# Critical Design Review

## LFEV-Y5-2017

Lafayette Formula Electric Vehicle

Year 5

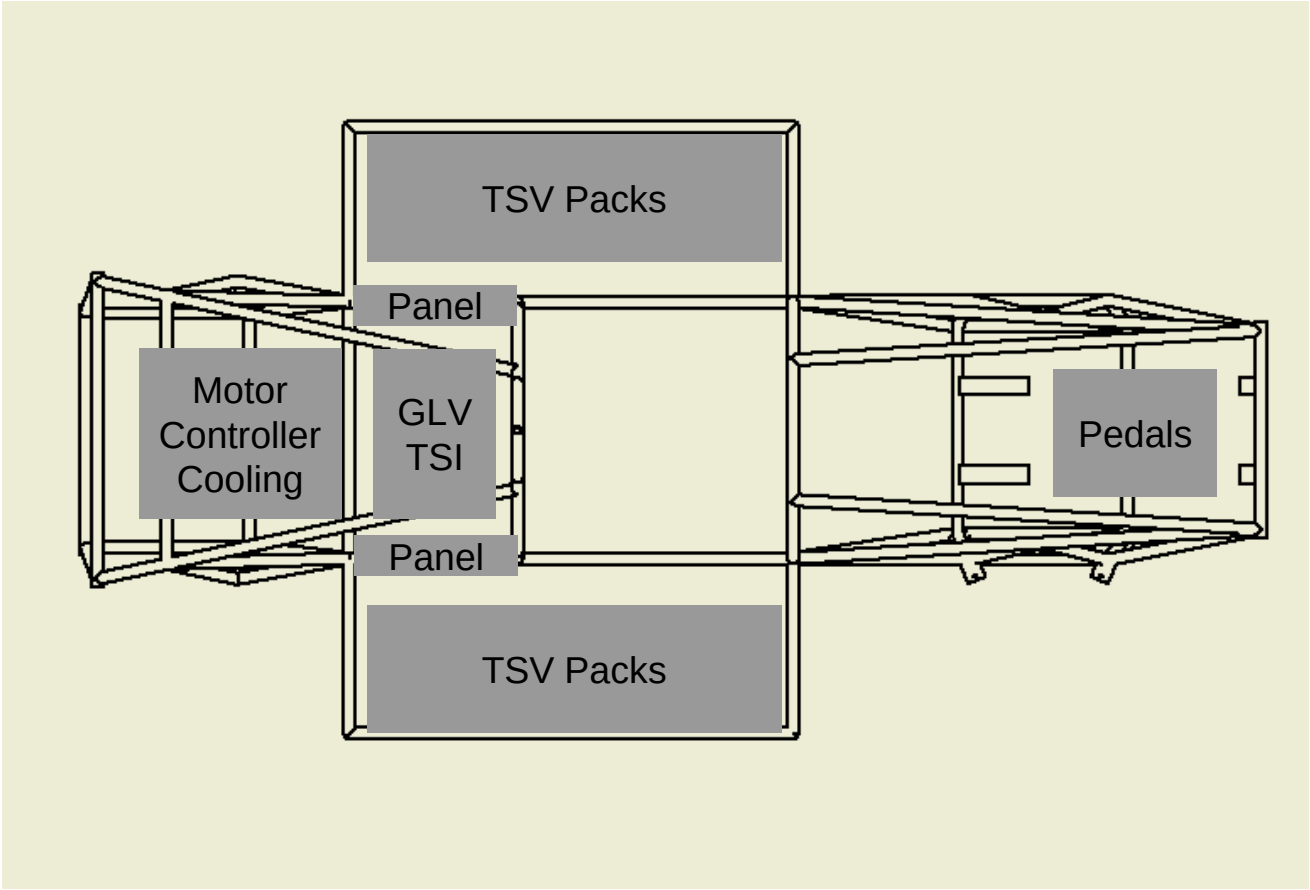
ECE 492 - Spring 2017

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

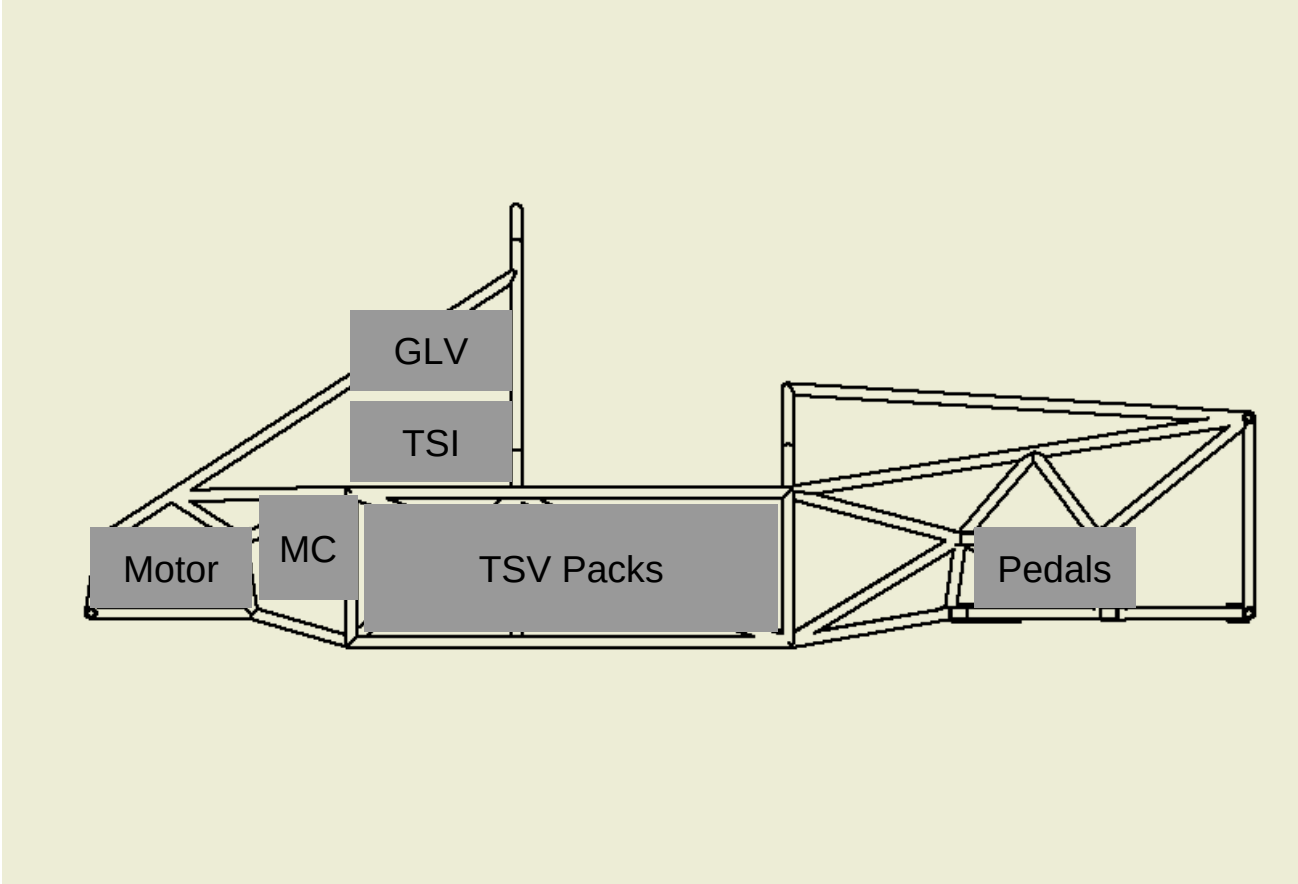
# Roadmap

1. **System Overview**
2. Schedule
3. Cost Analysis
4. System States
5. Demo in Dynamometer Room
6. Vehicle Supervisory Control and Data Acquisition (VSCADA)
7. Cell App
8. Tractive System Interface (TSI)
9. Grounded Low Voltage (GLV)
10. Controller Cooling System
11. System Test Plan

# System Overview - Top



# System Overview - Side



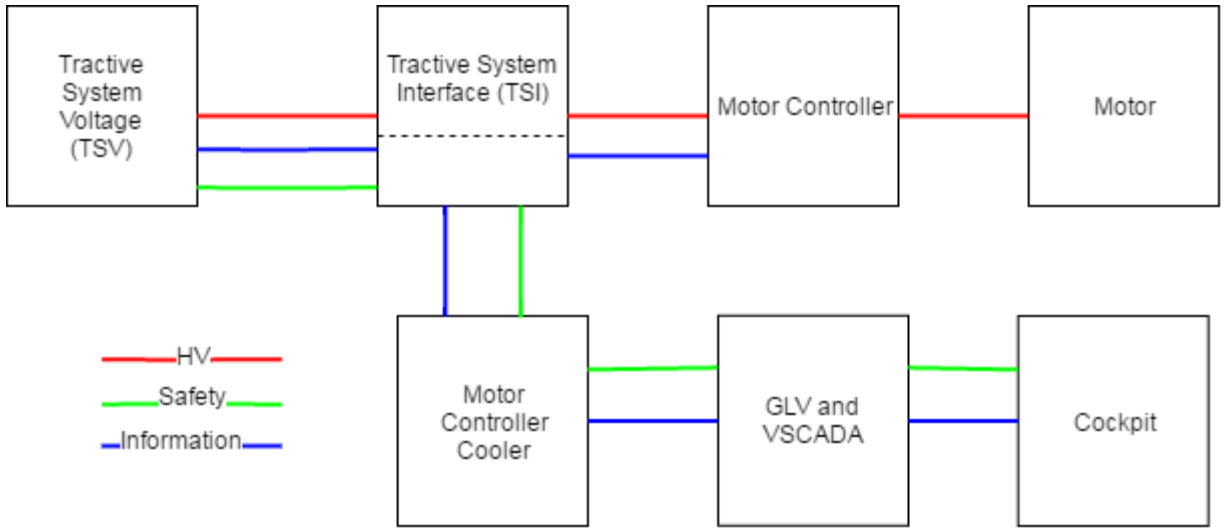
# System Overview - System Objectives

- **TSI**: Provide connection and safety for the power supply of the motor
- **GLV**: Provide 24V to all systems, excluding the motor
- **VSCADA**: Provide data acquisition capability, as well as diagnostics
- **Cell App**: Be able to wirelessly interface with SCADA system
- **Cooling**: Using 24V, provide constant feedback to SCADA while cooling the motor
- **Cabling**:  Provide safe and consistent connections between subsystems.

# System Overview - System Objectives Cont.

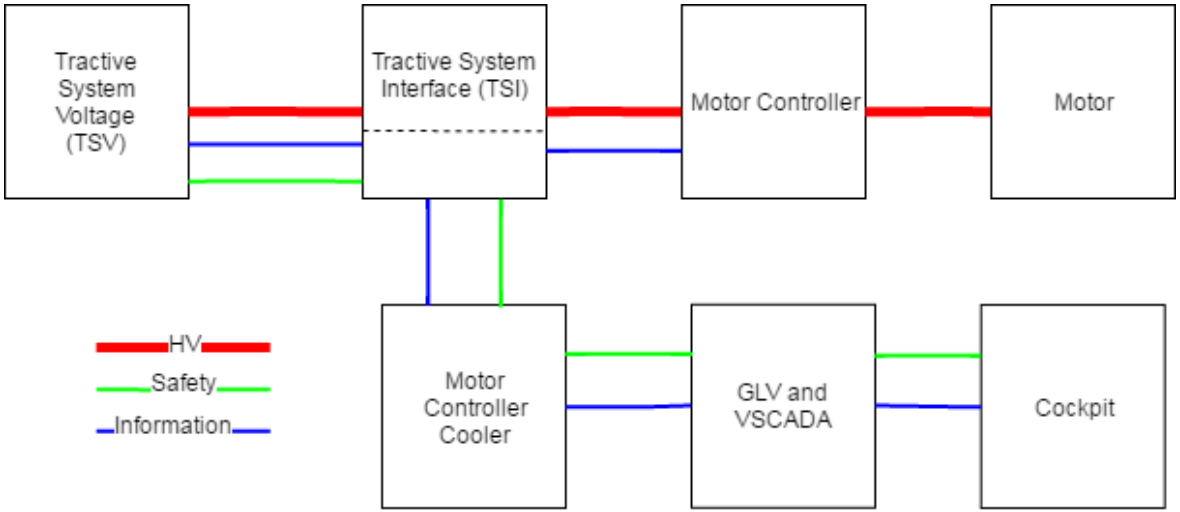
- **Interface Control Document**: Provide documentation for both hardware and software and interfaces.
- **Dyno**: Build and prepare Dyno room for testing for all sub-systems
- **TSV**: Provide 96V to the motor, as well as diagnostic information, and update its charging algorithm
- **Physics**: Helping TSV team understand relevant research, as well as physical modeling of the car, and developing a cruise control algorithm

# System Overview - High Level System Block Diagram



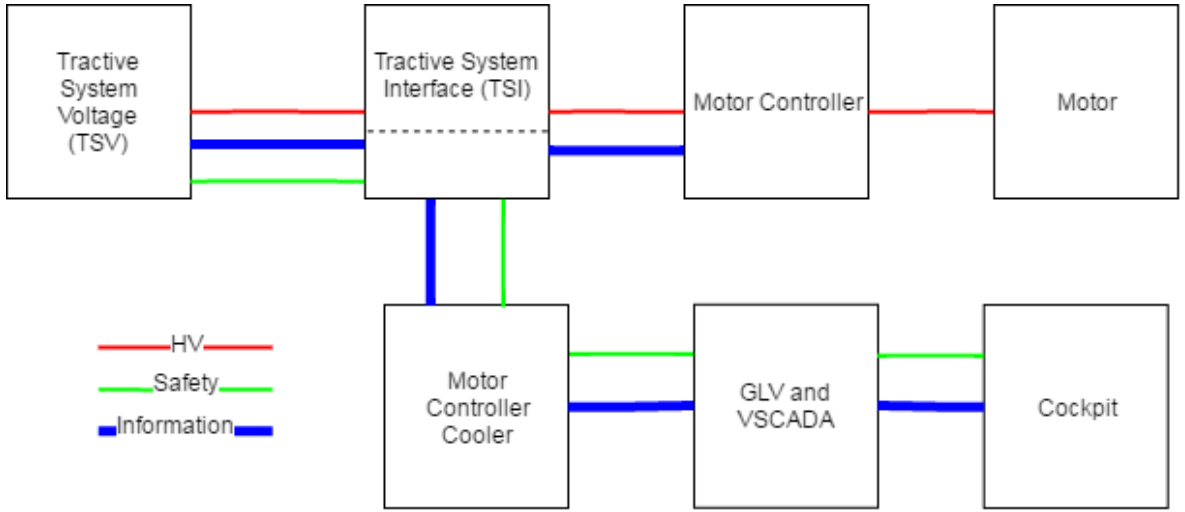
# System Overview - High Voltage Connections

- 96V
- 2/0 Cable



# System Overview - Communication Protocol

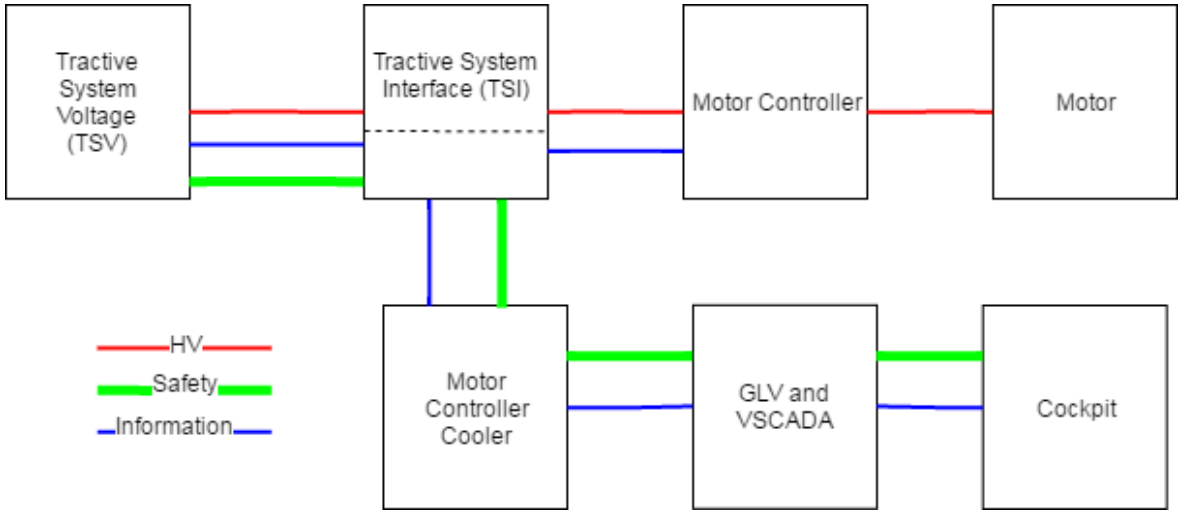
- CAN Bus
- All sensors have unique ID
- All stations jabber
  - Settable period



# System Overview - Safety Loop Faults

- All systems access safety loop
- Driver resettable section
- Non driver resettable section

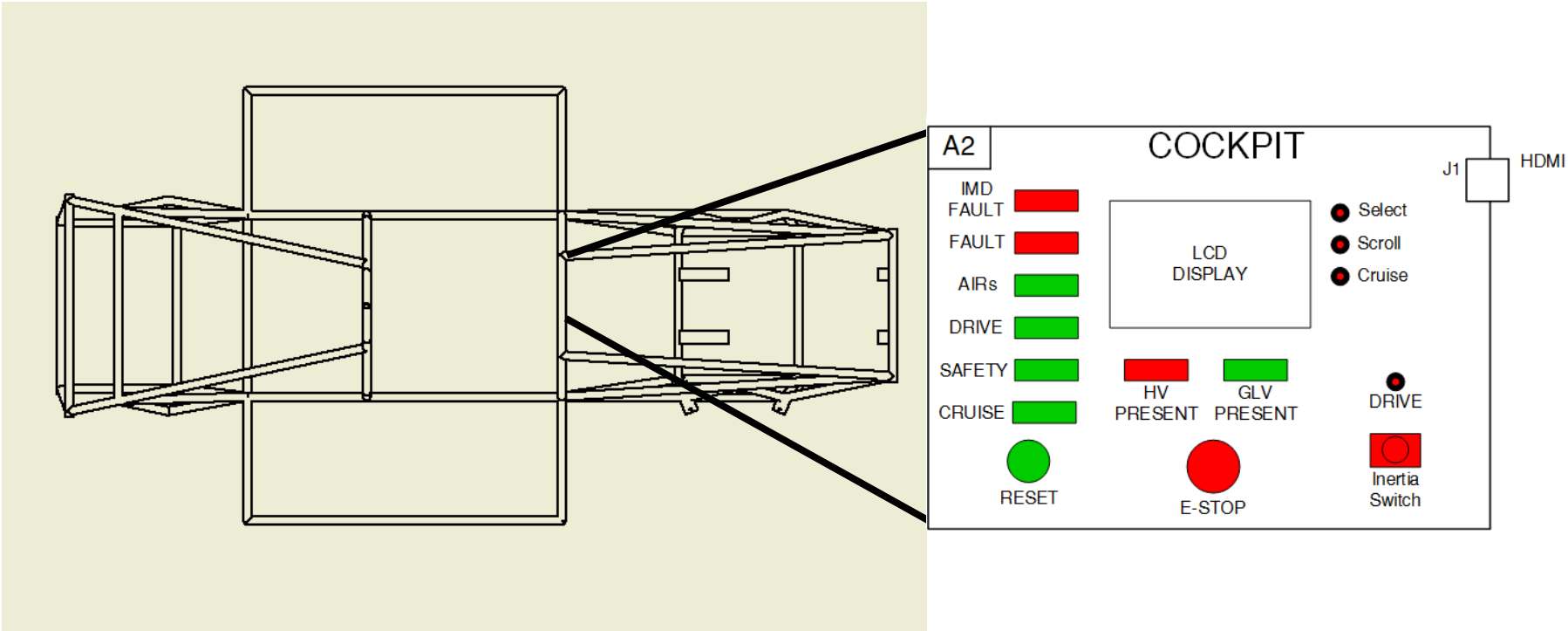
Systems announce status on CAN Bus



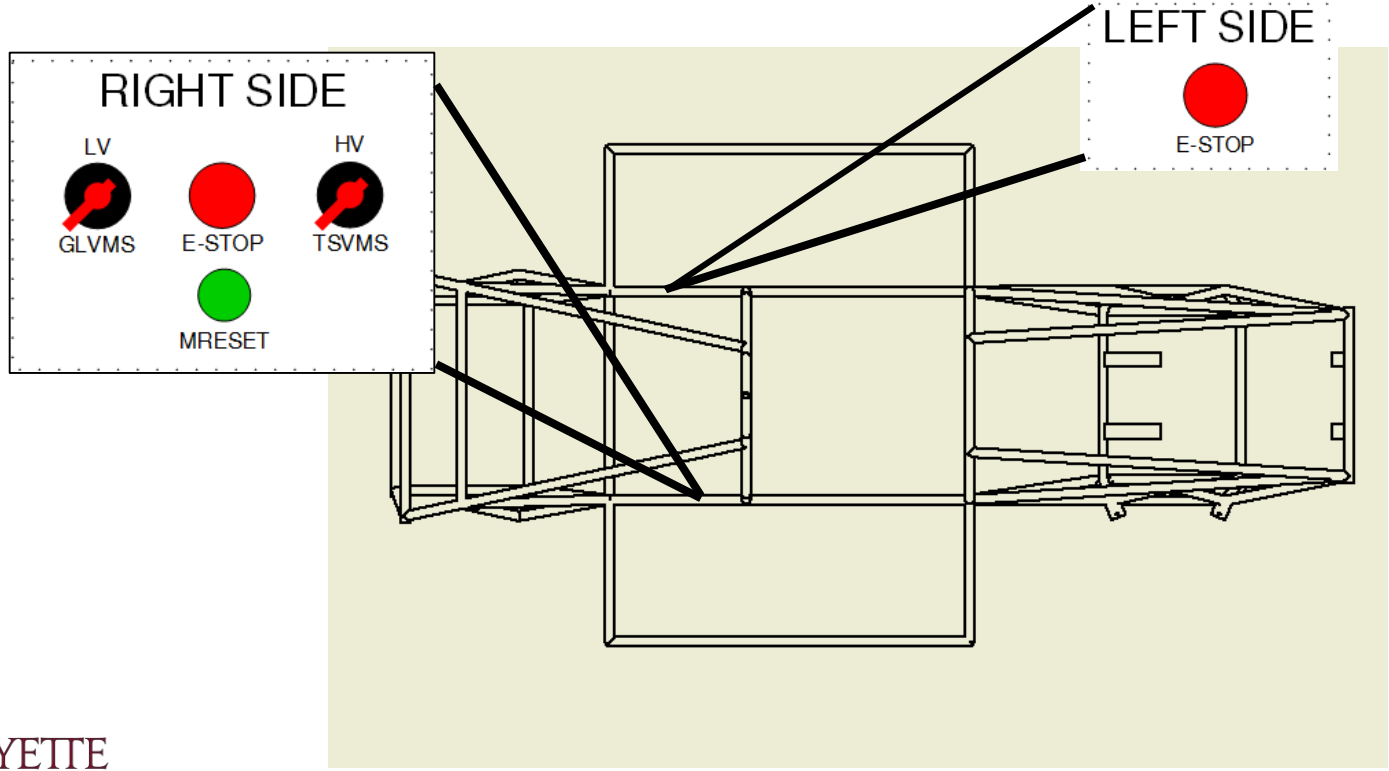
# System Overview - Interfaces

- Hardware
  - Cockpit
  - Panels
- Software
  - Dash
  - Remote Computer
  - Cell phone

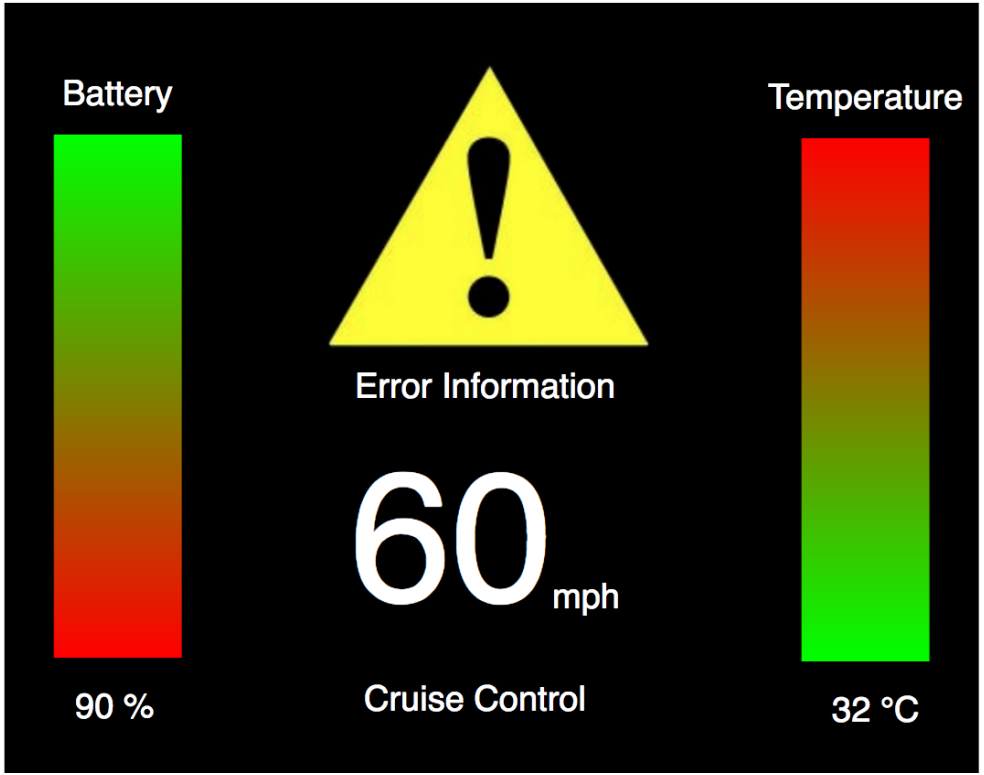
# Hardware Interfaces - Driver Accessible



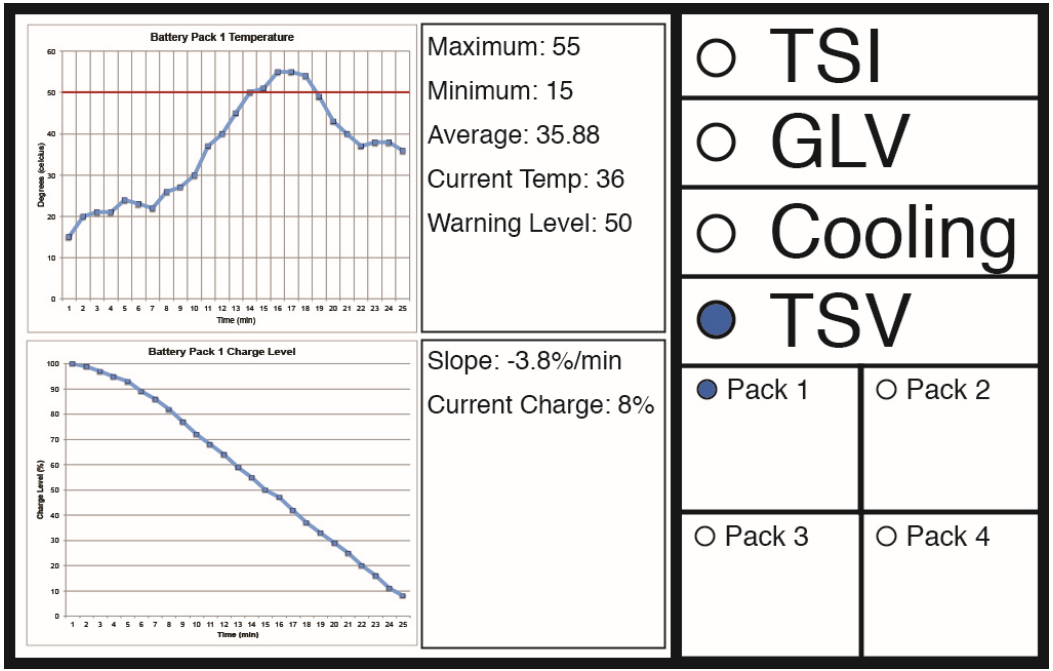
# Hardware Interfaces - Driver Inaccessible



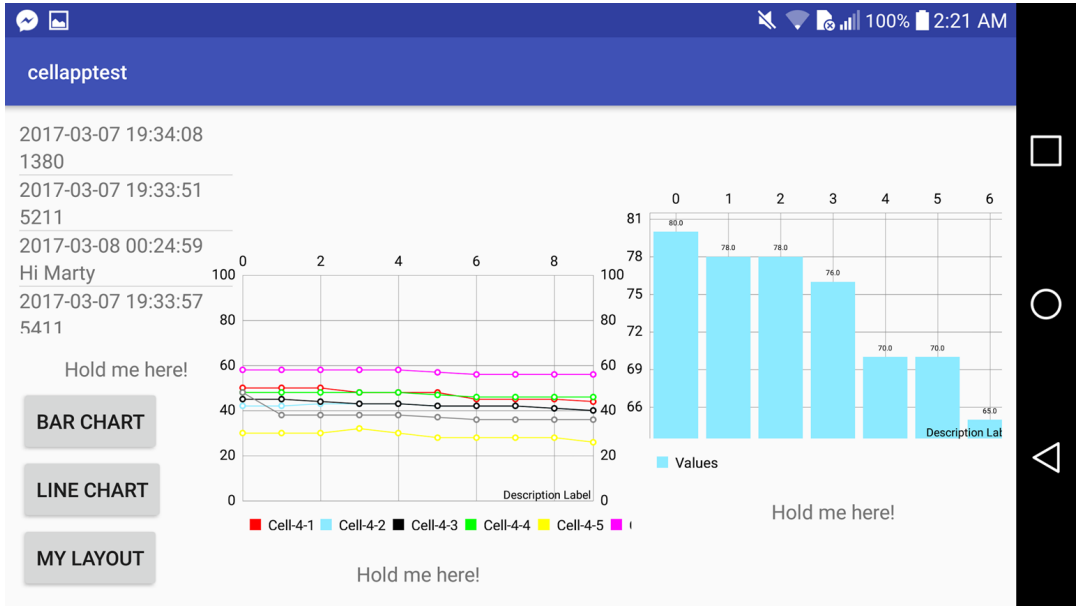
# Software Interfaces - LCD Display



# Software Interfaces - Remote Displays



# Software Interfaces - Cell Phone



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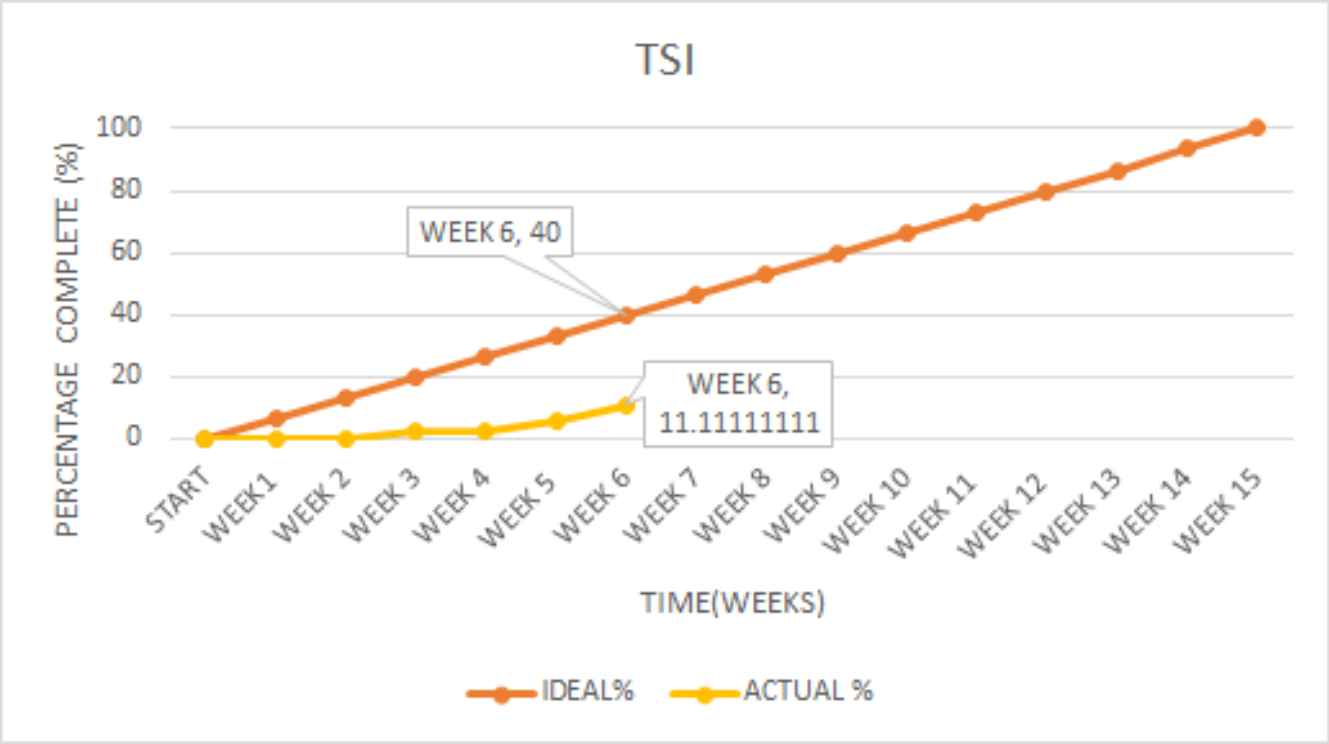
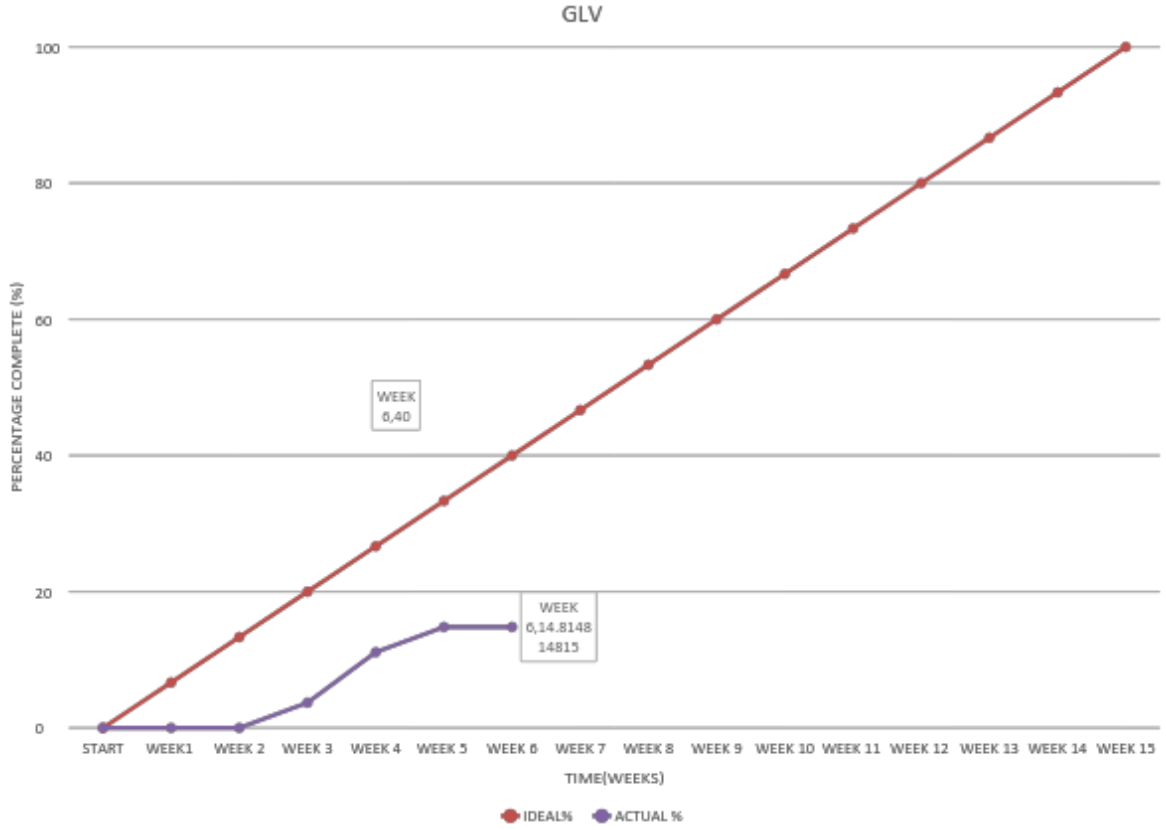
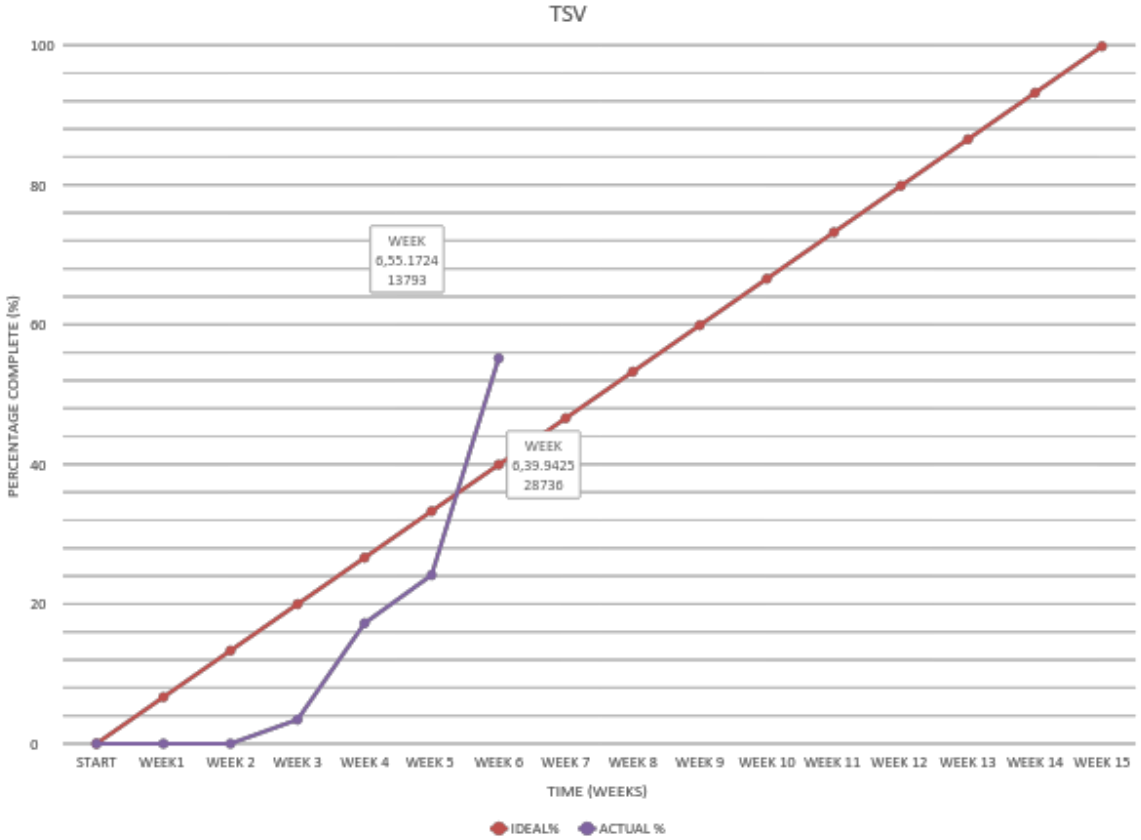
# Schedule - TSI



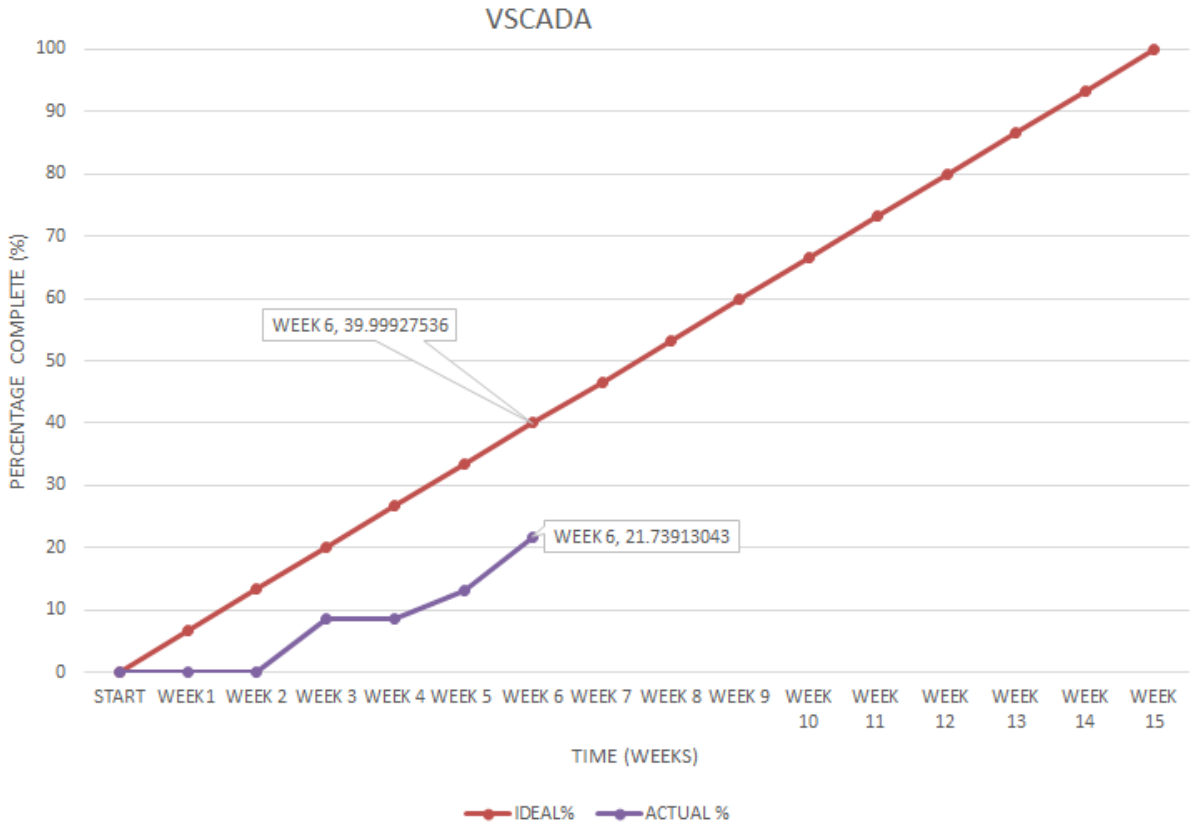
# Schedule - GLV



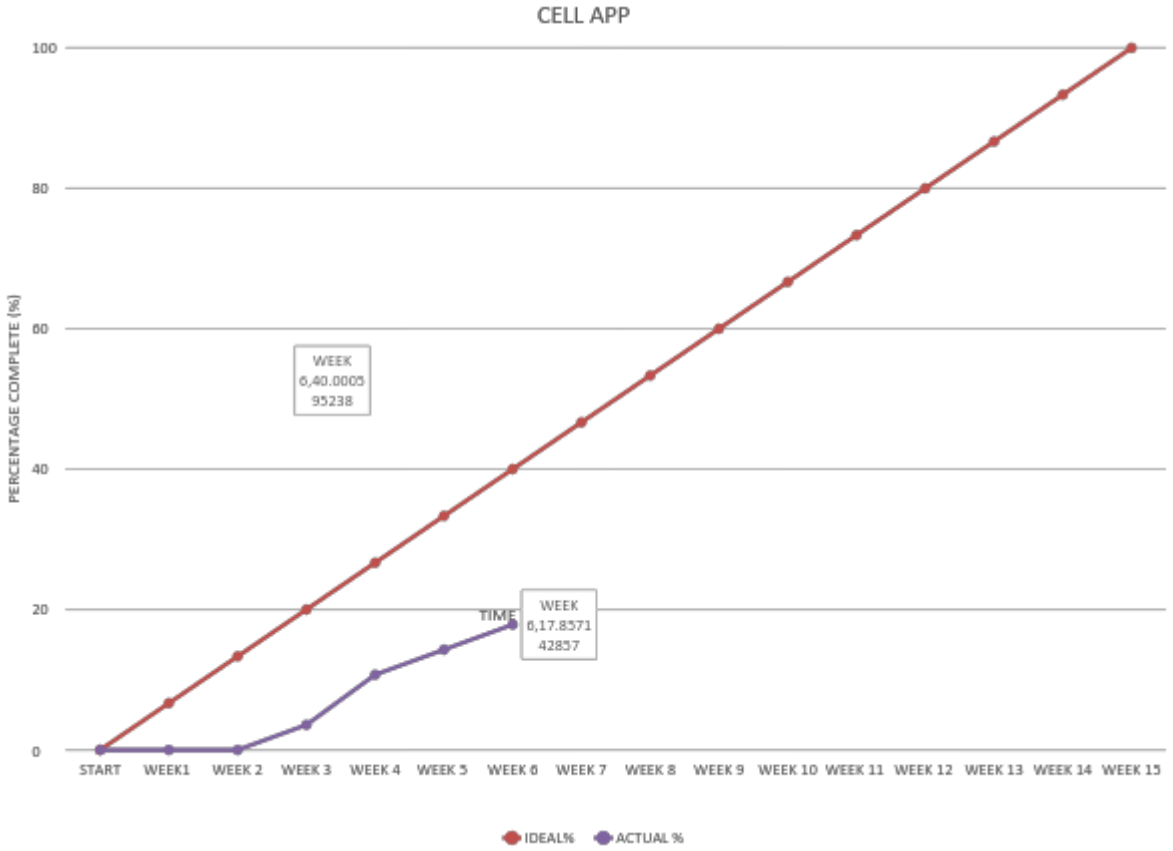
# Schedule - TSV



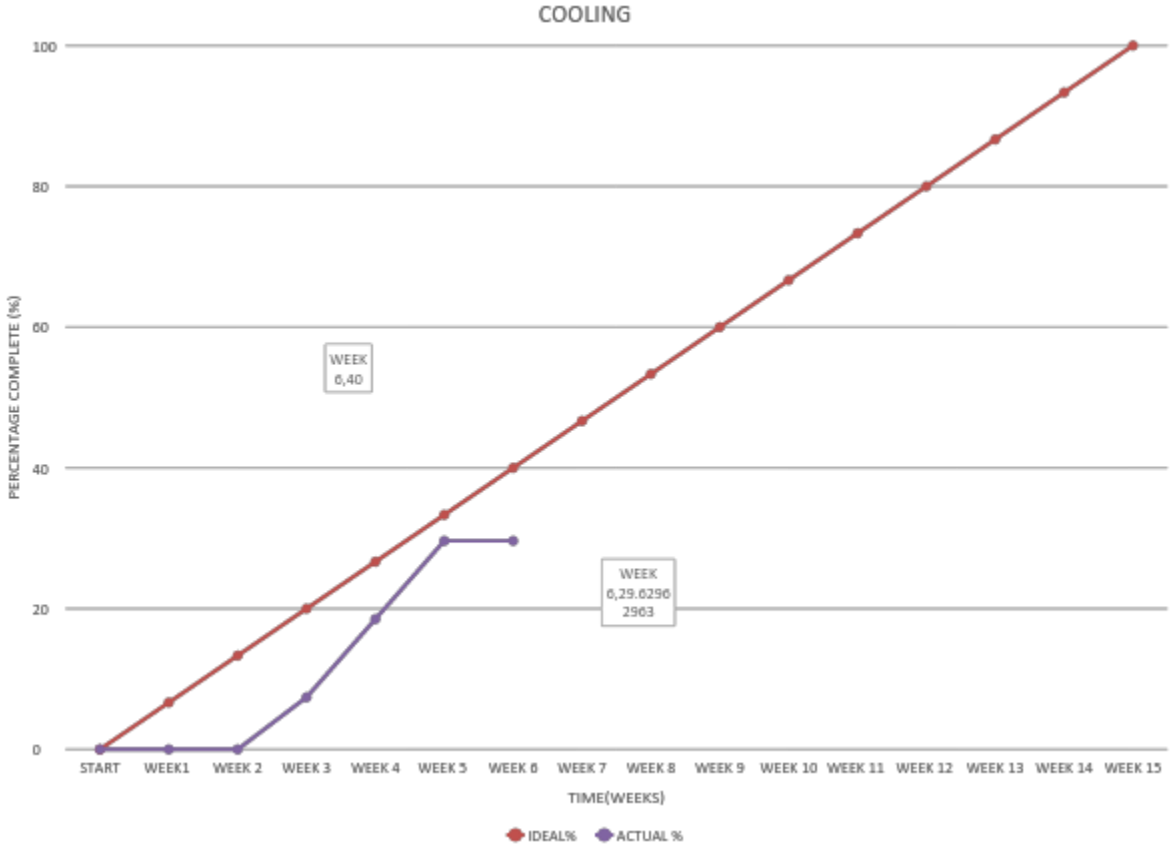
# Schedule - VSCADA



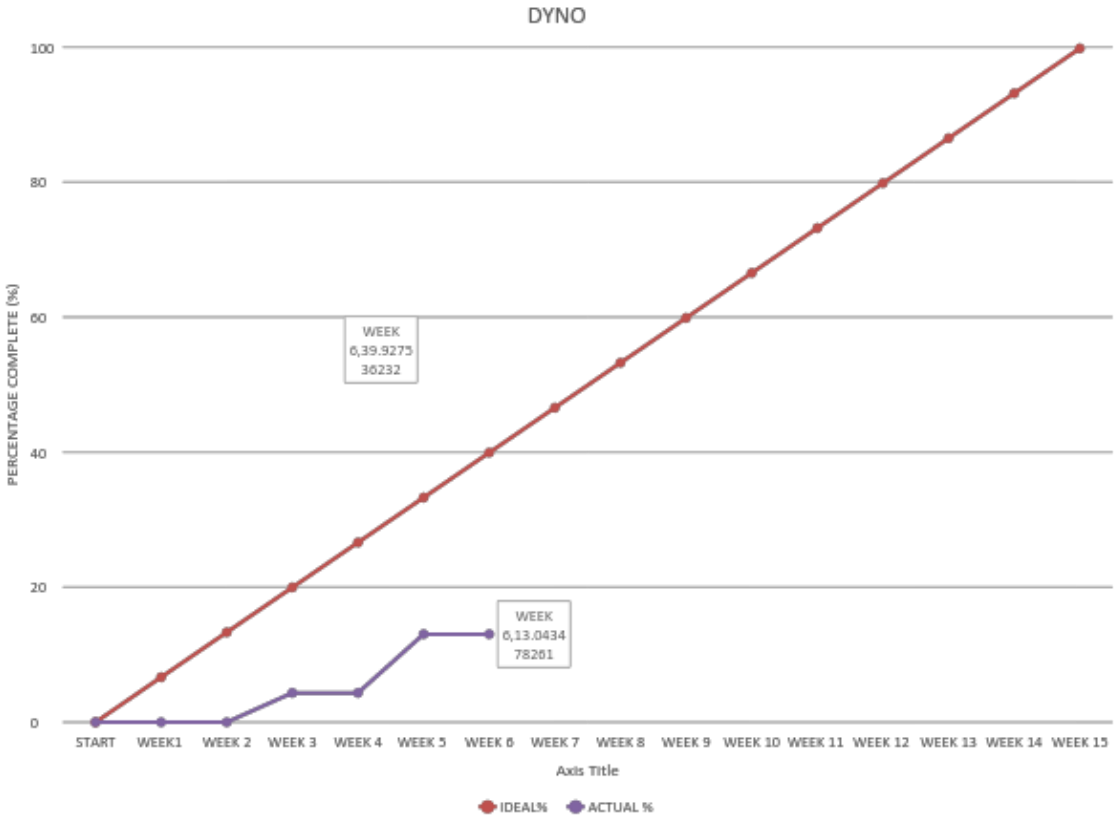
# Schedule - Cell App



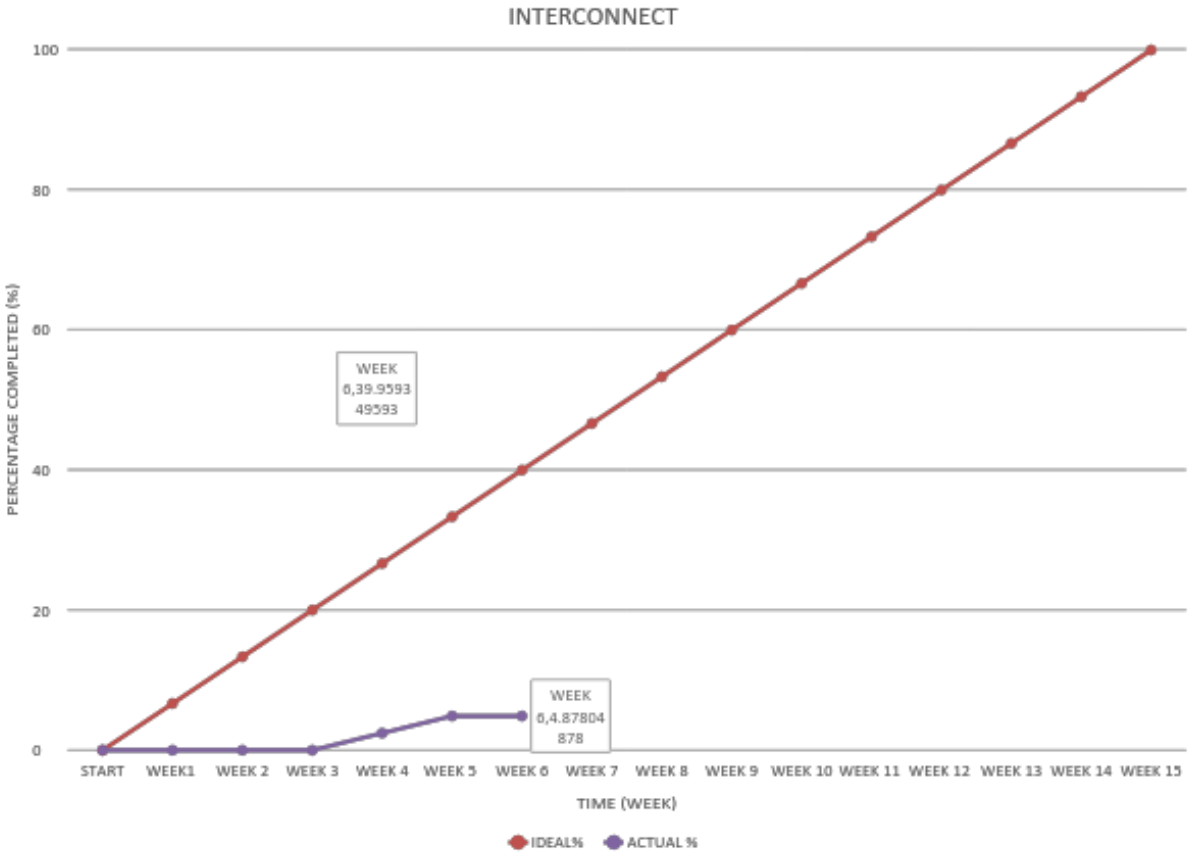
# Schedule - Cooling



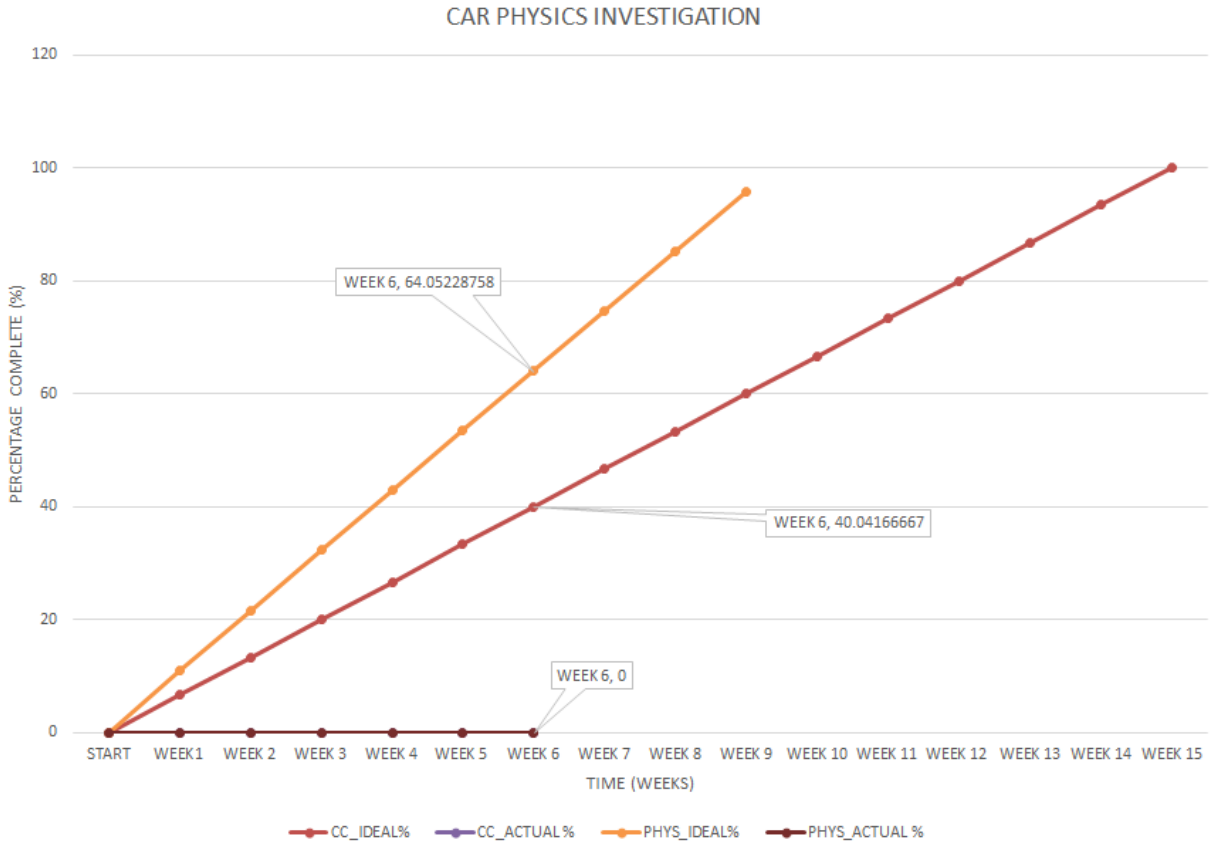
# Schedule - DYNO



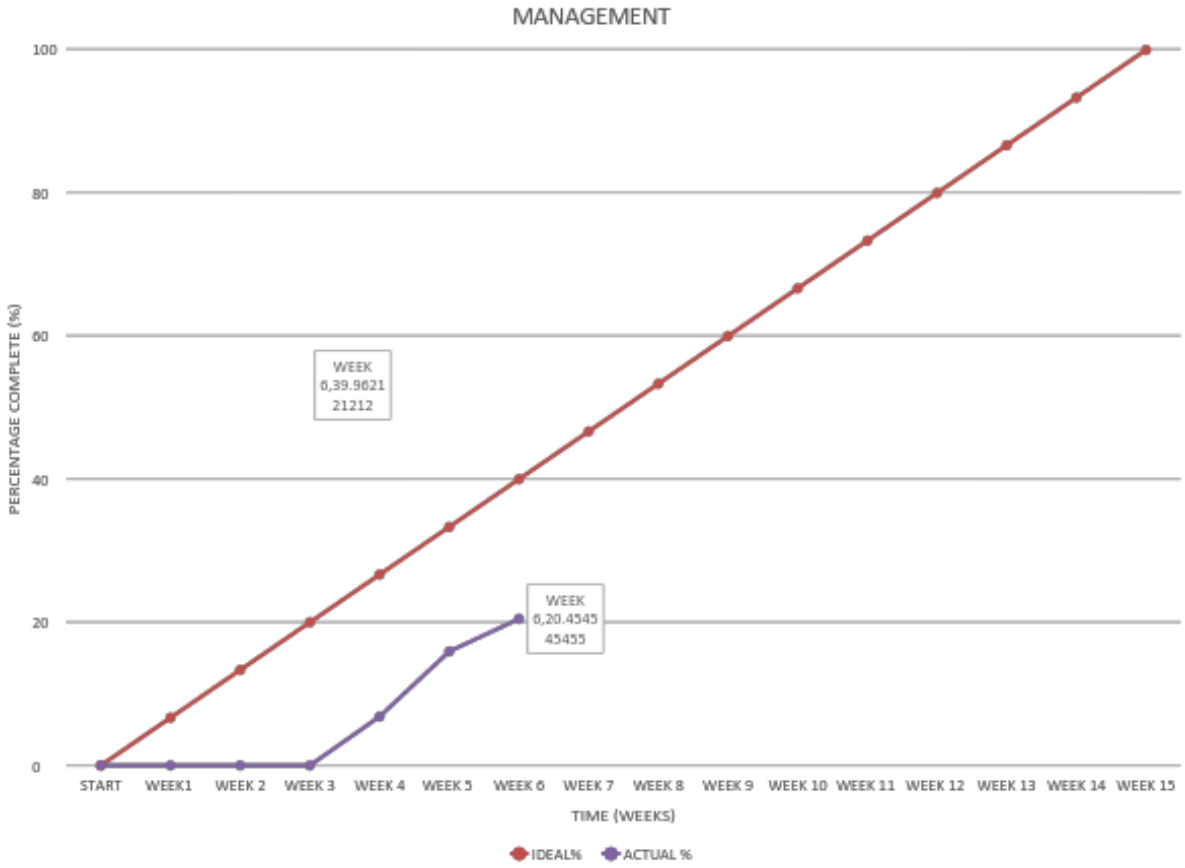
# Schedule - Interconnect



# Schedule - Car Physics Investigation



# Schedule - Management



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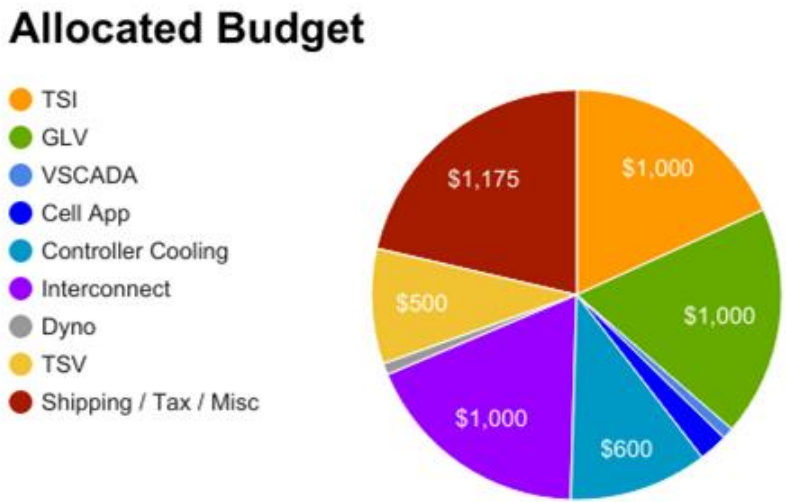
# Cost Analysis

| Team | Allocated Budget | Total Spent | Budget Remaining | Percentage Spent |
|---|---|---|---|---|
| TSI | $1,000 | $153.61 | $846.39 | 15.36% |
| GLV | $1,000 | $275.82 | $724.18 | 27.58% |
| VSCADA | $50 | $0.00 | $50.00 | 0.00% |
| Cell App | $125 | $0.00 | $125.00 | 0.00% |
| Controller Cooling | $600 | $452.92 | $147.08 | 75.49% |
| Interconnect | $1,000 | $1122.20 | -$122.20 | 112.20% |
| Dyno | $50 | $0.00 | $50.00 | 0.00% |
| TSV | $500 | $388.95 | $111.05 | 77.79% |
| Shipping / Tax / Misc | $1,175 | $159.94 | $1,015.06 | 13.61% |
| **TOTAL** | **$5,500** | **$2,553.44** | **$2,946.56** | **46.43%** |

http://sites.lafayette.edu/ece492-sp17/cost-summary/

# Cost Analysis - Allocated Budget

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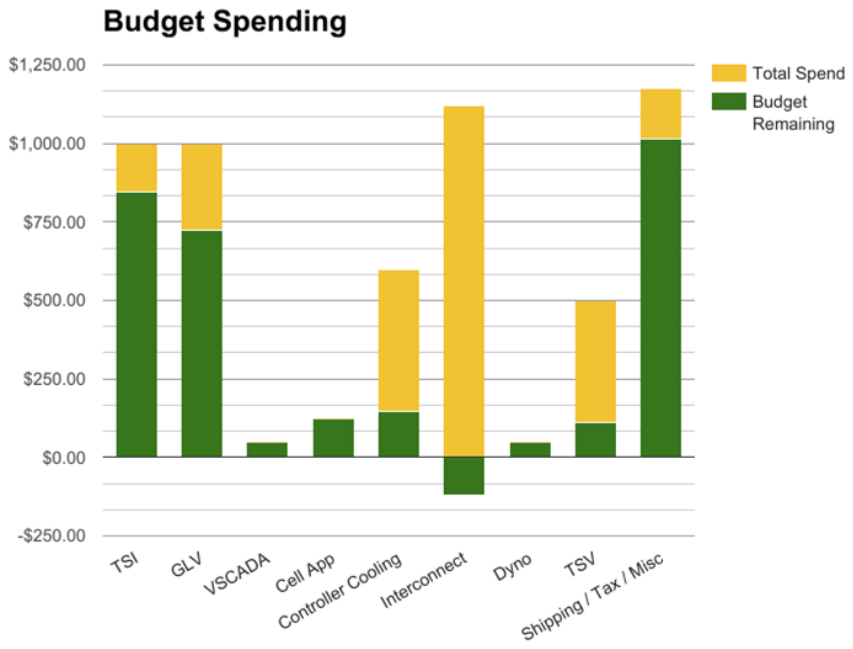
| VSCADA | $50 |
| Cell App | $125 |
| Controller Cooling | $600 |
| Interconnect | $1,000 |
| Dyno | $50 |
| TSV | $500 |
| Shipping / Tax / Misc | $1,175 |
| **TOTAL** | **$5,500** |

# Cost Analysis - Current Budget Status

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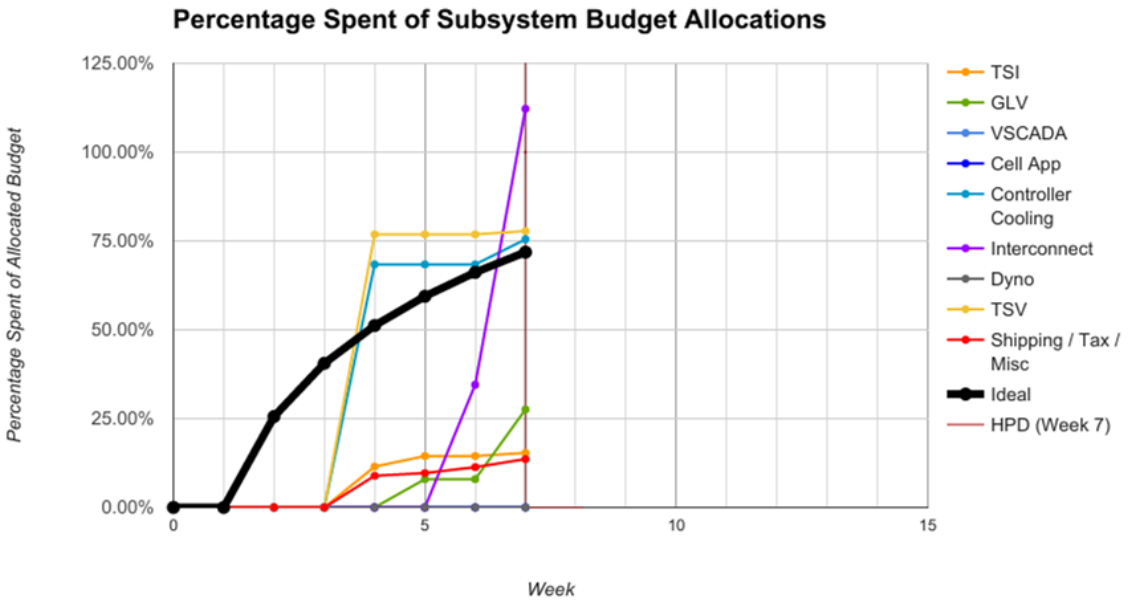
| **TOTAL** | **$5,500** | **$2,553.44** | **$2,946.56** |

# Cost Analysis - Percentage Spent per Subsystem

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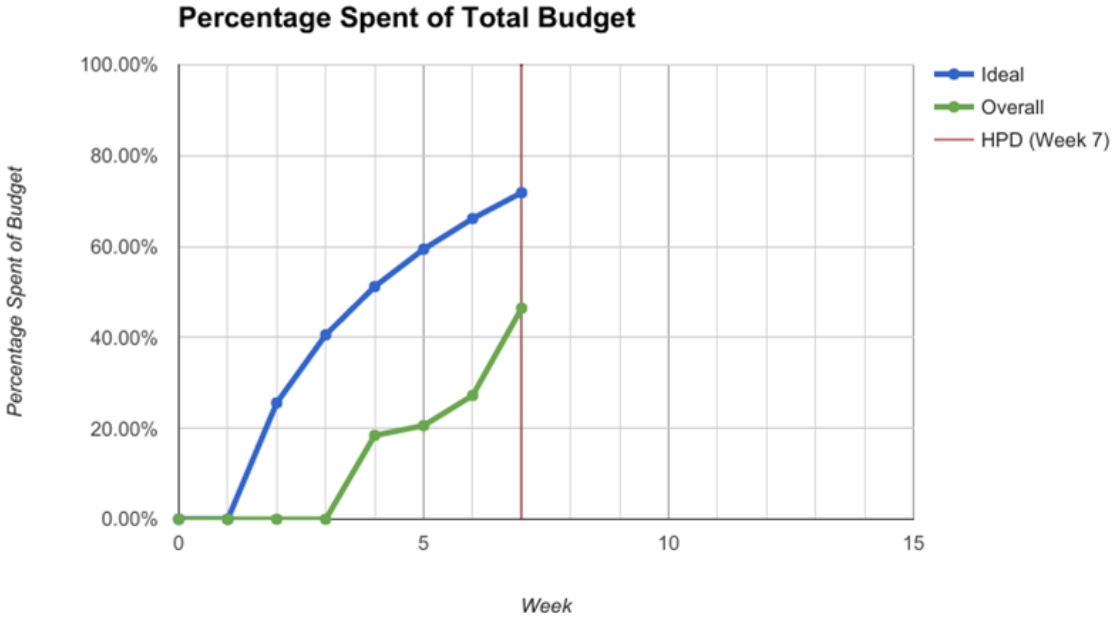
| Interconnect | 112.20% |
| Dyno | 0.00% |
| TSV | 77.79% |
| Shipping / Tax / Misc | 13.61% |
| **TOTAL** | **46.43%** |
| *Ideal* | *71.86%* |

# Cost Analysis - Percentage Spent Overall

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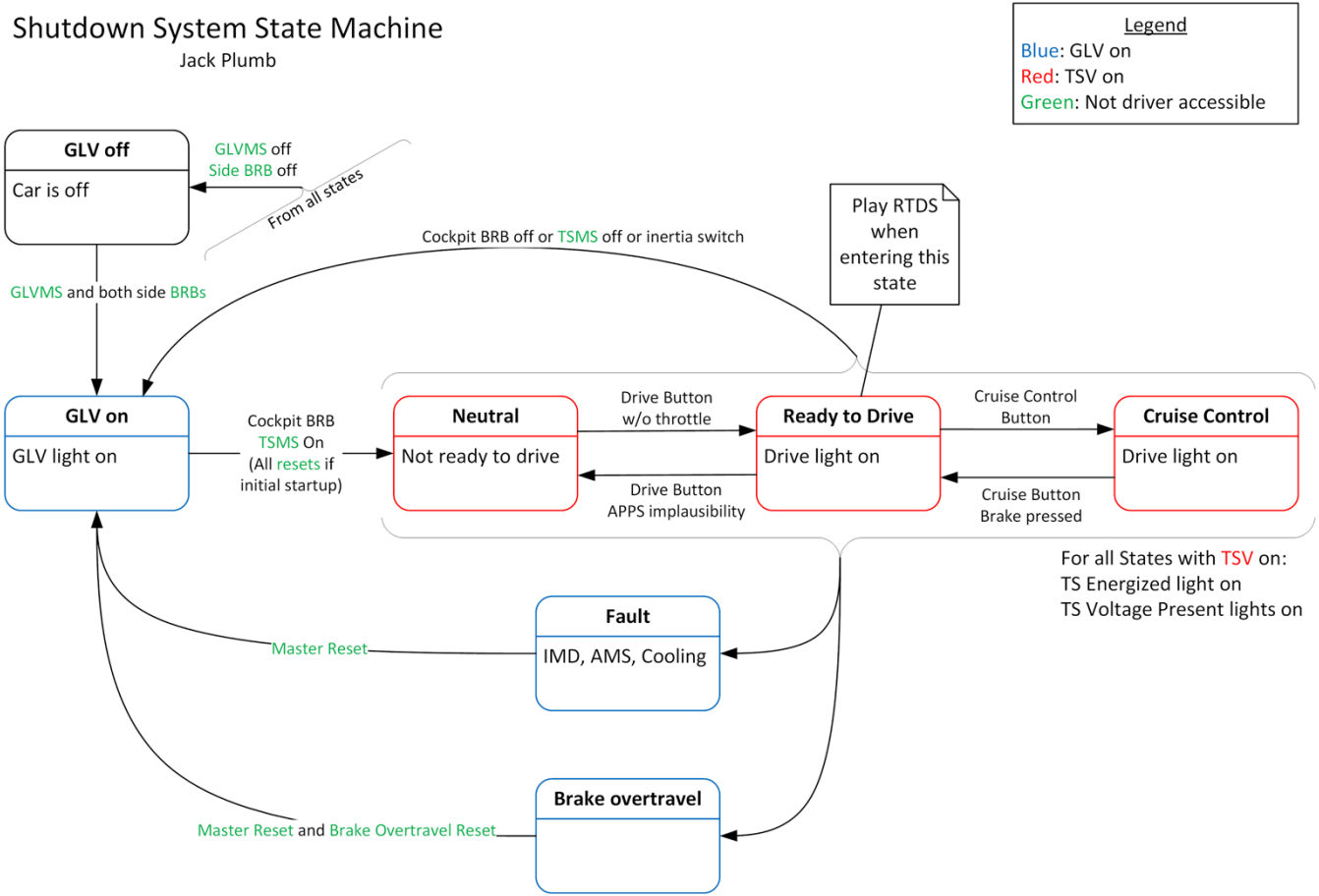
# System States



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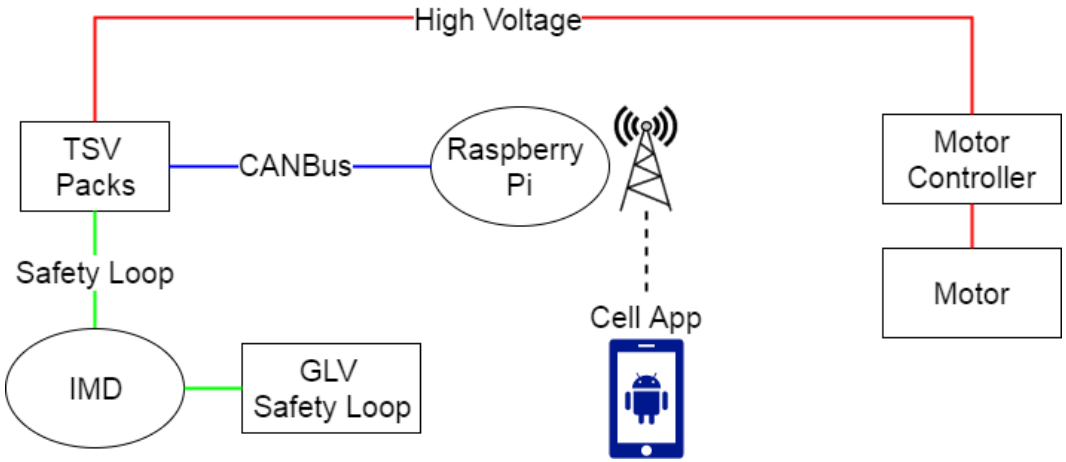
# Demo Plan

- 4 Packs
- Spin motor
- Safety Loop
- CAN Bus communication
- Cell communication
- IMD Fault safety loop



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# VSCADA

Craig Lombardo & Austin Wiles

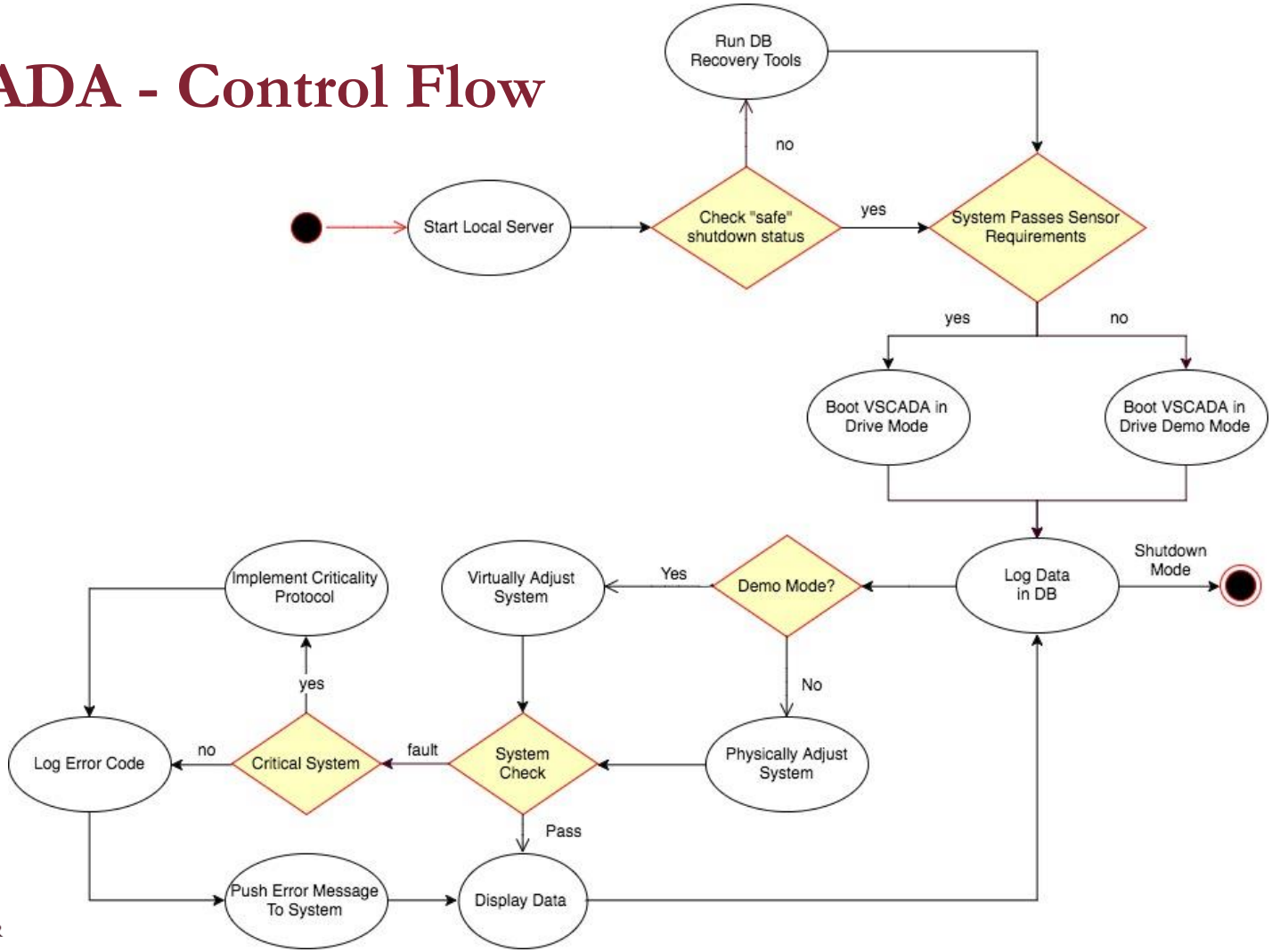
# Why Do We Need VSCADA?

- VSCADA acts as the “brains” of the car
- Comprehensive control and monitoring of the subsystems in the LFEV
- Dynamometer control to simulate operations of an actual car
  - Physics Modeling
- VSCADA displays information to both the driver and developers
  - Driver: limited information
  - Developer: extensive information

# VSCADA - Installing Software

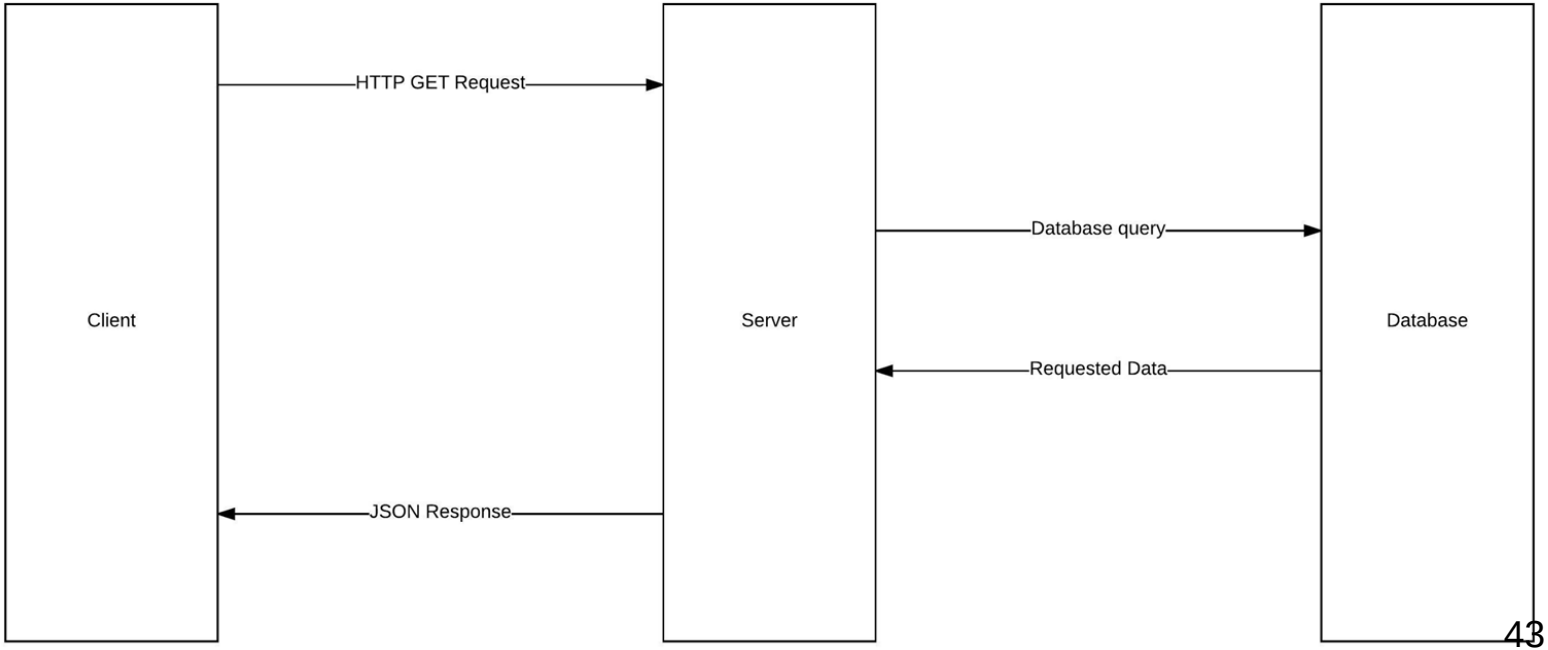
1. git clone https://github.com/LafayetteFormulaElectricVehicle/VSCADA.git
2. cd VSCADA/
3. make install
4. ./scada or ./configuration

# VSCADA - Control Flow



# VSCADA - Web Server

- HTTP Web Server
- Can query database using endpoints provided by web API
- Information sent to Cell in JSON format



# VSCADA - Database Structures

| SensorLabels | | | | |
|---|---|---|---|---|
| ID | SensorName | System | Category | Units |
| 1 | CellV1 | TSV | Cell | V |
| 2 | CellV2 | TSV | Cell | V |
| . | . | . | . | . |

| Data | | | |
|---|---|---|---|
| sensorID | raw | calibrated | TimeStamp |
| 1 | 0x29 | 4.30 | 2017-02-23 13:43:04 |
| 2 | 0x28 | 4.20 | 2017-02-23 13:43:04 |
| . | . | . | . |

# VSCADA - Database Structures cont.

| Configurations | | | | | | | |
|---|---|---|---|---|---|---|---|
| sensorID | stableLow | stableHigh | criticalLow | criticalHigh | criticality | slope | offset |
| 1 | 4.1 | 4.5 | 3.9 | 4.7 | 1 | 9 | -0.25 |
| 2 | 4.1 | 4.5 | 3.9 | 4.7 | 1 | 9 | -0.25 |
| . | . | . | . | . | . | . | . |

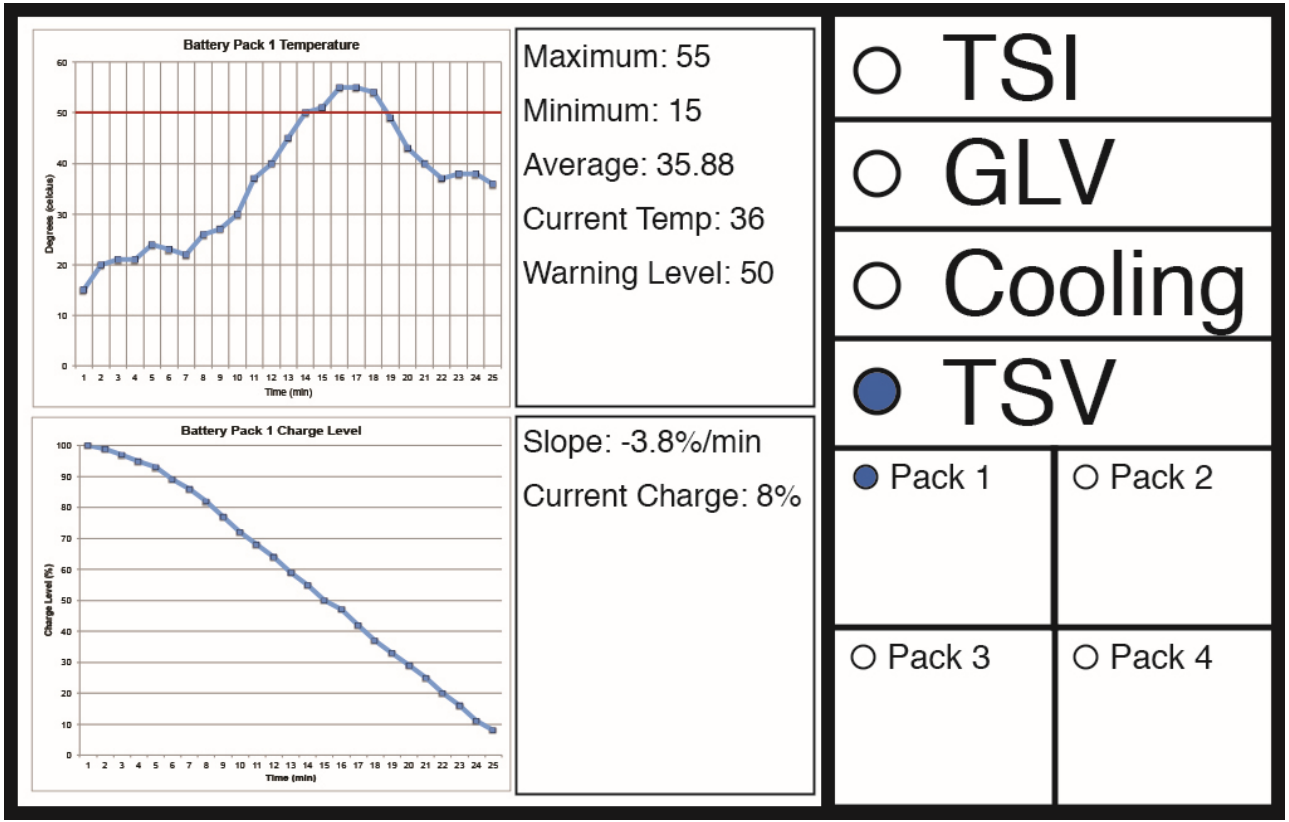
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Low | | Neutral | | High |

Criticality Scale

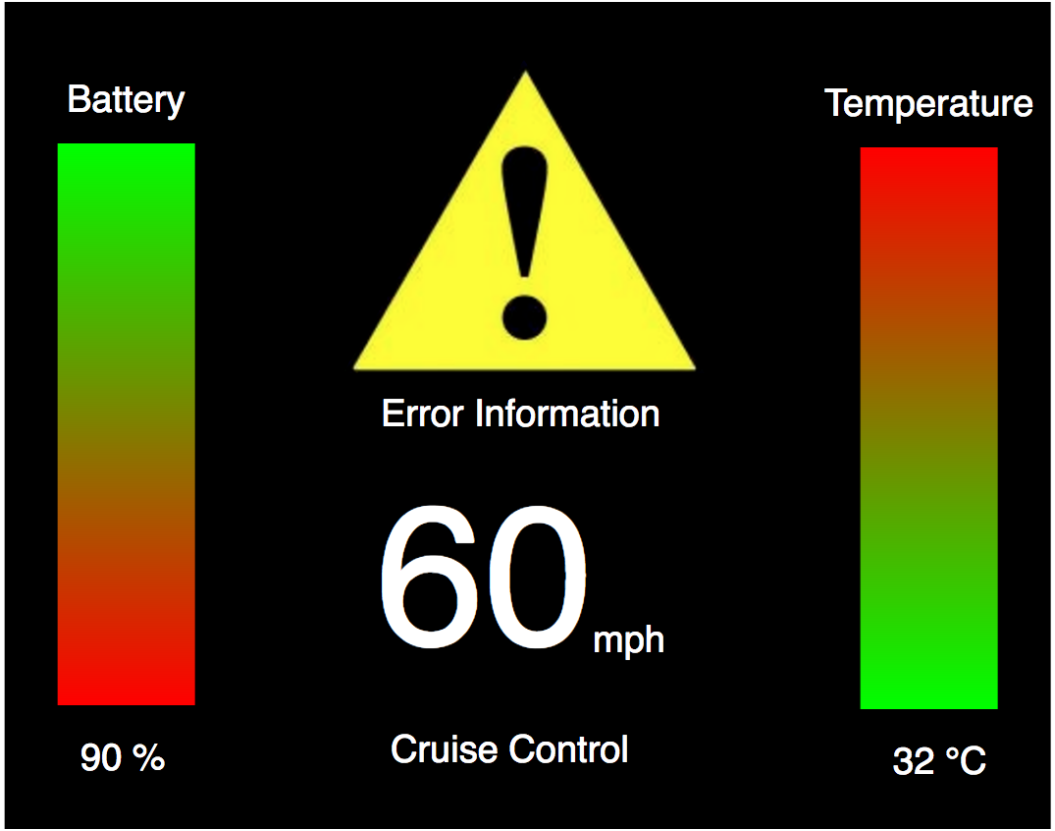
# VSCADA - Database Structures cont.

| Errors | | |
|---|---|---|
| sensorID | calibrated | TimeStamp |
| 1 | 4.6 | 2017-02-23 13:46:04 |
| 2 | 4.9 | 2017-02-23 13:46:04 |
| . | . | . |

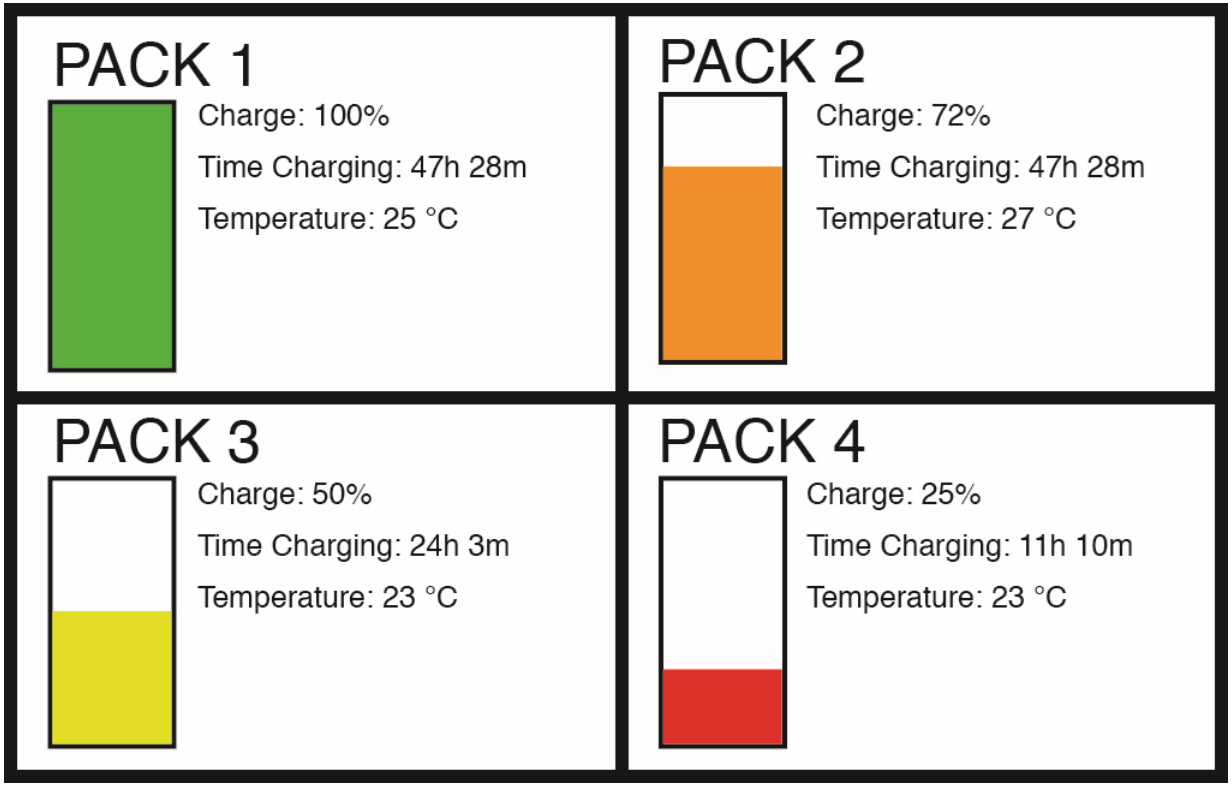
# VSCADA - Maintenance View



# VSCADA - Drive View



# VSCADA - Charging View



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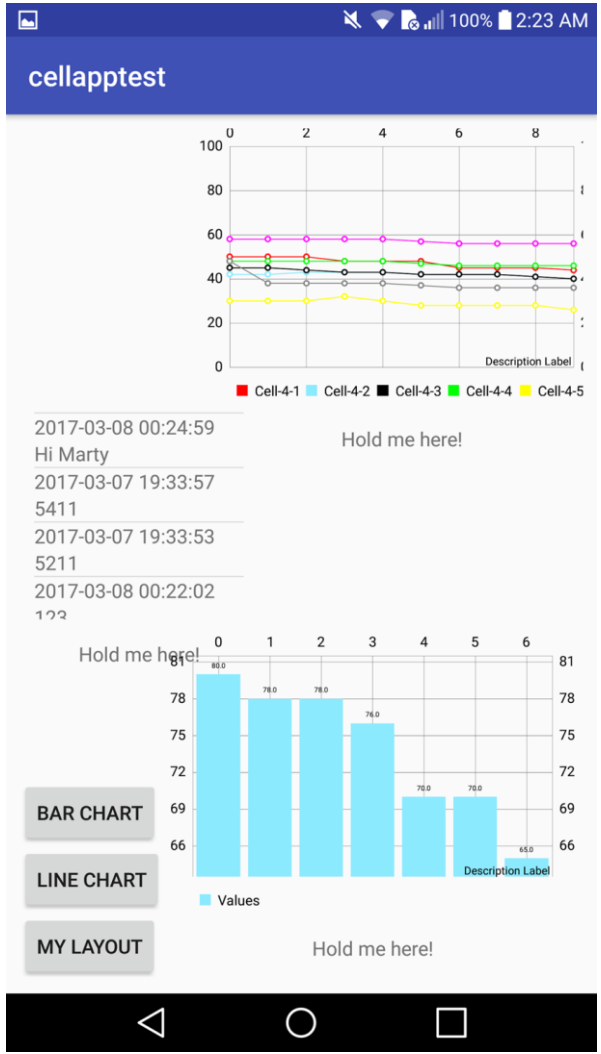
# Cell App

Kemal Dilsiz & Raji Birru

# Cell App - In depth design - Layout

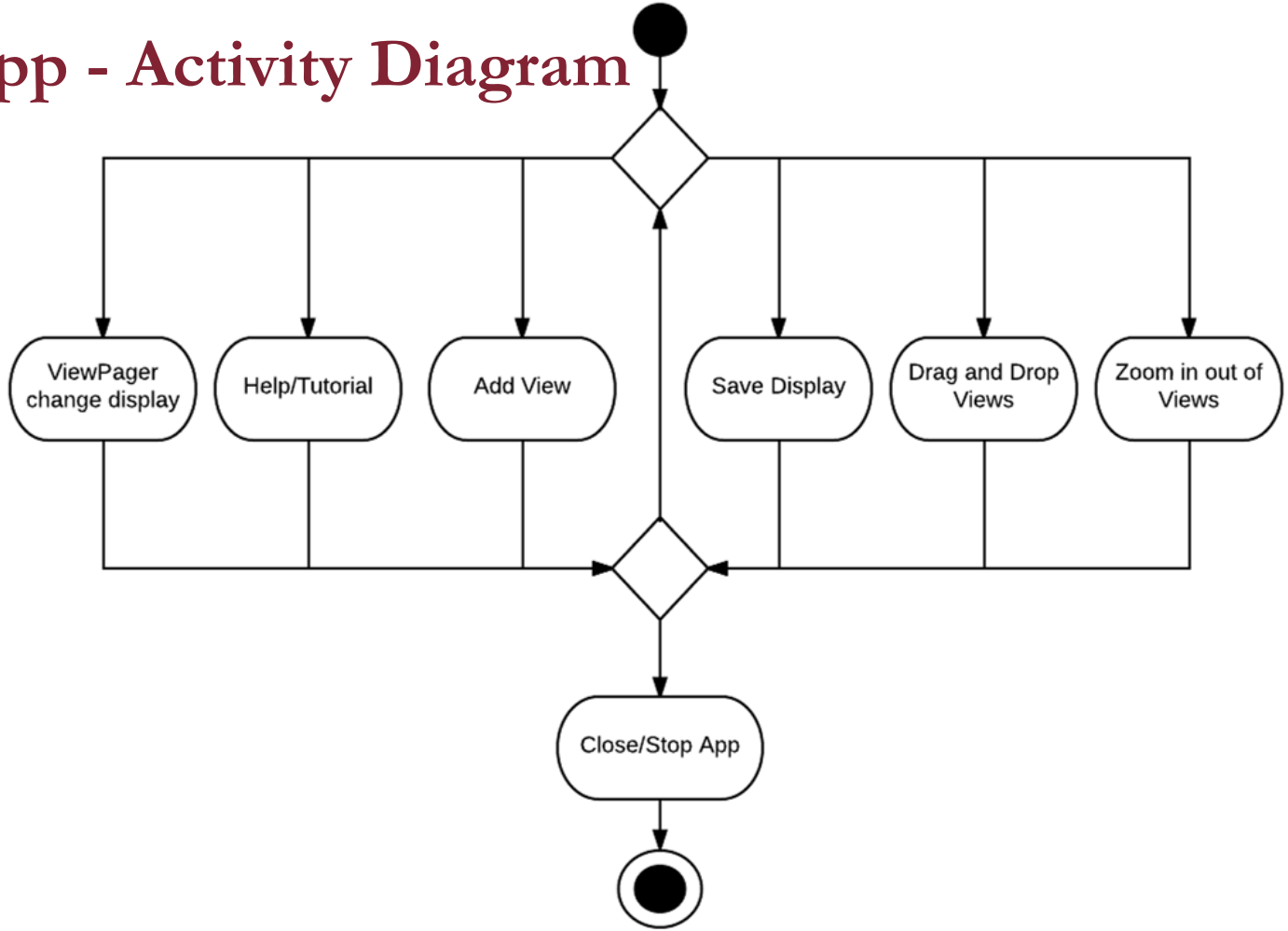
- Customizable Display
- Automatically generated generic data availability
- ViewPager for multiple display tabs

| TSV | Cell | 1 | Voltage |
|---|---|---|---|
| TSI | Pack | 2 | Current |
| Dyno | Accumulator | 3 | SOC |
| Cooling | | 4 | Temperature |
| Physics | | 5 | |
| ... | | 6 | |
| | | ... | |



# Cell App - Landscape Layout

# Cell App - Activity Diagram



# Cell App - In-Depth Design - Data Structures

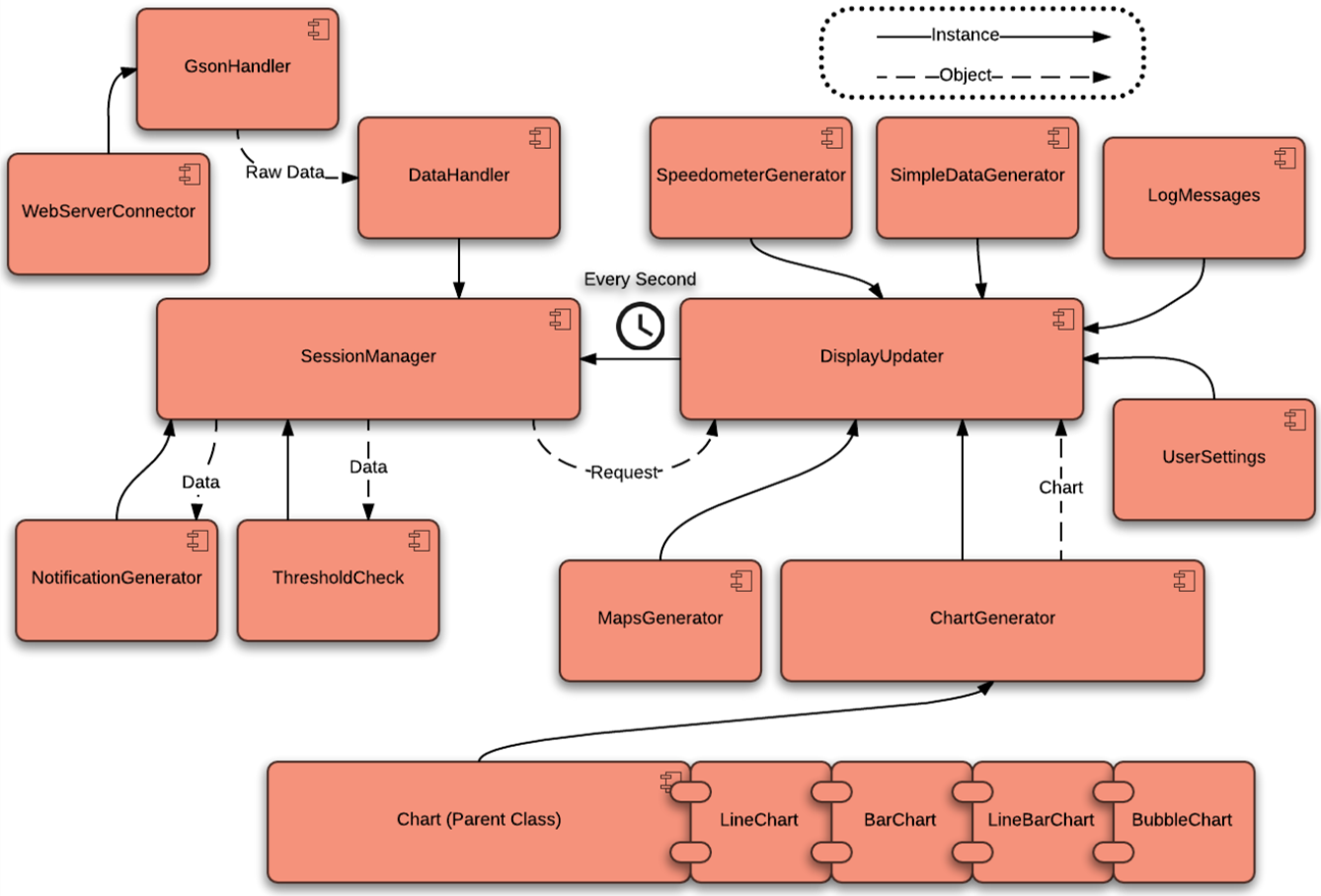
Dictionary of dictionaries, provides a generic way to locally store data temporarily

Hashcodes

> "tsvcell1voltage"
> "03/03/2017 17:56:34"

```
newSystem.put("03/03/2017 17:56:34", "8.1");
allSystems.put("tsvcell1voltage", newSystem);
```

# Cell App - Content Diagram



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# TSI

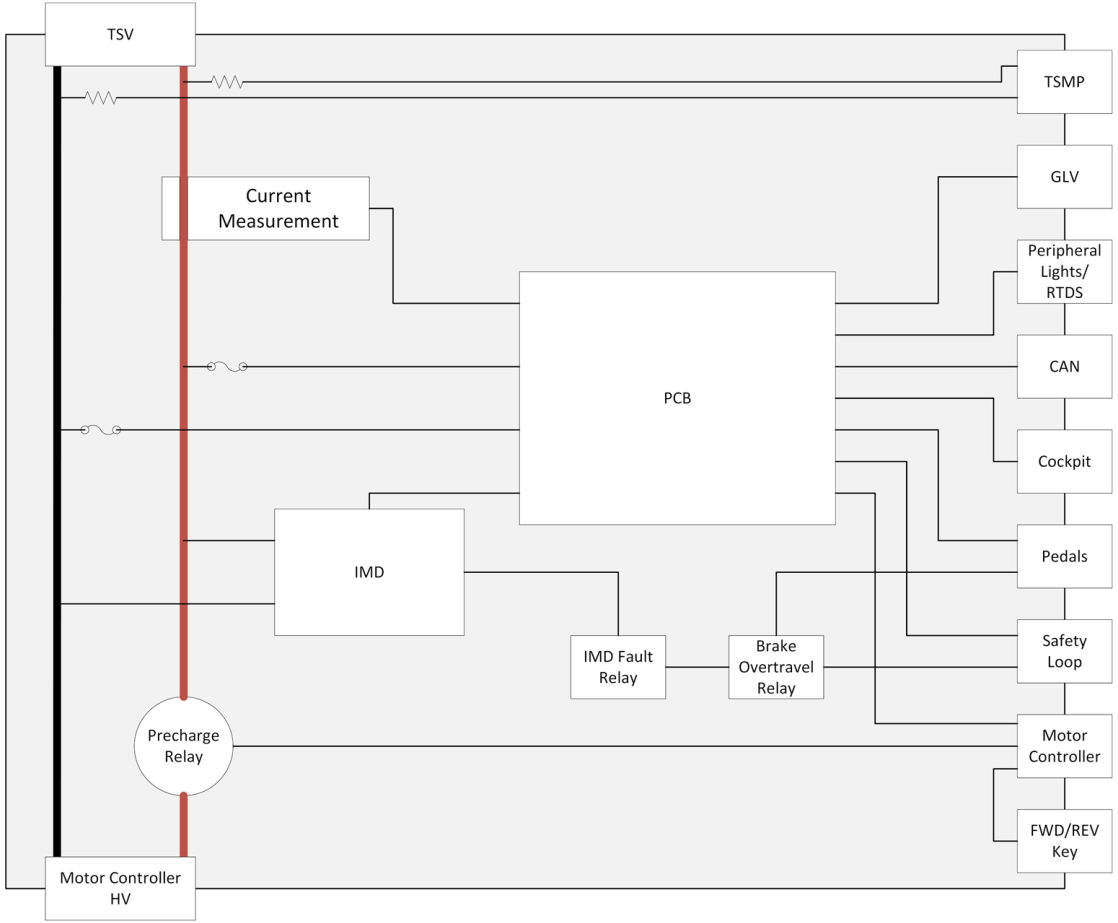
Christer Hoeflinger, Jack Plumb,
& Adam Ness

# TSI - System Overview

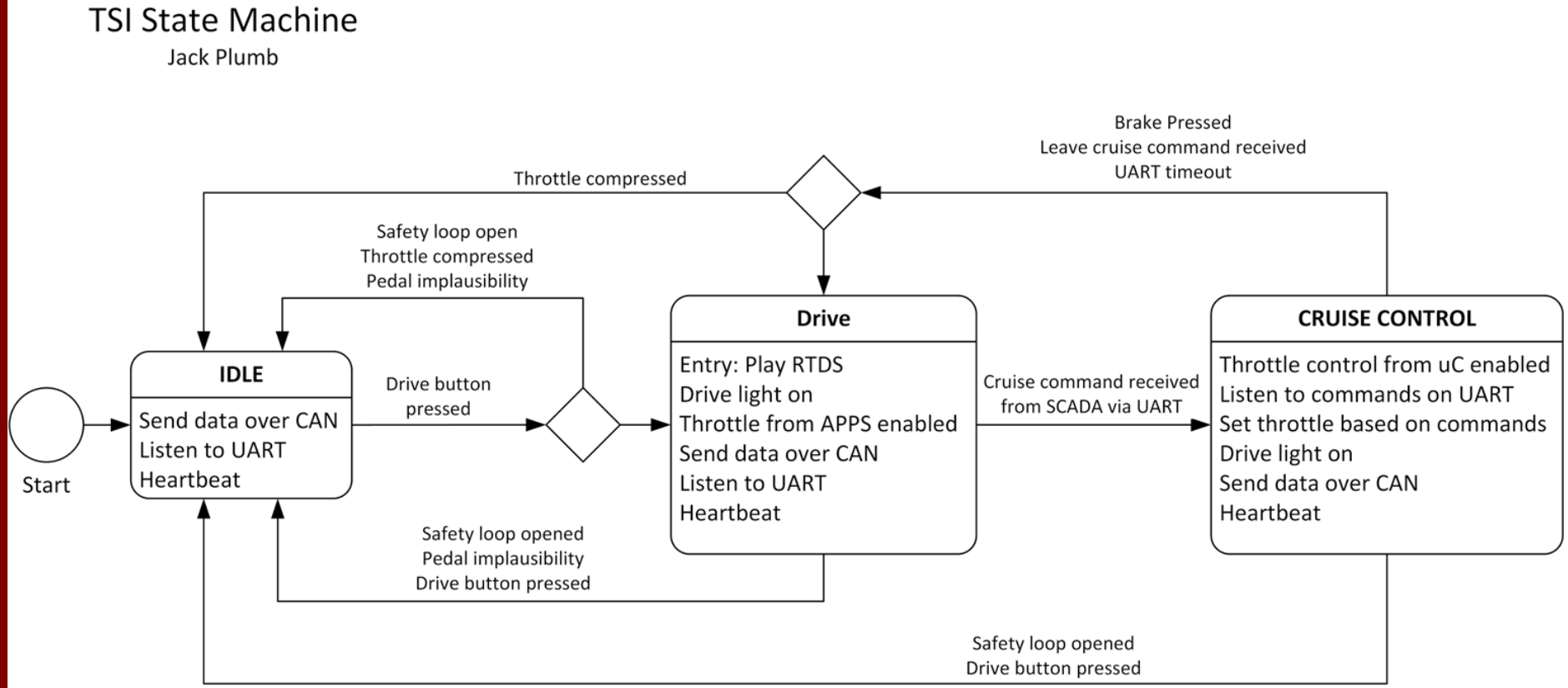
Safely connect tractive system voltage to motor controller

- Interface with throttle and brake pedals
- Interface with Insulation Monitoring Device (IMD)
- Send voltage, current, and IMD resistance to SCADA
- Control drive state
- Tractive System Measuring Point

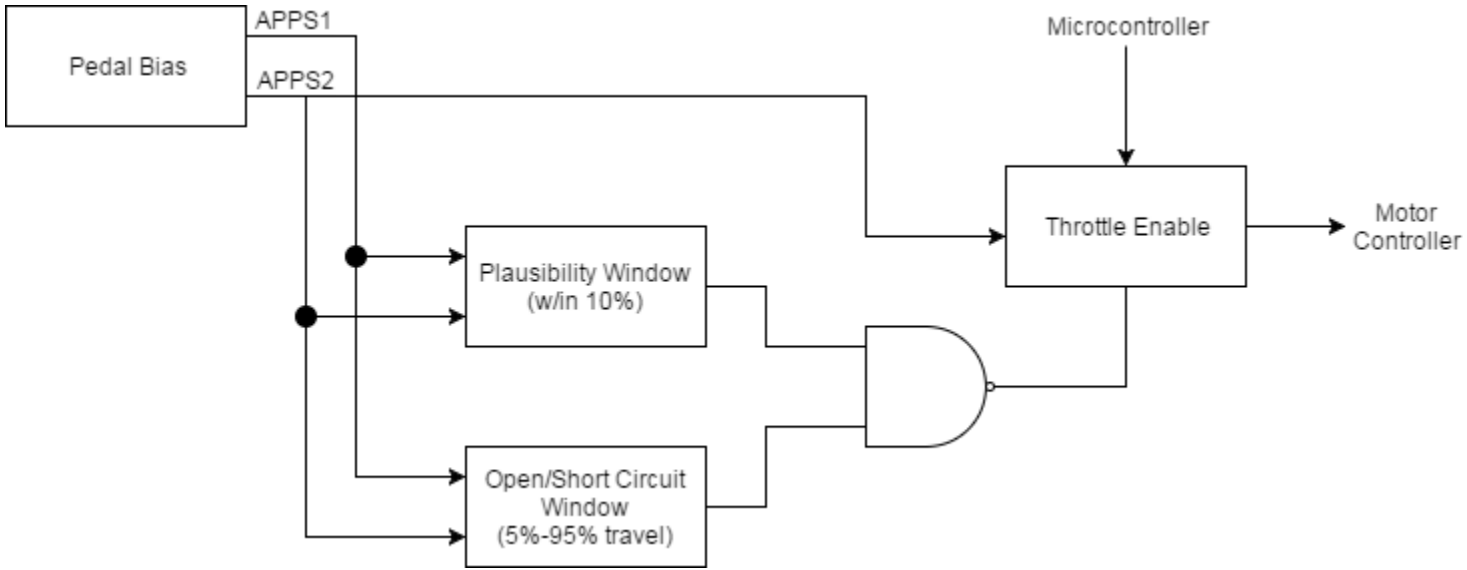
# TSI - High Level Block Diagram



# TSI - System State Diagram

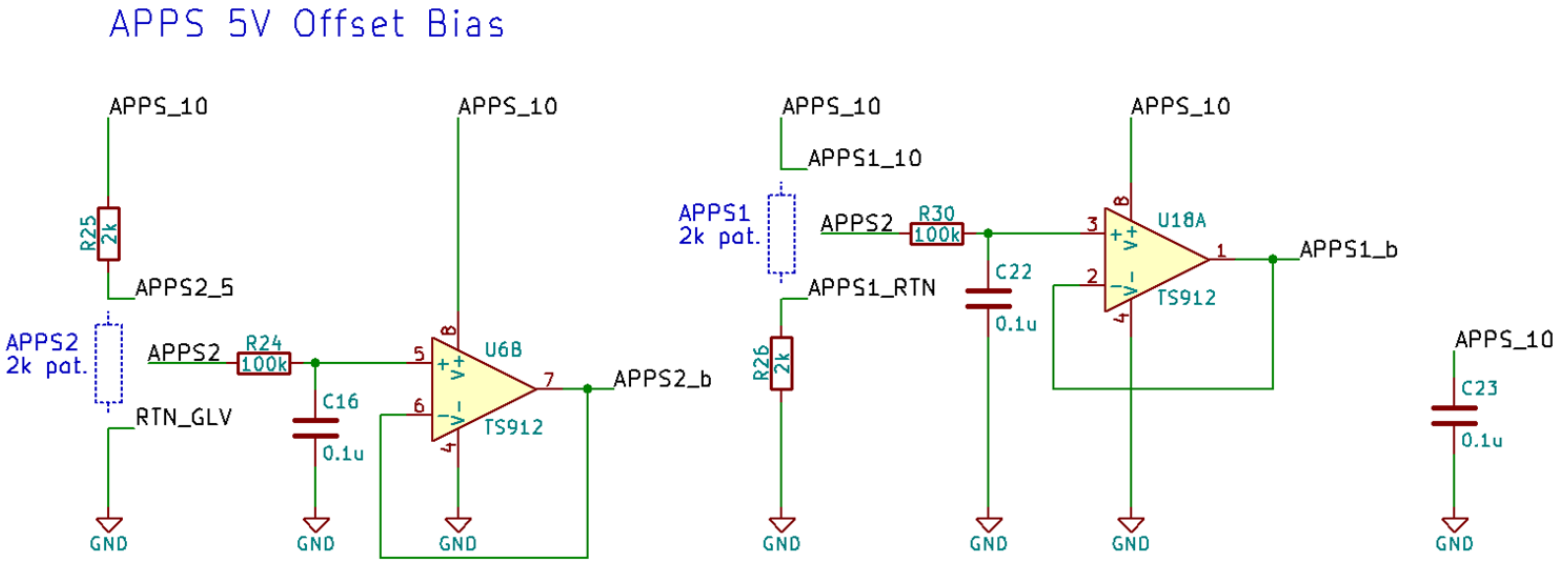


# TSI - Circuit Schematic - Throttle Plausibility Overview



# TSI - Circuit Schematic - Throttle Plausibility

- Two separate, linear potentiometers
- Biased 5V apart

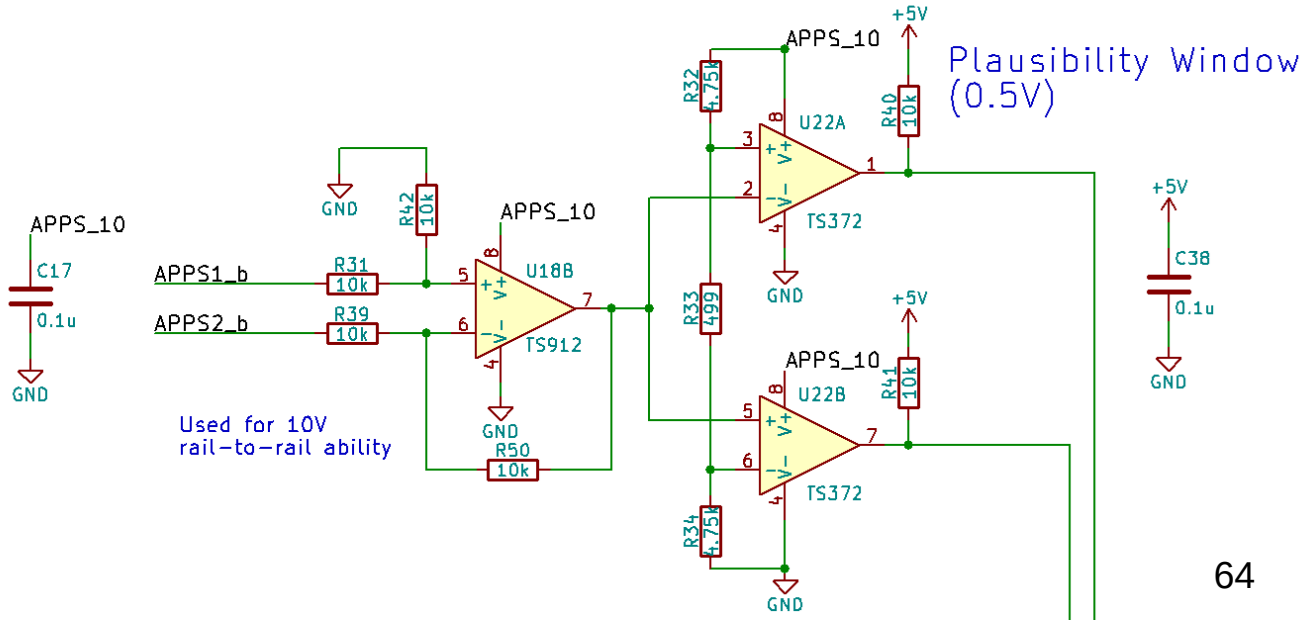


# TSI - Circuit Schematic - Throttle Plausibility cont'd

Multiple Failure Modes

1. Deviation of more than 10% pedal travel between the sensors[1]

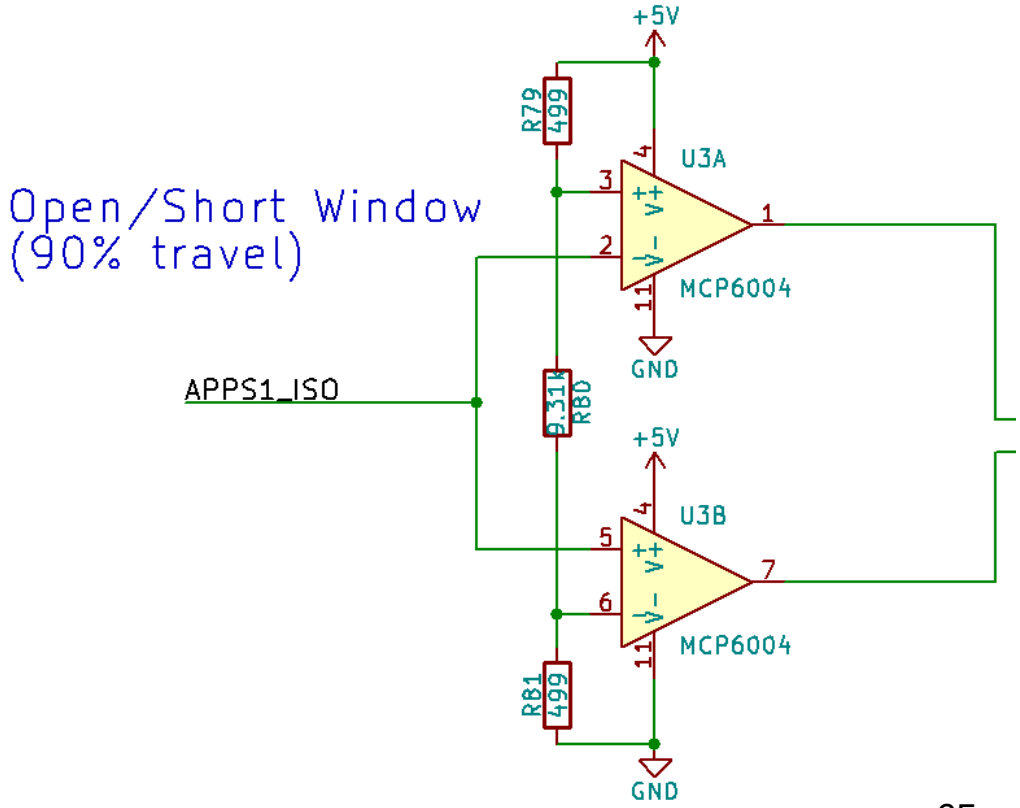
[1]2017-18 Formula SAE Rules Rev. A



# TSI - Circuit Schematic - Throttle Plausibility cont'd

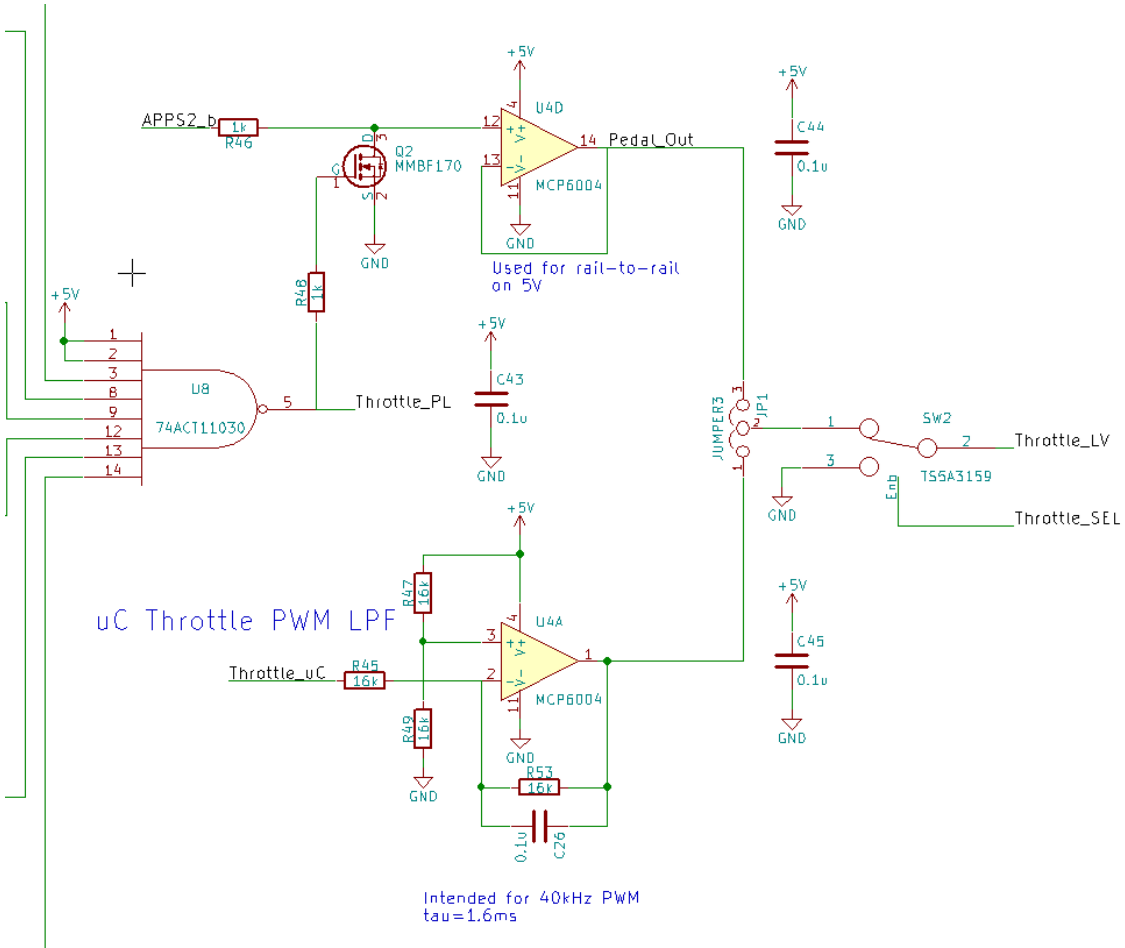
Multiple Failure Modes

2. Open or short circuit condition which generates a signal outside of the normal operating range (5% - 95% travel).

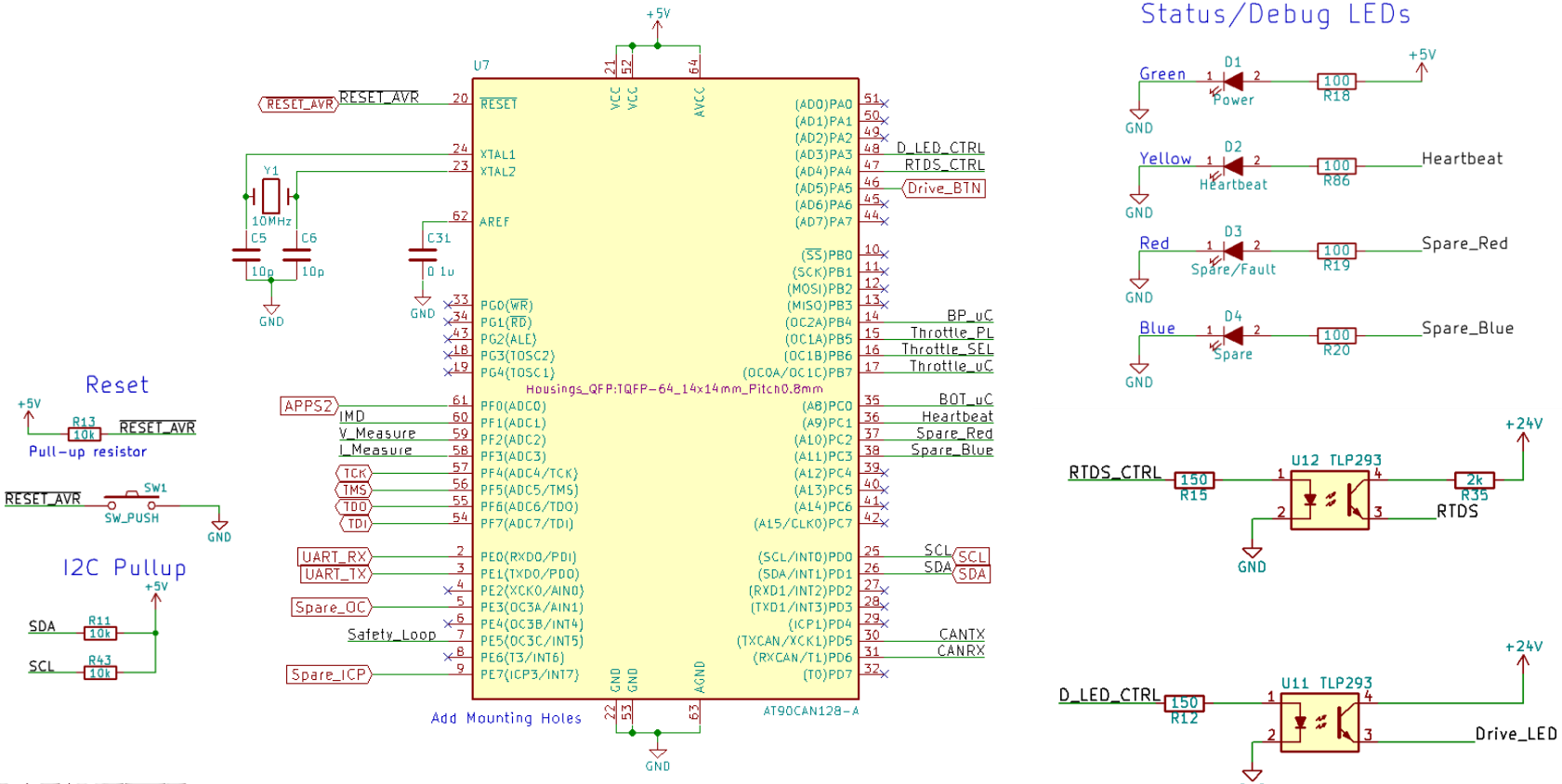



[1]2017-18 Formula SAE Rules Rev. A

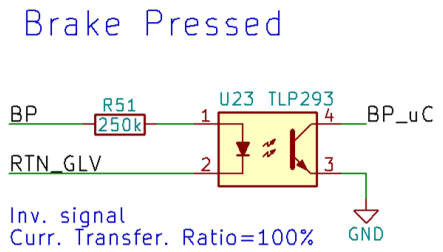
# TSI - Circuit Schematic - Throttle Enable

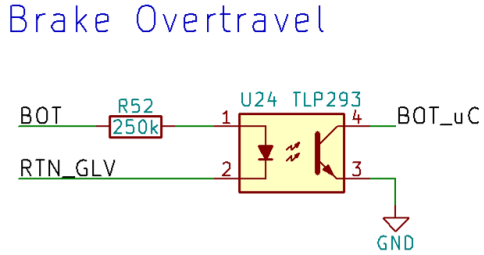


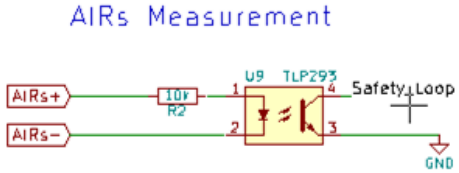
# TSI - Circuit Schematic - Microcontroller

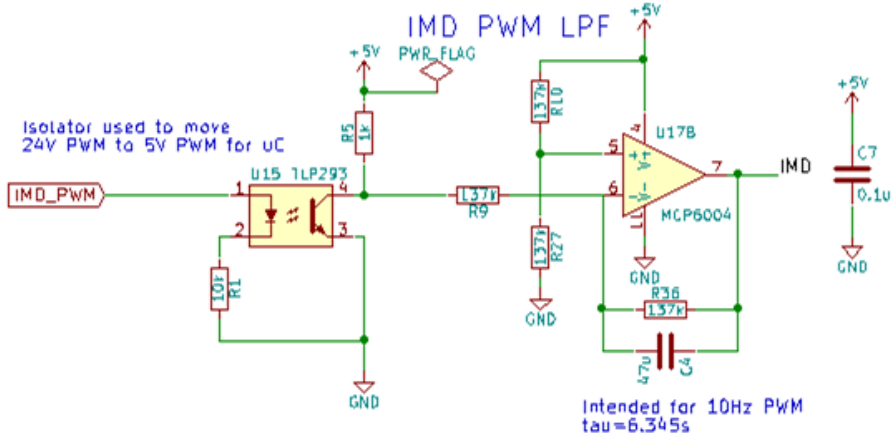


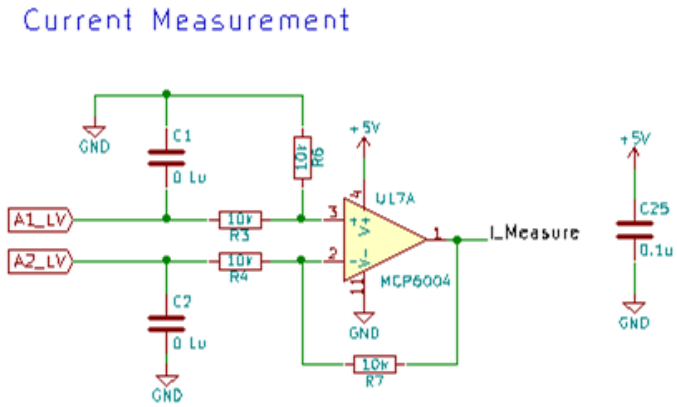
# TSI - Circuit Schematic - High Voltage Inputs



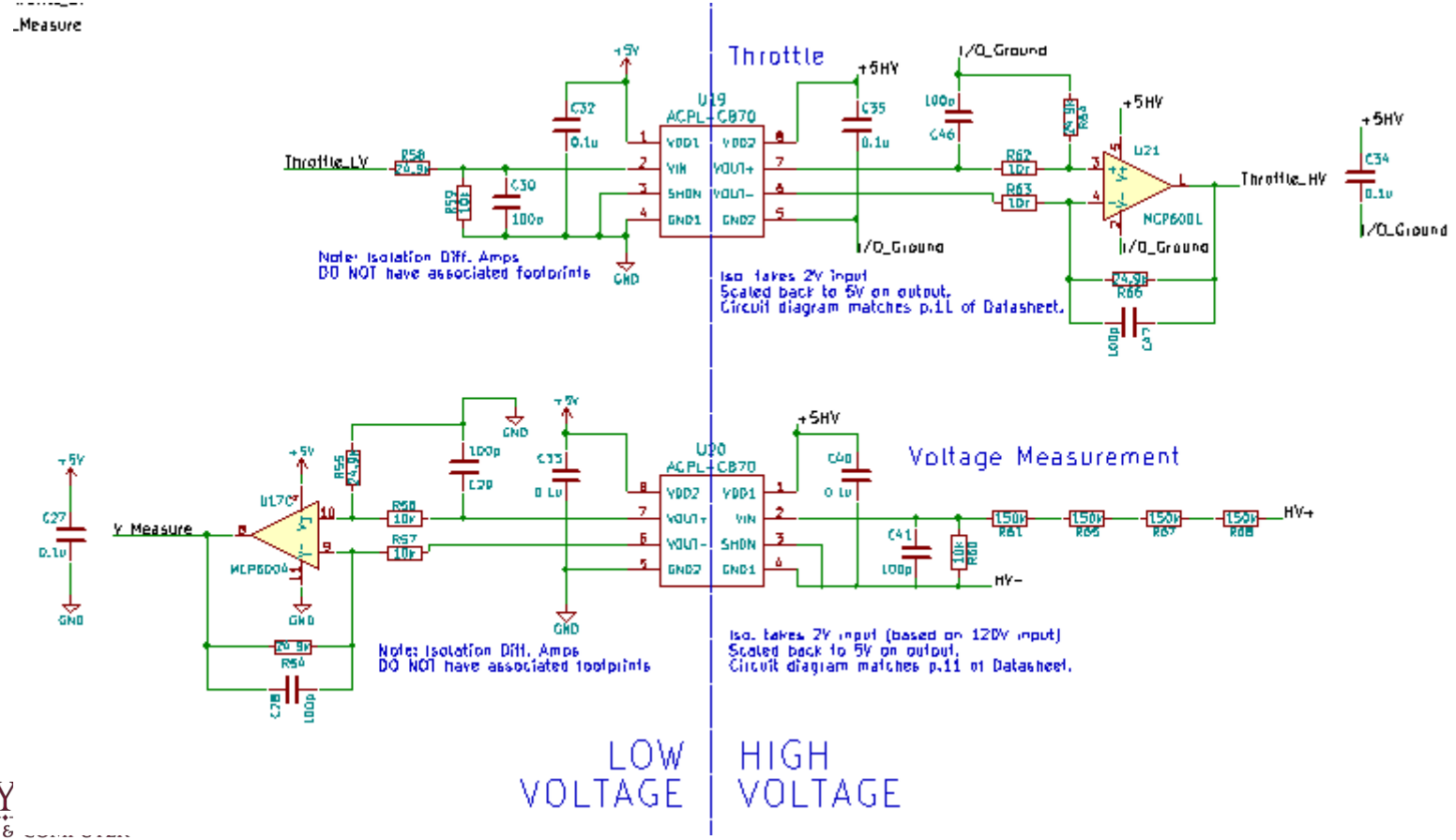



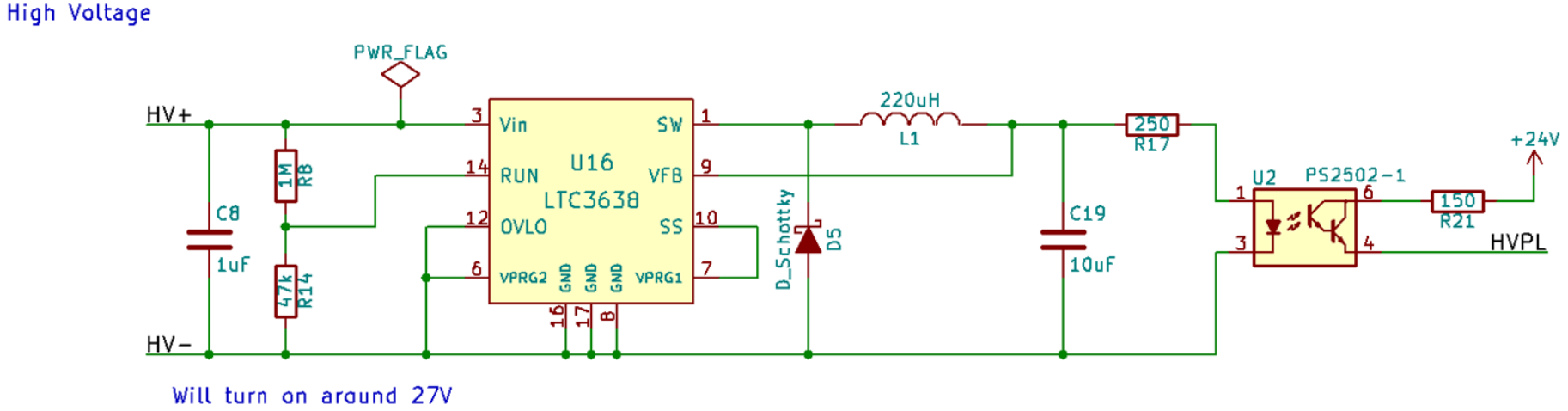



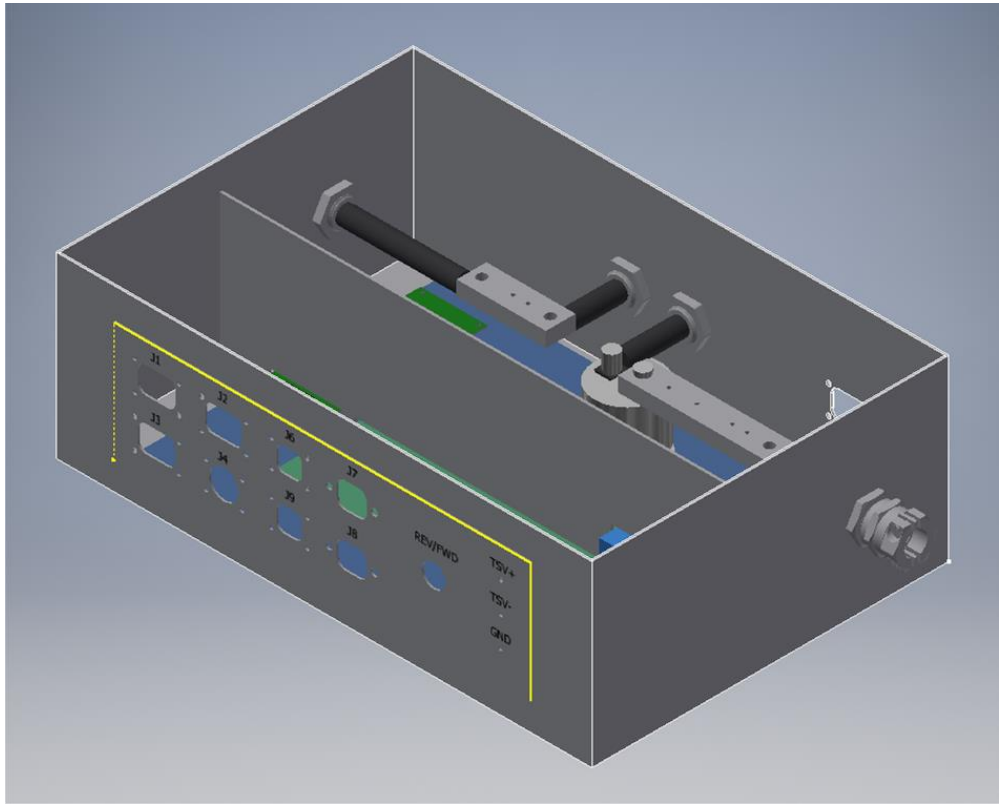
# TSI - Circuit Schematic - Throttle/Voltage Isolation



# TSI - Circuit Schematic - High Voltage Present Light



# TSI - Box Inventor



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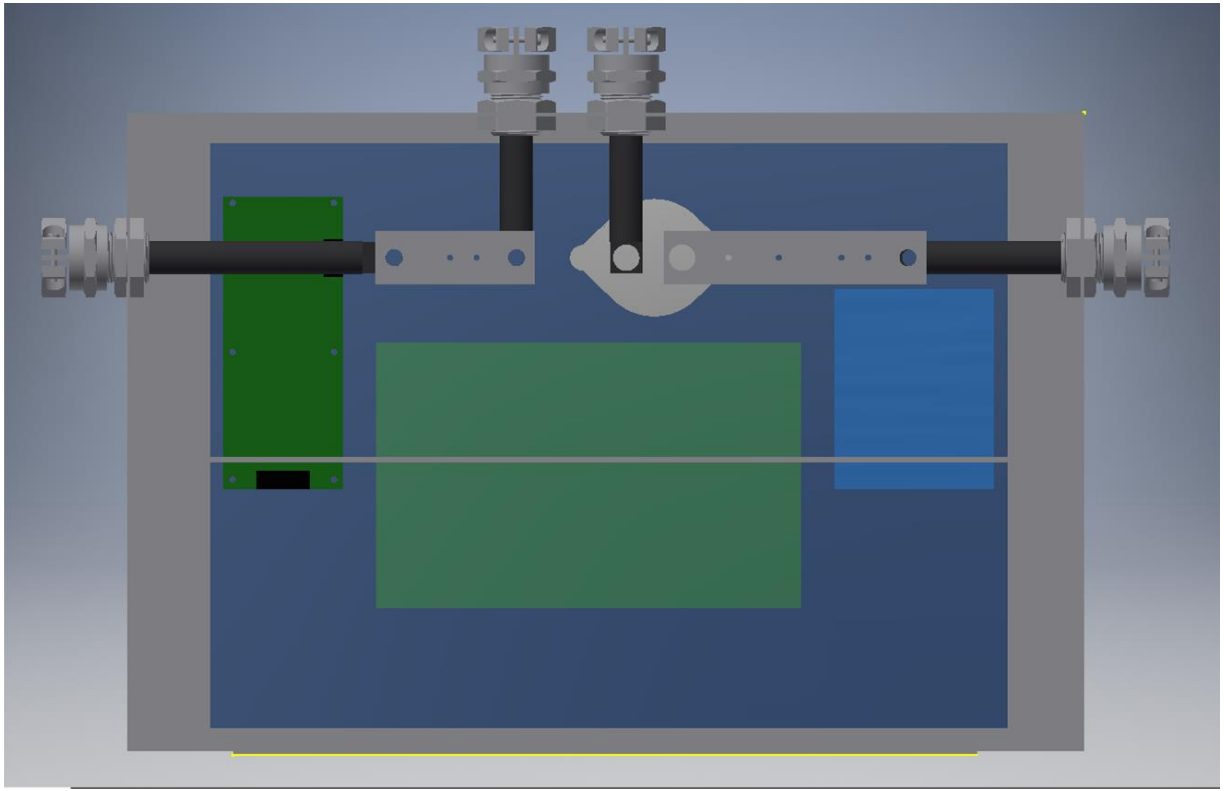

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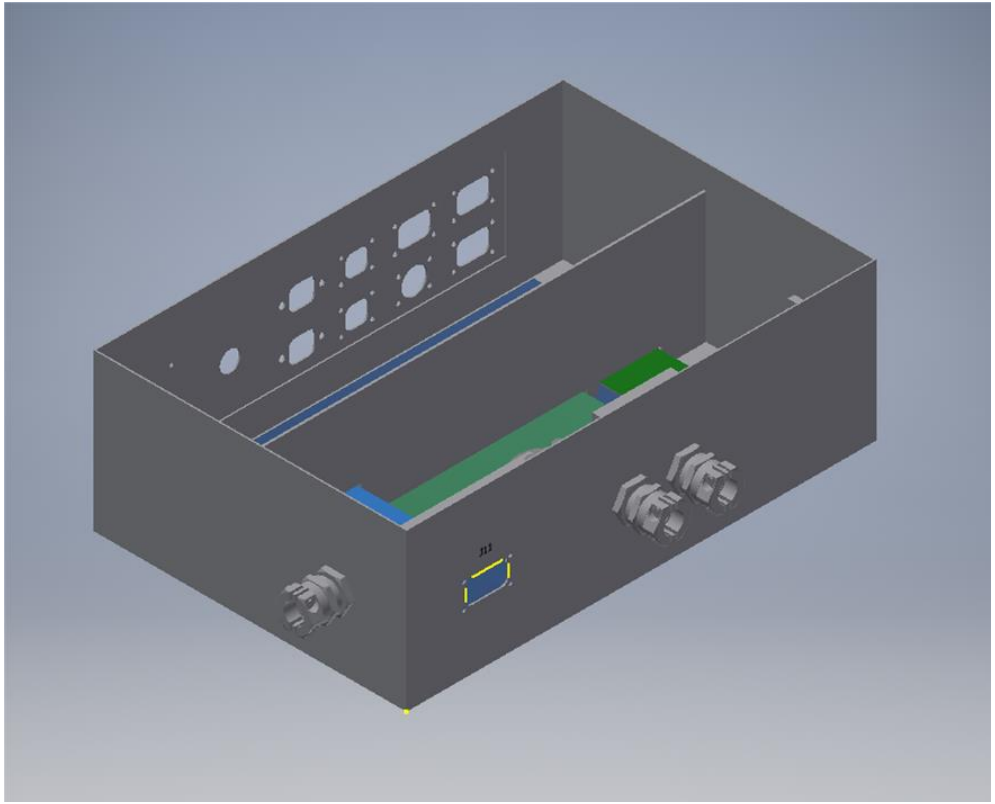

# Roadmap

1. System Overview
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5. Demo in Dynamometer Room
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7. Cell App
8. Tractive System Interface (TSI)
9. **Grounded Low Voltage (GLV)**
10. Controller Cooling System
11. System Test Plan

# GLV

Kyle Phillips, Joe Sluke, & Chris Bennett

# GLV - Sub-Systems

Responsibilities of GLV can be divided into 4 main sub-systems.

1) GLV Power - providing 24V to all the main systems of the vehicle.

1) Safety Loop - serve as the direct means to control the Accumulator Isolation Relays in the packs (enable/disable of high voltage systems).

1) Vehicle Computer Interface (VCI) - deliver information about GLV Power and the Safety Loop to the VSCADA computer and route the CANBUS to the VSCADA computer

1) Vehicle User Interface (VUI) - includes physical panels, buttons, switches, screens and lights on the car, such as the exterior panels and the cockpit panel

# GLV - GLV Power

Requirements:

- Provide 24V to all subsystems for 3 hours
- Rechargeable battery
- Protected from overcharge, overcurrent, overdischarge and overvoltage.

Battery Choice

- 24V, LiFeP04 (Lithium Iron Phosphate Battery),  10Ah.
- Internal battery management system
- Lightweight (2.63 kg)

# GLV - Safety Loop

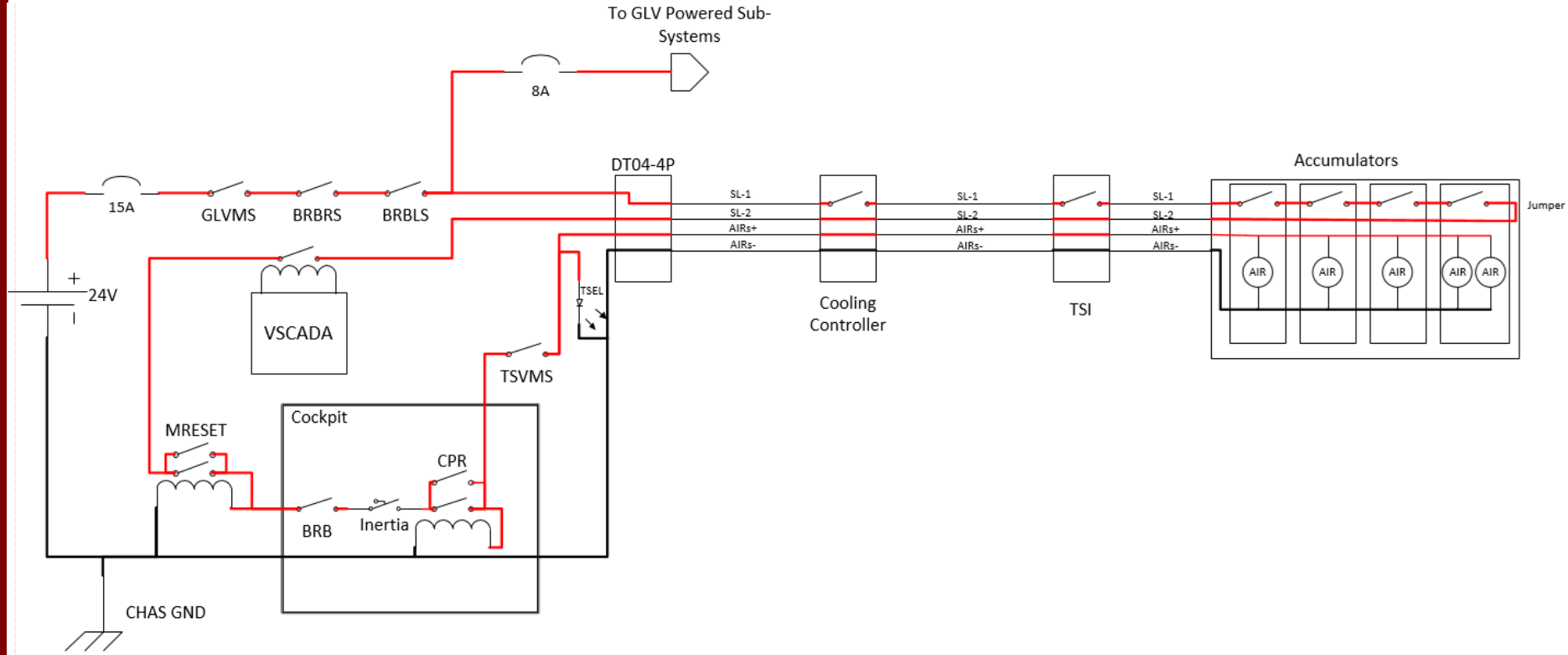
Requirements:

- Drive the coils of the Accumulator Isolation Relays (AIRs) with 24V
- Trippable by VSCADA, TSI, Cooling Controller, TSV
- Trippable internally and externally by E-STOP Big Red Buttons.

# GLV - Safety Loop - Components

| Switch | Description | Effect |
|---|---|---|
| Circuit Breaker | A basic resettable circuit breaker | Powers Cooling System, Dashboard, VSCADA, and TSI |
| GLVMS | Grounded Low Voltage Master Switch | |
| BRBLS | Big Red Button Left Side | |
| BRBRS | Big Red Button Right Side | |
| Cooling System Fault Switch | Allows Cooling System to trigger fault | 24V to Accumulator Isolation Relays |
| IMD Switch | Insulation Monitoring Device, triggers fault if HV and GLV are galvanically isolated | |
| PACKMAN Fault Control | Allows PACKMAN board on any pack to trigger a fault | |
| SCADA Relay | Allows SCADA computer to trigger fault | |
| MRESET (Latching) | Exterior Master Reset Button | |
| BRB (Car Dash) | Driver accessible Big Red Button | |
| Inertia Switch | Driver accessible Inertial switch, opened by a 6g+ collision. | |
| CPR(Latching) | Driver accessible Collision Protection Reset Latching Relay. | |
| TSVMS | Tractive System Voltage Master Switch | |

# GLV - Safety Loop

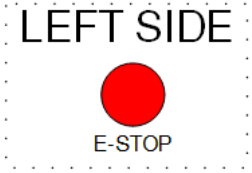


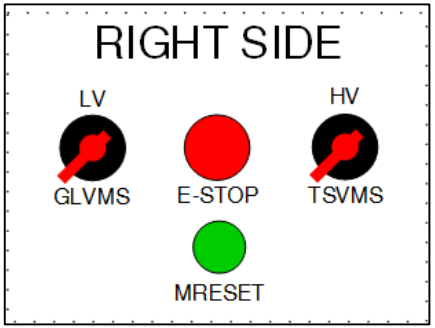
# GLV - Vehicle User Interface (VUI)

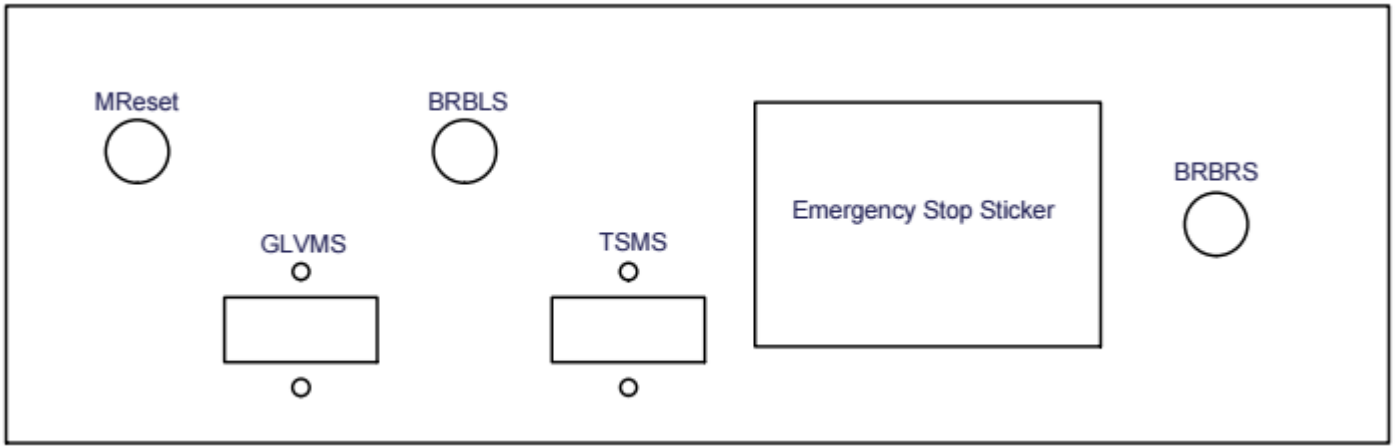
Requirements:

- Design panels for dyno room
- Design panels for interior and exterior of vehicle
- Provide interface for VSCASA

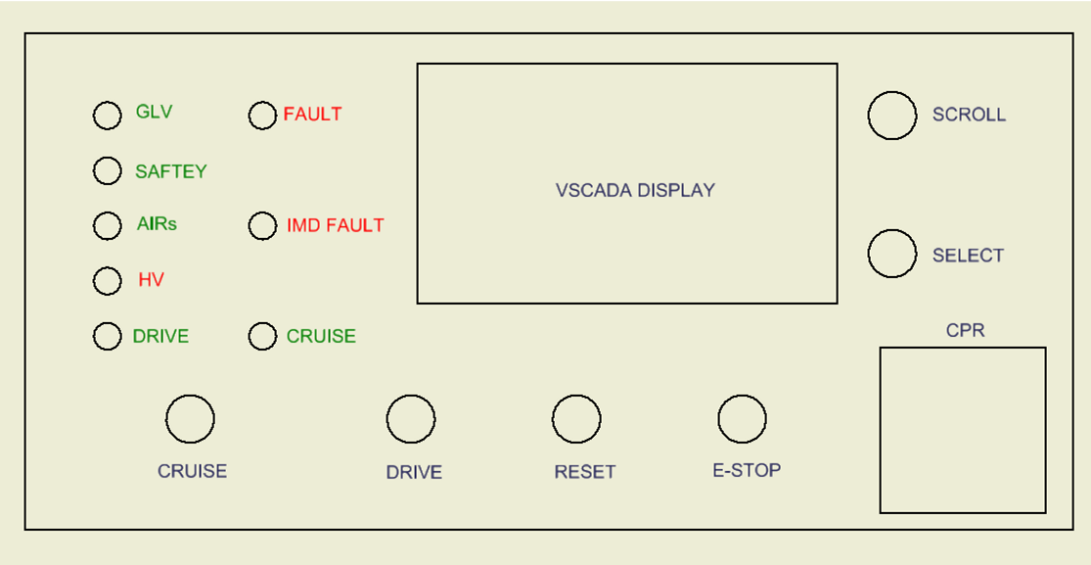
# GLV - Exterior Panel

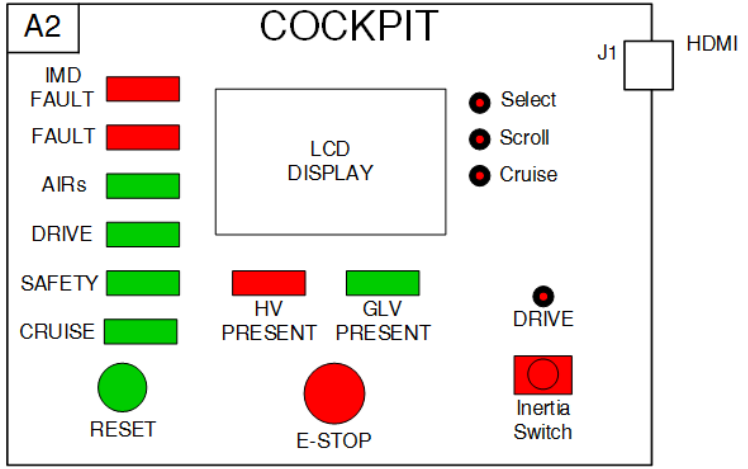


# GLV - Cockpit Panel



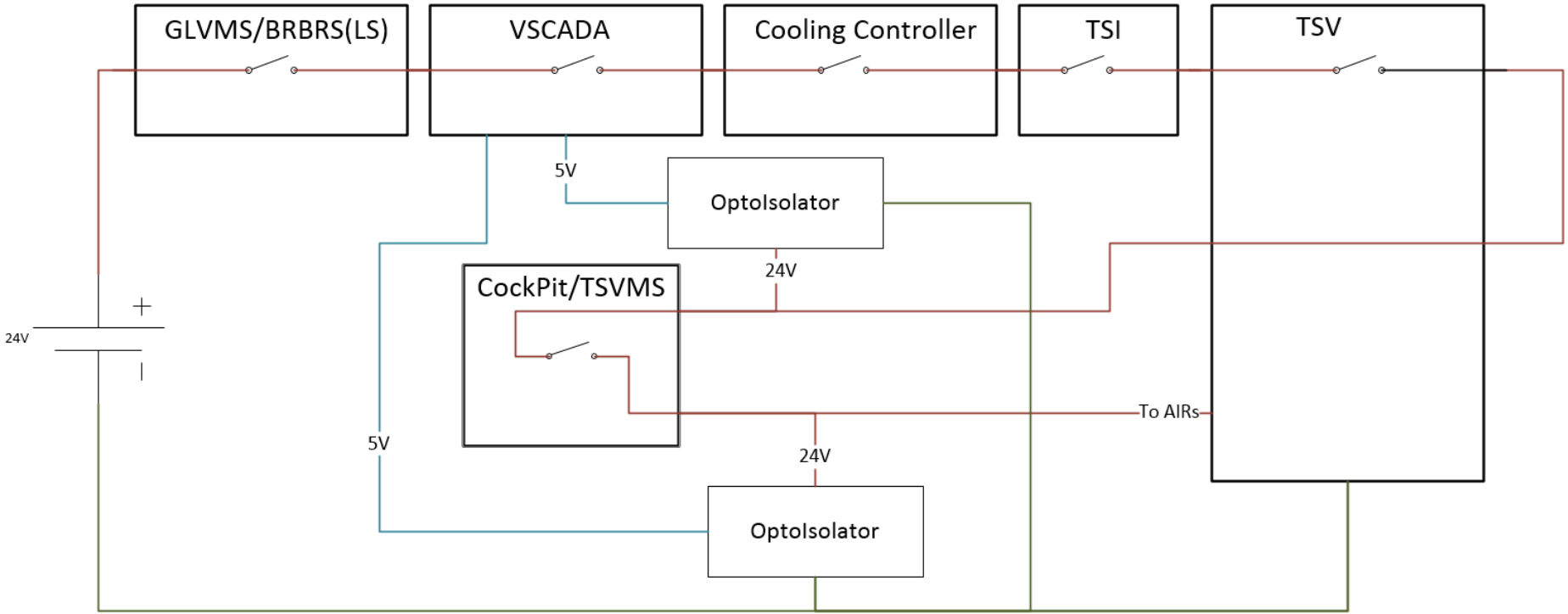



# GLV - Vehicle Computer Interface (VCI)

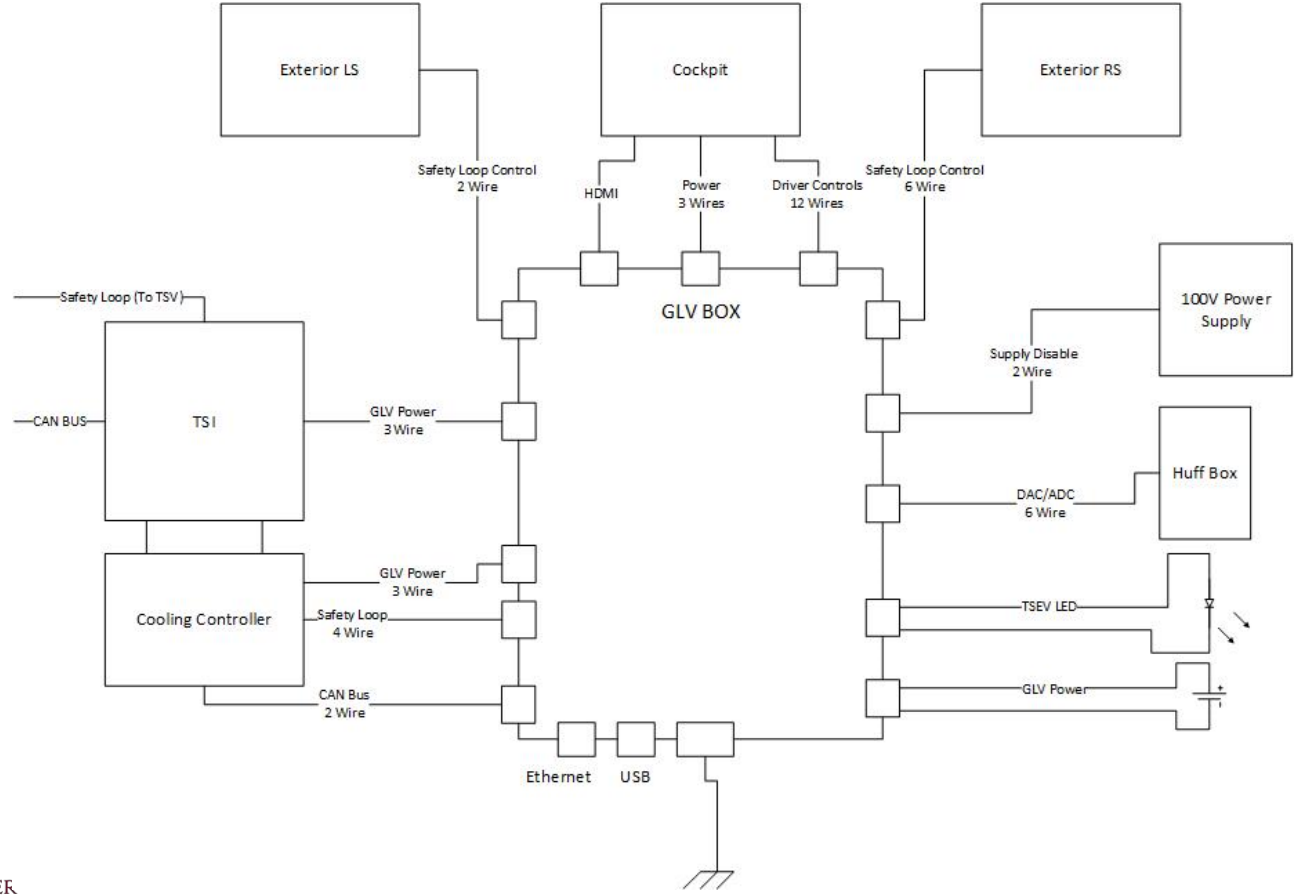
Requirements:

- GLV Battery State of Charge Monitoring
- CAN2USB Interface
- $I^2C$ Bus
- UART Bus
- Safety Loop Monitoring

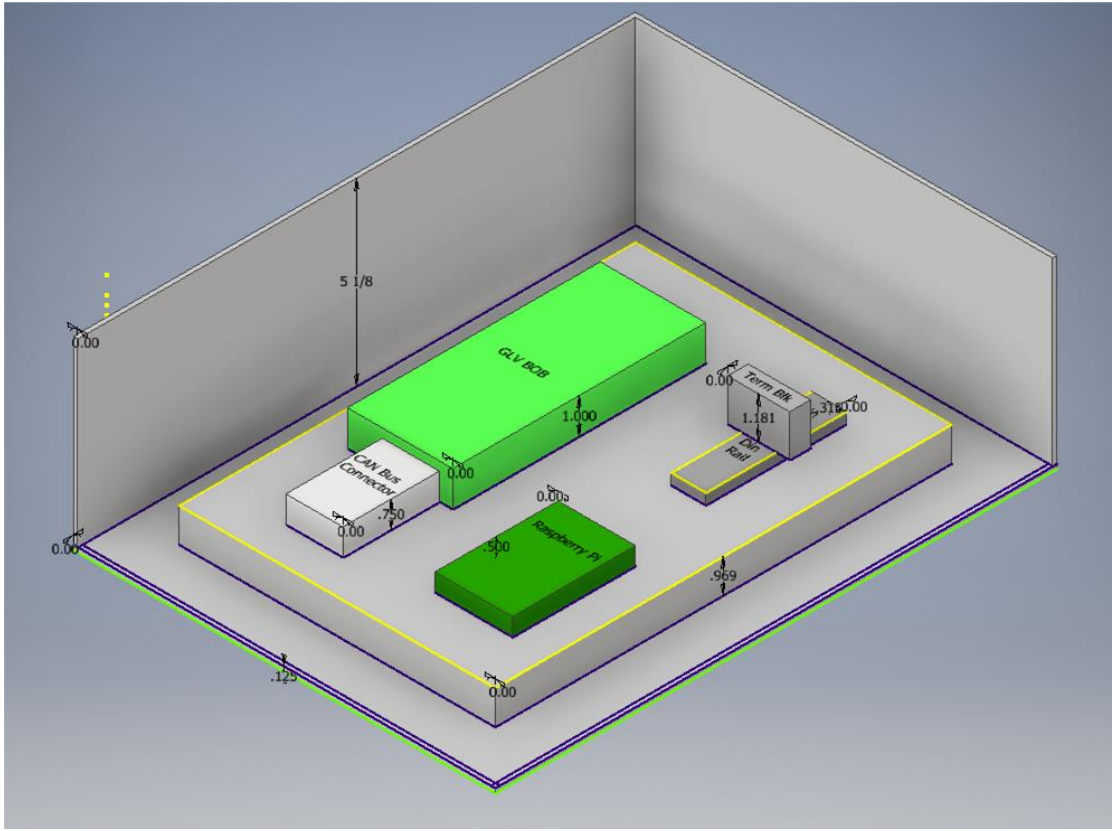
# GLV - Safety Loop Monitoring



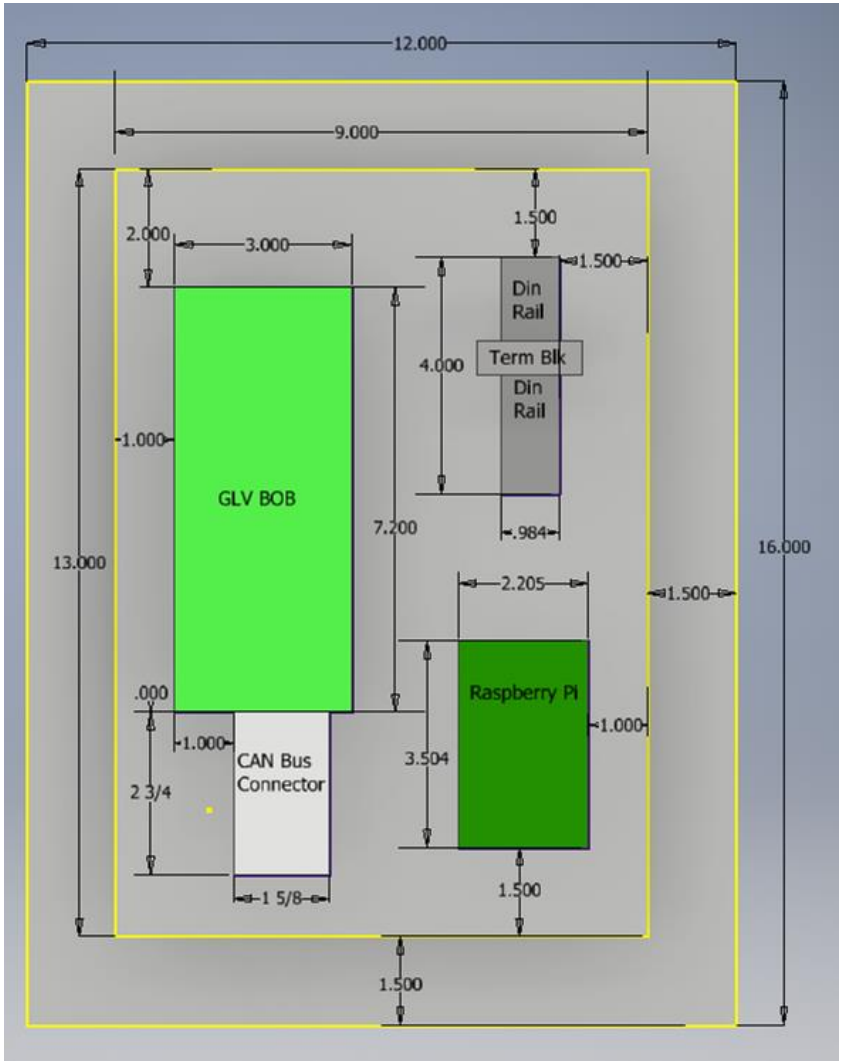
# GLV - High-Level System Design



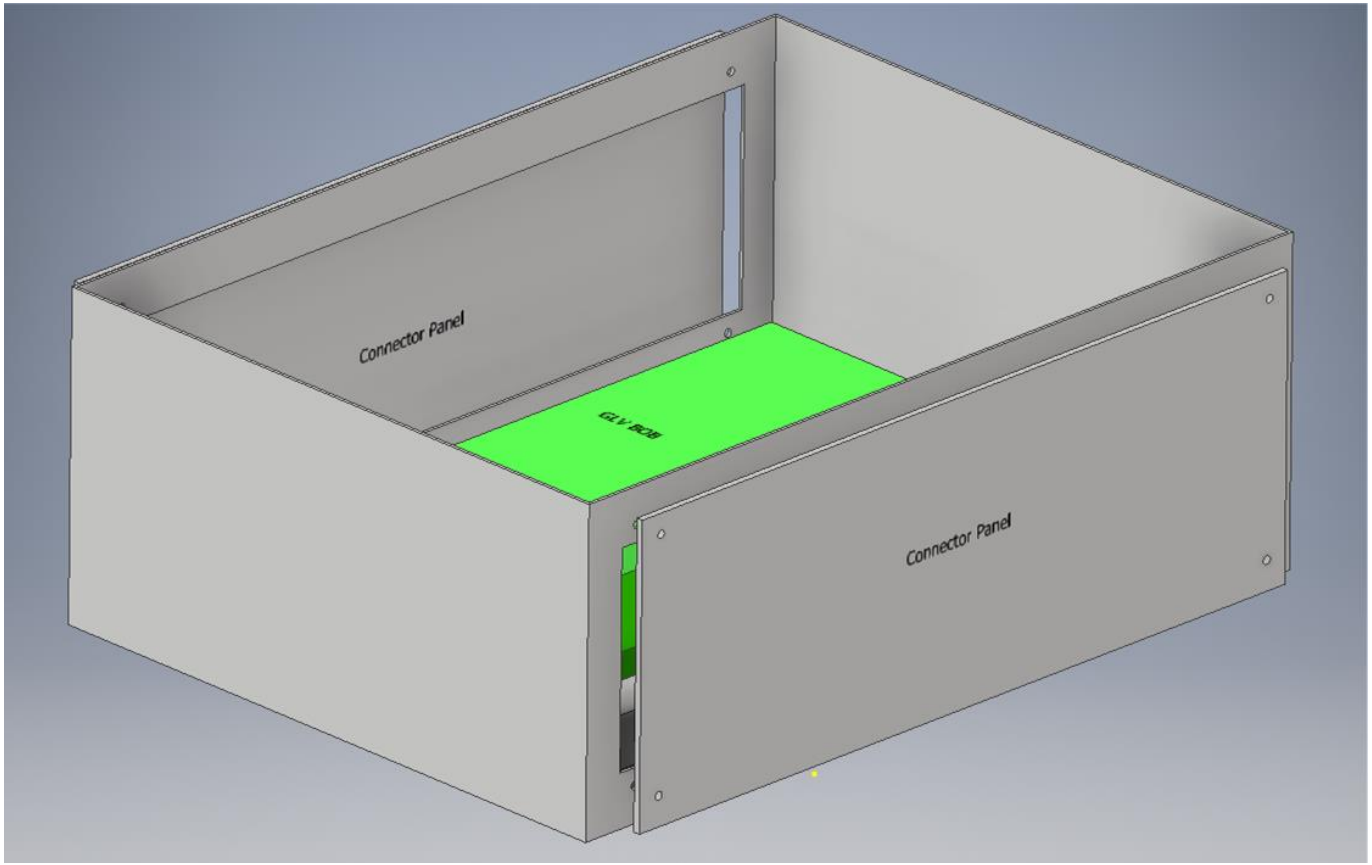
# GLV - Physical Layout



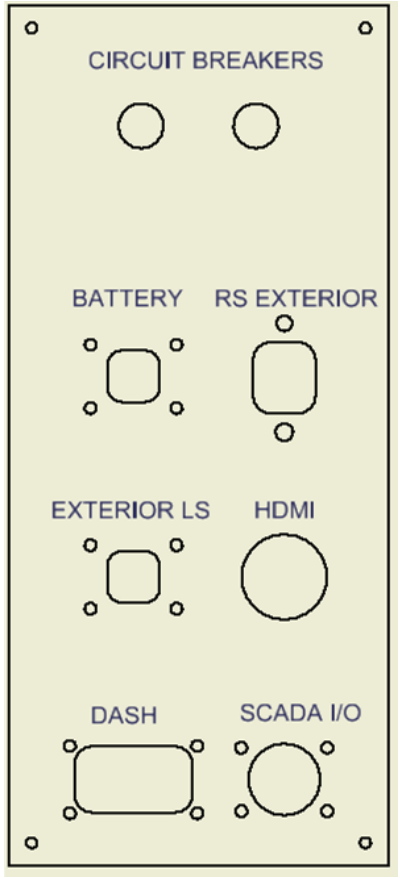
# GLV - Physical Layout

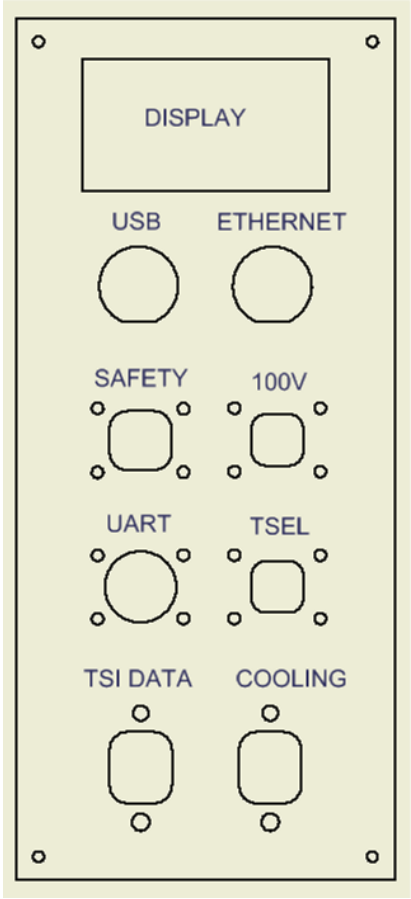


# GLV - Physical Layout

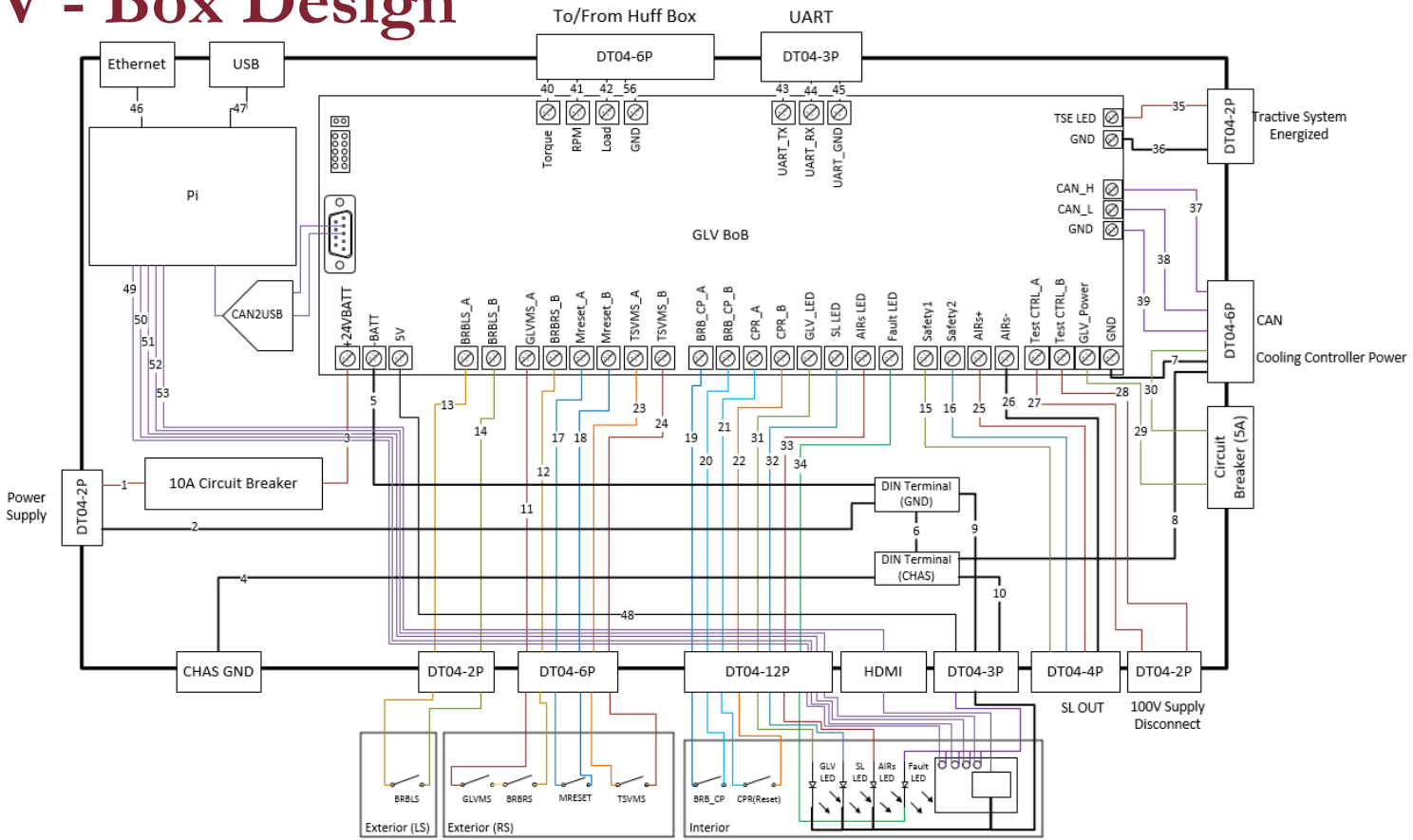


# GLV - Physical Layout



# GLV - Box Design



# GLV - Break Out Board (BOB)

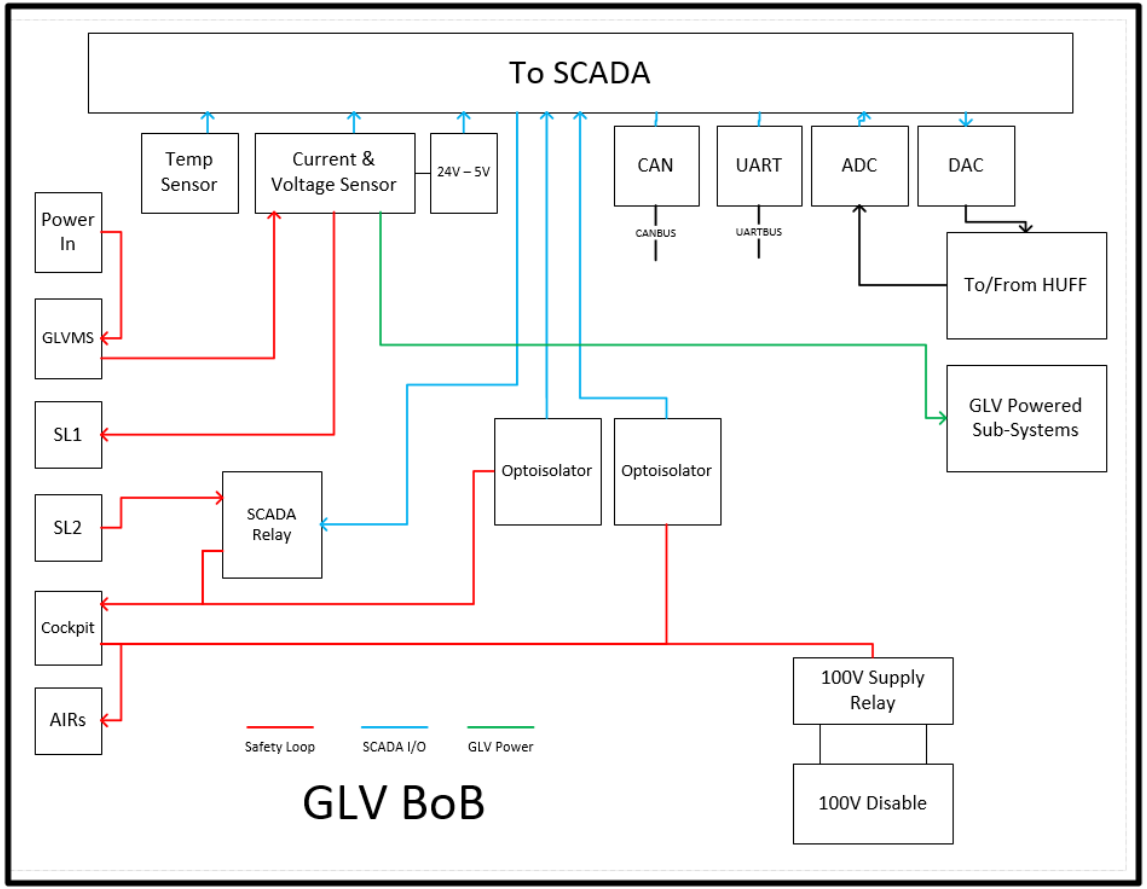
Last year's BoB shortcomings:

- Did not address VCI requirements (safety loop, temp, current monitoring…)
- Inadequate number of relays used
- Inadequate containment of safety loop circuit

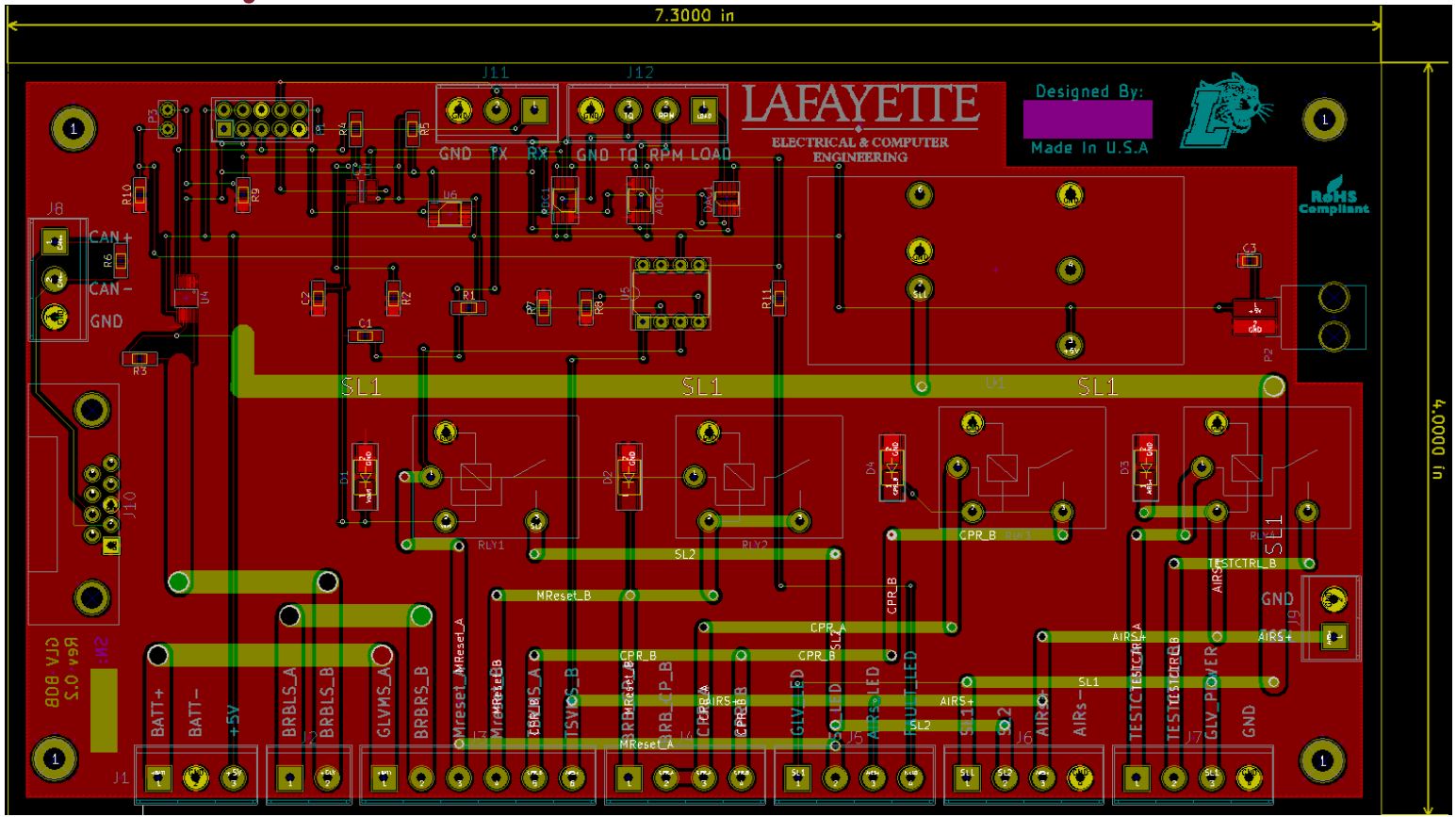
Our proposed changes:

- Add opto-isolators for safety loop monitoring
- Add more relays and move more of safety loop on board
- Use I2C capable chips to relay temp and current readings to SCADA
- Connect TSI and VSCADA via UART for throttle control
- Add DAC and ADC chips to connect VSCADA and Huff Box.

# GLV - BoB High Level



# GLV - BoB Layout



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10. **Controller Cooling System**
11. System Test Plan

# Controller Cooling System

Xingyuan Guo & Yi Han

# Cooling System

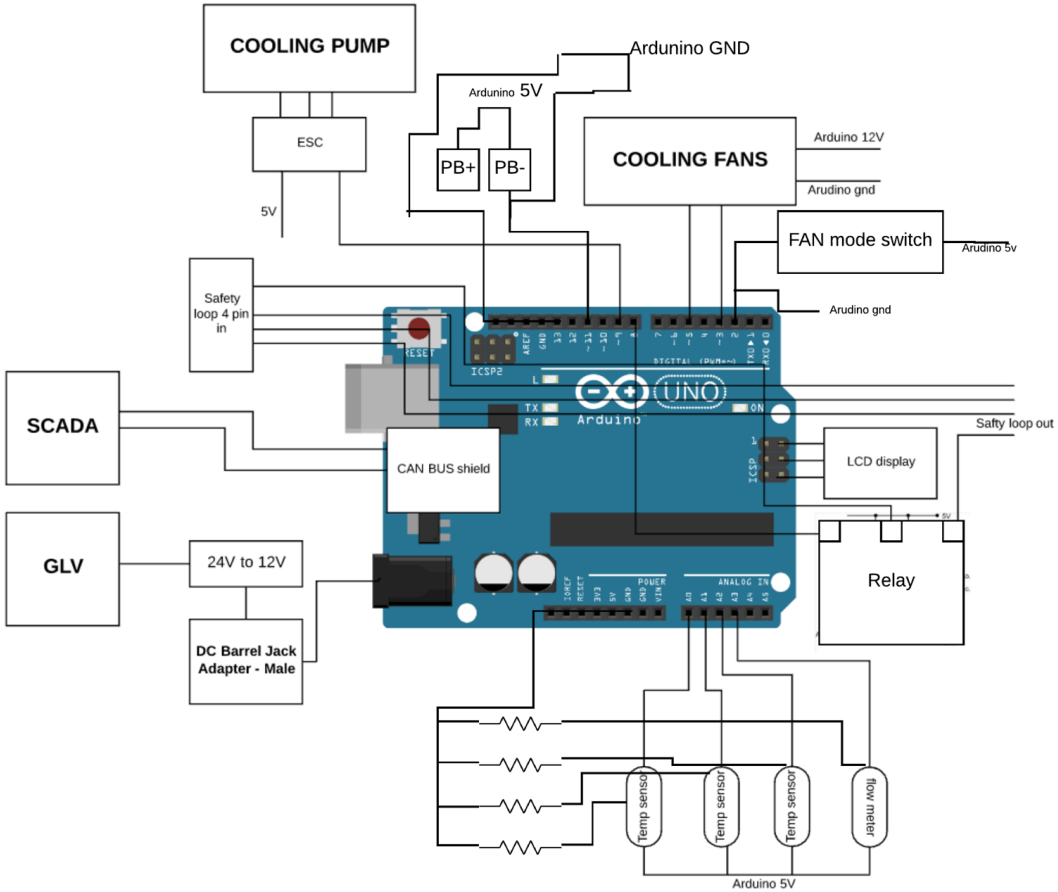
**Major Goal:**

- Cool the motor controller, provide information to SCADA, shut system down when necessary using safety loop.

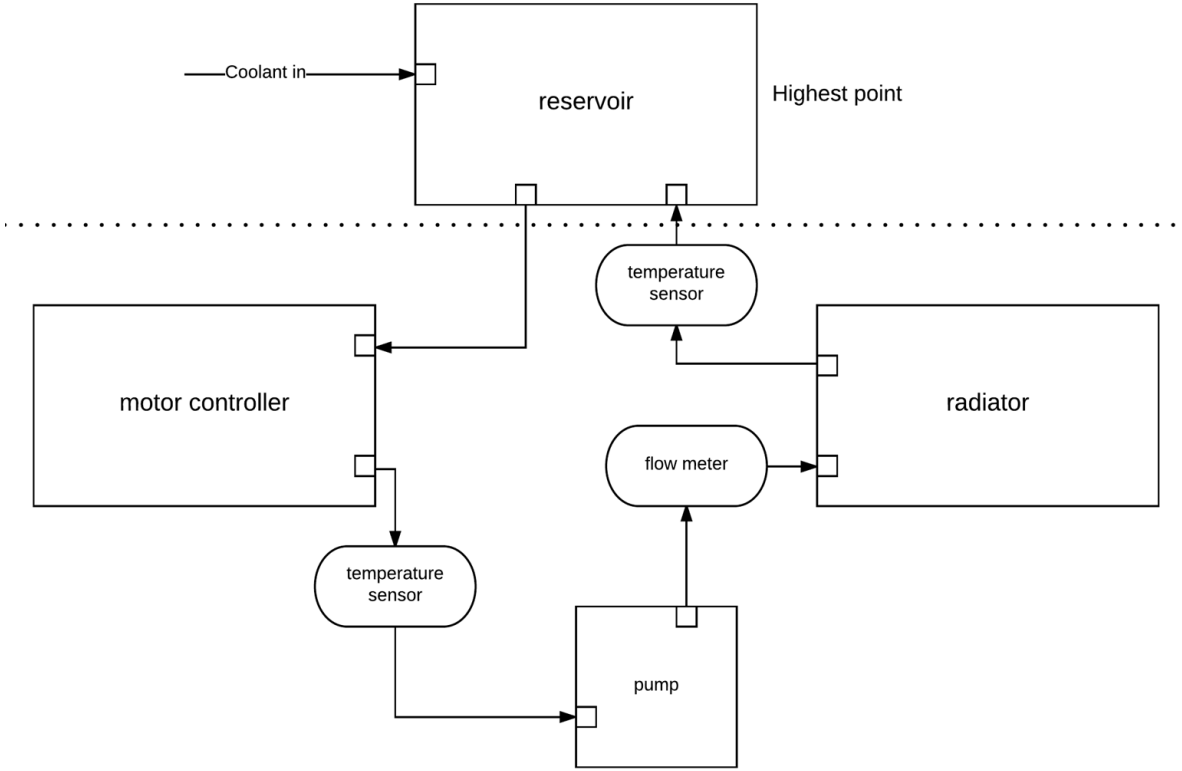
**Objectives:**

- Automatic fan, pump speed control; as well as manual override
- CAN interface
- Safety loop interface
- Mechanical design

# Cooling System - Overall Electrical Connections



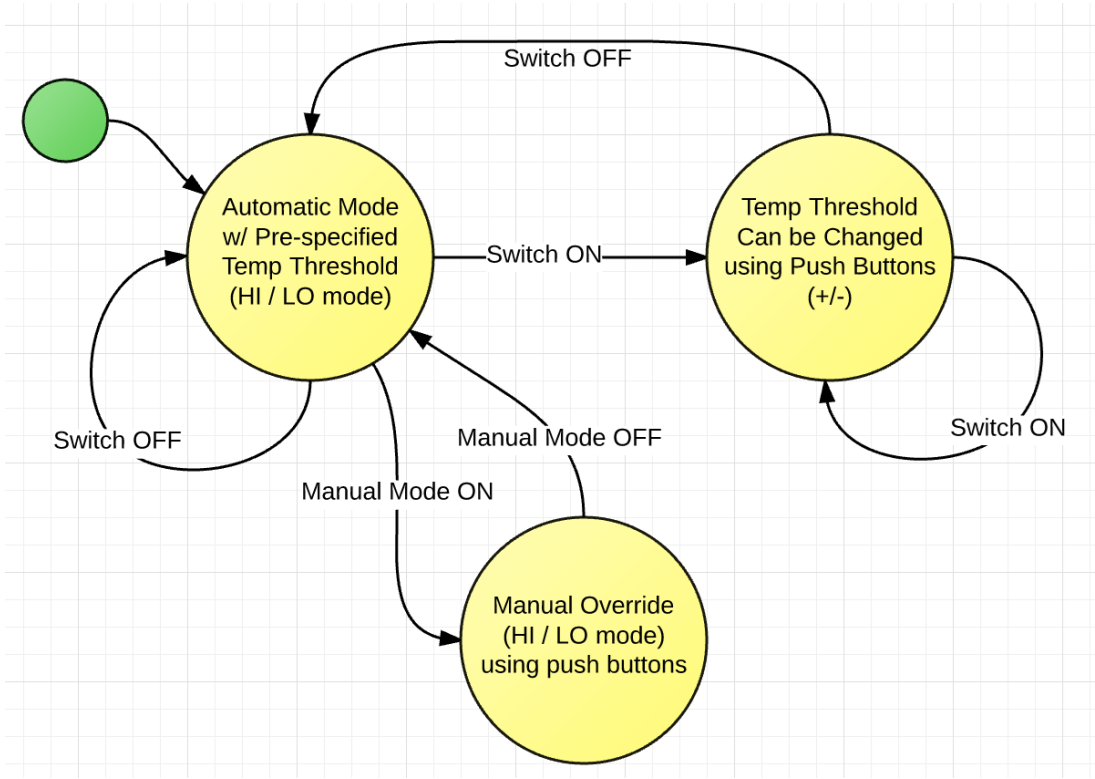
# Cooling System - Water Cooling Layout



# Cooling System - Compatibility and Independence

- 24 VDC
- Koolance products (compatible with dyno, easy to integrate)
- Run independently

# Cooling System - Automatic Speed Control w/ Manual Override




Overall Process

# Cooling System - CAN Bus Interface


**Oscilloscope displaying 2 types of data frames**

**(Through stackable CAN shield using MCP2515 CAN controller)**

# Cooling System - Safety Loop

- Open the safety loop when fluid temperature is too high

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11. **System Test Plan**

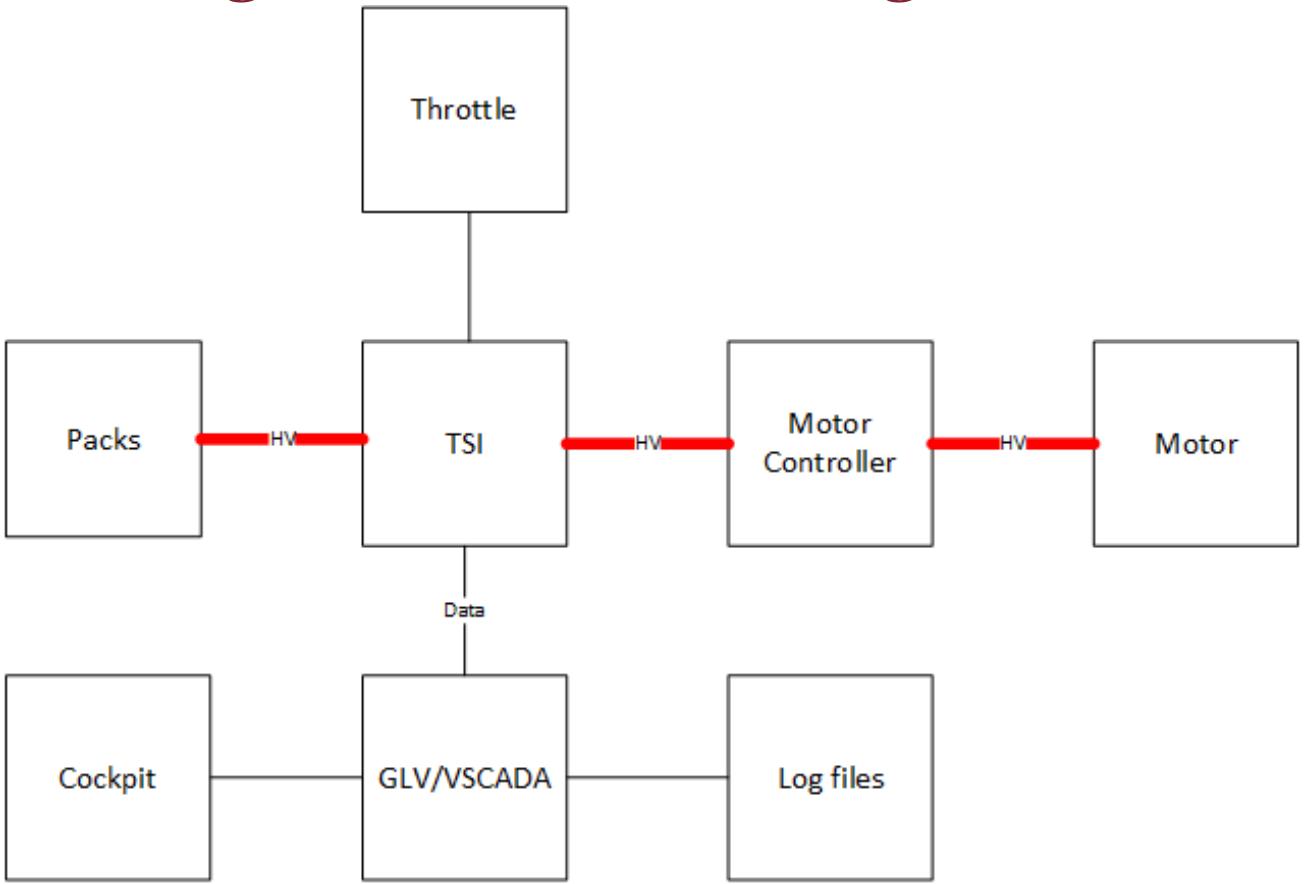
# System Test Plan

Greg Flynn

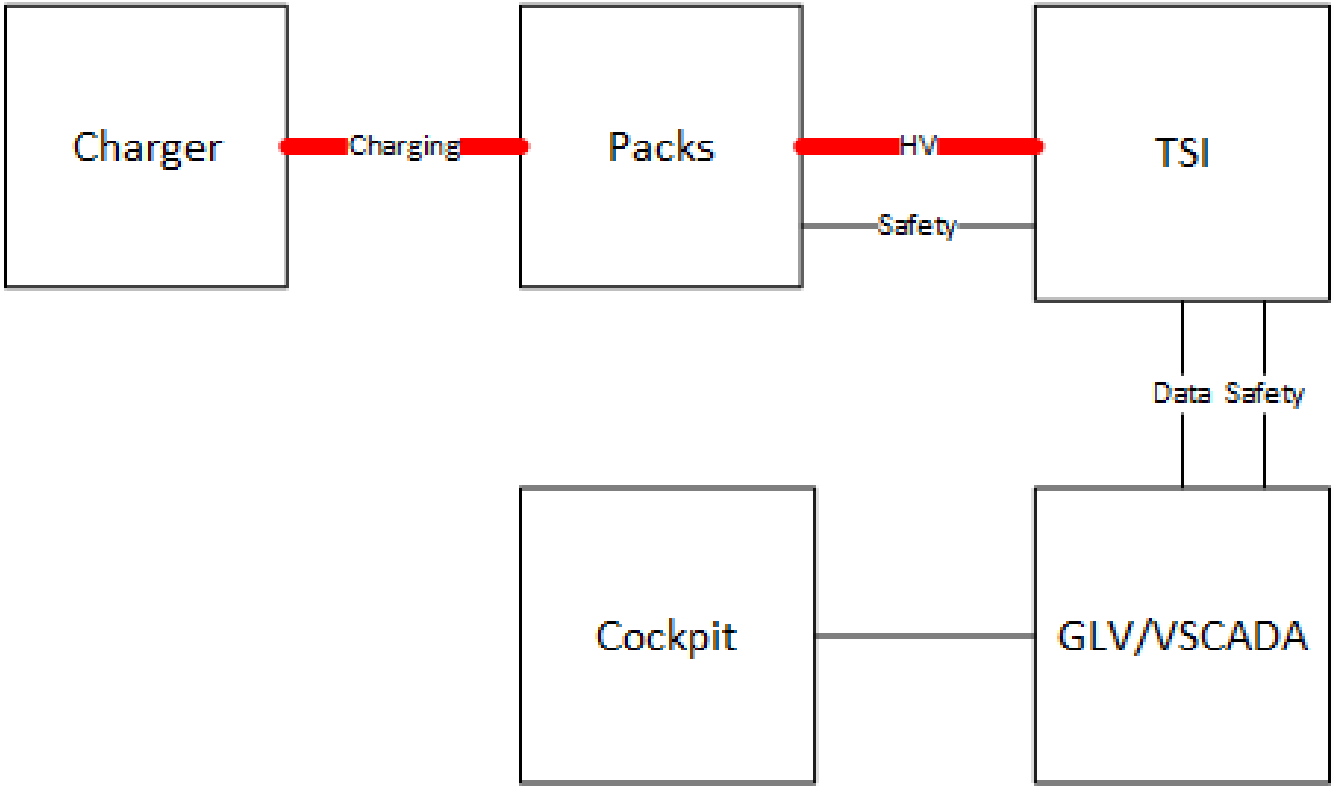
# System Testing - Overview

- 7 Major tests
  - Accumulator integration
  - Accumulator charging
  - CAN Bus link
  - Safety loop
  - Cruise Control
  - 24h endurance test
  - Shutdown

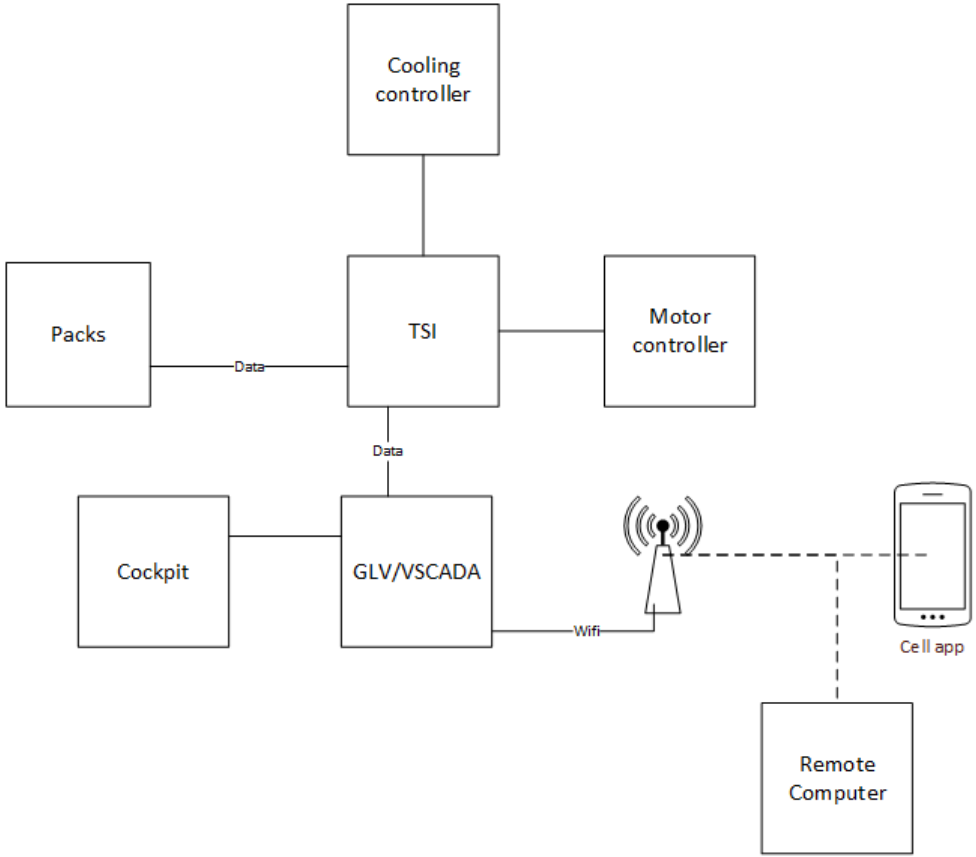
# System Testing - Accumulator Integration



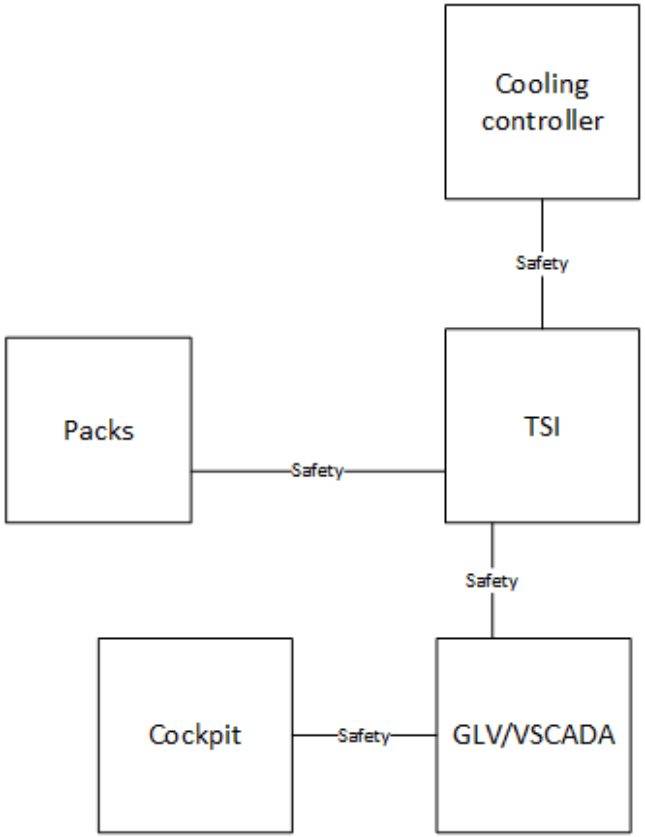
# System Testing - Accumulator Charging



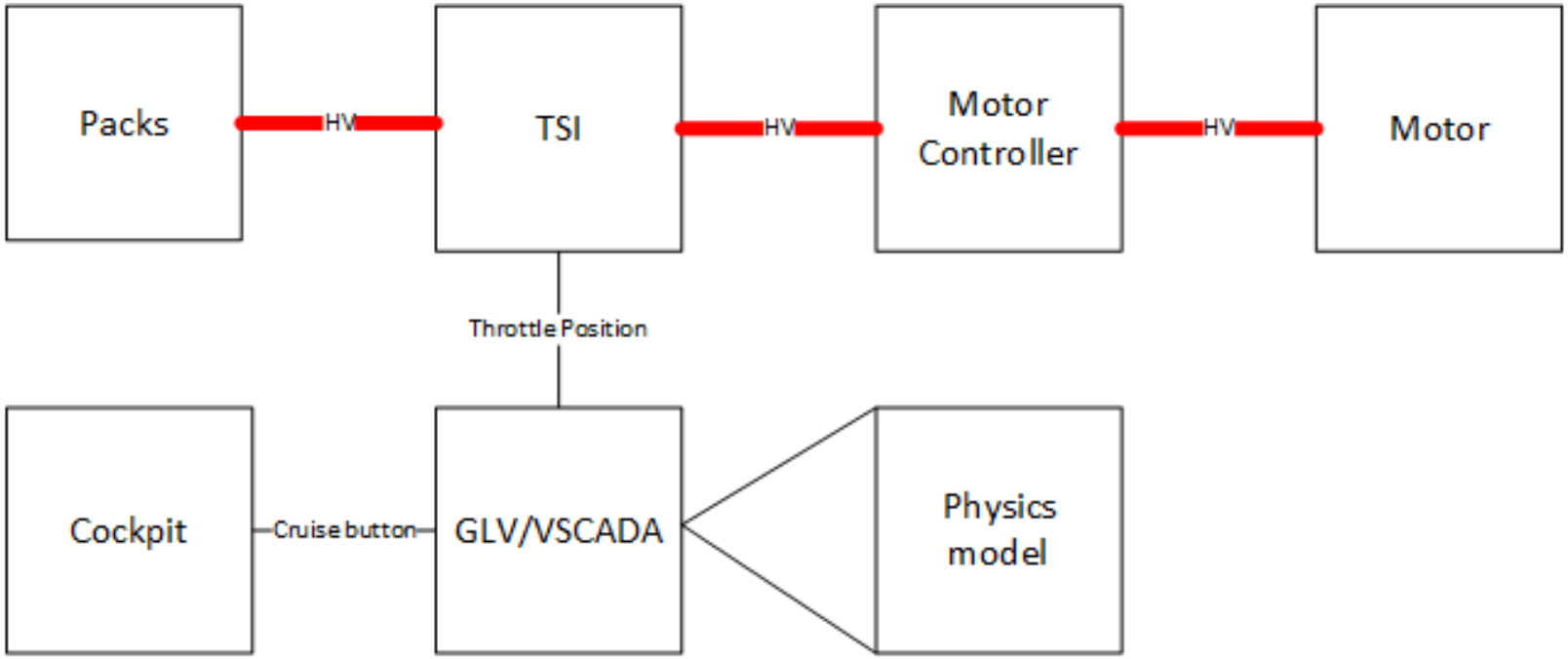
# System Testing - CAN Bus link



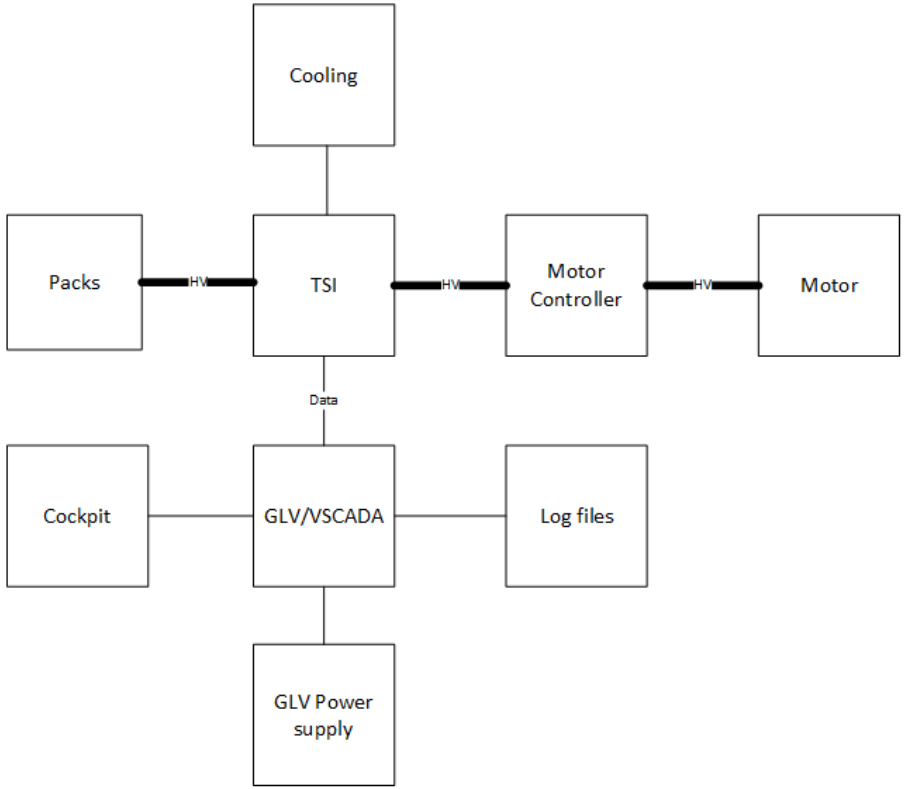
# System Testing - Safety Loop



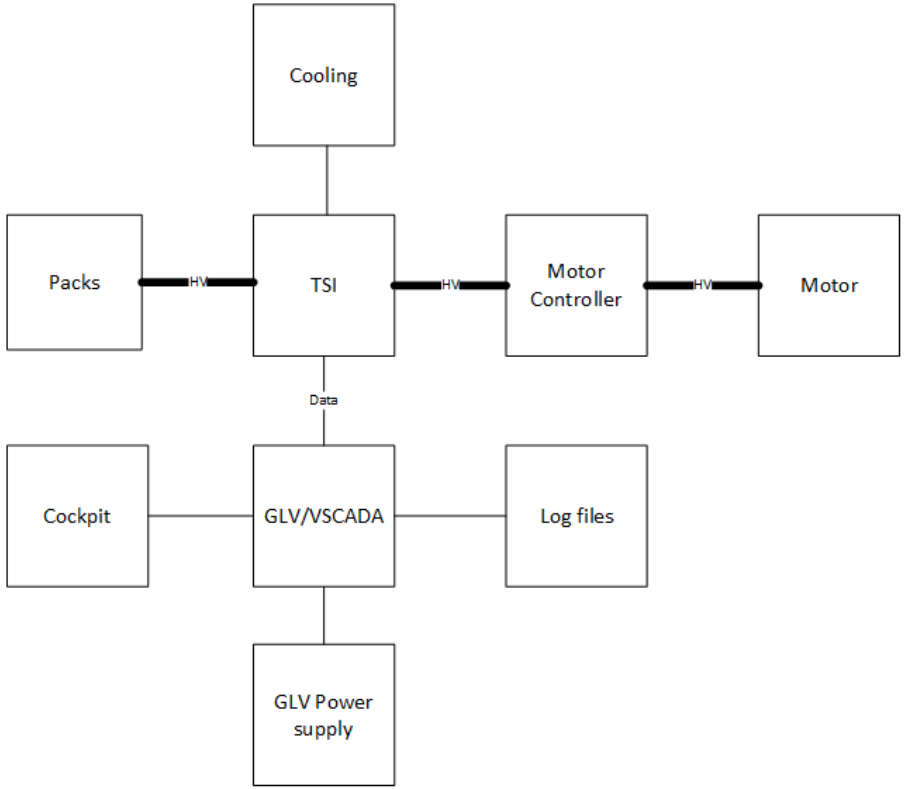
# System Testing - Cruise Control

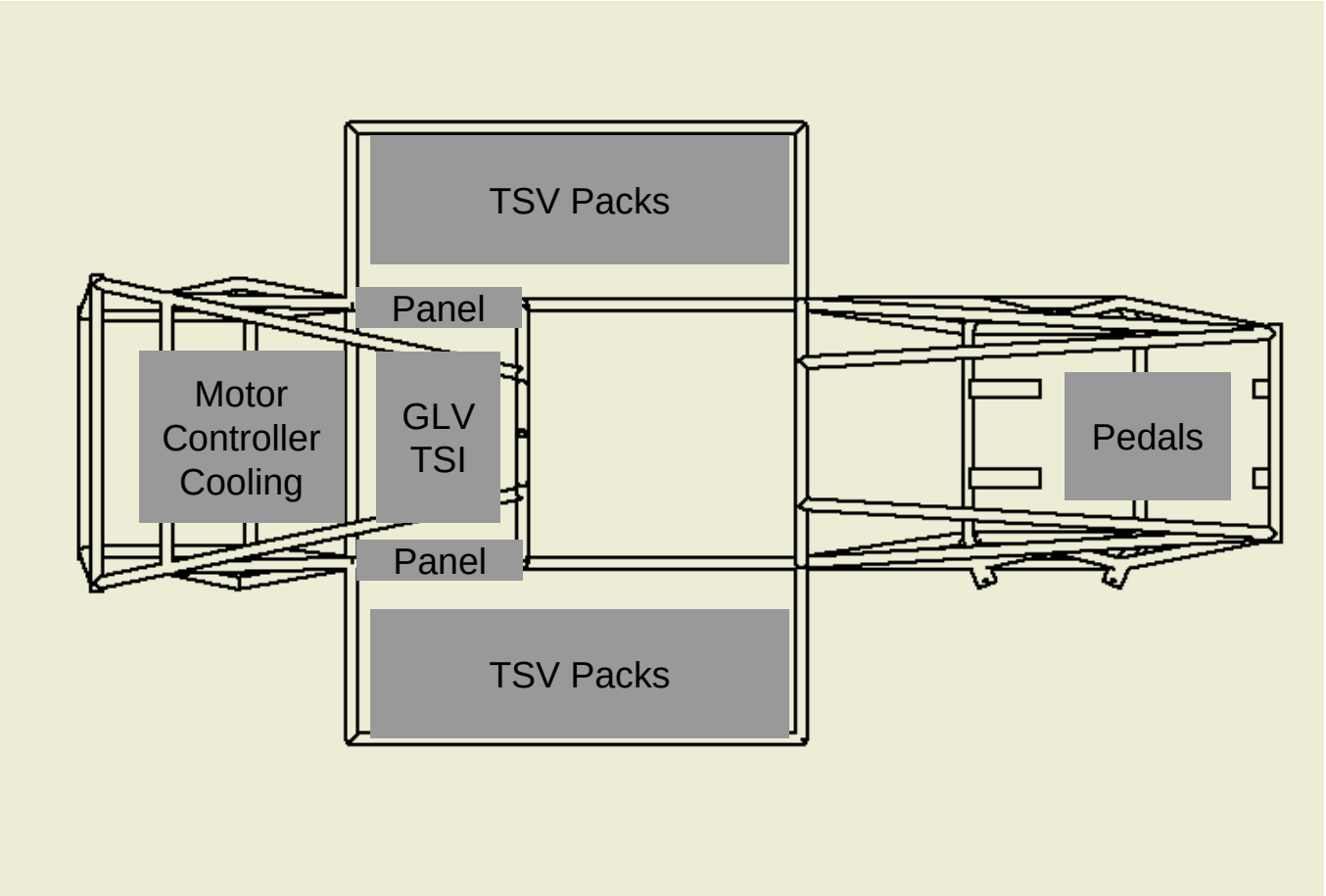


# System Testing - 24h Endurance Test



# System Testing - Shutdown




TSV Packs
Panel
Motor
Controller
Cooling
GLV
TSI
Pedals
Panel
TSV Packs