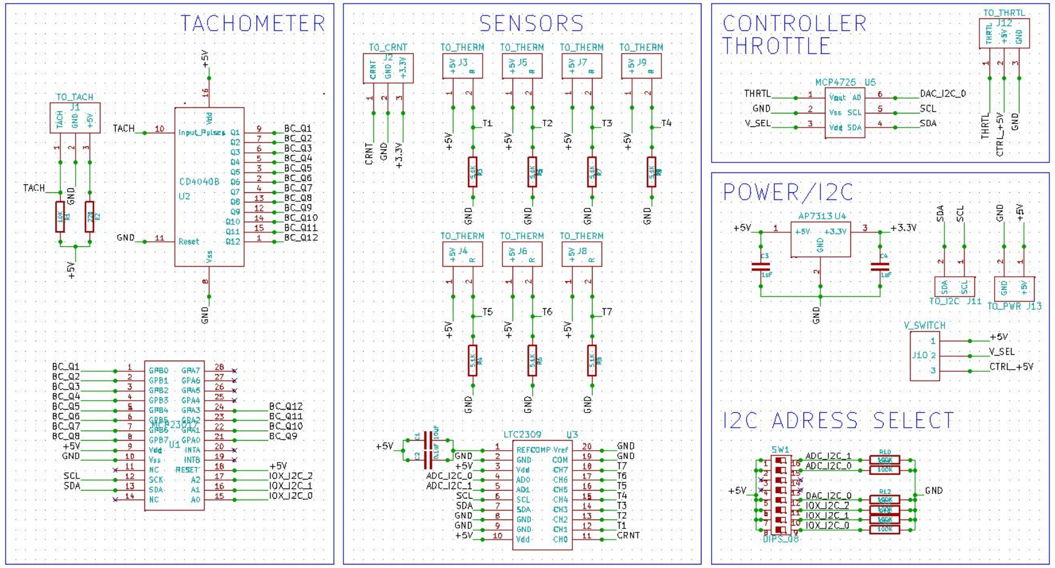
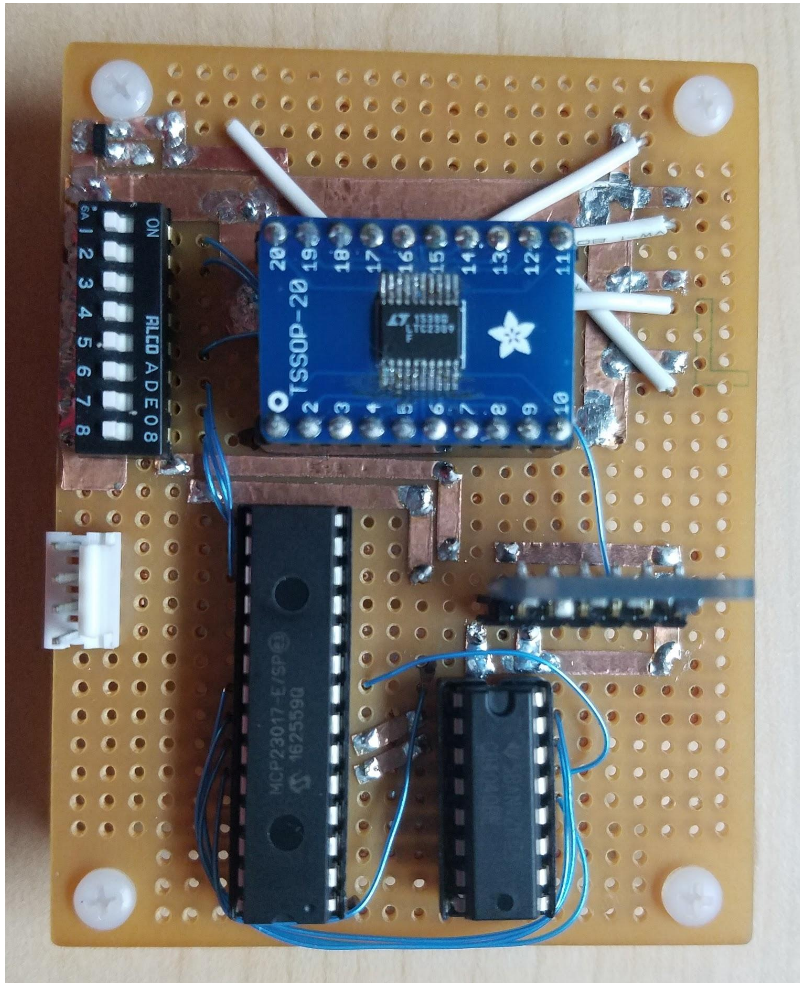


Figure: Prototype Motor Board CAD



MOTOR BOARD

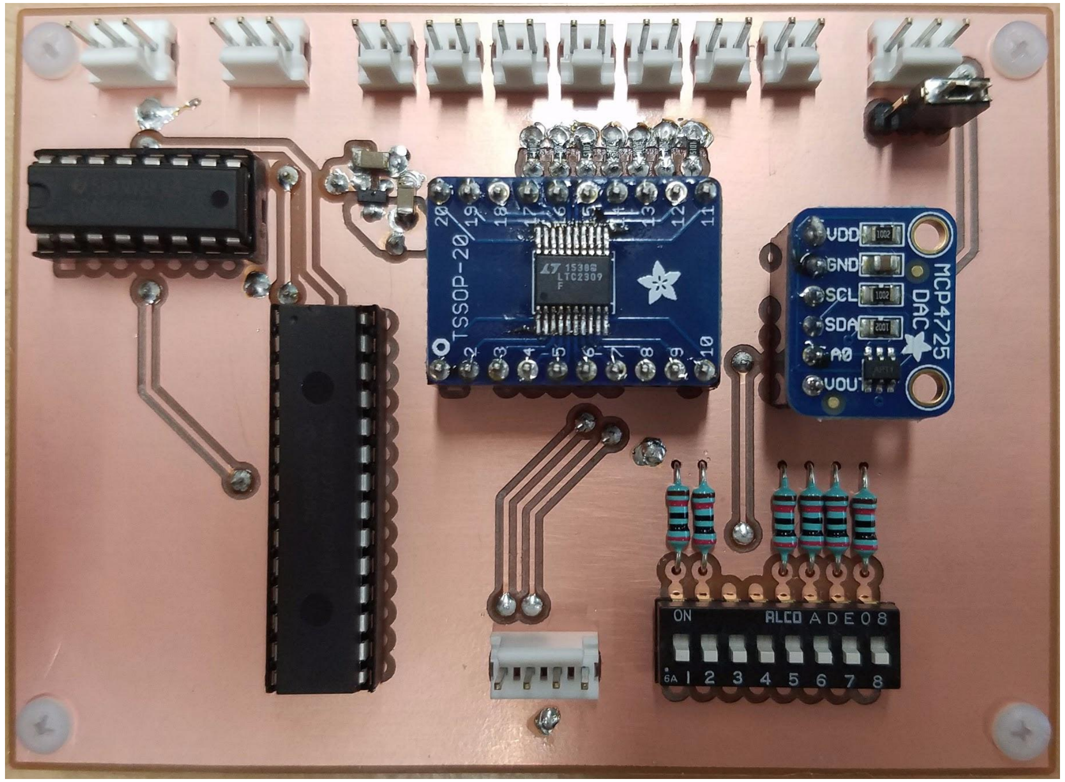


Figure: Motor Board v1.3

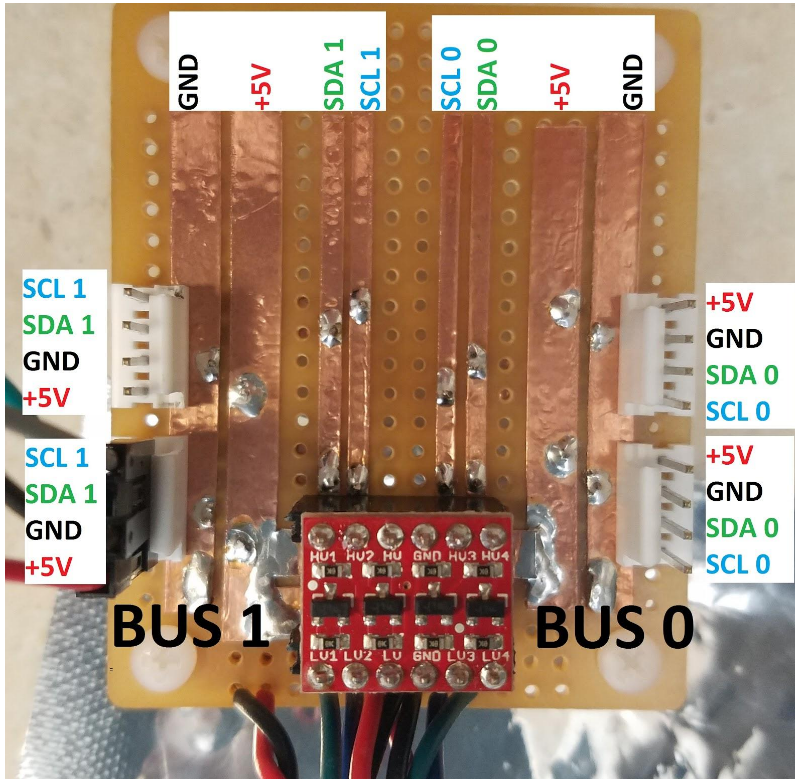
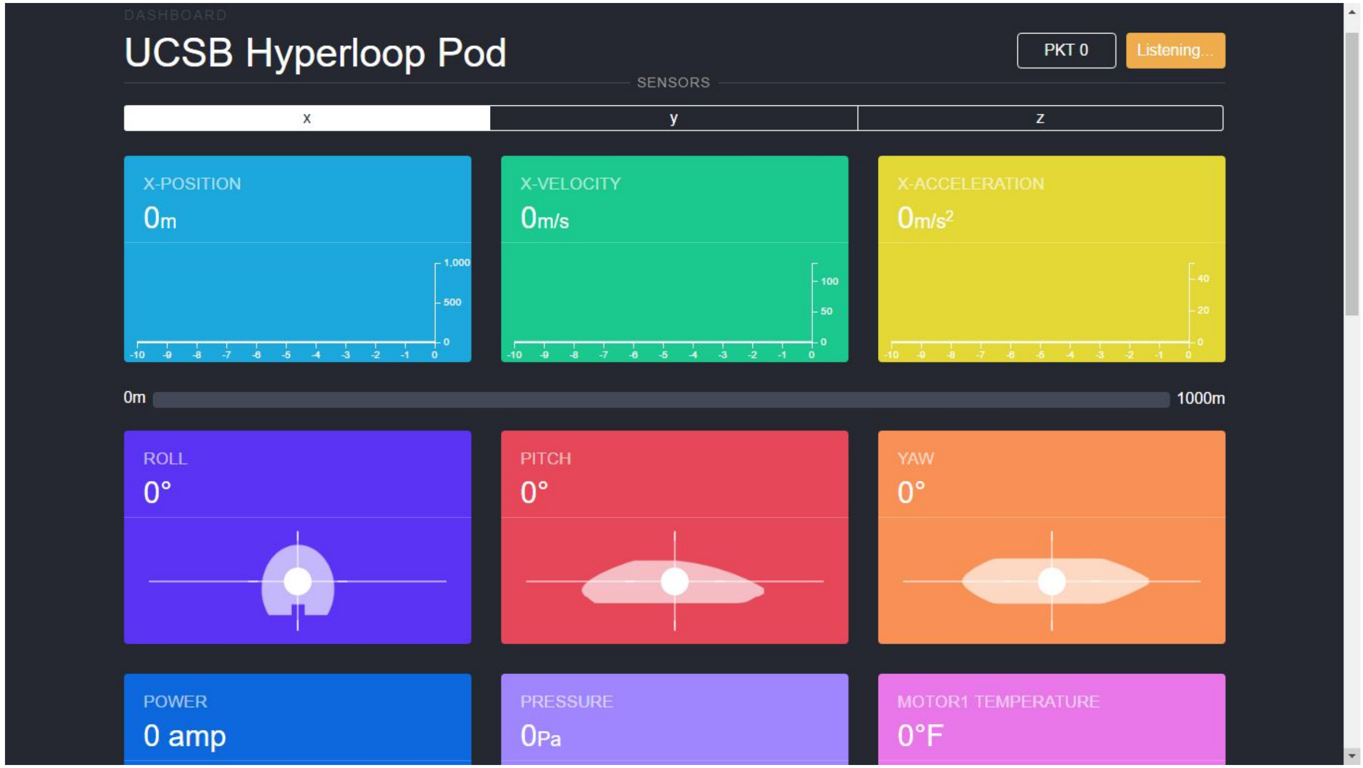


Figure: Motor Board I2C Router

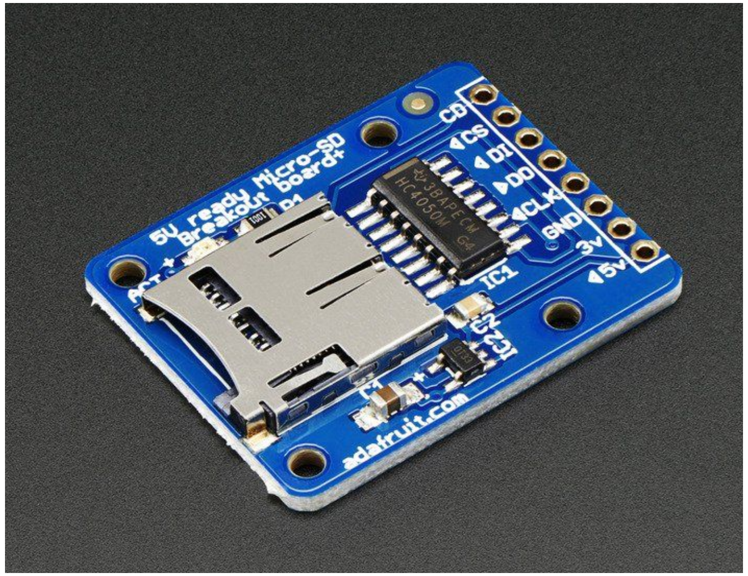
WEB APP

- Graphical display for pod data
- Control signals: powering on, emergency braking
- Connection to the pod established through SpaceX's Network Access Panel and the PCB's ethernet module



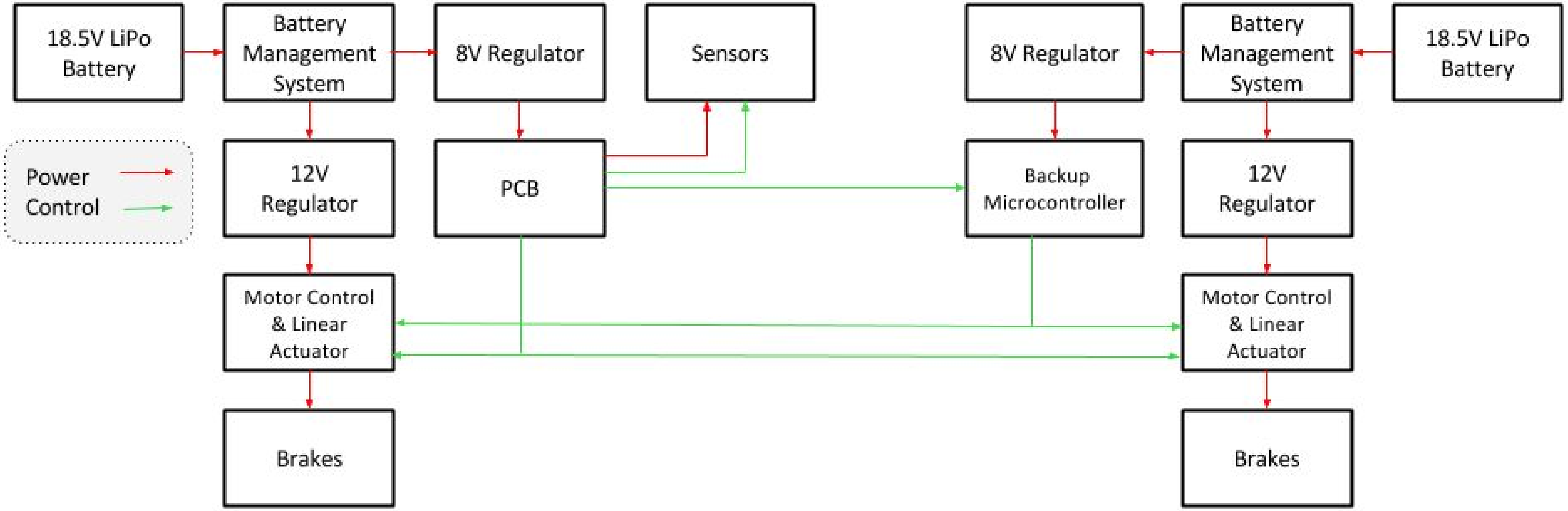
DATA STORAGE

- Web App
  - Sensor data sent to the web app can be saved into files on the hosting machine
- MicroSD Card
  - Data storage & event logging
  - Fat32 file system library used to write data/logs to individual files
  - New sets of files are created for each session, starting from when the pod is powered on
  - Entries in data/log files are preceded with time stamps



POWER SCHEMATIC

Overall Power Schematic



SAFETY MEASURES

- Emergency Braking
  - Redundancy:
    - Either pair of friction brakes can independently stop the pod
    - Powered by main battery:
      - Outer set of friction brakes and PCB uController
    - Powered by second battery:
      - Inner set of friction brakes and a backup uController
    - Both PCB uController and backup uController can activate any of the brakes

  - In the case where main PCB uController or main battery fails:
    - The backup uController has a keep-alive timer
    - Activates functional brakes if it the PCB fails to send a keep-alive message

SAFETY MEASURES

- SpaceX Requirement: Prevent the activation of brakes during pod acceleration phase

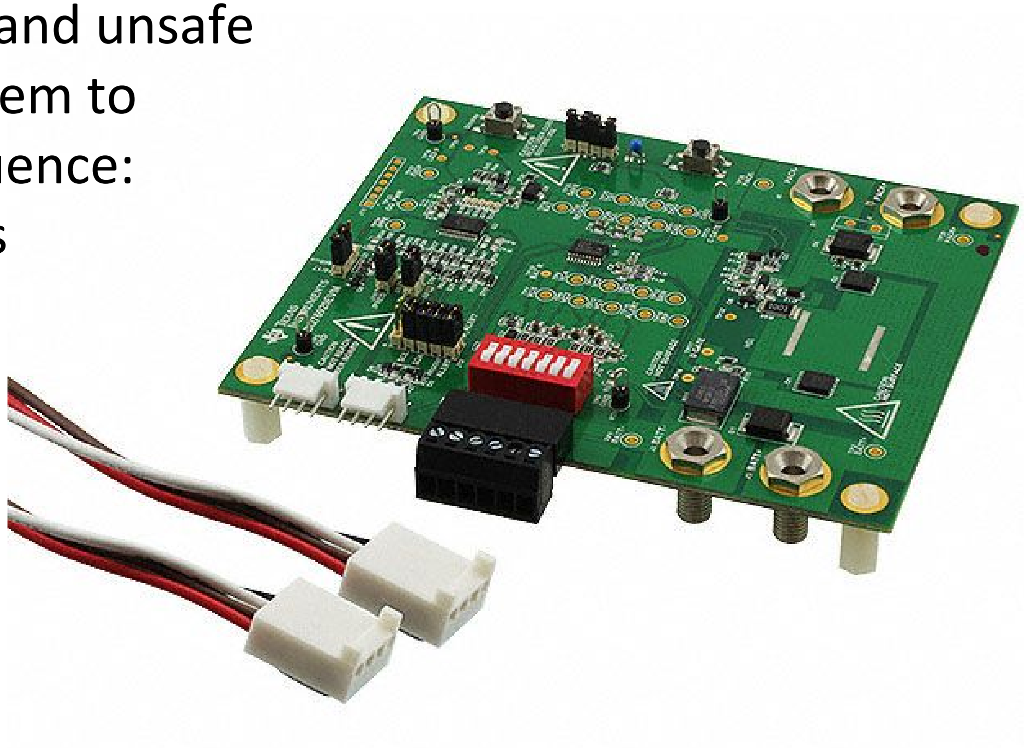
  - Software restrictions
    - Positioning and contact sensors will determine if pod is accelerating / being pushed
    - Brakes will be enabled/disabled accordingly

  - Worst case: both uControllers or both batteries fail
    - Without power, the electromechanical brakes will stay disengaged

SAFETY MEASURES

- Battery Management System (BMS)
  - All batteries will be monitored using temperature and current sensors
  - The PCB / braking batteries have a dedicated I2C BMS board
  - The levitation batteries contain an integrated BMS

- Failures due to discharge, current, and unsafe imbalances initiate the control system to start an emergency shutdown sequence:
  - Electrically isolate the batteries via relays
  - Power down systems
  - Stop the pod



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CONCLUSION

- Fall Quarter
  - Selecting and interfacing with sensors
- Winter Quarter
  - State machine control system
  - System integration
- Spring Quarter
  - System-wide testing
- Questions?