Lafayette Electric Vehicle 2015

ECE 492: Senior Design II
Morning Critical Design Review
March 11, 2015
Hugel 100

Roadmap

1. Meet the Morning Teams
2. Introduction: Motivation
3. Interface Control
    a. System Assemblies Layout/Interfaces (Car)
    b. System Assemblies Layout/Interfaces (Rack)
    c. Interconnects
    d. Panel Drawings and Hubs
4. Grounded Low Voltage (GLV)
    a. Safety Loop
    b. GLV Power
    c. VCI
    d. TSI
5. GLV BOM and Budget

Roadmap Cont.

6. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

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   c. VCI
   d. TSI
5. GLV BOM and Budget

Meet the Morning Teams

- Grounded Low Voltage (GLV)
  1. Dan Zakzewski
  2. Alo Posillico
  3. Nick DiNino
  4. Jordan Frank
  5. Zach Helwig
- Tractive System Voltage (TSV)
  1. William Stathis
  2. Duhang “Hansen” Liang
  3. Katherine Nellis
  4. Jaejoon Yang
  5. Jordan Blake
- Mechanical Engineering Team
  1. Ben Prevoznak
  2. Kailan Ottaway
  3. A. Freddie Hess

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Introduction: Motivation

- Formula Hybrid Competition Vehicle
  - Electric Car
- Capable of Vehicle Integration
- Four Team Integration
- Integrate with Mechanical Engineering Department
- Provide next year's team with a well-structured Formula Hybrid Vehicle ready for integration

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Interface Control

An Interface Control Document was created to accurately and completely define all (electrical, mechanical, semantic) aspects of top-level interfaces to allow different designers to coordinate with each other successfully.

Next, we will discuss these top-level interfaces.

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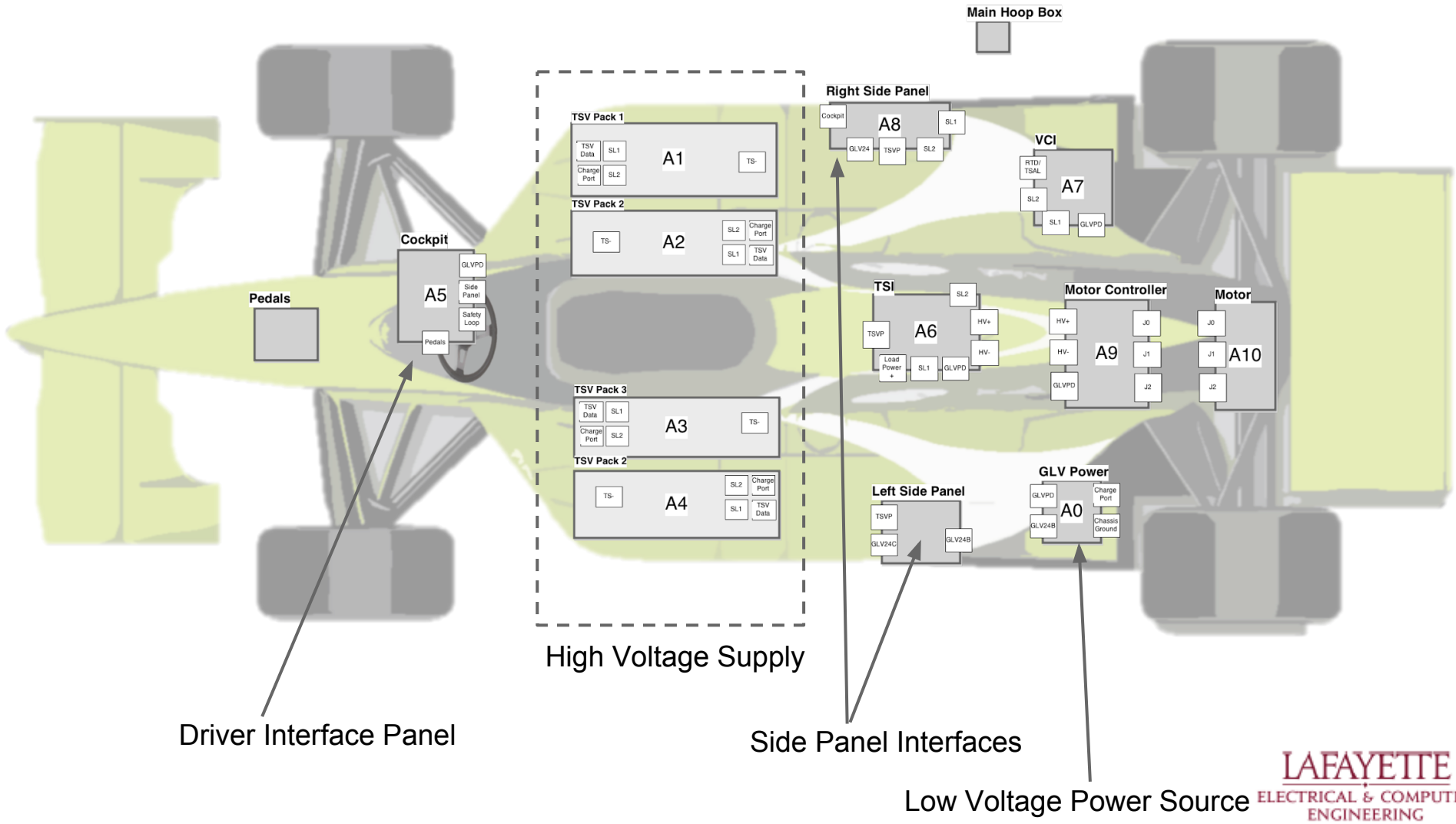
System Assemblies Layout - Top View



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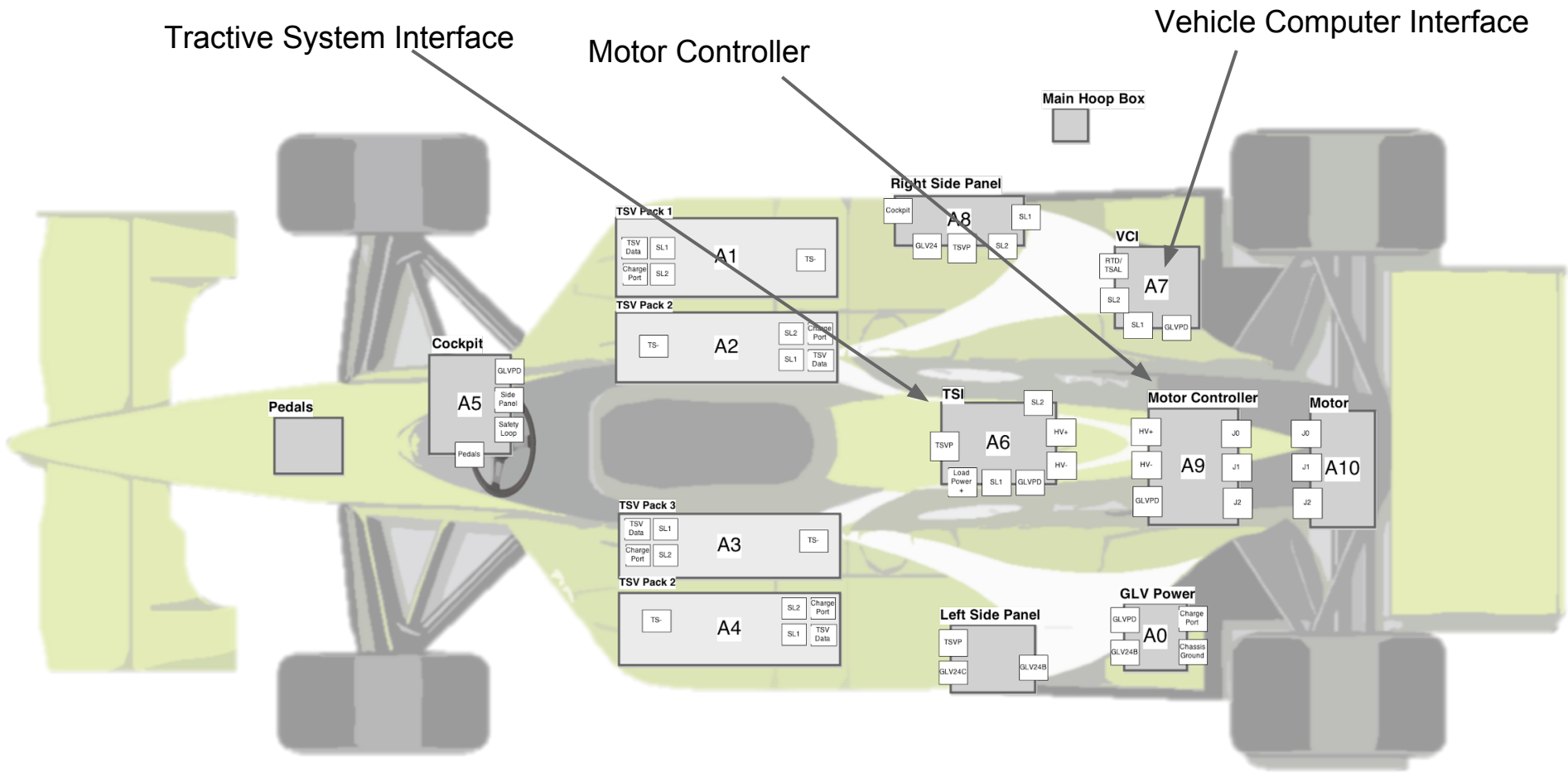
System Assemblies Layout - Top View



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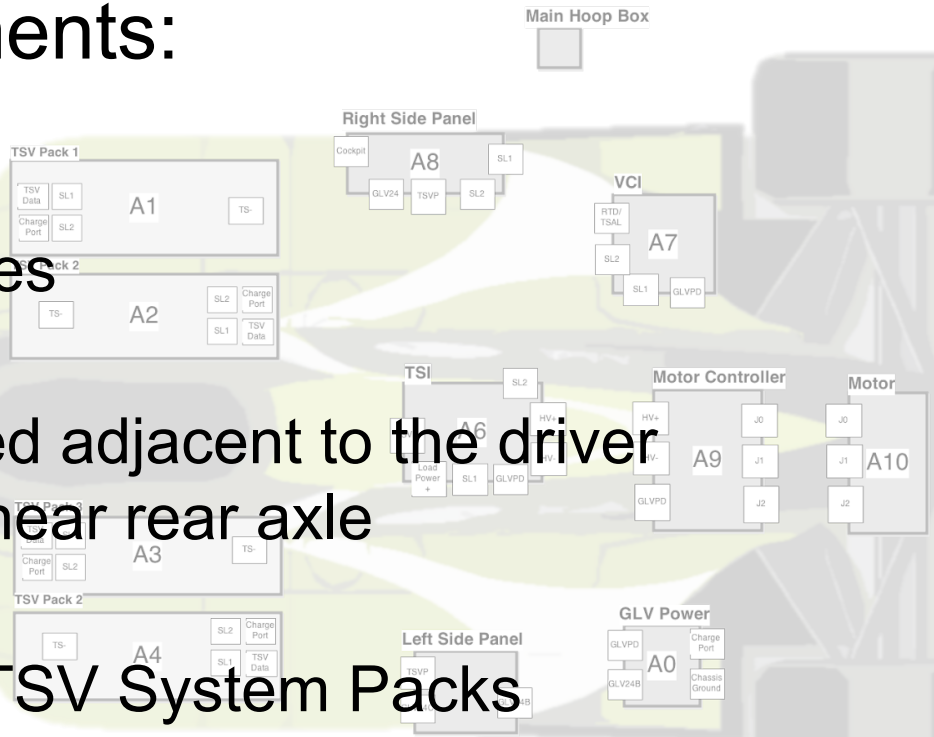
Layout Selection

- SAE Requirements:
  - Side Panels
  - Cockpit Panel
  - Warning Devices
- Mechanical:
  - TSV best placed adjacent to the driver
  - Motor located near rear axle
- Cabling
  - Orientation of TSV System Packs
  - TSI, Motor Controller, and Motor all adjacent
- Interfacing
  - VCI accessible by pit station crew



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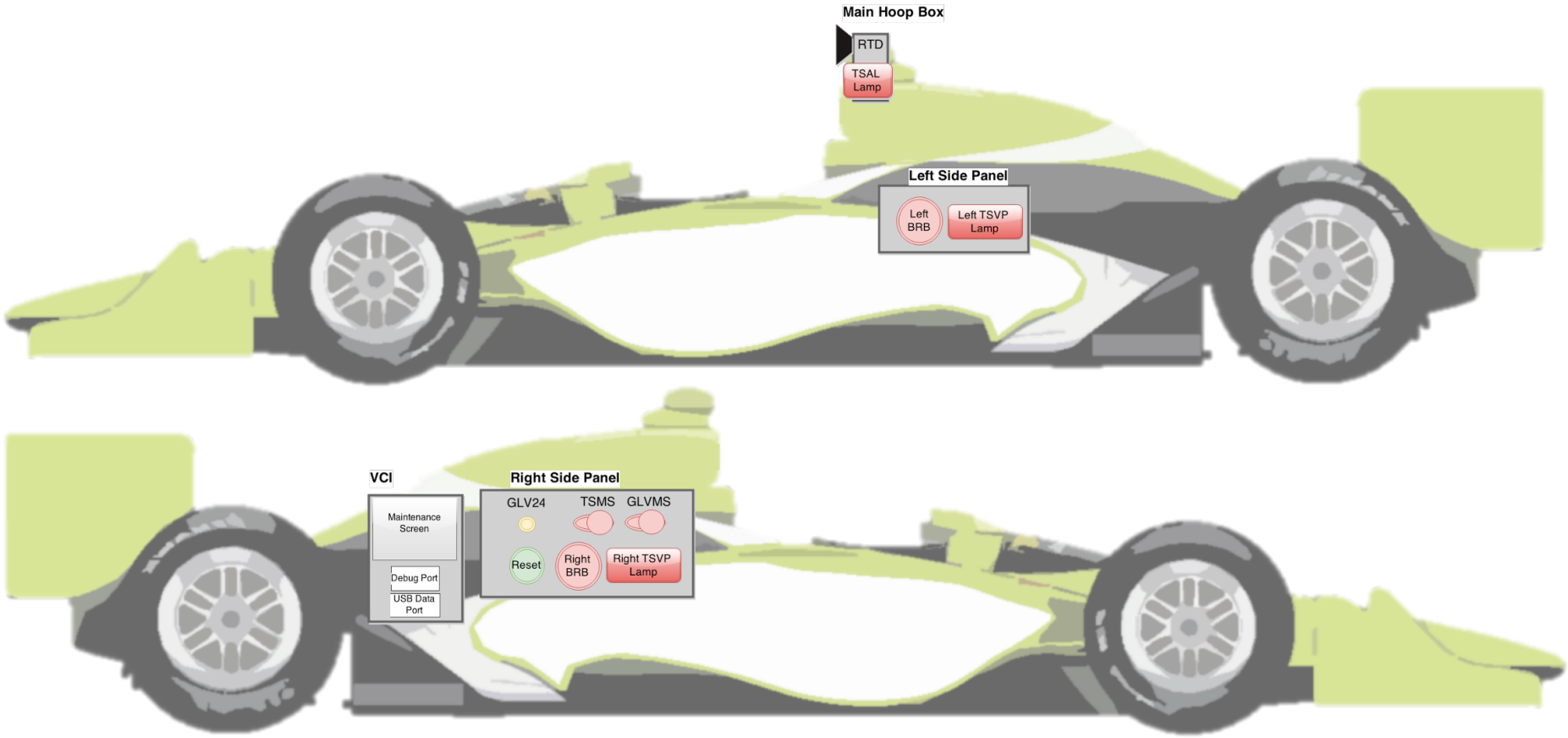
Physical Interfaces Layout - Side View



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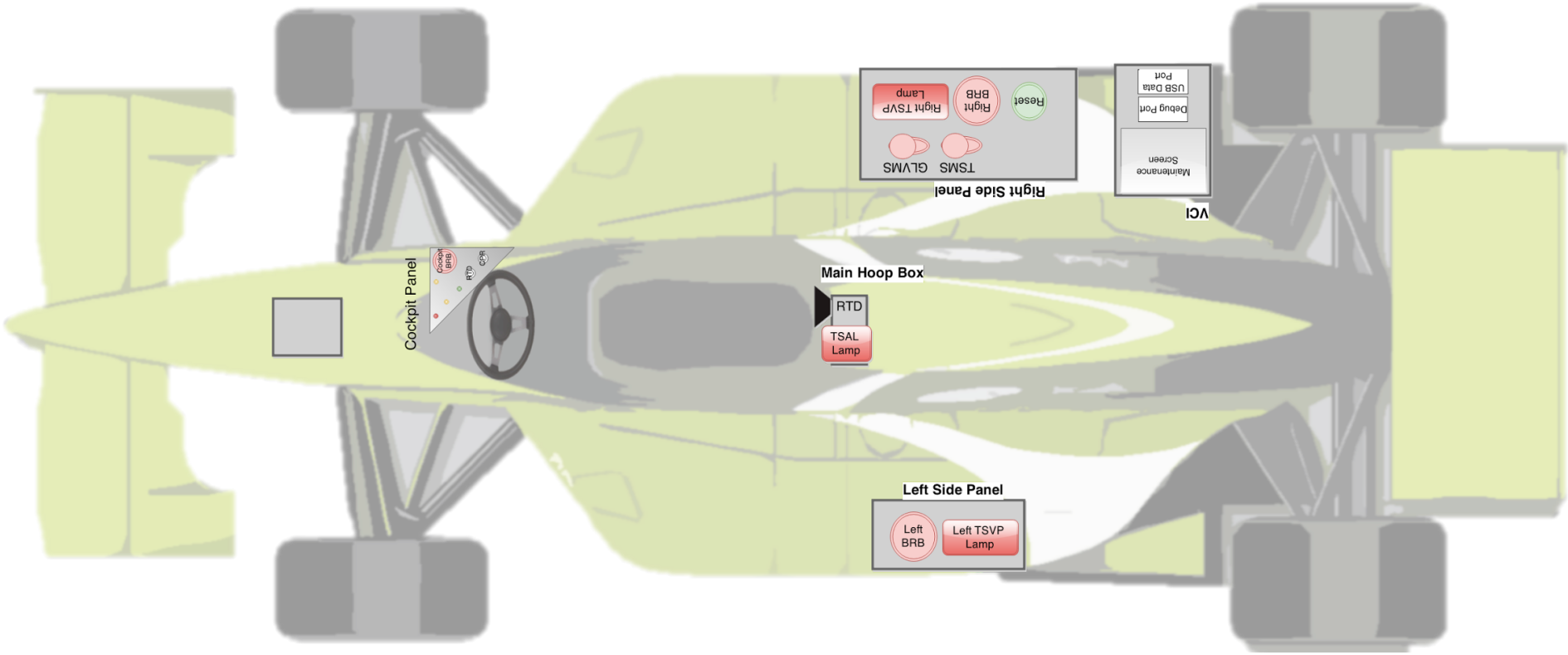
Physical Interfaces Layout - Top View



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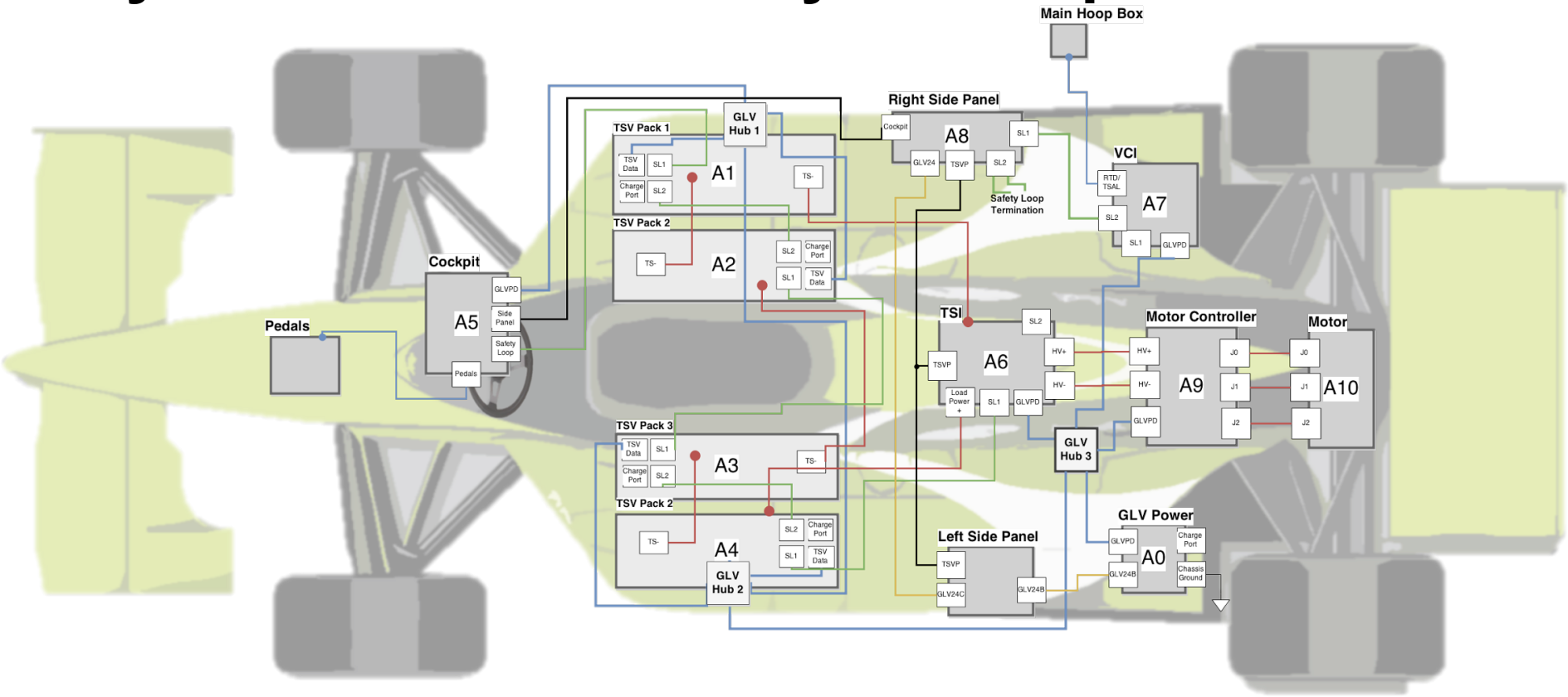
System Assemblies Layout - Top View



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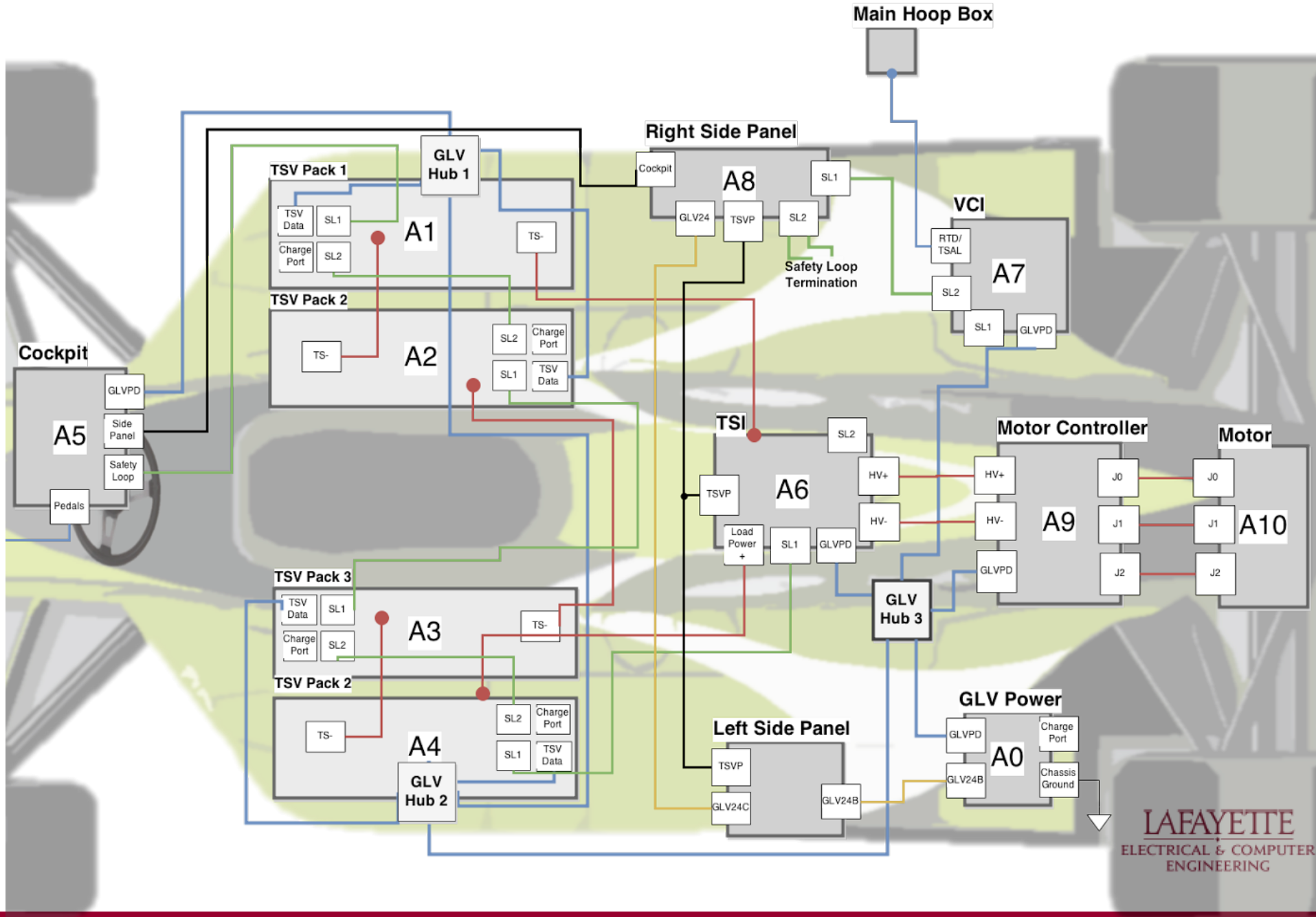
Main Hoop Box
Right Side Panel
Cockpit
A8
SL1
GLV24
TSVP
SL2
Safety Loop Termination
VCI
RTD/ TSAL
A7
SL2
SL1
GLVPD
GLV Hub 1
TSV Pack 1
TSV Data
SL1
A1
Charge Port
SL2
TS-
TSV Pack 2
TS-
A2
SL2
Charge Port
SL1
TSV Data
Cockpit
GLVPD
A5
Side Panel
Safety Loop
Pedals
TSI
SL2
HV+
TSVP
A6
HV-
Load Power +
SL1
GLVPD
Motor Controller
HV+
HV-
A9
GLVPD
J0
J1
J2
Motor
J0
J1
A10
J2
GLV Hub 3
TSV Pack 3
TSV Data
SL1
A3
Charge Port
SL2
TS-
TSV Pack 2
TS-
A4
SL2
Charge Port
SL1
TSV Data
GLV Hub 2
Left Side Panel
TSVP
GLV24C
GLV24B
GLV Power
GLVPD
A0
GLV24B
Charge Port
Chassis Ground
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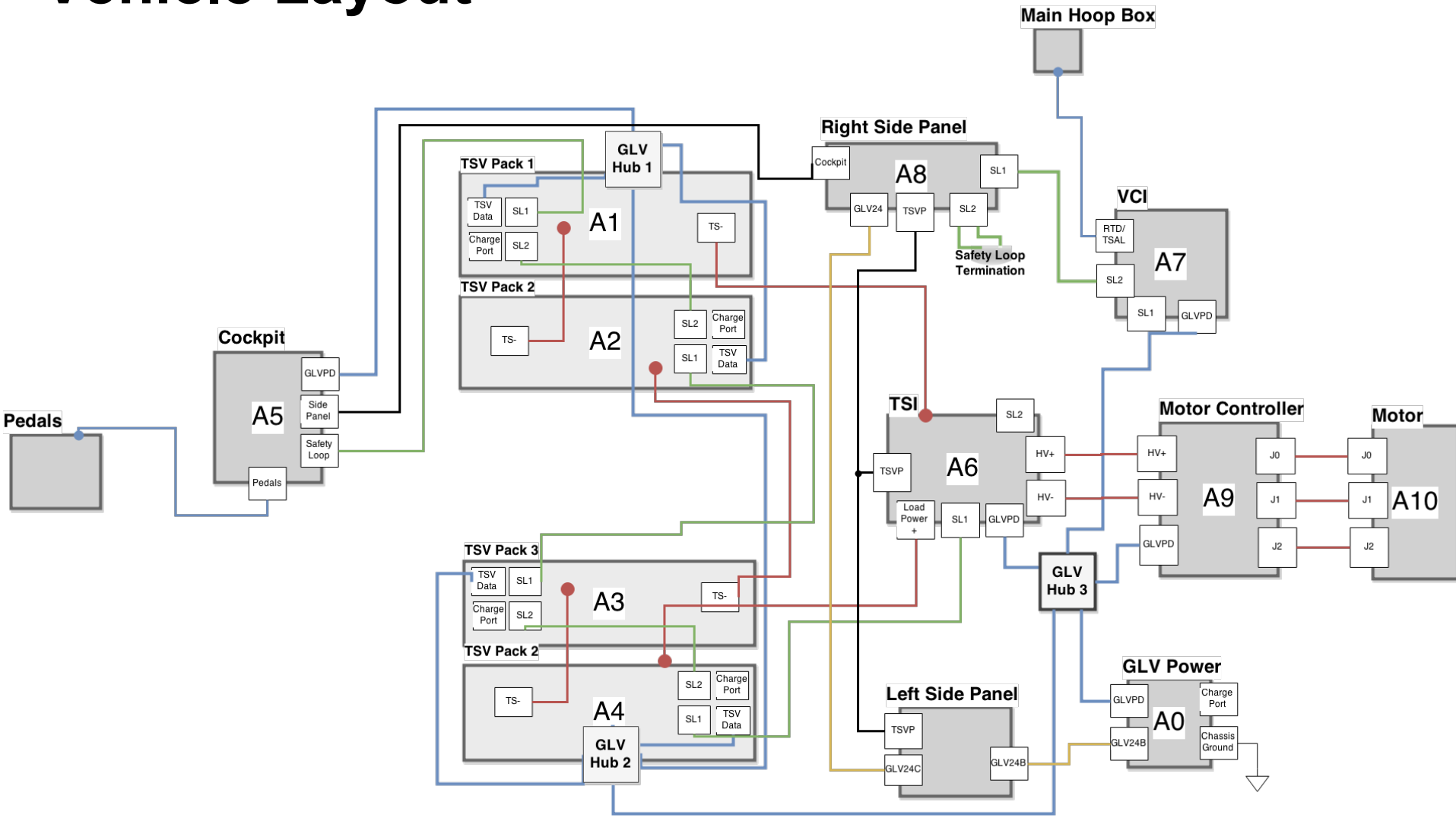
Vehicle Layout



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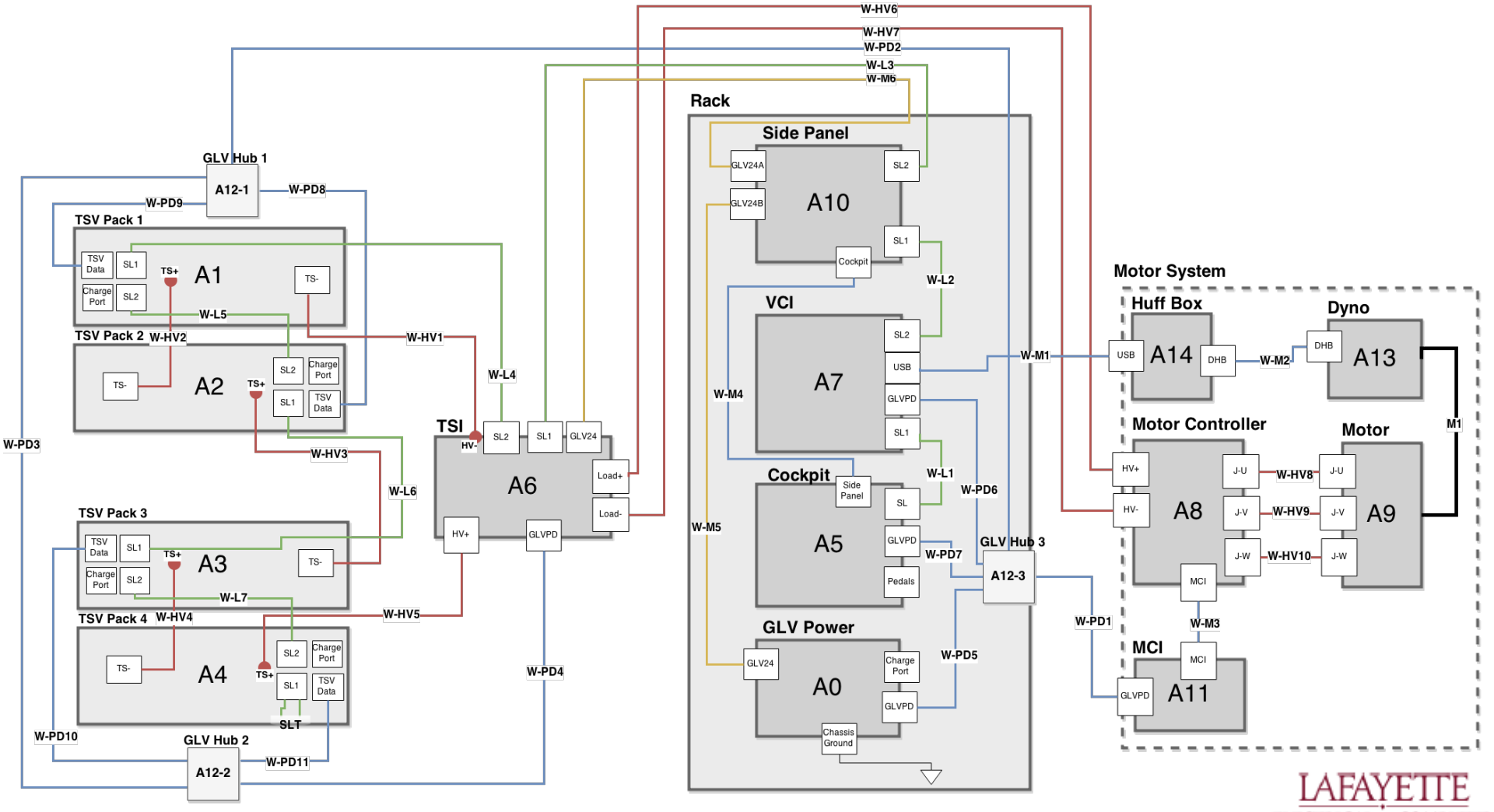
End-of-Term Integration Layout



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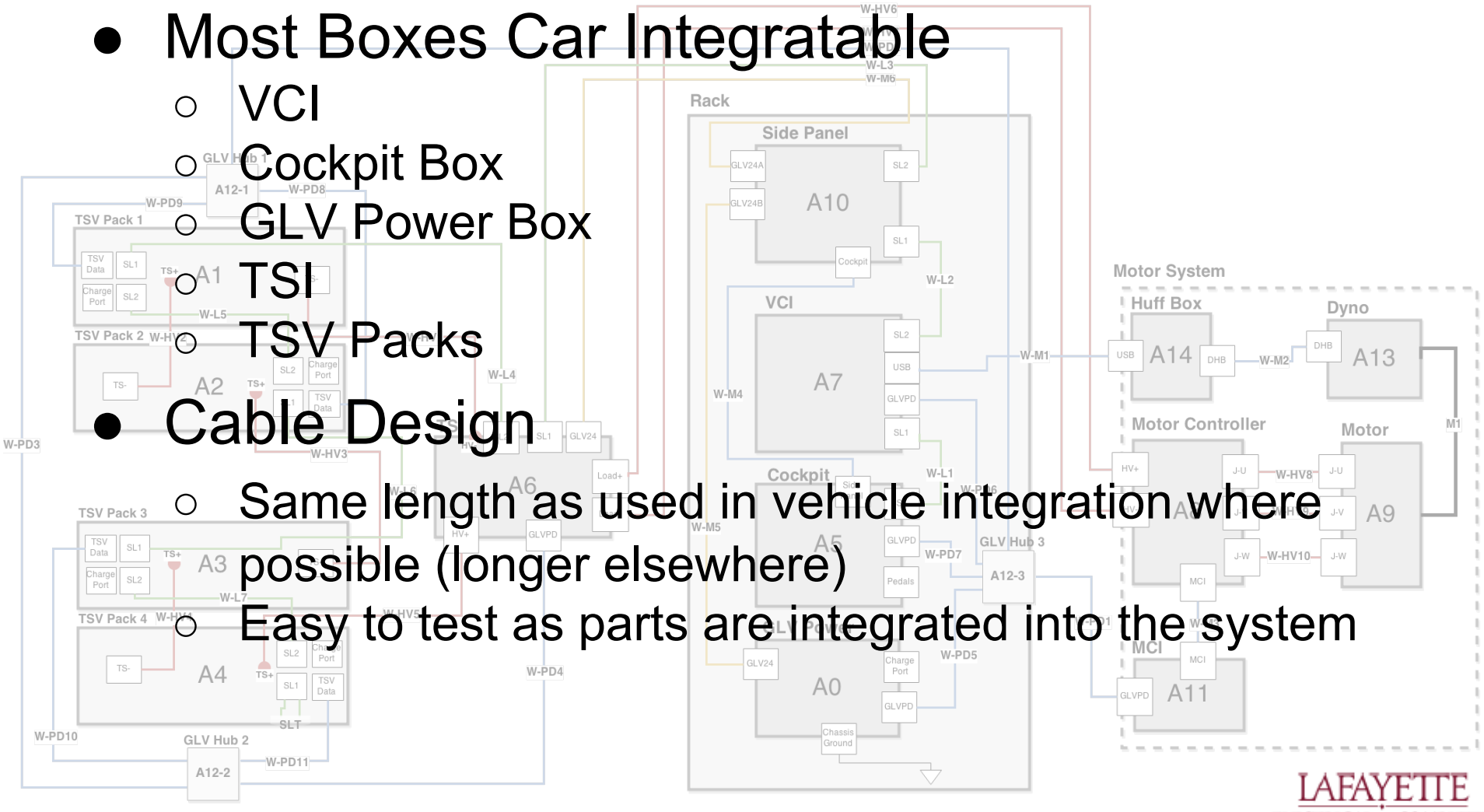
End of Term Integration Layout

- Most Boxes Car Integratable
  - VCI
  - Cockpit Box
  - GLV Power Box
  - TSI
  - TSV Packs
- Cable Design
  - Same length as used in vehicle integration where possible (longer elsewhere)
  - Easy to test as parts are integrated into the system



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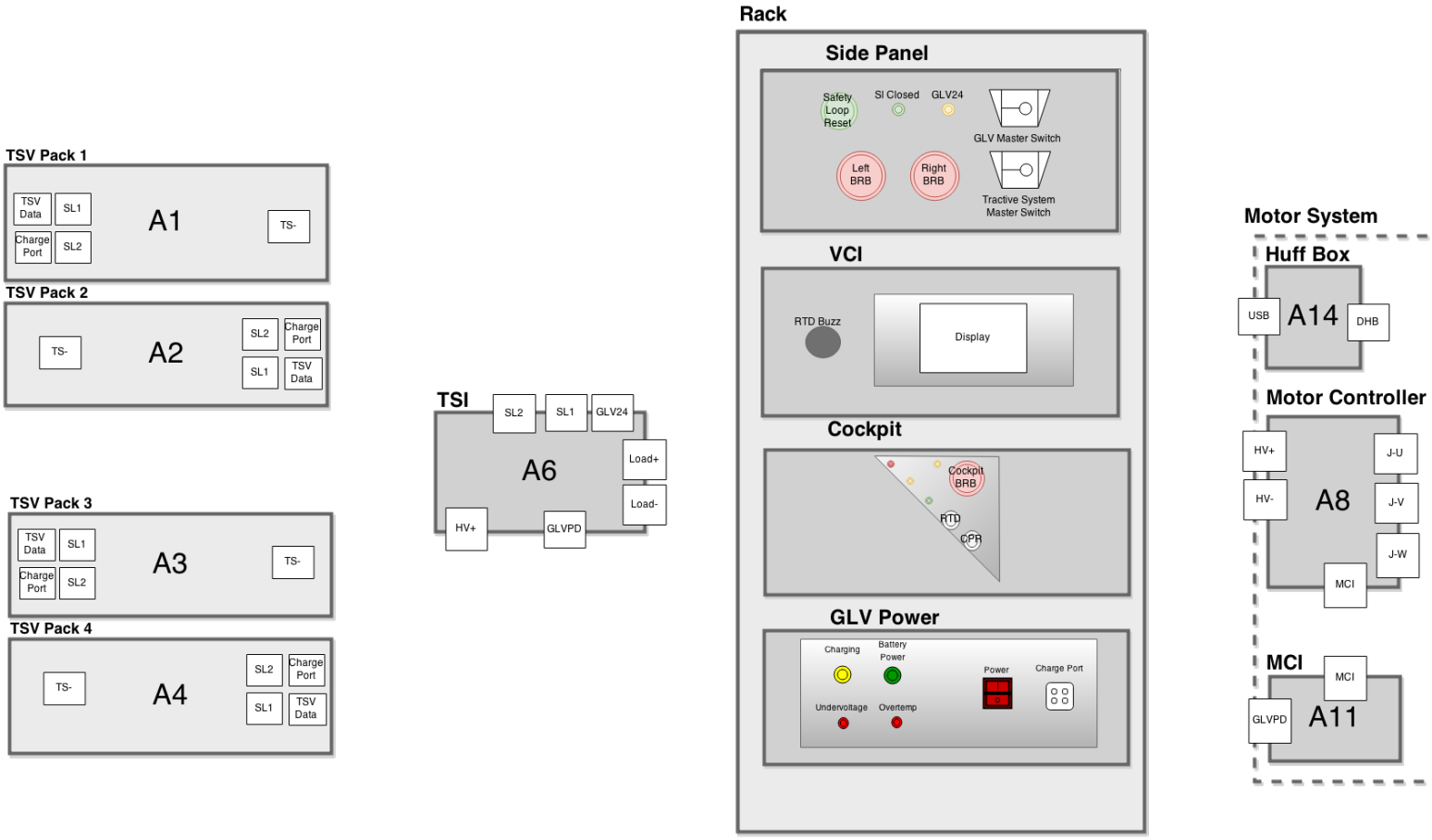
Semester Integration Physical Interfaces



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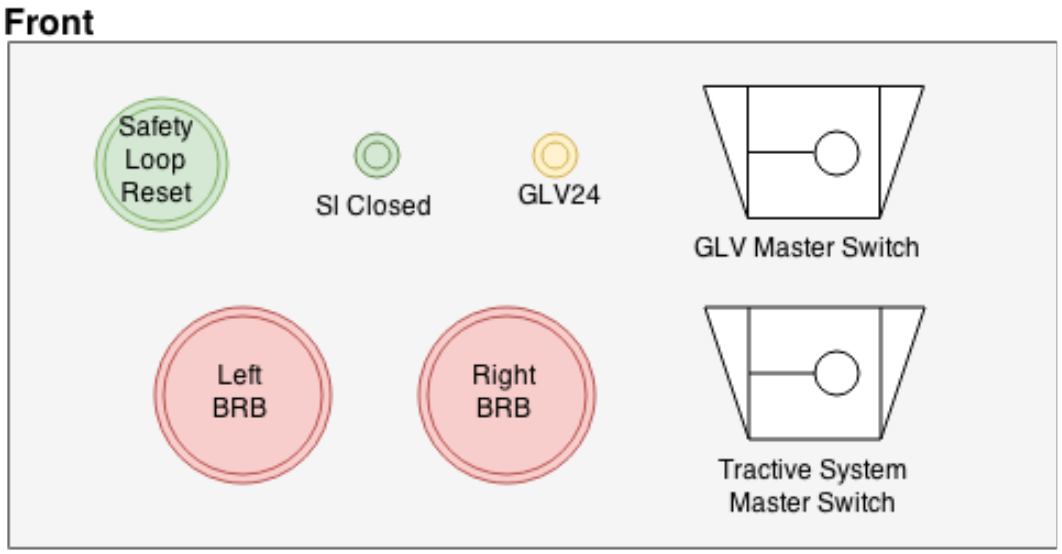
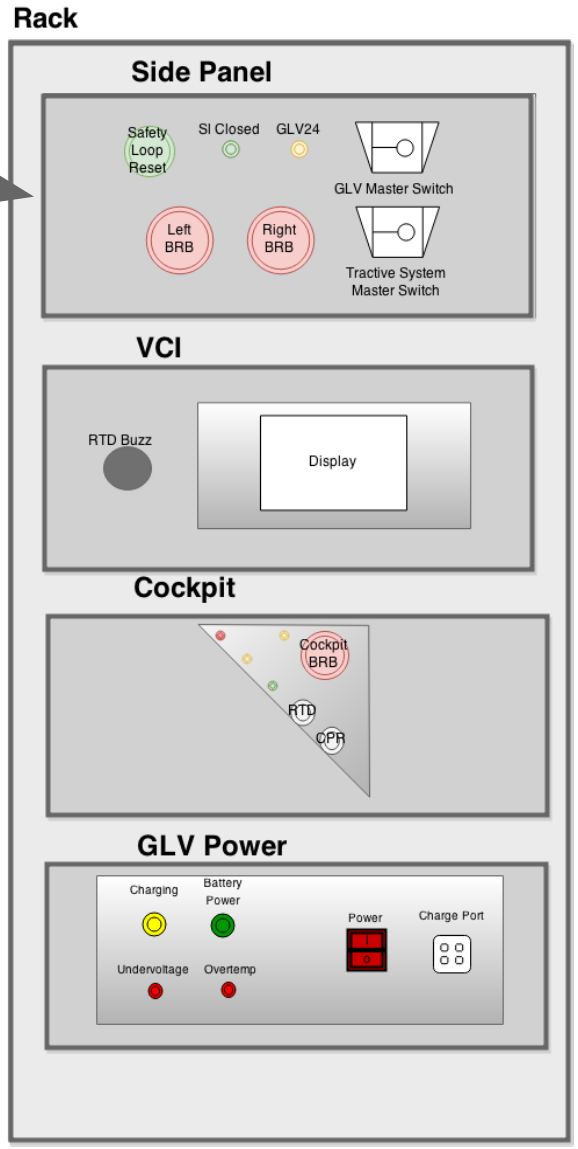
Physical Interfaces

- Side Panel
  - Contains Master Switches
  - Safety Loop Interface
  - Power Indicators





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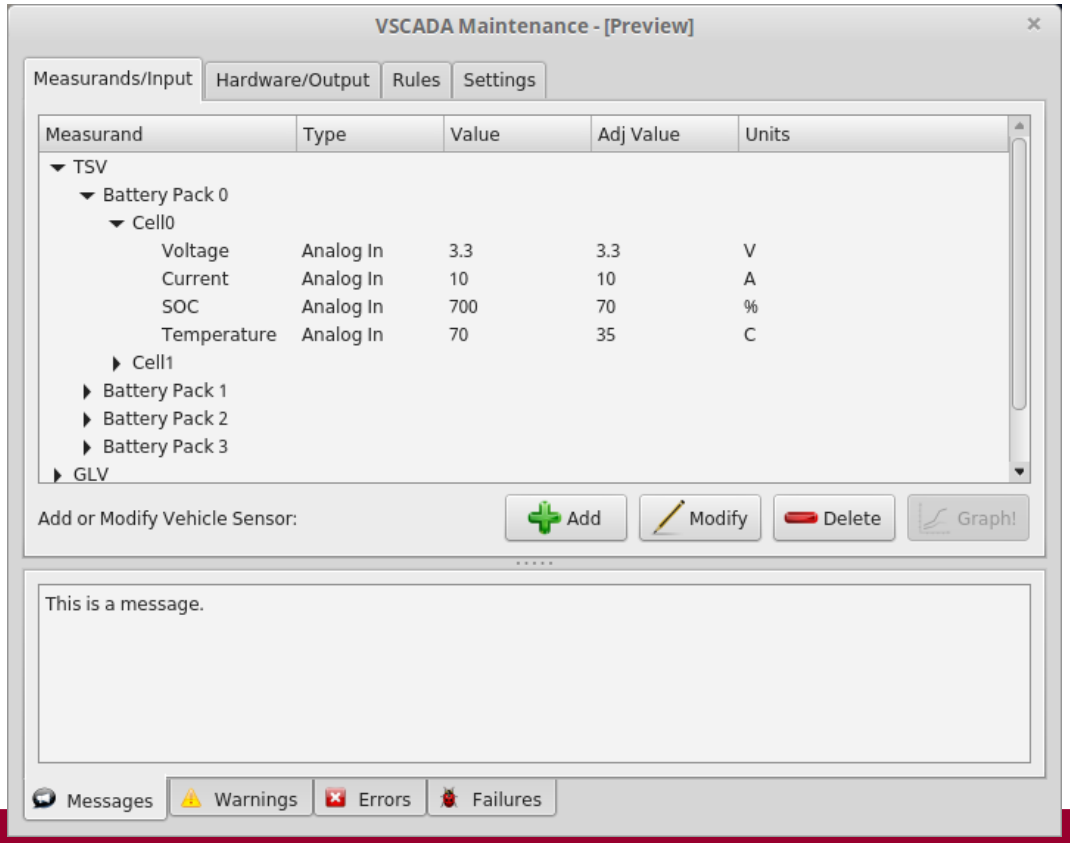
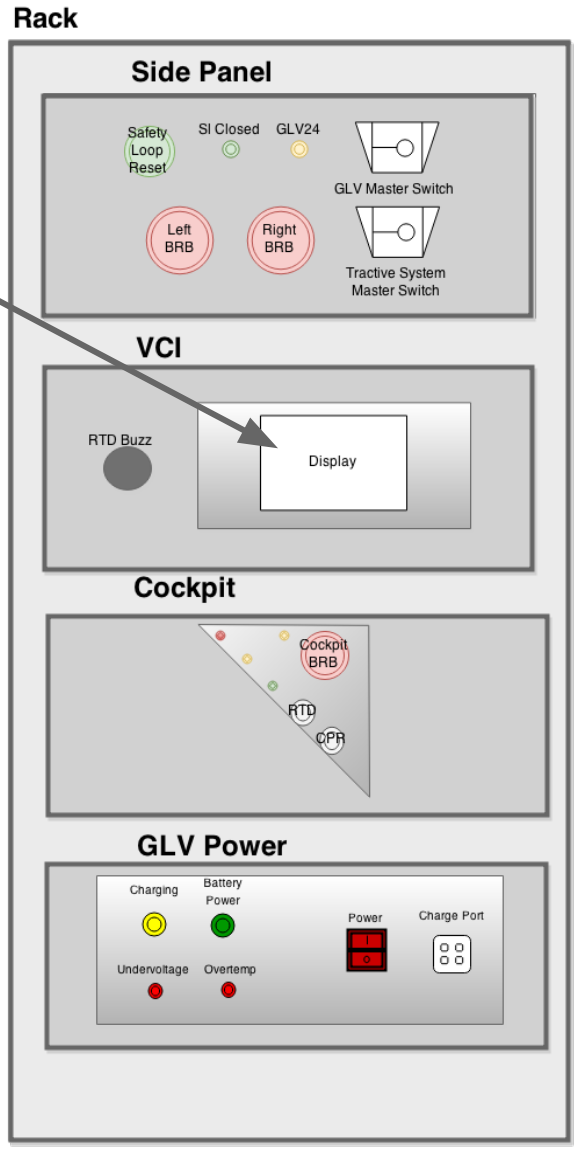
Physical Interfaces

- VCI Display
  - 9 Inch Touchscreen
  - Direct VSCADA Maintenance
  - System Parameter Control





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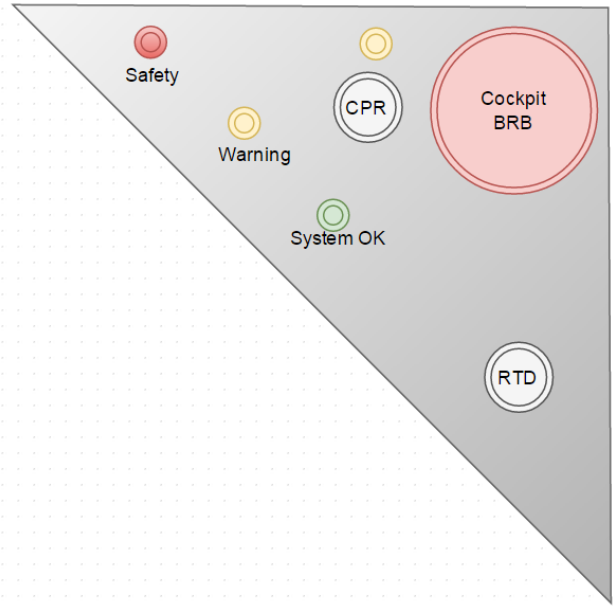
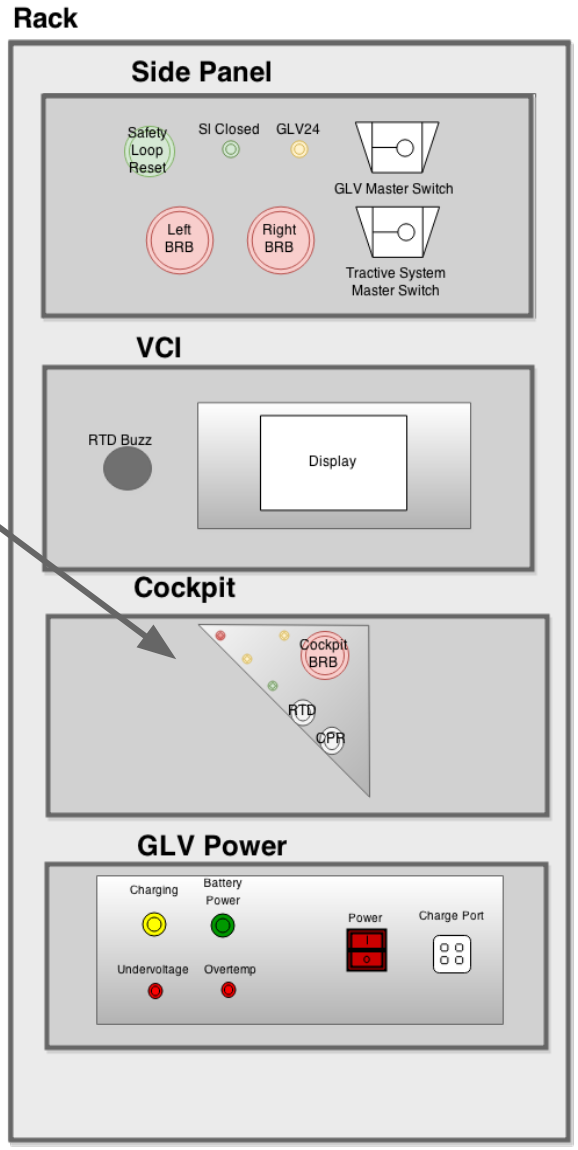
Physical Interfaces

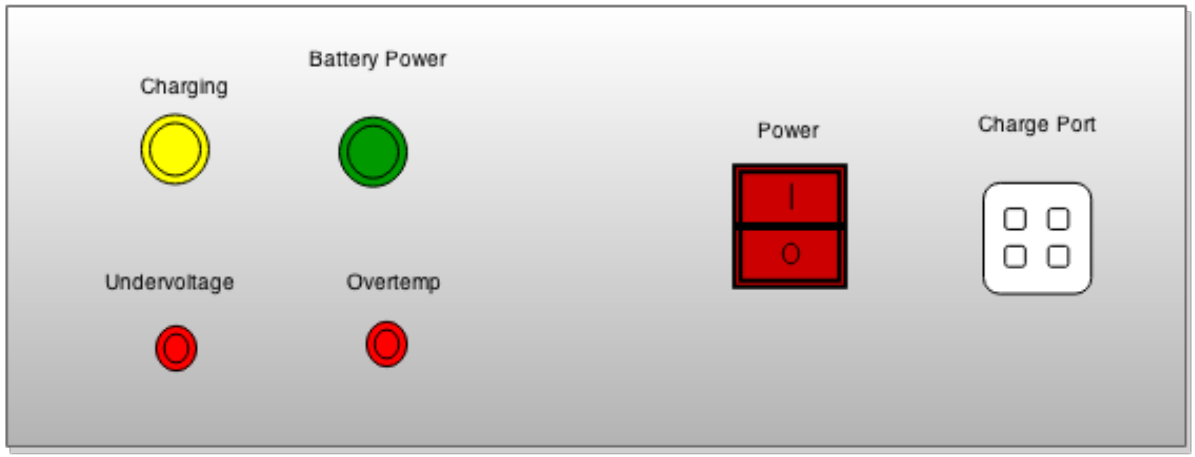
- Cockpit Panel
  - Driver Interface
  - E-Stop (BRB) and Reset (CPR)
  - Indicators
  - Key Start Switch

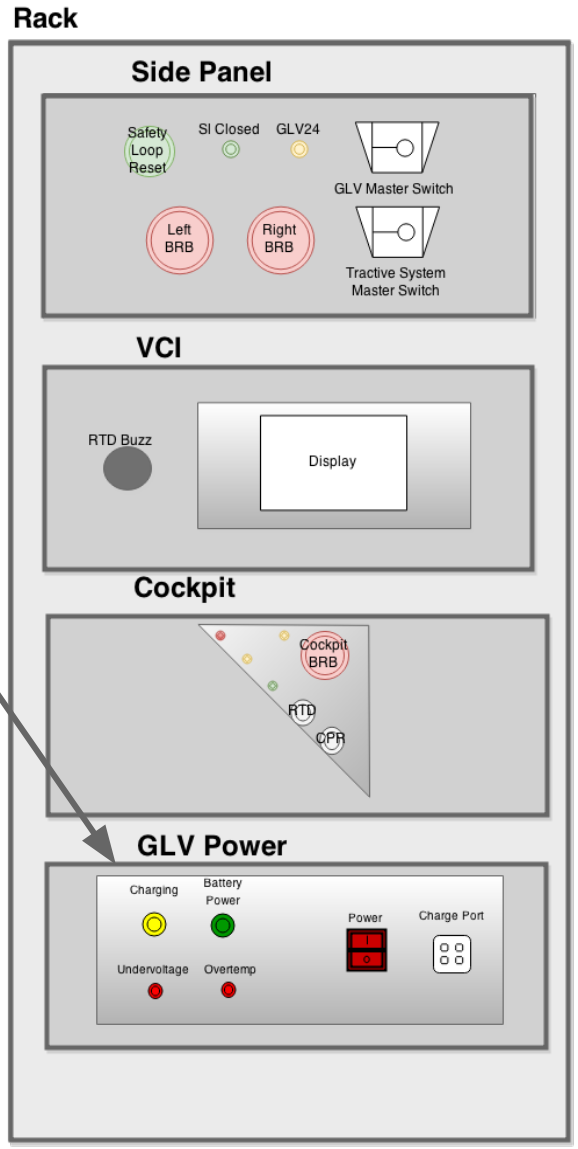




Physical Interfaces

- GLV Power Panel
  - Low Voltage Battery Indicators
  - GLV Power Switch





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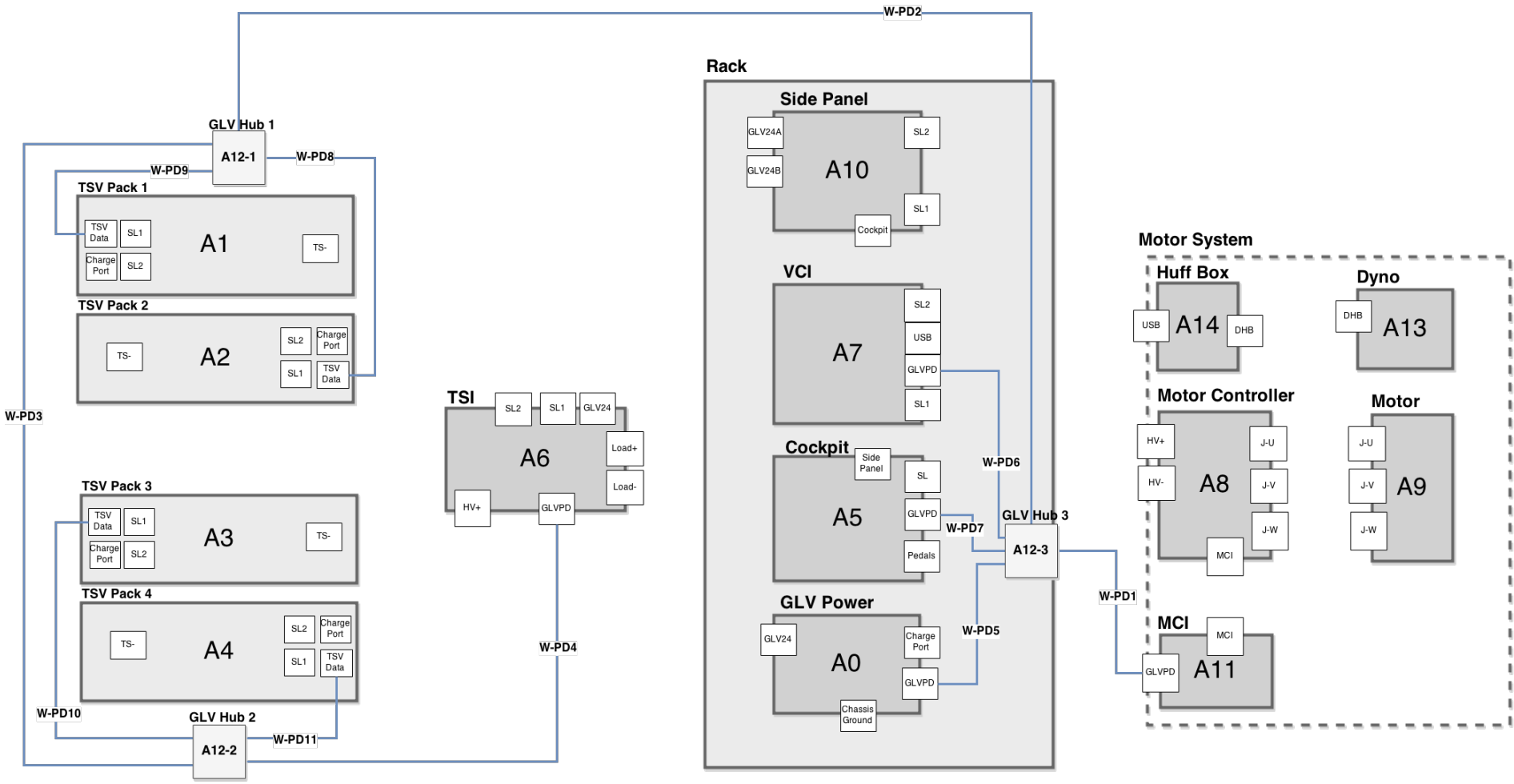
GLV Power and Data Distribution



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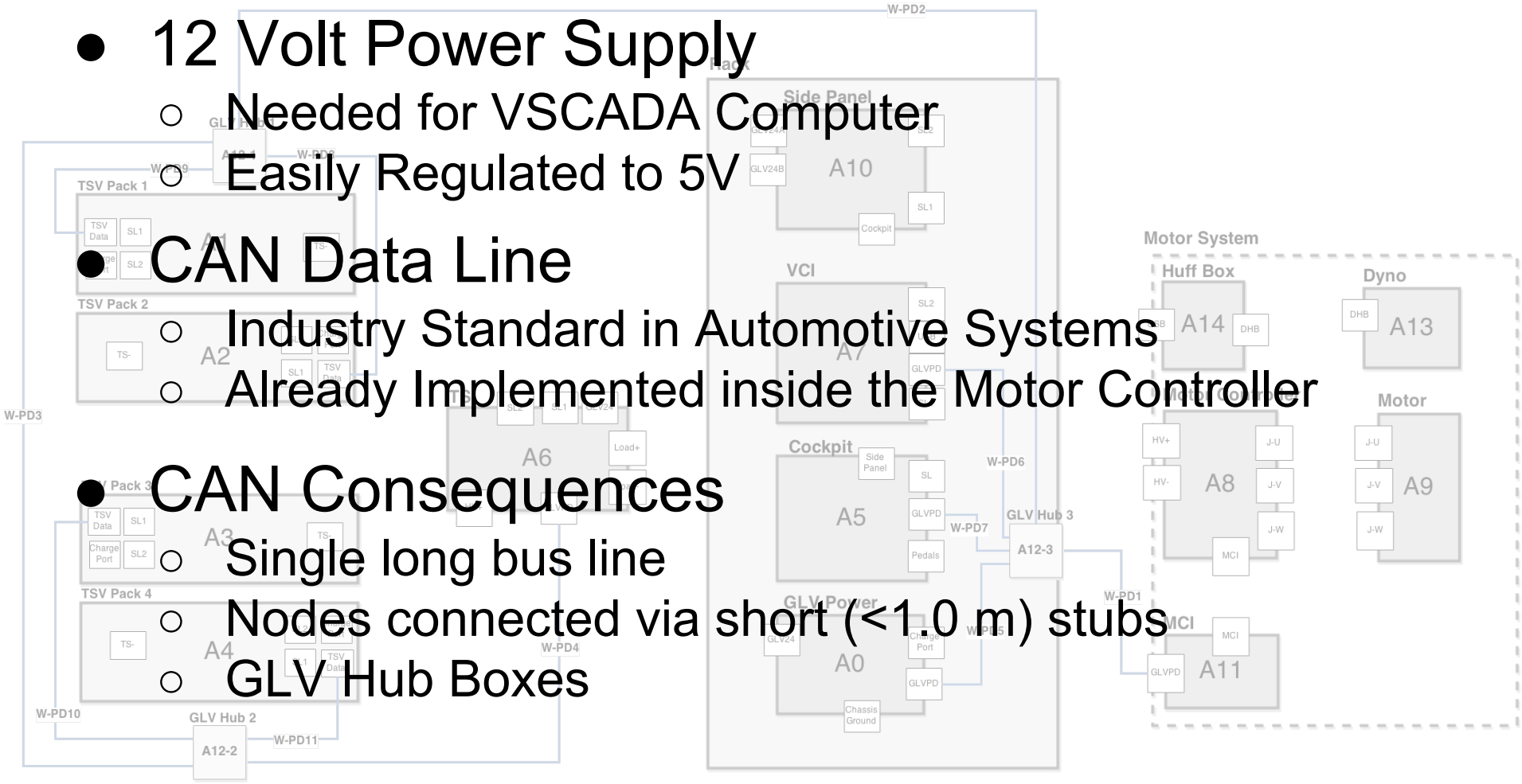
GLV Power and Data Distribution

- 12 Volt Power Supply
  - Needed for VSCADA Computer
  - Easily Regulated to 5V
- CAN Data Line
  - Industry Standard in Automotive Systems
  - Already Implemented inside the Motor Controller
- CAN Consequences
  - Single long bus line
  - Nodes connected via short (<1.0 m) stubs
  - GLV Hub Boxes



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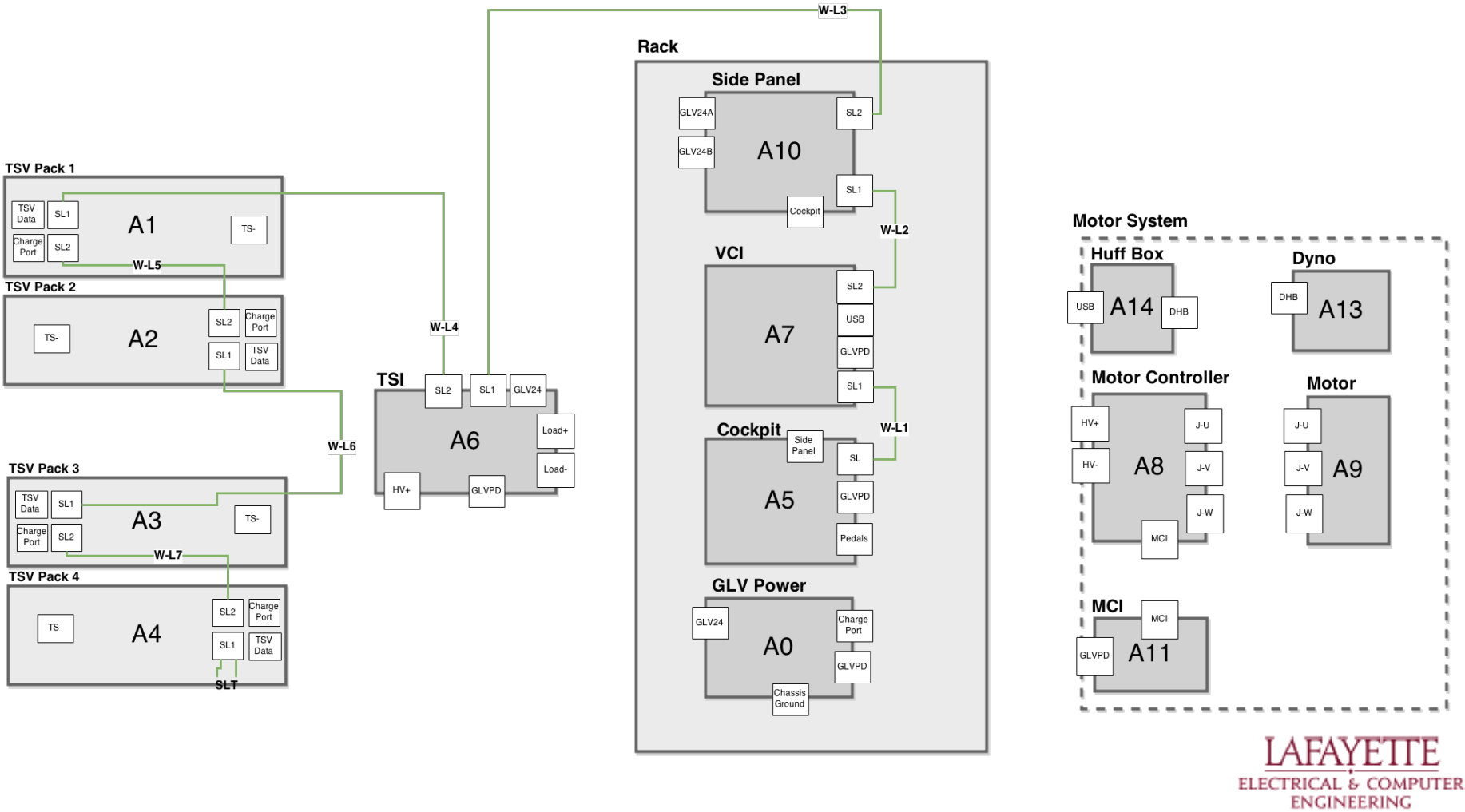
Safety Loop Connections



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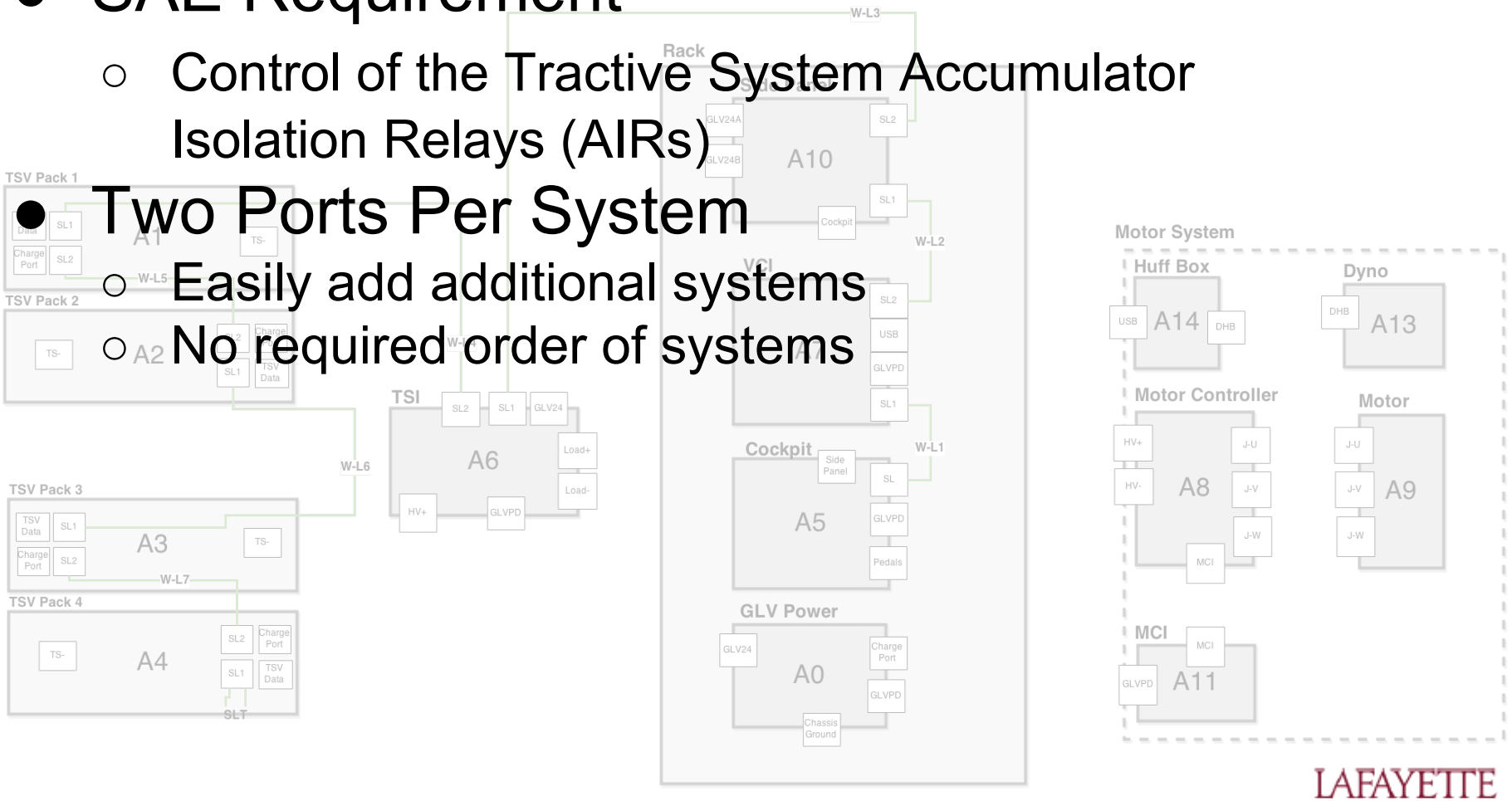
Safety Loop Connections

- SAE Requirement
  - Control of the Tractive System Accumulator Isolation Relays (AIRs)
- Two Ports Per System
  - Easily add additional systems
  - No required order of systems



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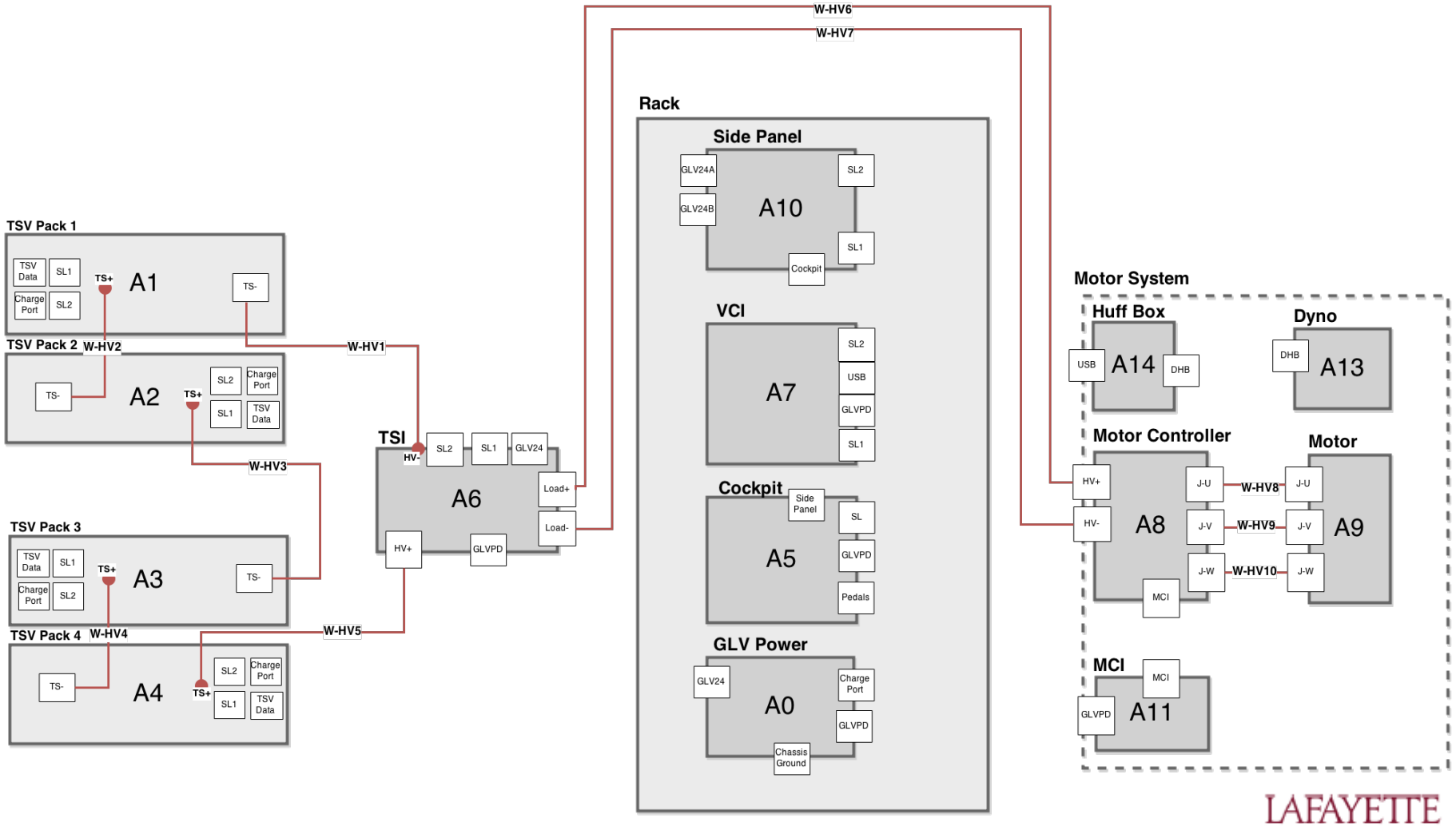
Tractive System High Voltage Path



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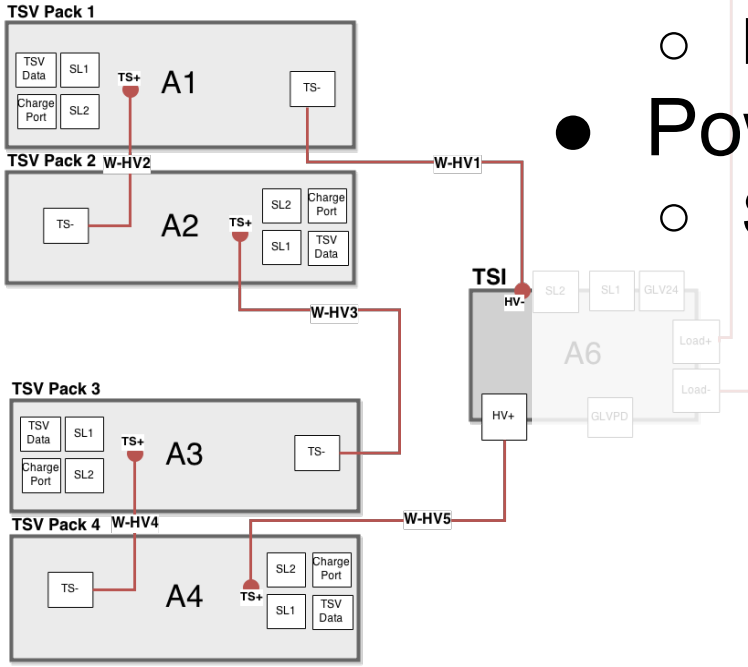
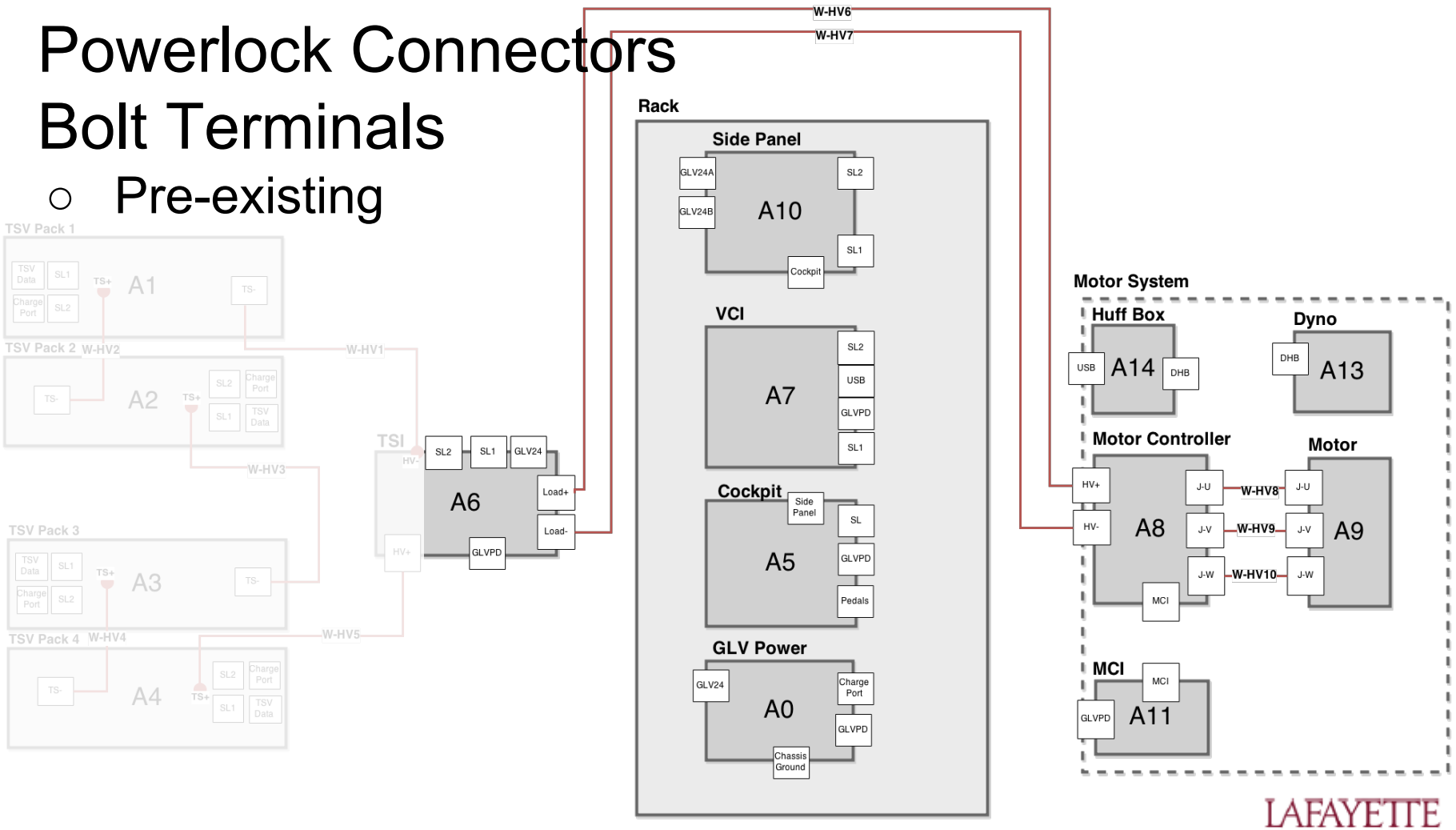
Tractive System High Voltage Path

- Internally Hardwired Connections
  - Less Cables
  - Less Interconnects
- Powerlock Connectors
  - SAE Requirements:
    - Easily Removable
    - Lockable



Tractive System High Voltage Path

- Powerlock Connectors
- Bolt Terminals
  - Pre-existing



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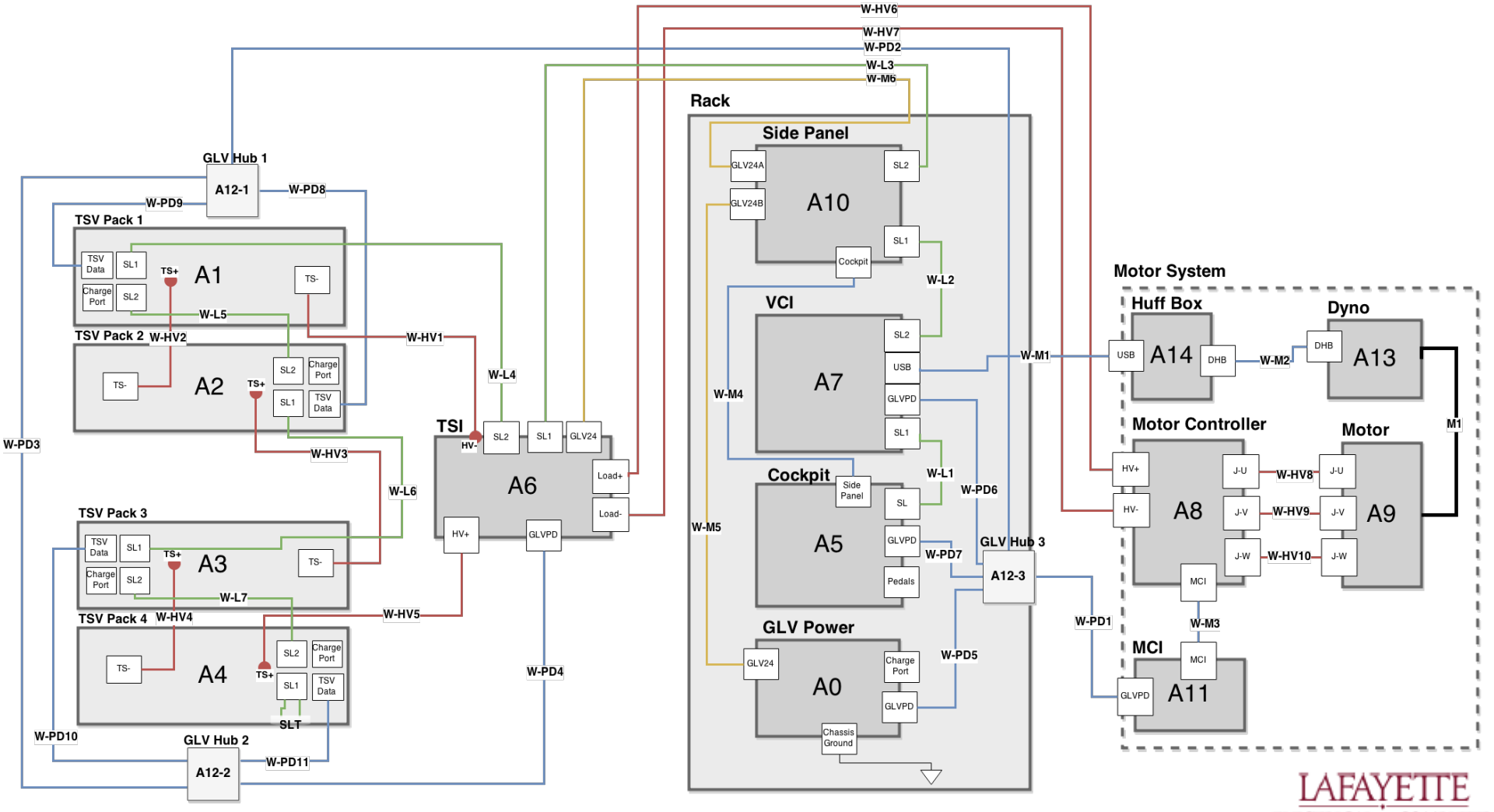
Semester Integration Layout



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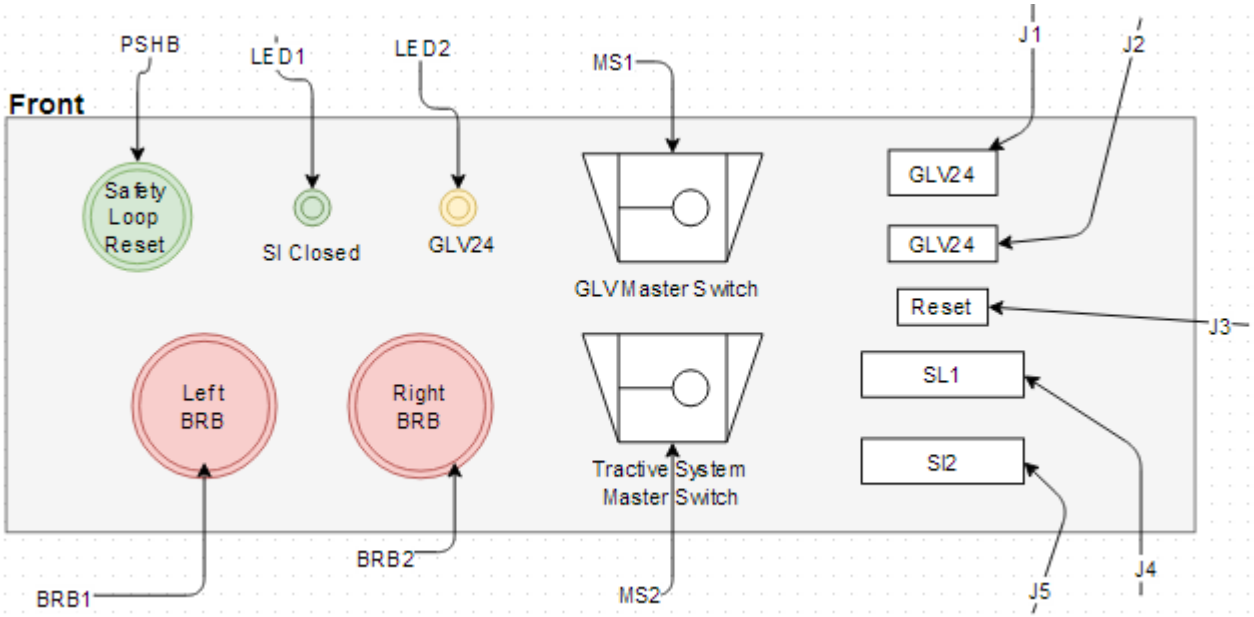
Side Controls Panel

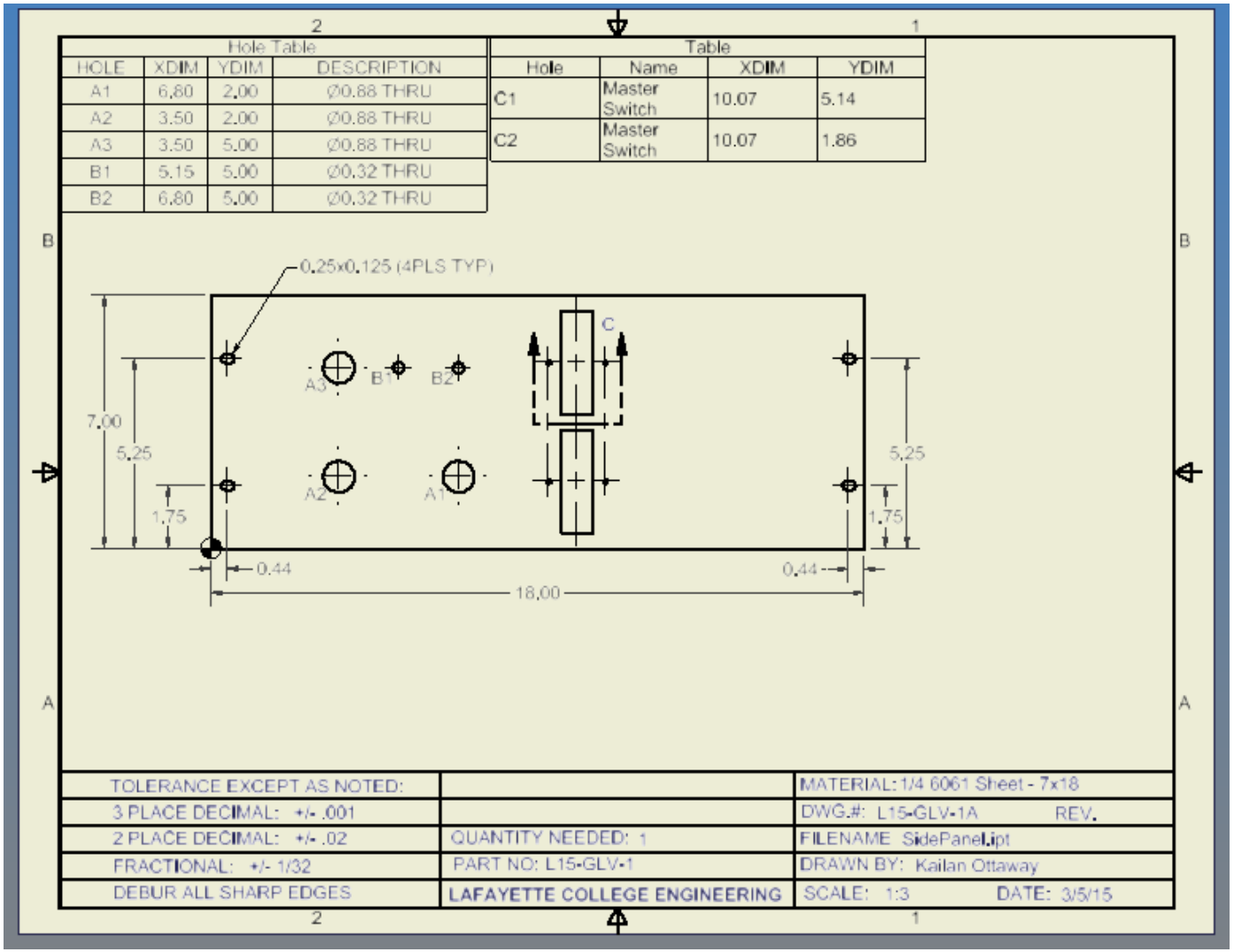
- Designed for testing purposes



Materials list:

Panel will be aluminum	18"x7"x1/4"
PSHB	Push button
BRB1	Big Red Button
BRB2	Big Red Button
LED1	Green LED
LED2	Amber LED
MS1	RotarySwitch
MS2	RotarySwitch
J1	3-pin TE ConnectivityConnectors
J2	3-pin TE ConnectivityConnectors
J3	2-pin TE ConnectivityConnectors
J4	4-pin TE Connectivity Connectors
J5	4-pin TE ConnectivityConnectors

Side Controls Panel Drawing



Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
A1	6.80	2.00	Ø0.88 THRU
A2	3.50	2.00	Ø0.88 THRU
A3	3.50	5.00	Ø0.88 THRU
B1	5.15	5.00	Ø0.32 THRU
B2	6.80	5.00	Ø0.32 THRU

Table

Hole	Name	XDIM	YDIM
C1	Master Switch	10.07	5.14
C2	Master Switch	10.07	1.86

TOLERANCE EXCEPT AS NOTED:		MATERIAL: 1/4 6061 Sheet - 7x18
3 PLACE DECIMAL: +/- .001		DWG.#: L15-GLV-1A REV.
2 PLACE DECIMAL: +/- .02	QUANTITY NEEDED: 1	FILENAME: SidePanel.ipt
FRACTIONAL: +/- 1/32	PART NO: L15-GLV-1	DRAWN BY: Kailan Ottaway
DEBUR ALL SHARP EDGES	LAFAYETTE COLLEGE ENGINEERING	SCALE: 1:3 DATE: 3/5/15

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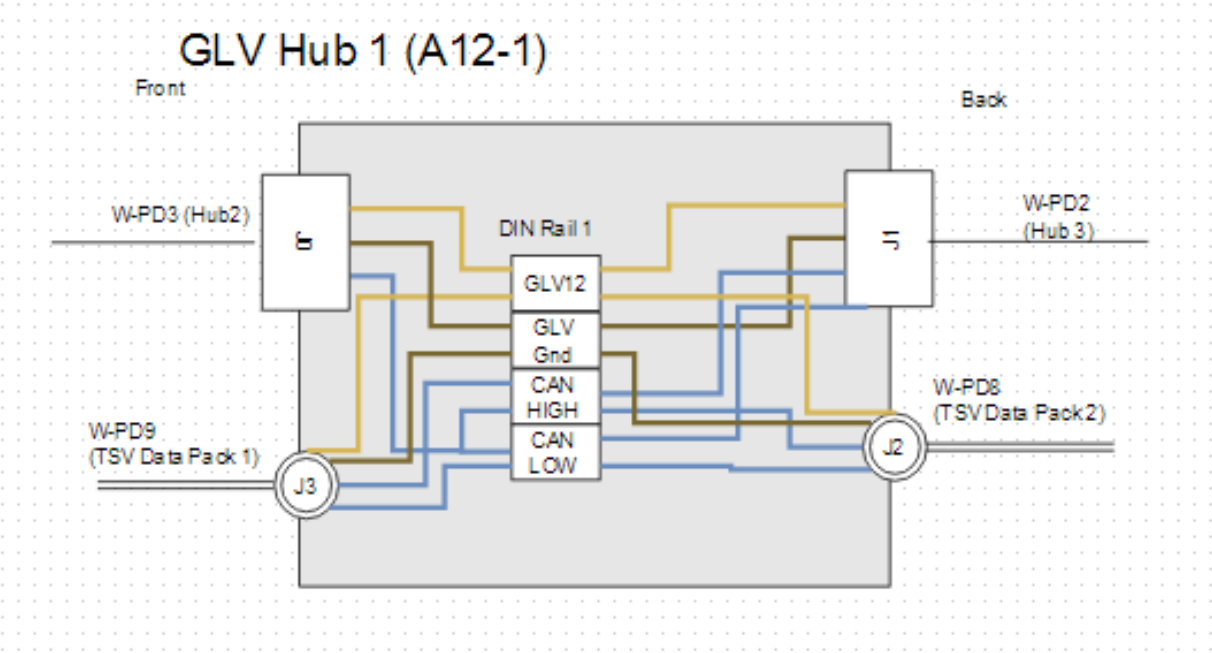
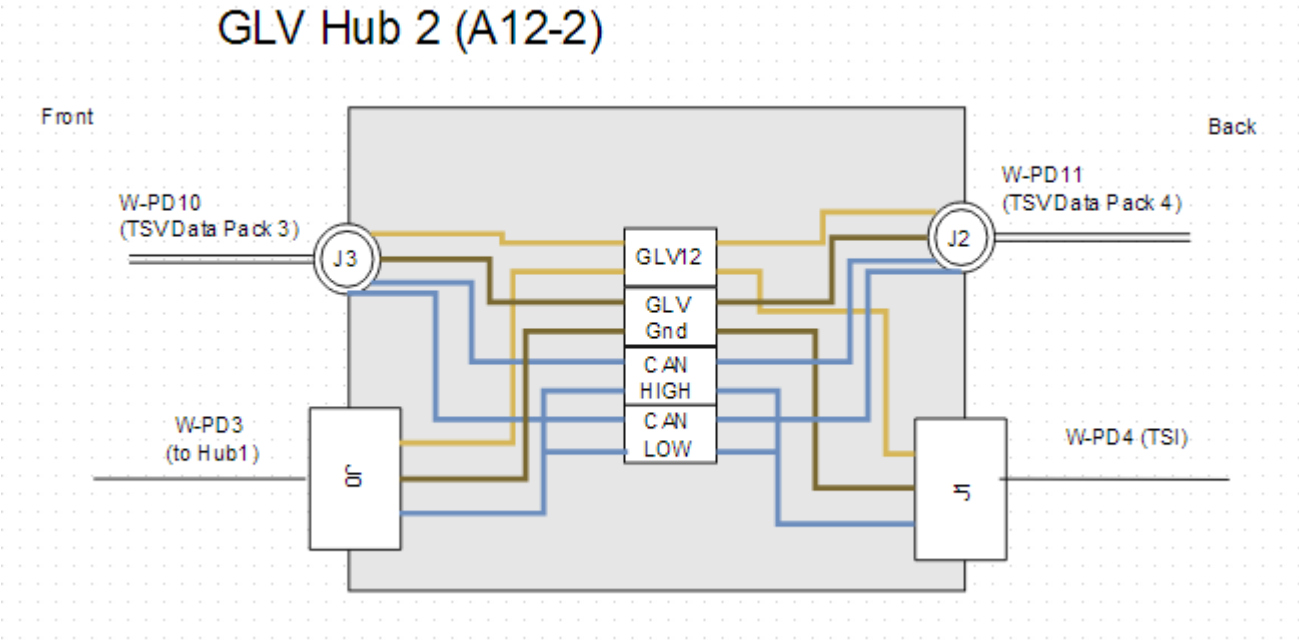
GLV Hub 1

- Connects to GLV Hub 2 and 3
- Dangly that connects to TSV Pack 1 data port
- Dangly that connects to TSV Pack 2 data port

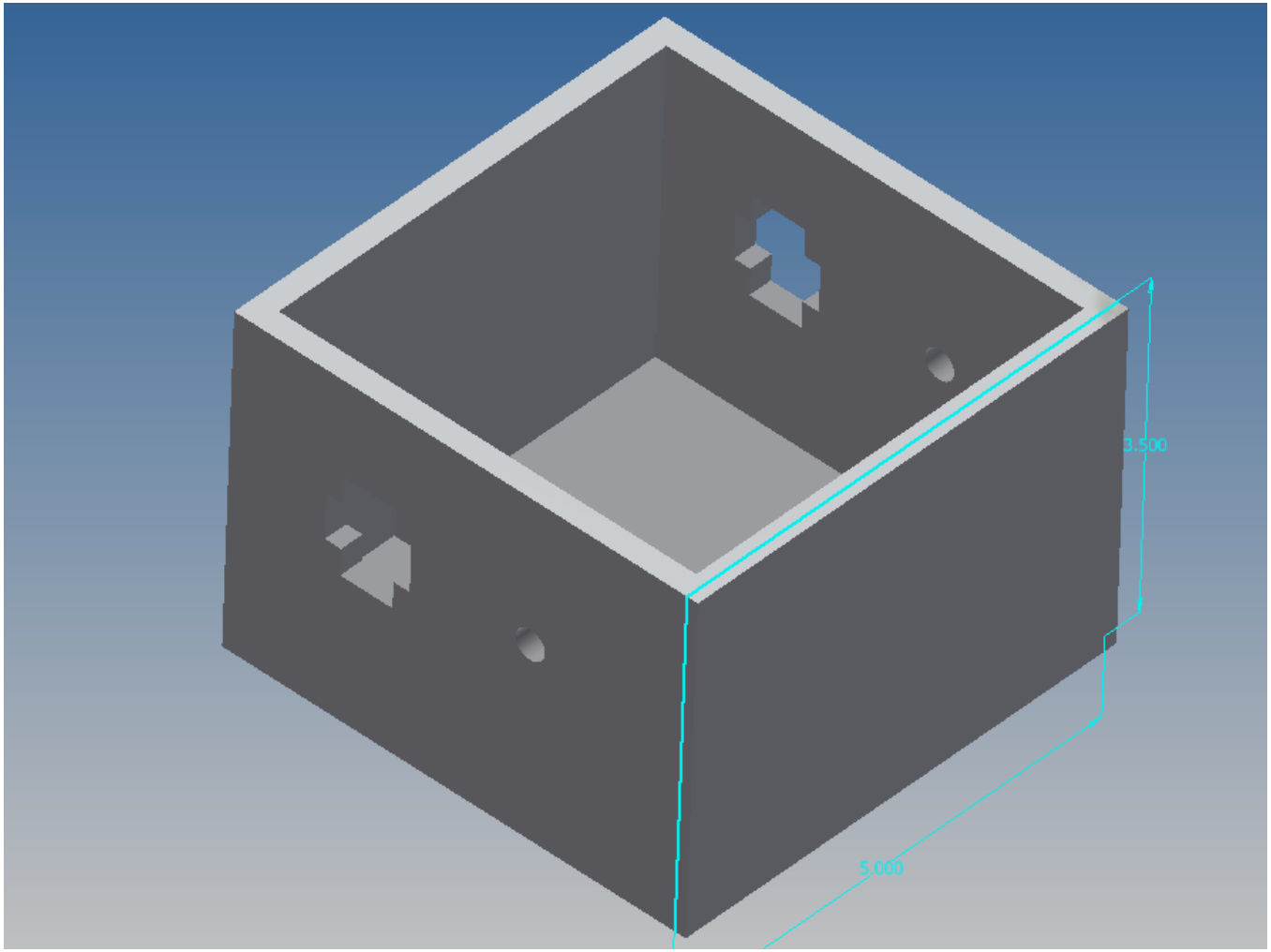


GLV Hub 2

- Connects to GLV Hub 1
- Connects to TSI
- Dangly that connects to TSV Pack 3 data port
- Dangly that connects to TSV Pack 4 data port



GLV Hub 1 & 2



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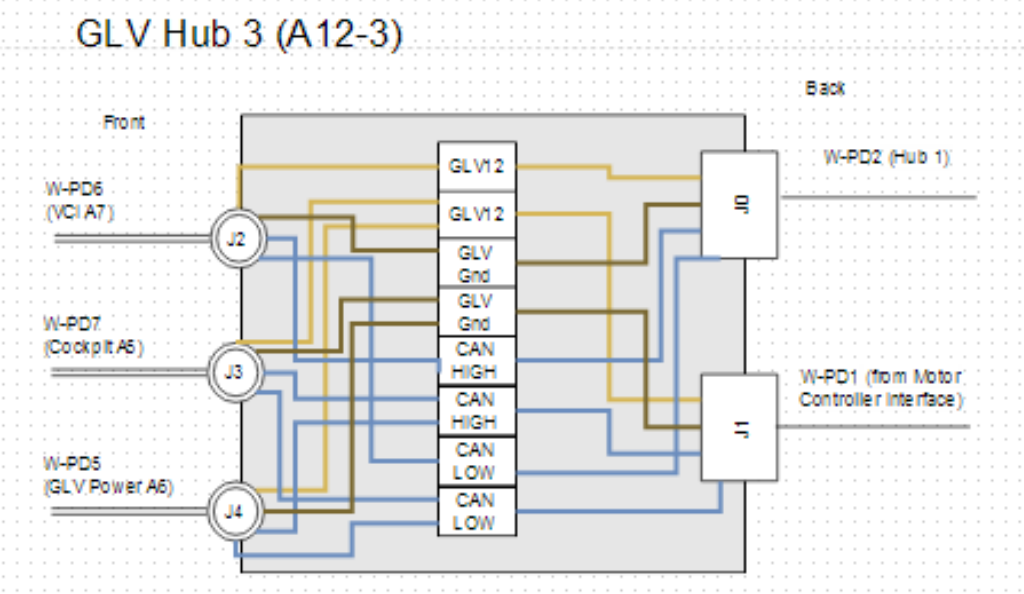
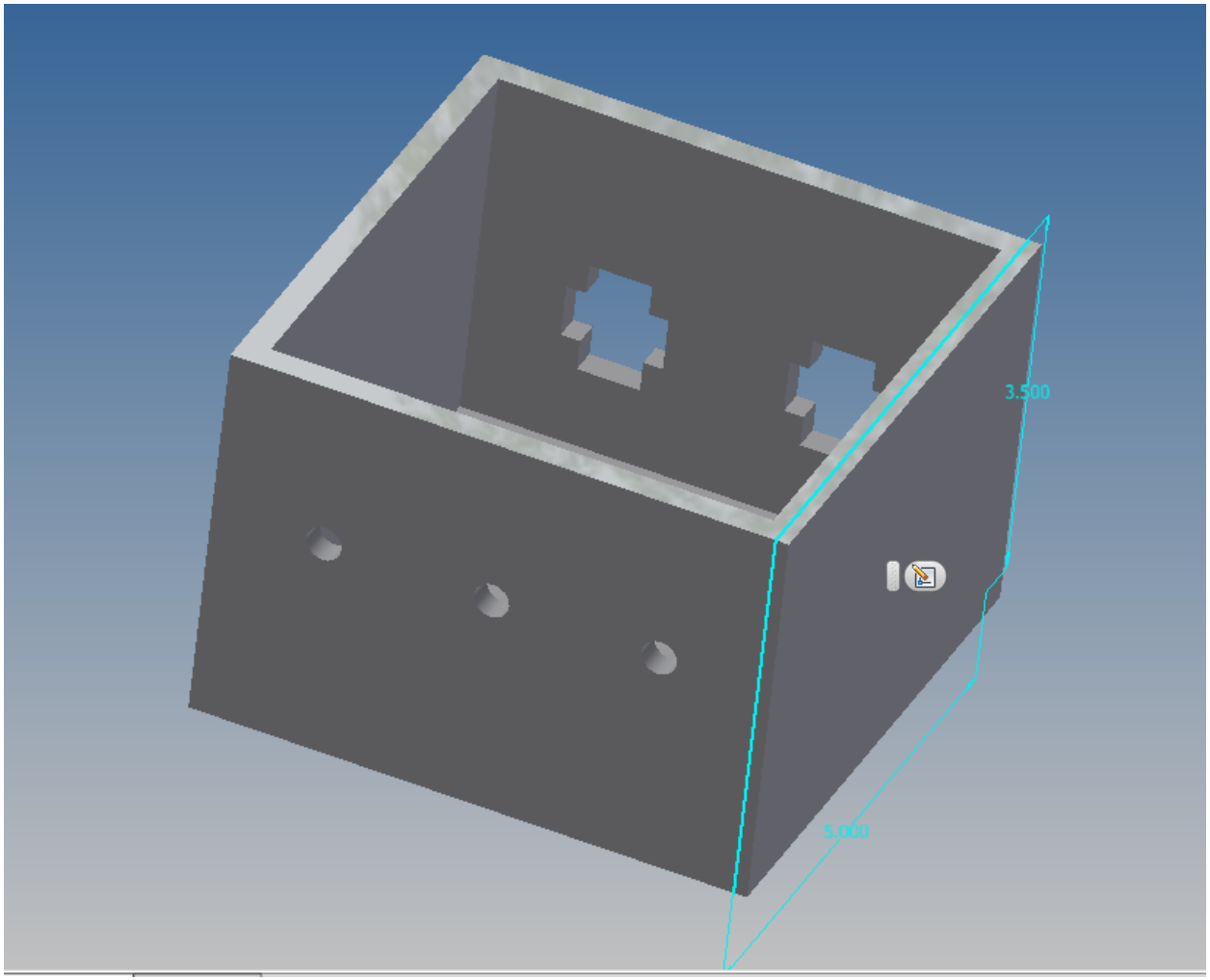
GLV Hub 3

- Connects to GLV Hub 1
- Connects to Motor Controller Interface
- Dangly that connects to the VCI
- Dangly that connects to the Cockpit
- Dangly that connects to GLV Power



GLV Hub 3



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    a. Safety Loop
    b. GLV Power
    c. VCI
    d. TSI
5. GLV BOM and Budget

Grounded Low Voltage

- GLV system is responsible for supplying power to all non-tractive devices on the vehicle, interfacing other subsystems together, and operating the safety circuit in accordance to the EV requirements.

Roadmap

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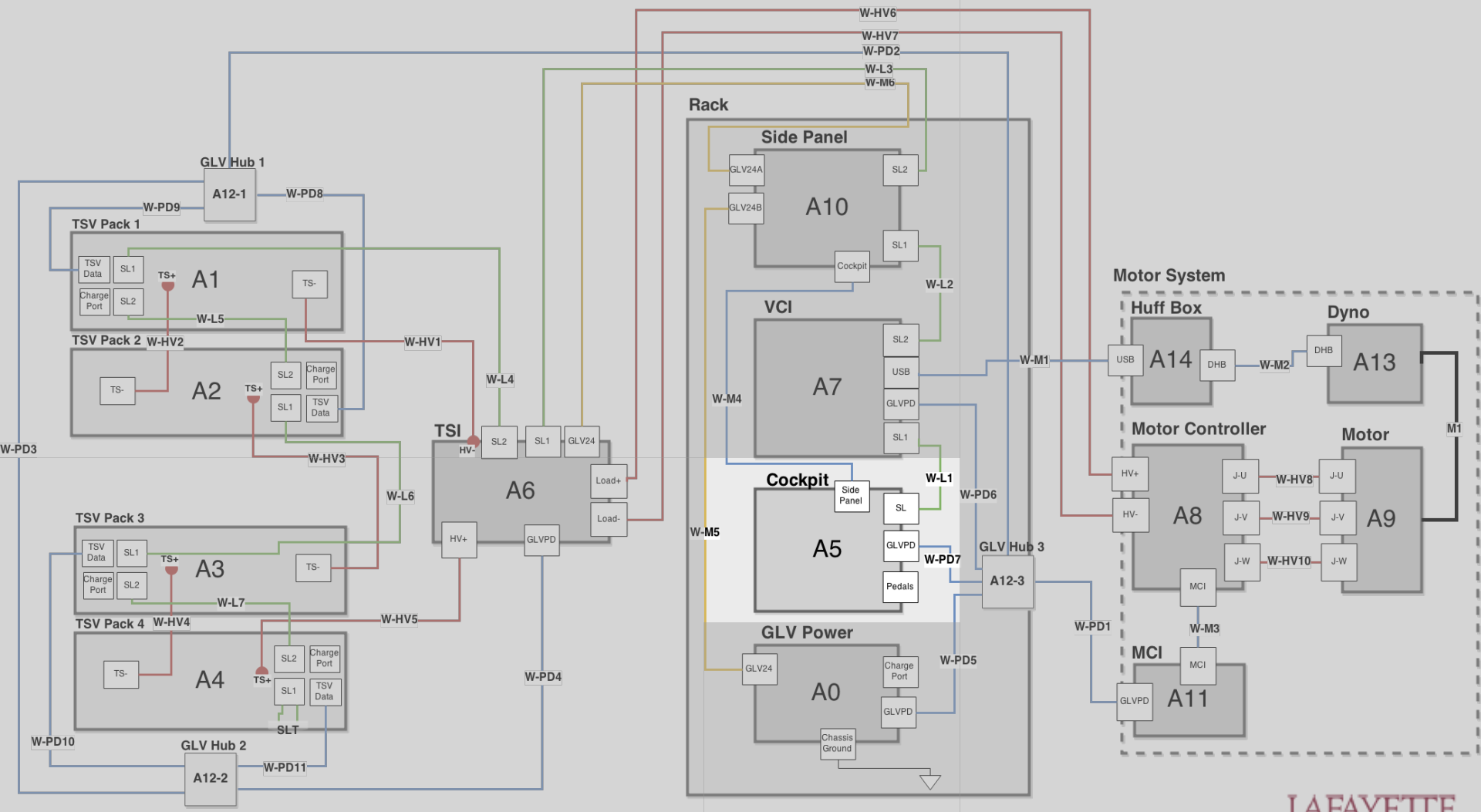
Cockpit and the Safety Loop



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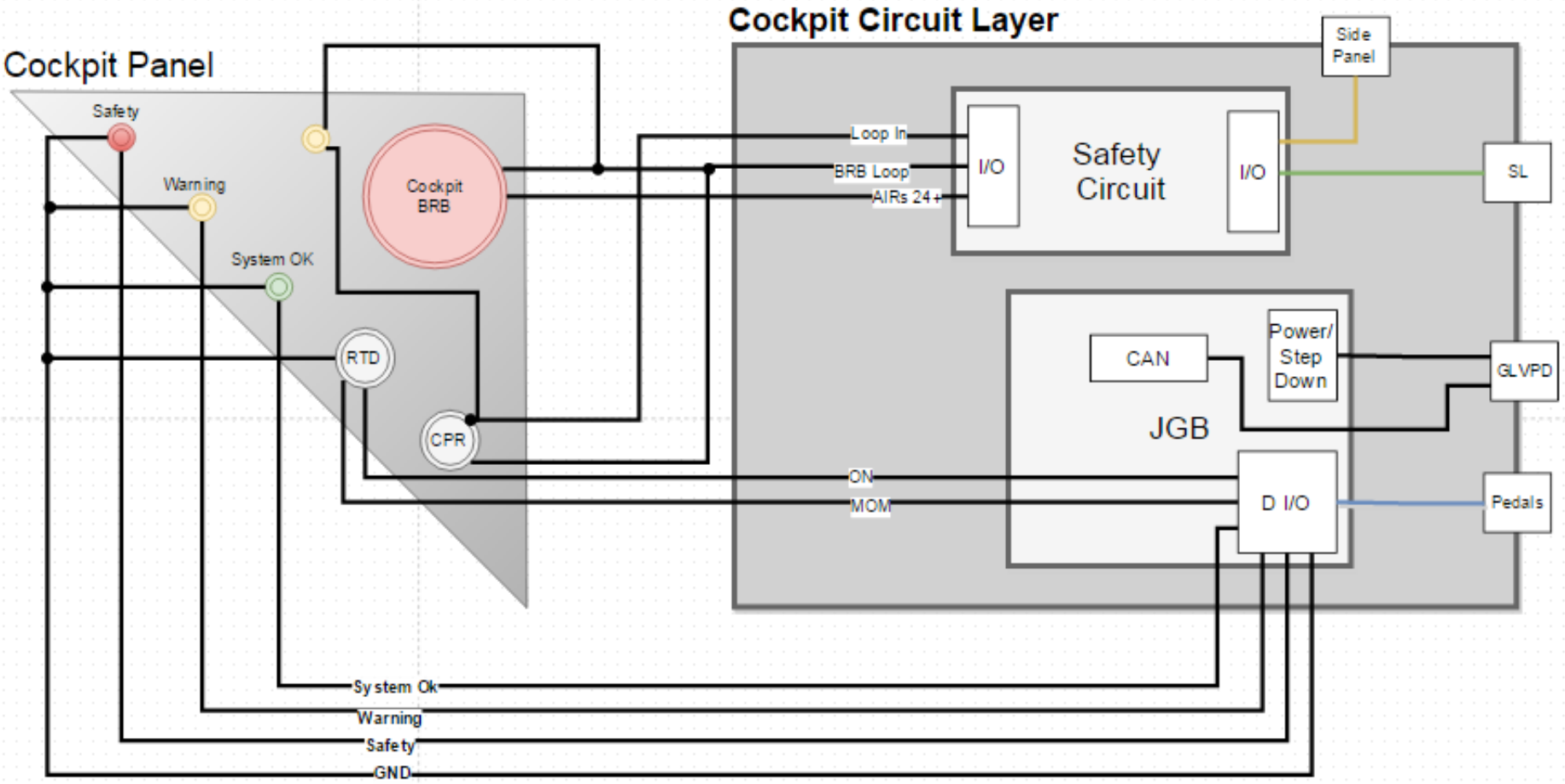
Cockpit Panel and Internals



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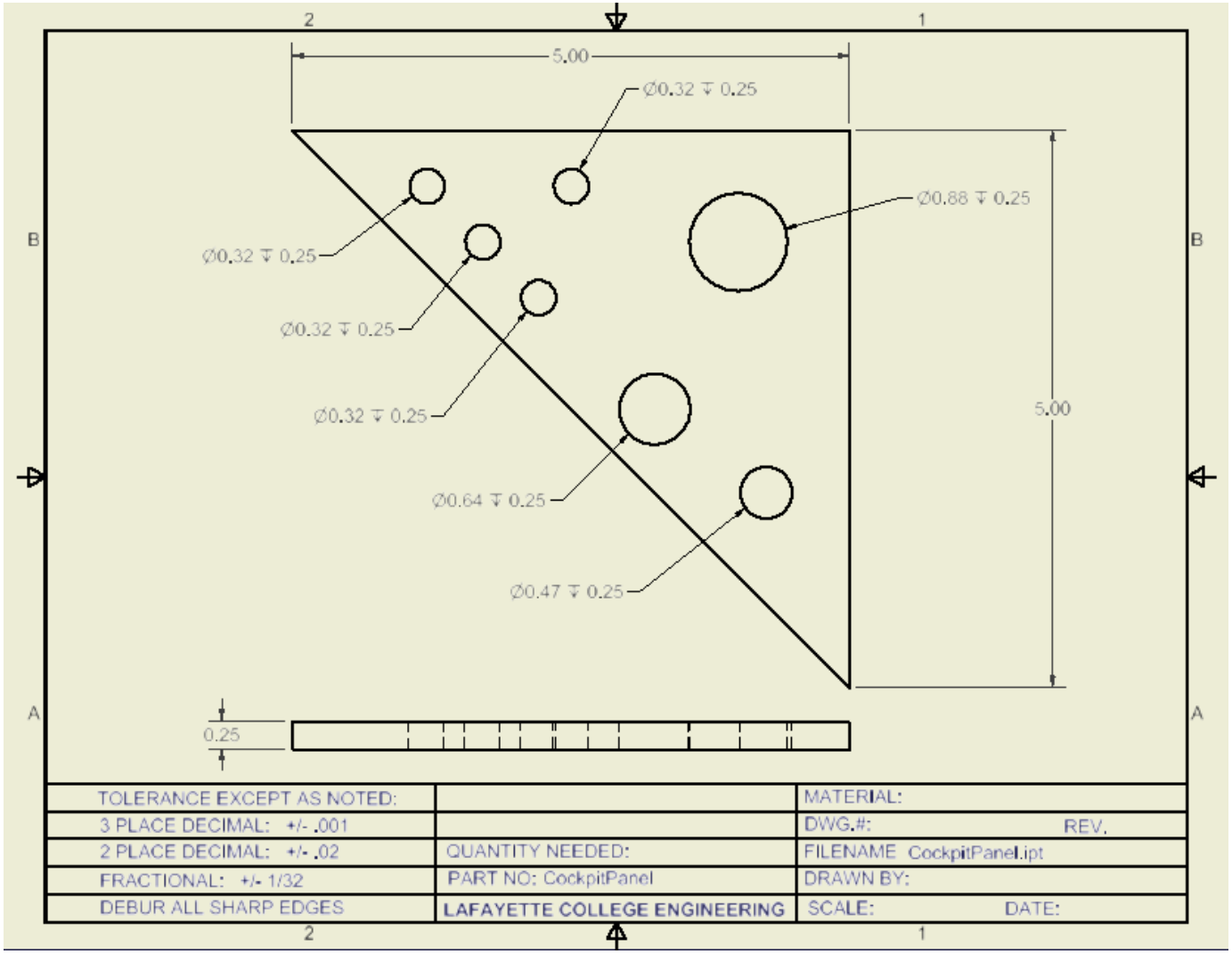
Cockpit Panel Drawing



Materials List:

Aluminum Panel 5"x5"x1/4"
CPR - Cockpit Reset Button
Cockpit BRB
Red 'Safety' LED
Amber 'Warning' LED
Green 'System OK' LED
Amber Indicator LED
RTD - Ready To Drive Key

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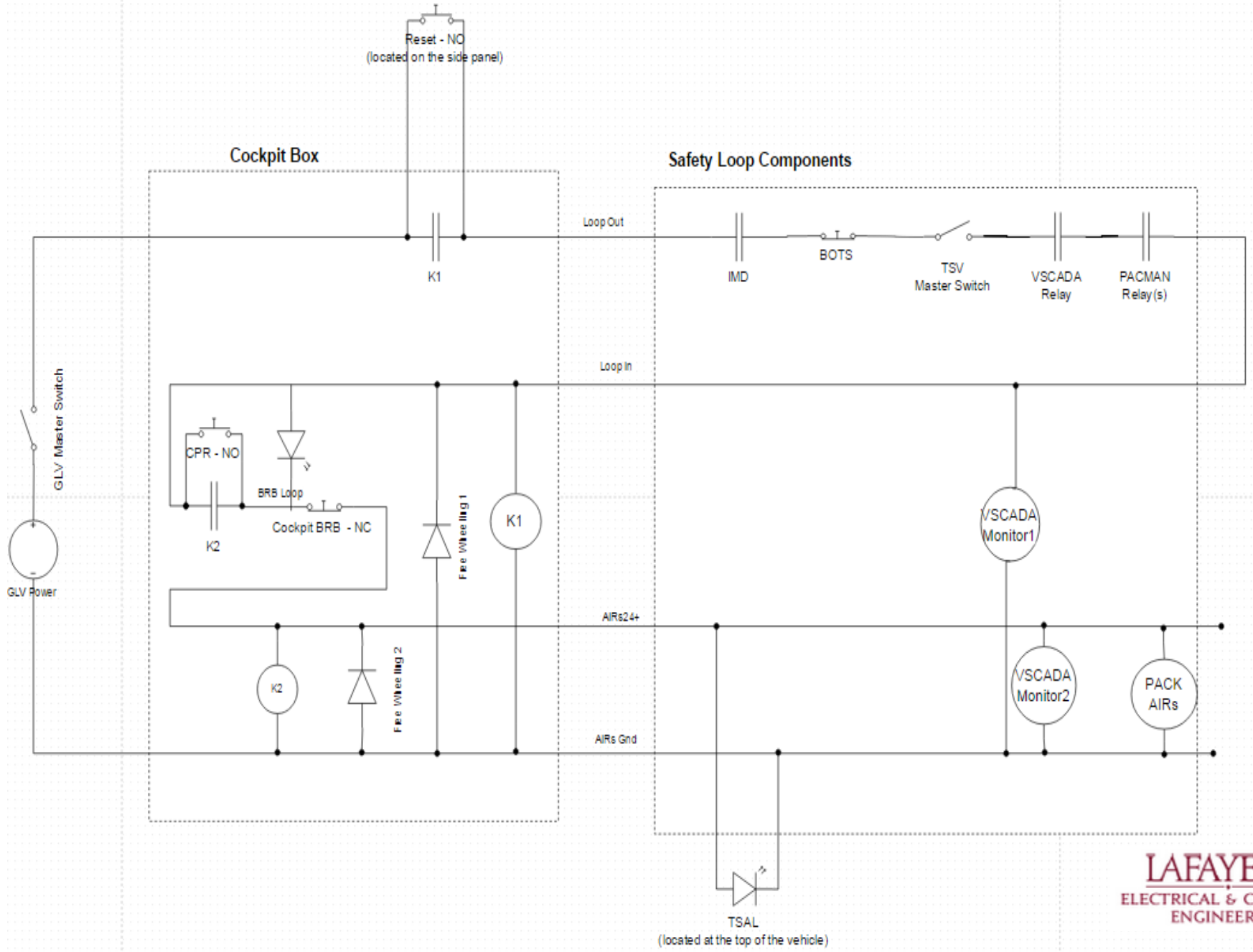
Safety Loop and Safety Circuit

- Keeps high level voltage system in a safe state
- Monitors status of the system and provides multiple shutdown options to both driver and surrounding personnel
- Interacts with each electrical subsystem



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Shutdown Priority Table

Shutdown Sources	Controlled Systems: GLV Supply to: Instrumentation, Data Acquisition, Computers, Telemetry, Etc.	Controlled Systems: AIRs (TS Voltage)
TSMS		OFF
Cockpit BRB		OFF
AMS		OFF
IMD		OFF
Brake Over-Travel		OFF
Side-Mounted BRBs	OFF	OFF
GLVMS	OFF	OFF

Safety Loop Summary

- Safety Loop accounts for failures/faults in the 4-wire safety loop
- Any failure in the safety loop will be appropriately reacted to within the time constraints provided by the Formula Hybrid Rules
- Appropriate steps must be taken in order to make the car ready-to-drive in each scenario
- The Test Plan for the Safety Loop does not have a threshold for any test; whether it be button/switch functionality or the shutdown circuit itself. The loop will function to the specifications provided.

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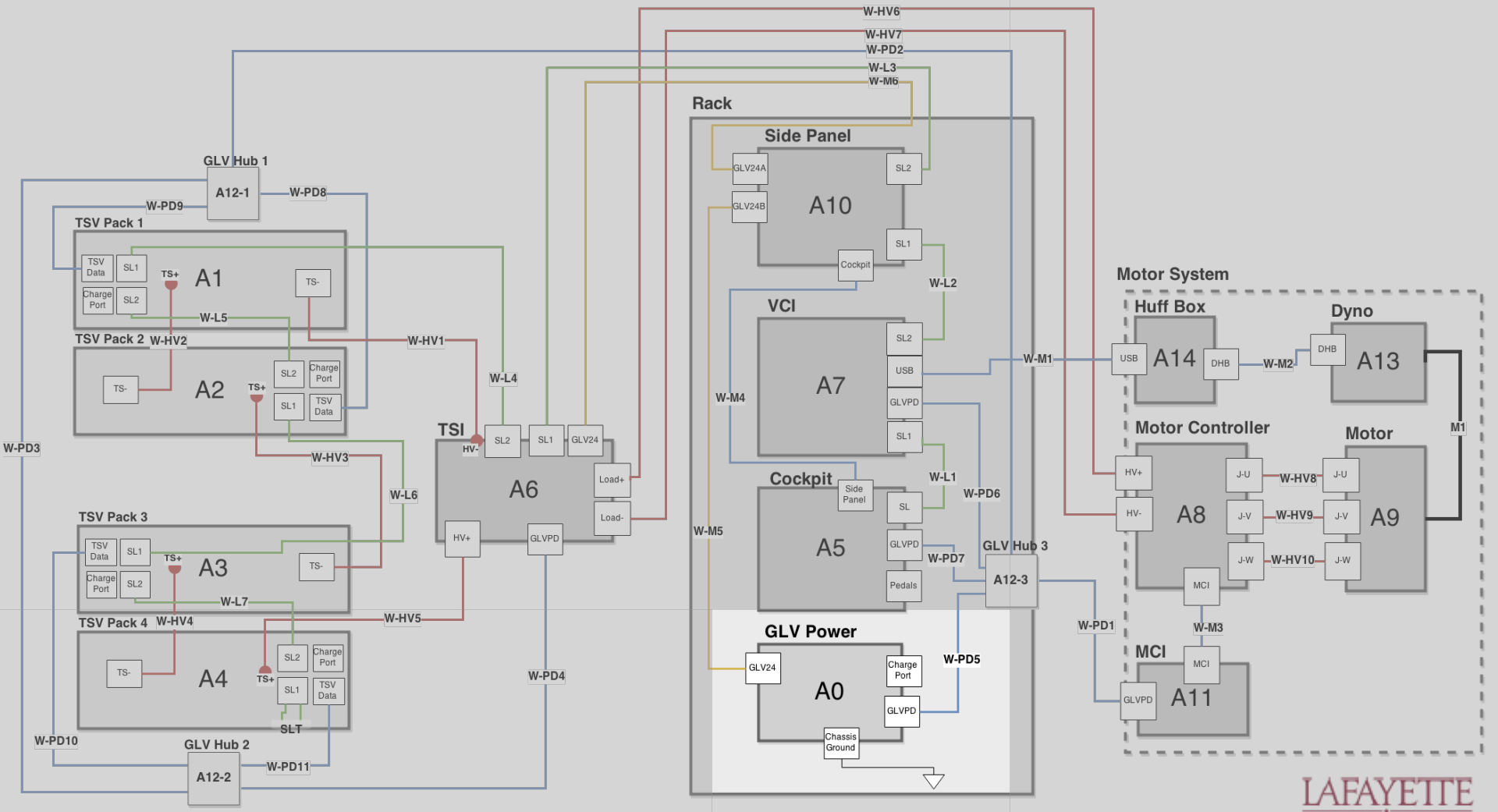
GLV Power



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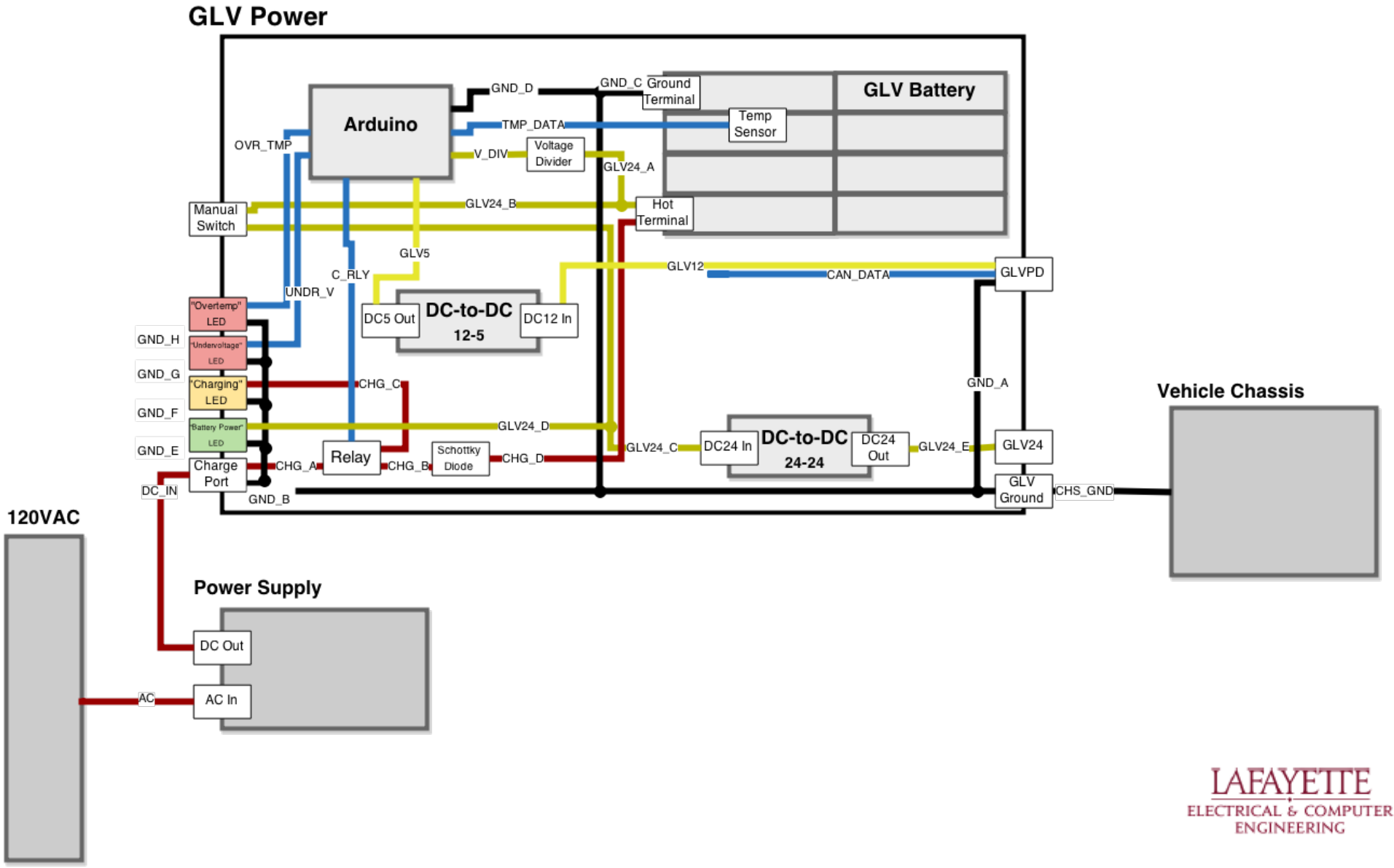
GLV Power Box and Dependents



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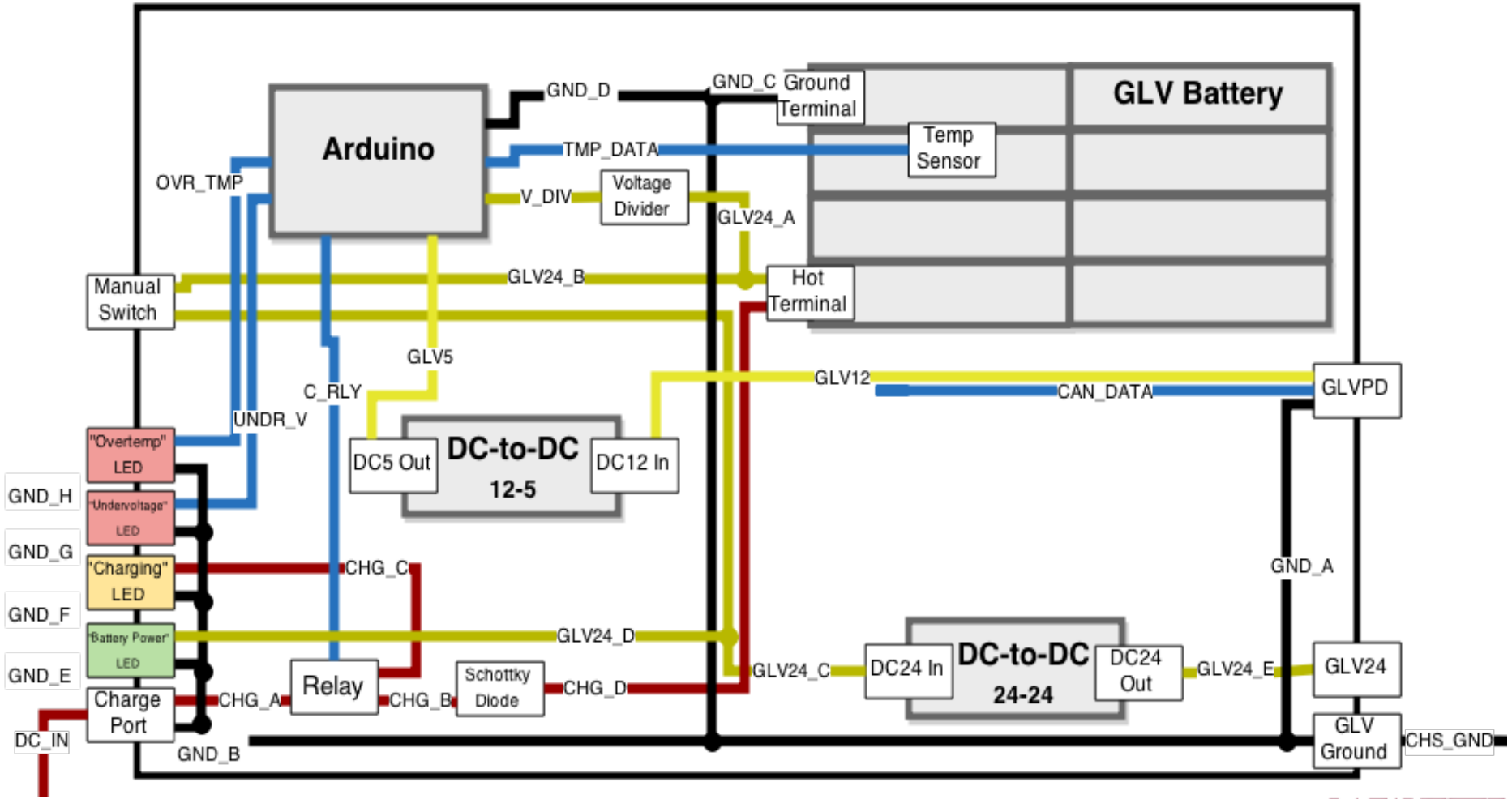
GLV Power Box



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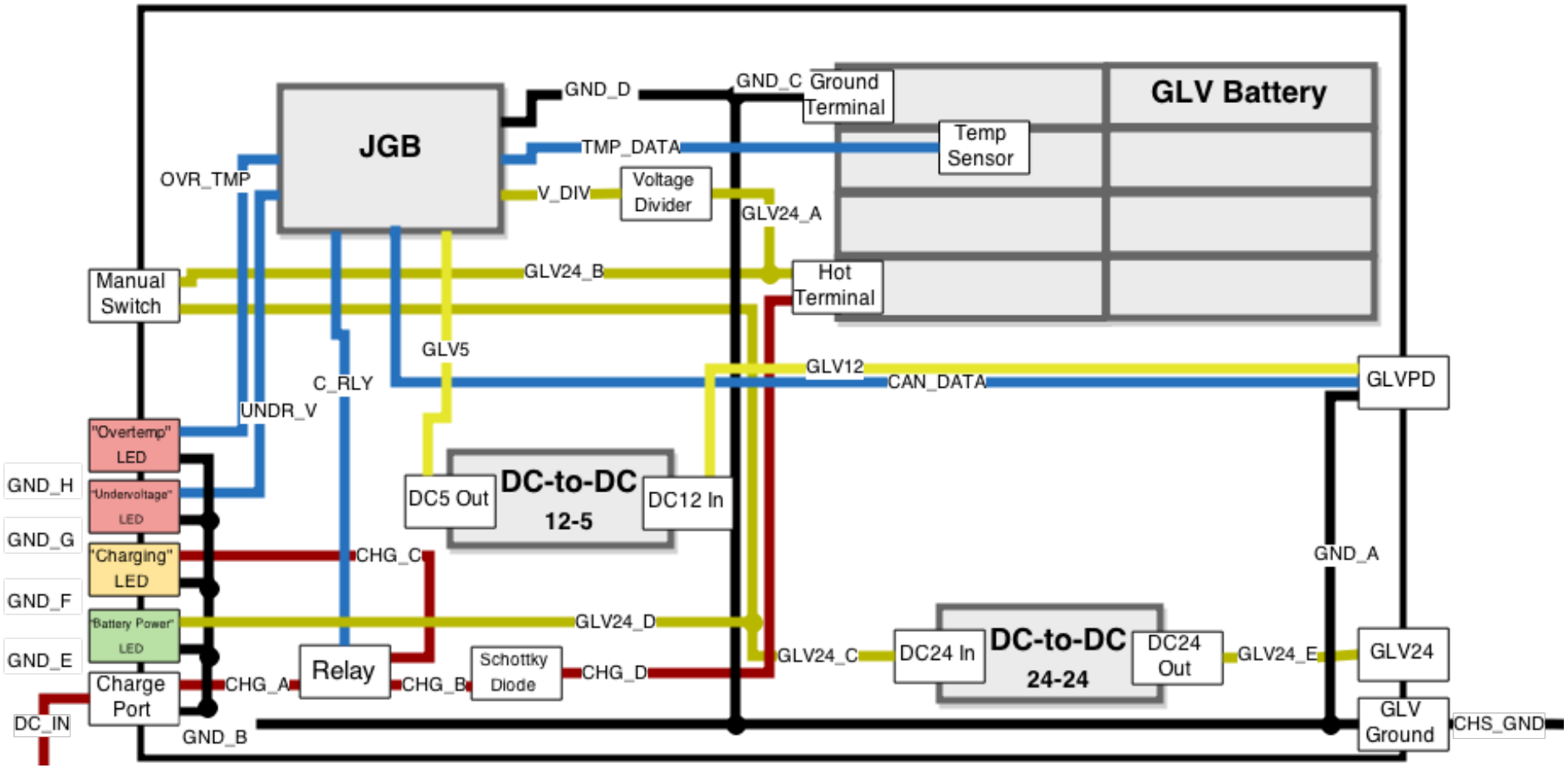
GLV Power Box - End Goal (JGB)



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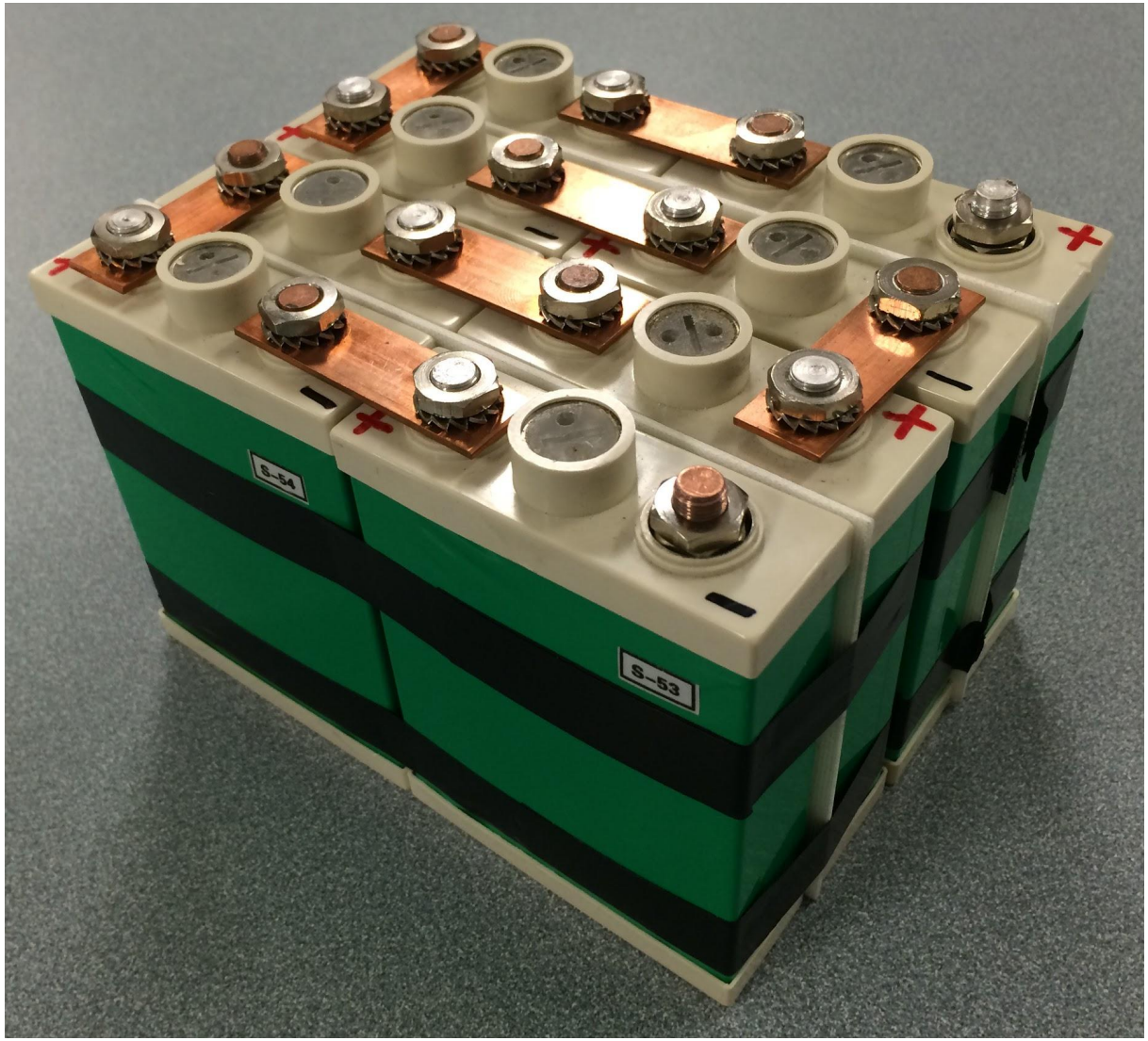
GLV Battery Cell

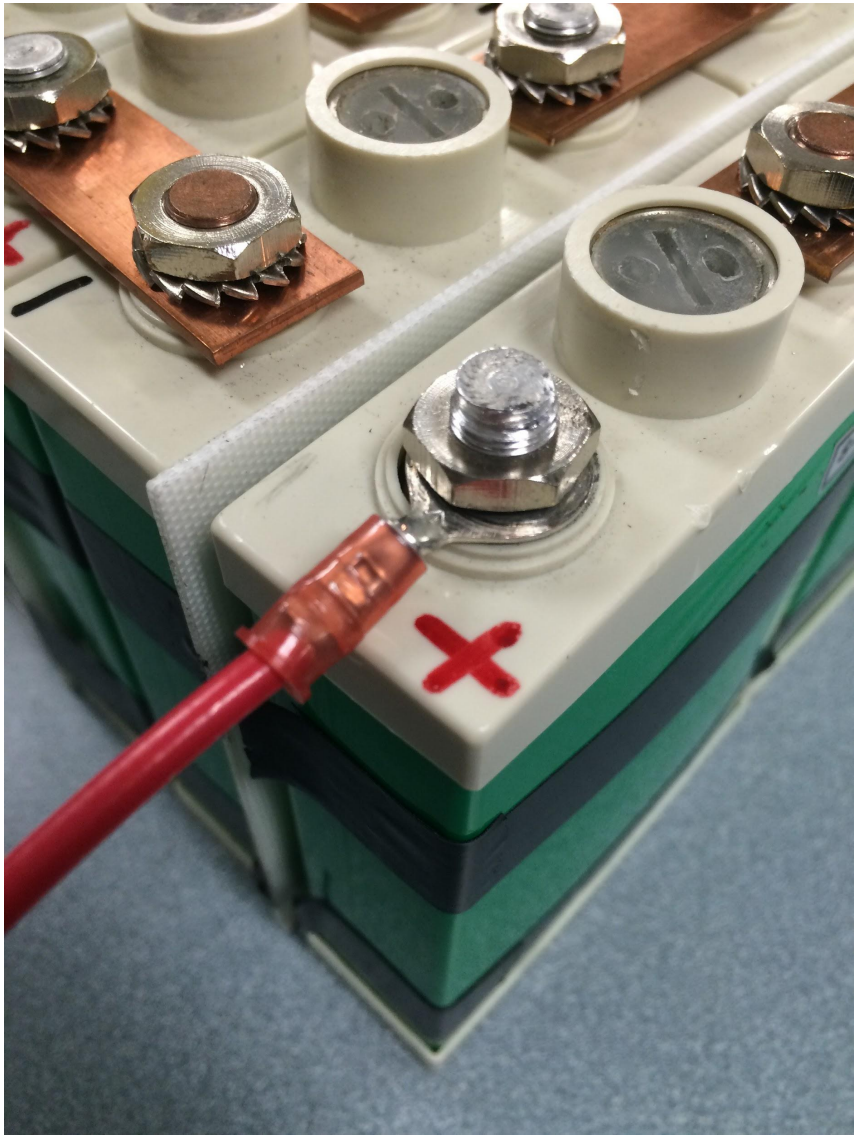
3.3V LiFePO4 10Ah

GLV Battery



Eight cells
24V
10Ah

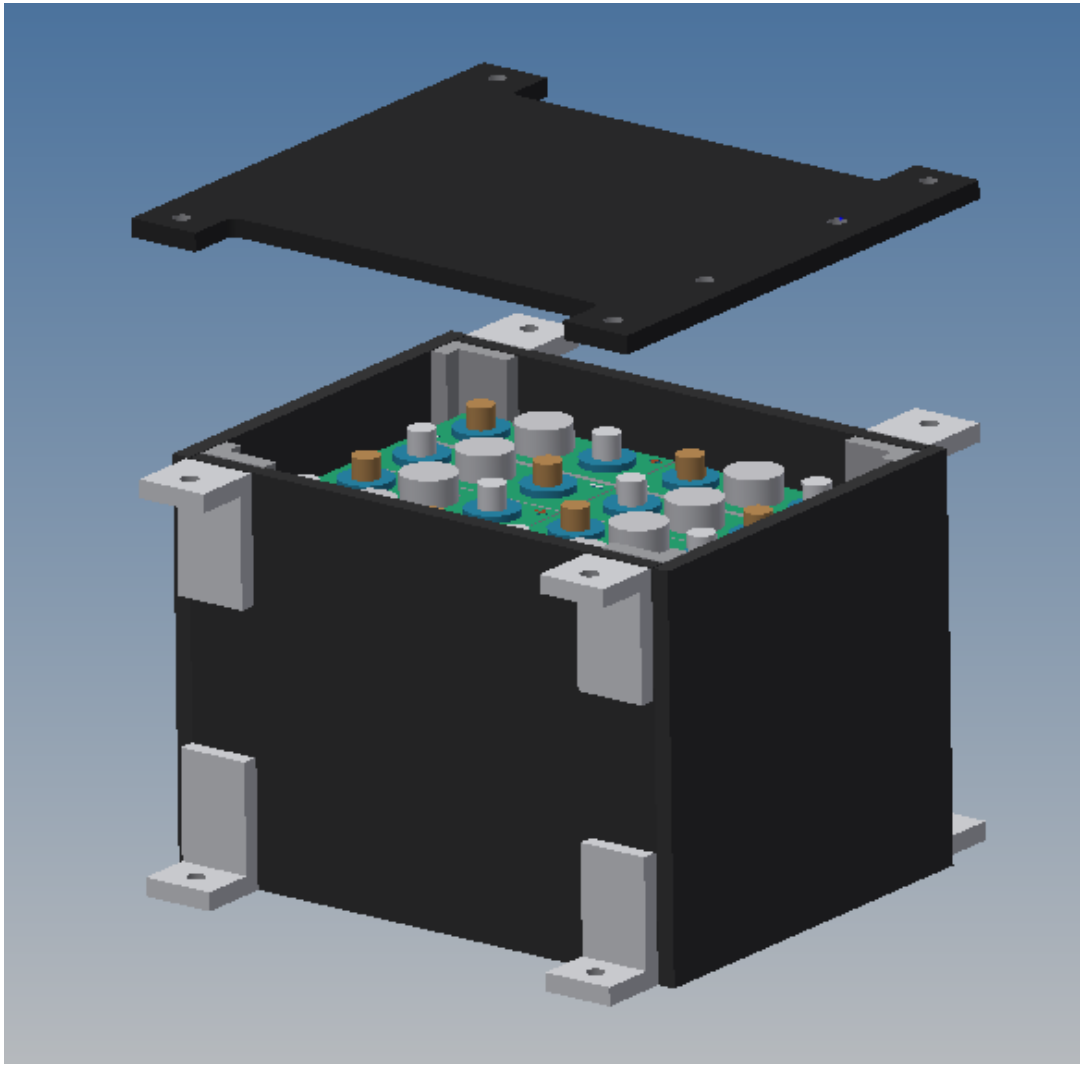
GLV Battery Connection



Crimped Terminal
(Open Barrel)

Battery Mounting

EV3.7.1- All GLV batteries must be attached securely to the frame.



GLV Battery Capacity Calculation

R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

GLV Relays	(2.04W x 2) = 4.08W + 1W (for microcontrollers, relays)		
AIRS	(2.04W x 2) = 8.16W + ~100mW (CAN transceivers)		
VSCADA	2.64W computer + 2W screen		
Total	17.88W / 24V = 0.745A x 1.5 =	1.1175Ah	1hr
		2.235Ah	2hr
		3.3525Ah	3hr
		4.47Ah	4hr
		5.5875Ah	5hr

Utilizes the measured power consumption of the VSCADA computer and a reasonable ceiling estimation for the screen.

GLV Battery Capacity Calculation

R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

GLV Relays	(2.04W x 2) = 4.08W + 1W (for microcontrollers, relays)		
AIRS	(2.04W x 2) = 8.16W + ~100mW (CAN transceivers)		
VSCADA	5.28W computer + 4W screen		
Total	25.52W / 24V = 1.06A x 1.5 =	1.595Ah	1hr
		3.19Ah	2hr
		4.785Ah	3hr
		6.38Ah	4hr
		9.57Ah	5hr

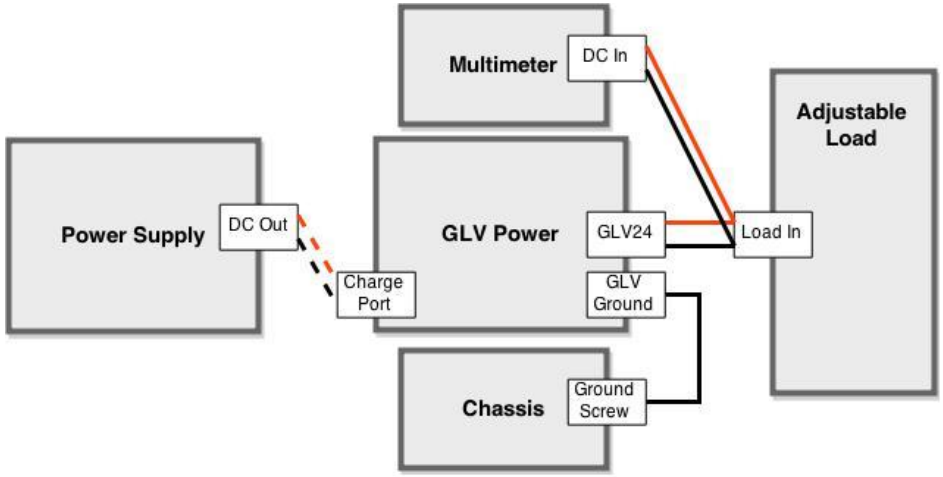
Utilizes the peak power consumption of the VSCADA computer and a higher ceiling estimation for the screen.

GLV Power and Battery Duration Test

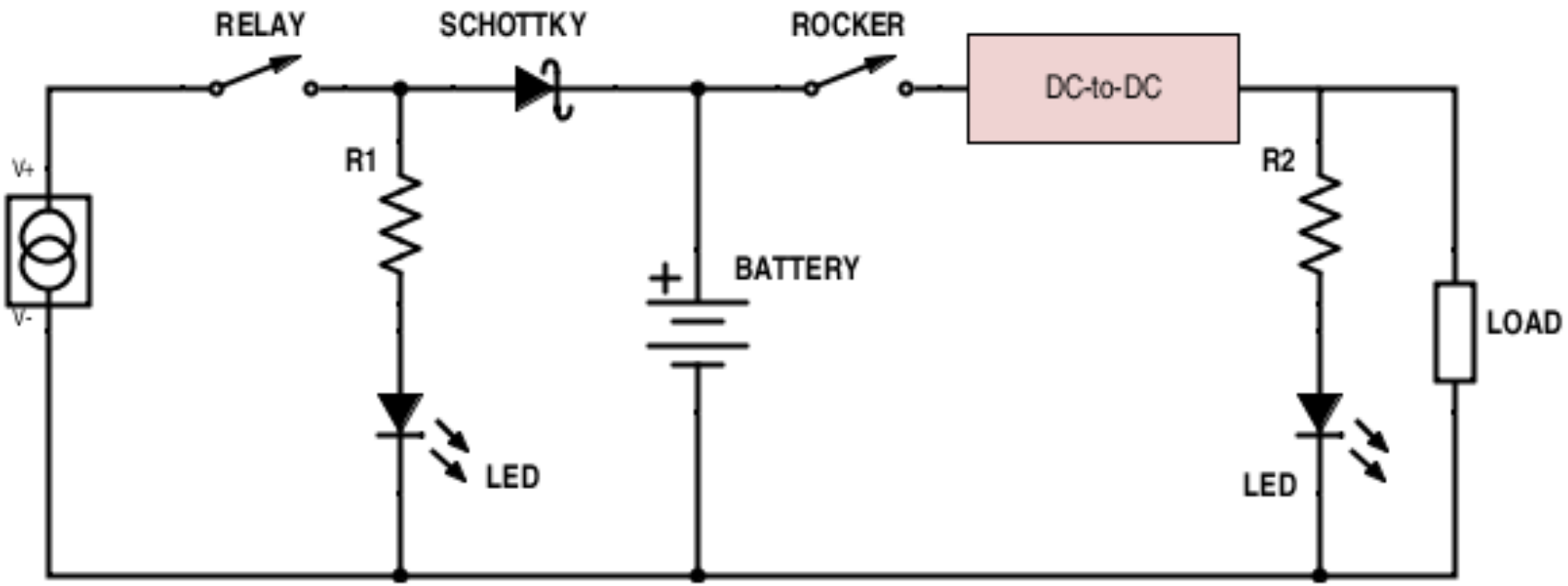
R006-0 The GLV system shall provide DC supply voltage with sufficient current to supply all the power needs of the GLV systems and other non-tractive systems.
R006-1 The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

Simplified Procedure:

1. Fully charge the battery.
2. Attach the Power Box to the adjustable load and set the current to simulate appropriate power consumption.
3. Record voltage at timing intervals.
4. Voltage must remain above designated value (21V) for three hours.

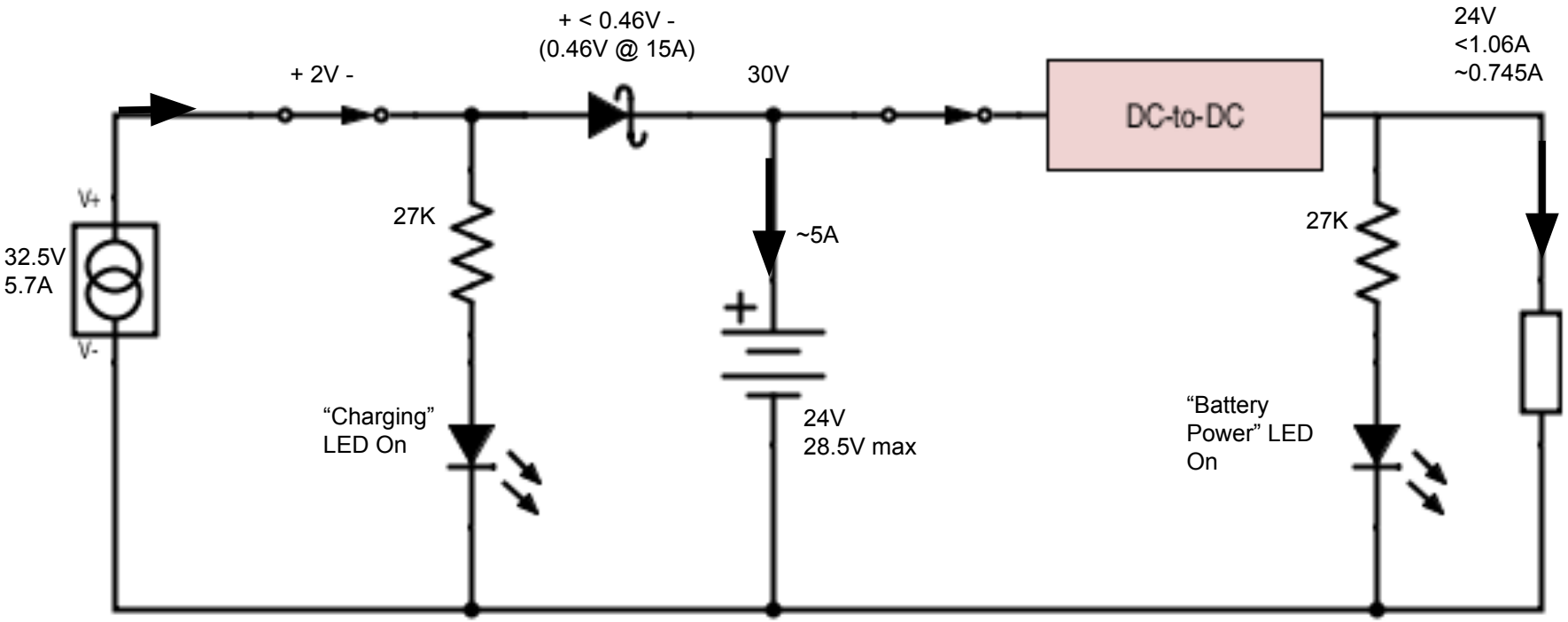


Charging Circuit

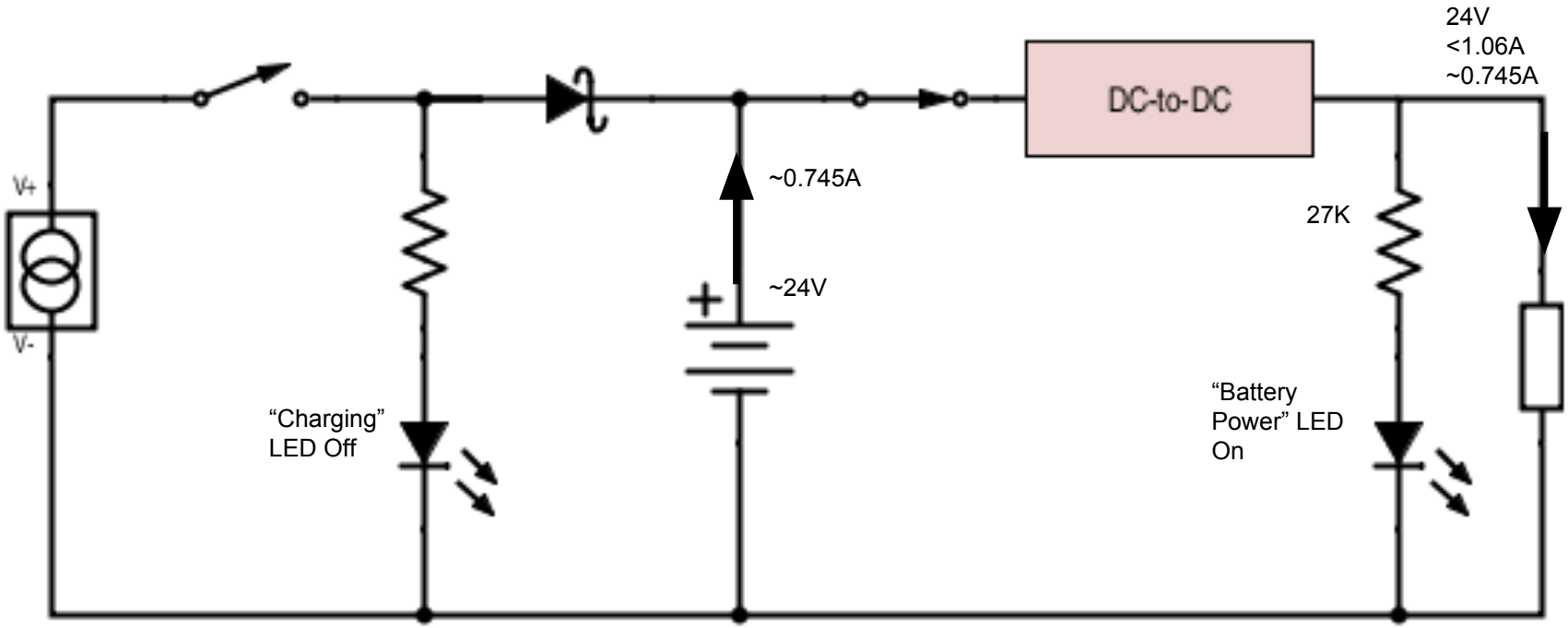


Charging Circuit - Charging

R006-2ii The charging system shall be capable of powering the GLV system indefinitely as it simultaneously charges the GLV battery in a *plug and forget* functionality.



Charging Circuit - Discharging



GLV Power - Charger

R006-2i The GLV system shall be rechargeable by means of a UL listed charging device that plugs into the 120 VAC mains.

www.trcelectronics.com

www.powergatellc.com

Battery Protection

R006-2iii It shall be possible to charge a fully discharged GLV battery without disassembly or special actions.
R006-2v The GLV battery shall be protected from full discharge, overcharge, overcurrent, and overvoltage.

Full Discharge:

- The 24-24 DC-to-DC Converter has an under voltage shutdown of 15.7 VDC.
- The solid-state relay controlling the charge circuit will be the normally closed type.

Overcharge:

- Discussed on previous slides.

Overcurrent:

- The 24-24 DC-to-DC Converter has a current limitation of 110% its typical, which is 2.5A for this device.
- 2.5A x 1.1 = 2.75A… Well above the expected range and below battery capabilities.

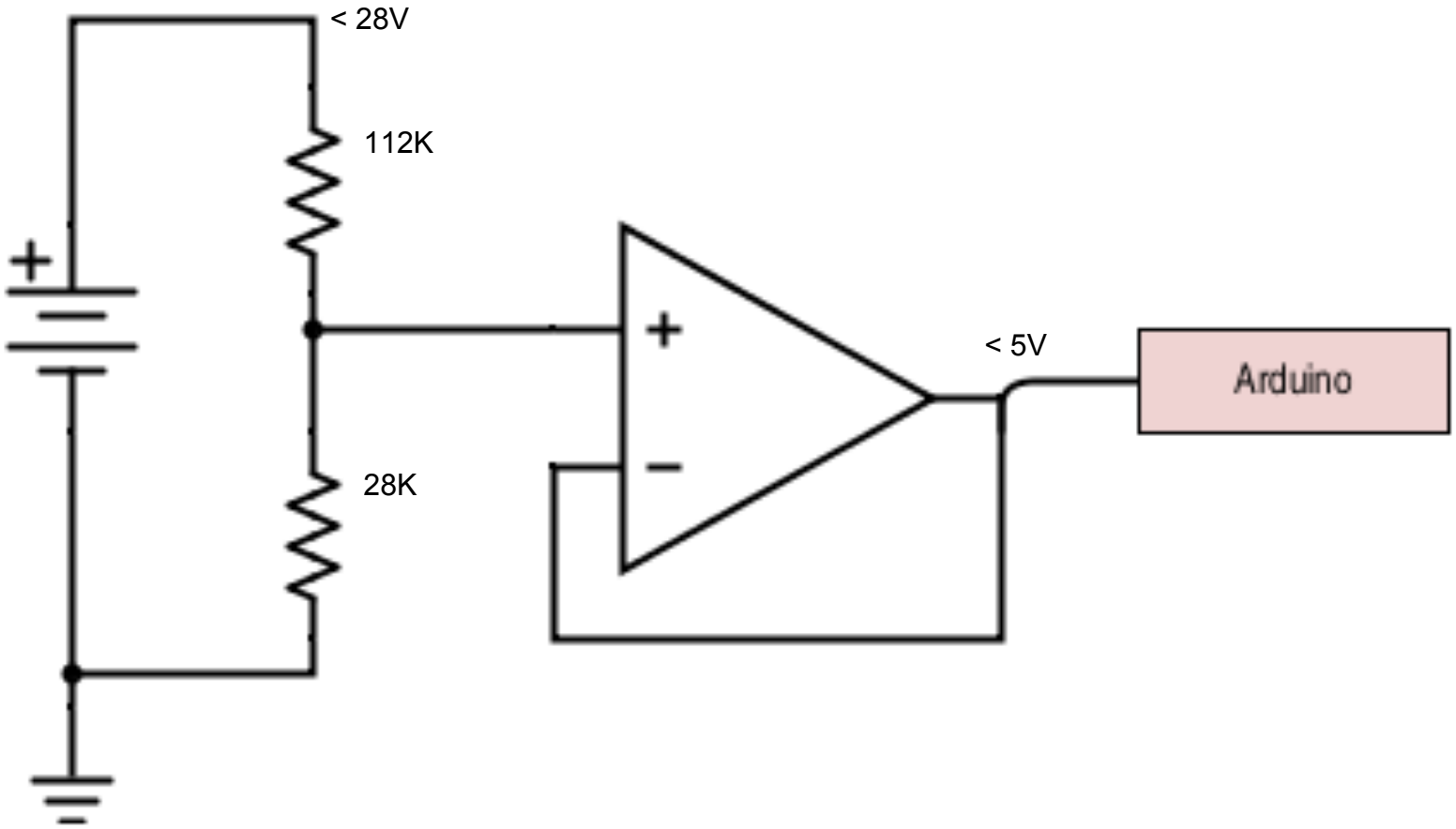
Overvoltage:

- The 24-24 DC-to-DC Converter has an overvoltage protection trigger point of <42V.

uk.farnell.com

Voltage Sensing

R006- The GLV battery shall be protected from overcharge.
GLV voltage shall be measured by VSCADA.



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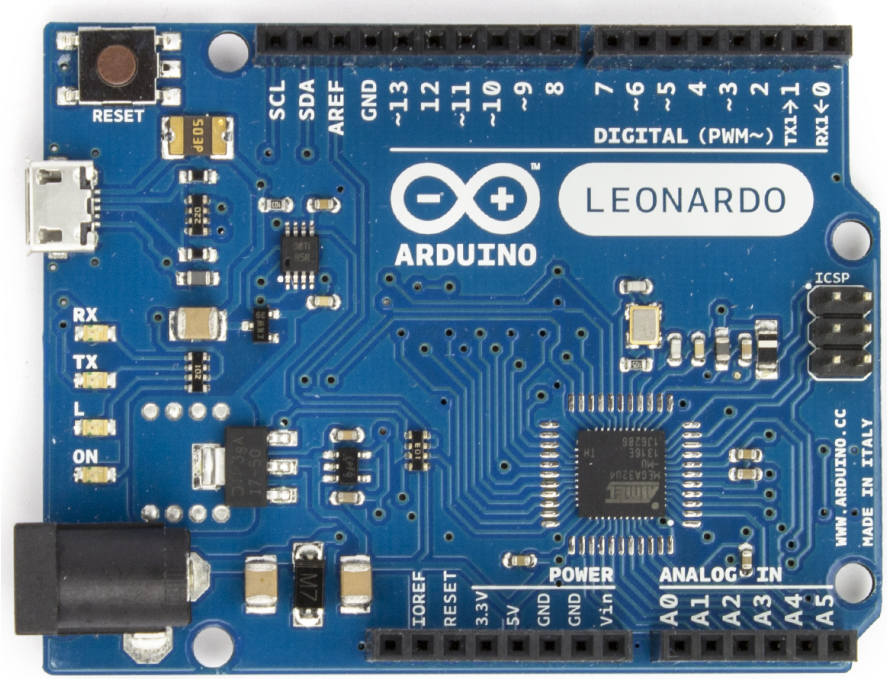
GLV Power Software

R006- GLV voltage, current, temperature, and SOC shall be measured by VSCADA.

GLV Power Arduino

Maintainability:

- Code will be written in C which is not going extinct in the near future.
- Files will be uploaded to the website containing the source code and Arduino ID.



www.arduino.cc

Roadmap

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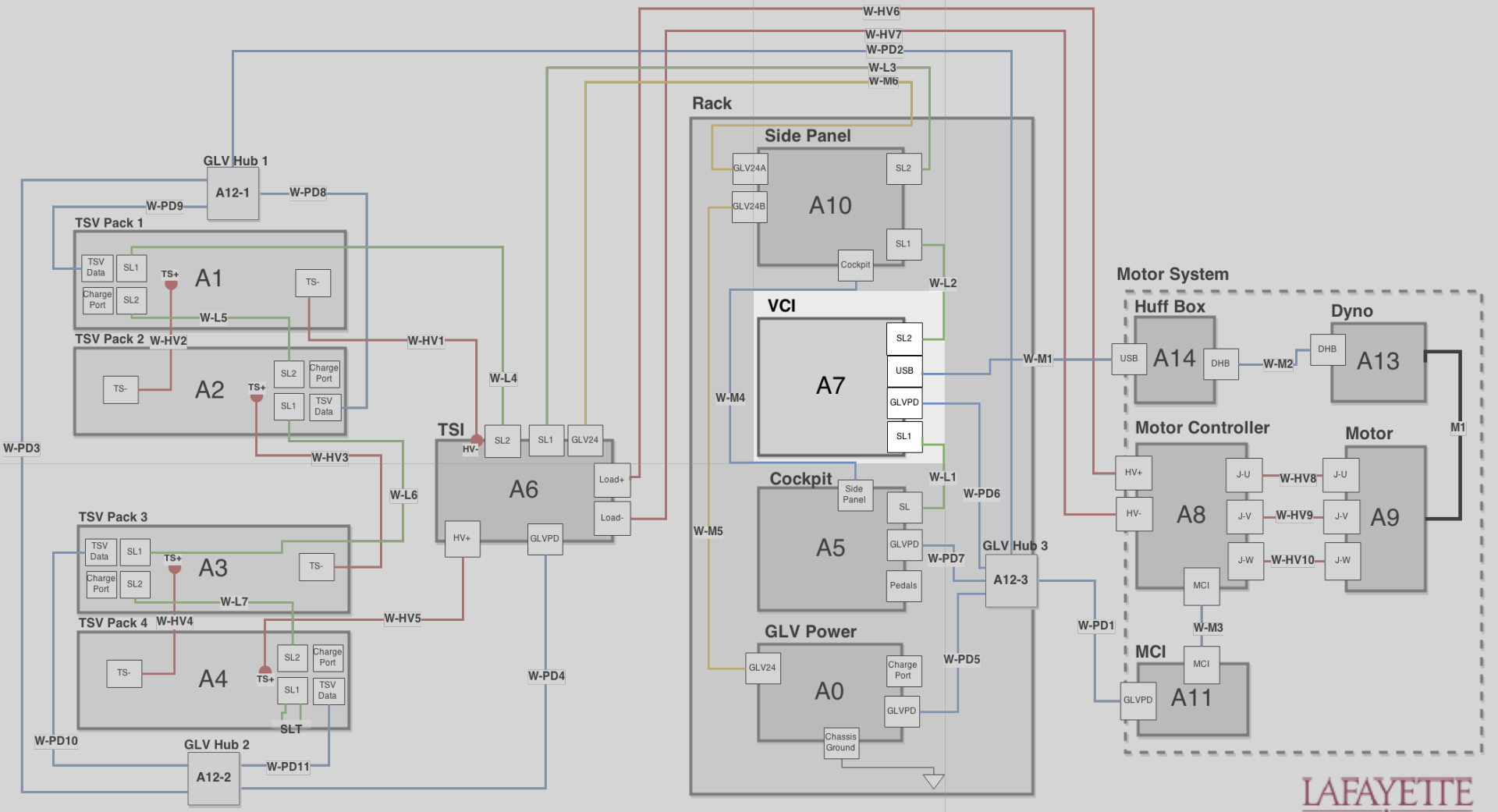
    d. TSI
5. GLV BOM and Budget

Vehicle Computer Interface



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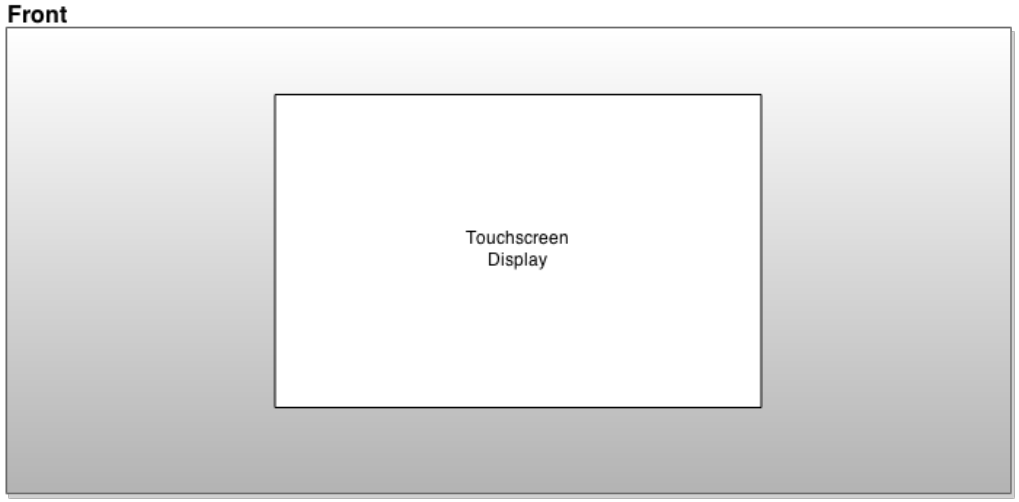
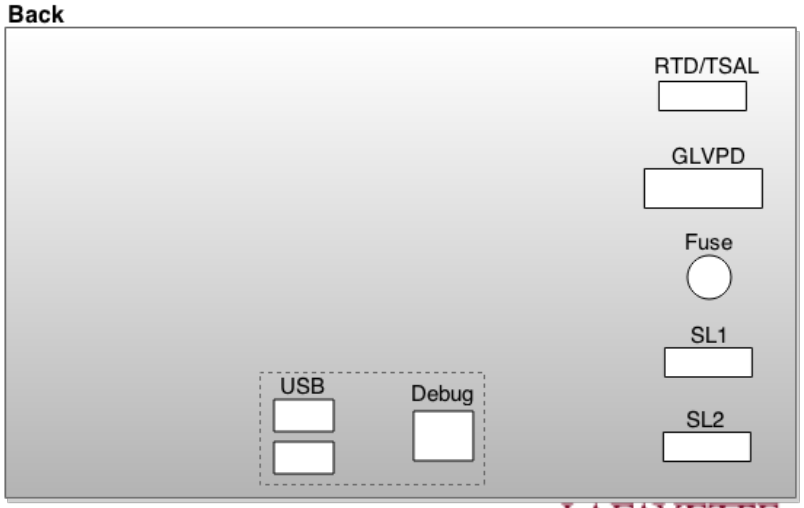
VCI

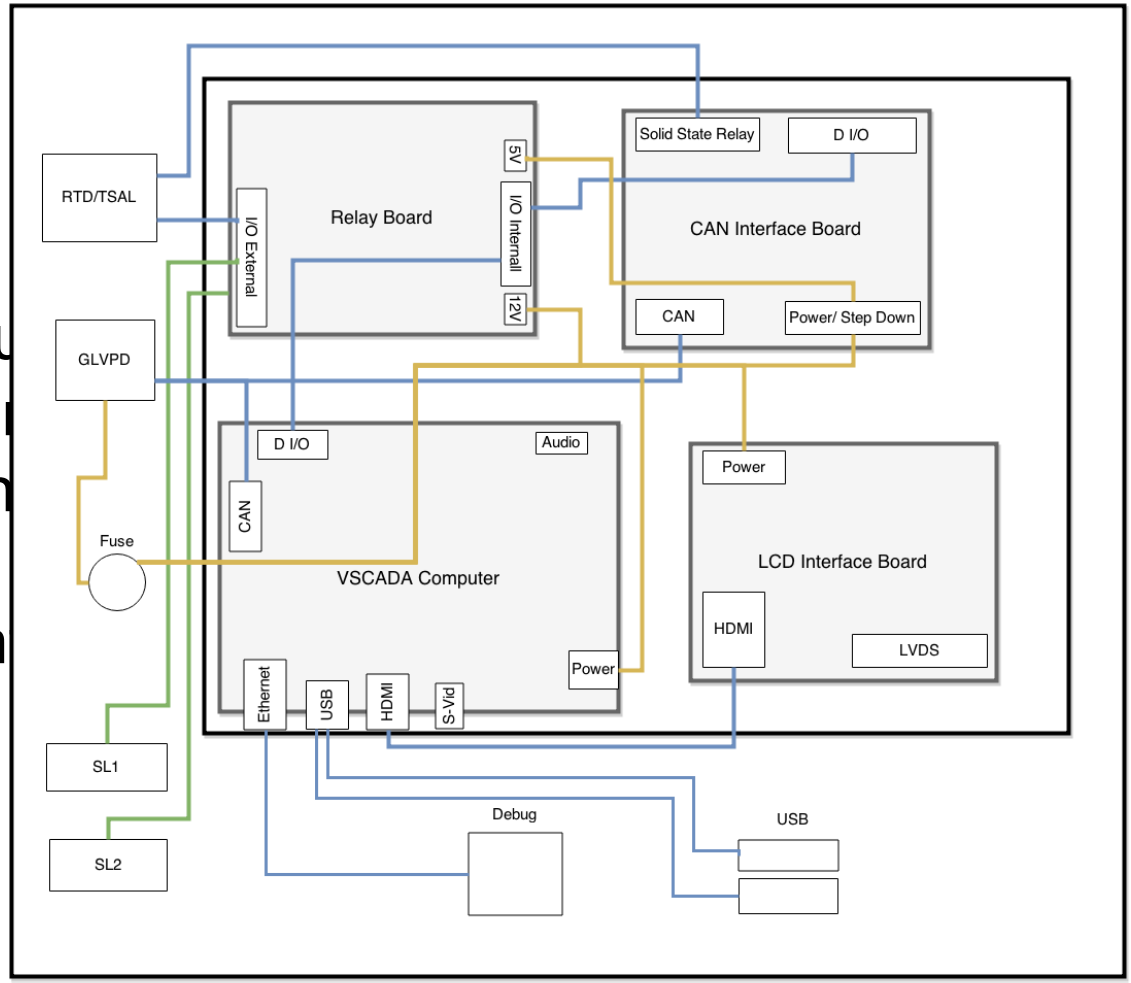
- Contains:
  - VSCADA Computer
  - Maintenance Panel Display
  - Safety Loop Control and Monitors
  - TSAL Circuit
  - RTD Sound Control





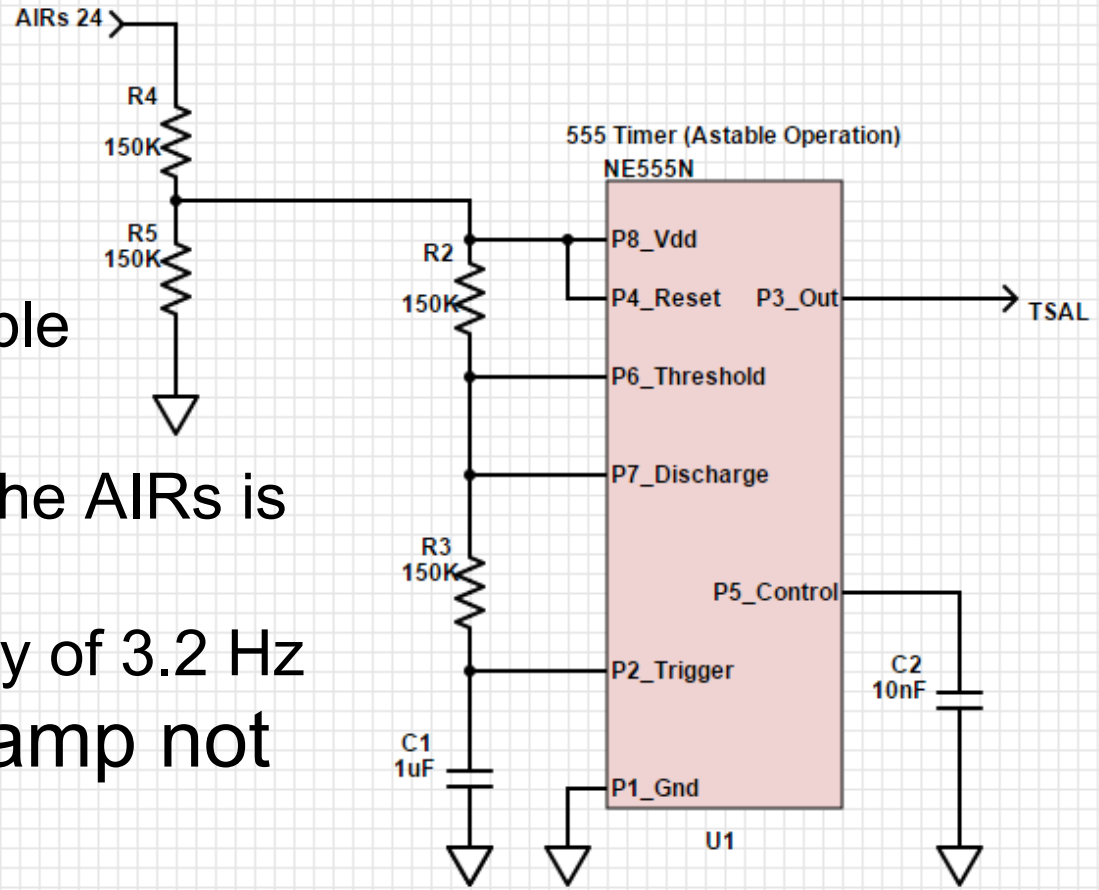
VCI

- Contains:
  - VSCADA Compu
  - Maintenance Pa
  - Safety Loop Con
  - TSAL Circuit
  - RTD Sound Con



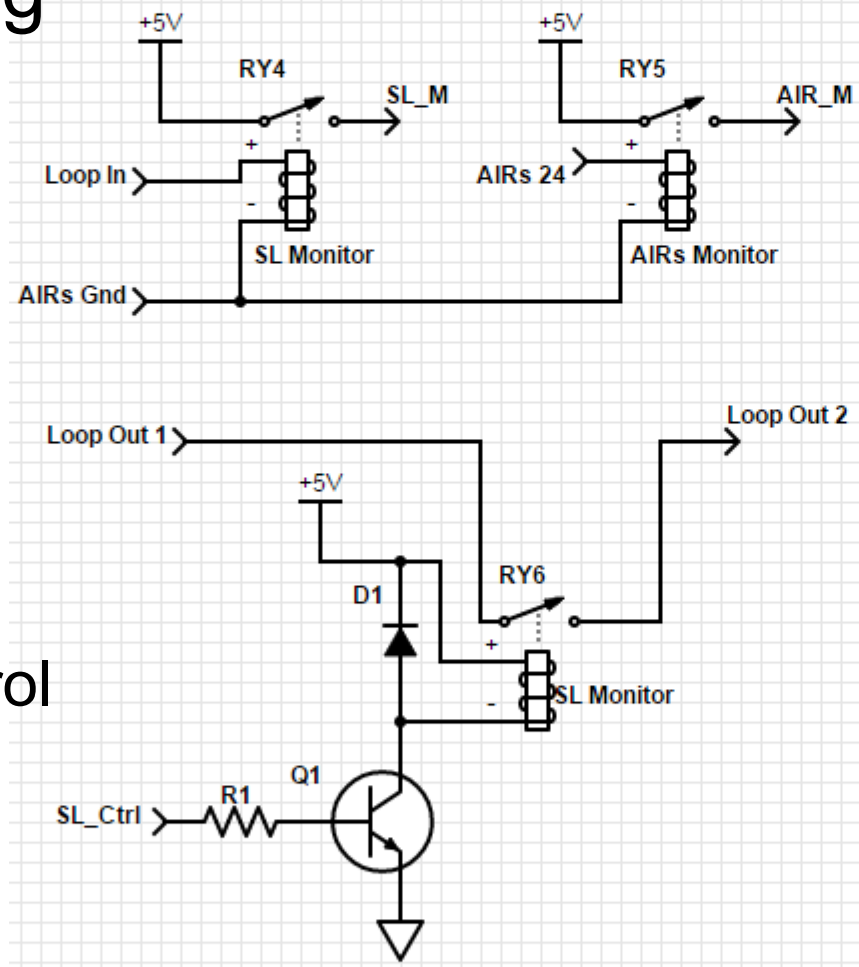
VCI

- TSAL
  - 555 Timer in astable configuration
  - Active whenever the AIRs is open
  - Set for a frequency of 3.2 Hz
- Physical TSAL Lamp not included
  - Tested using DDM
  - Expected output:
    - 12V
    - 50% duty cycle
    - 0.3125 second period



VCI

- Safety Loop Monitoring
  - Interfaced to the CAN Controller board
  - Safety Loop Monitor
  - AIRs State Monitor
- Safety Loop Control
  - Controlled by VSCADA digital I/O
  - Gives Safety Loop control to system software



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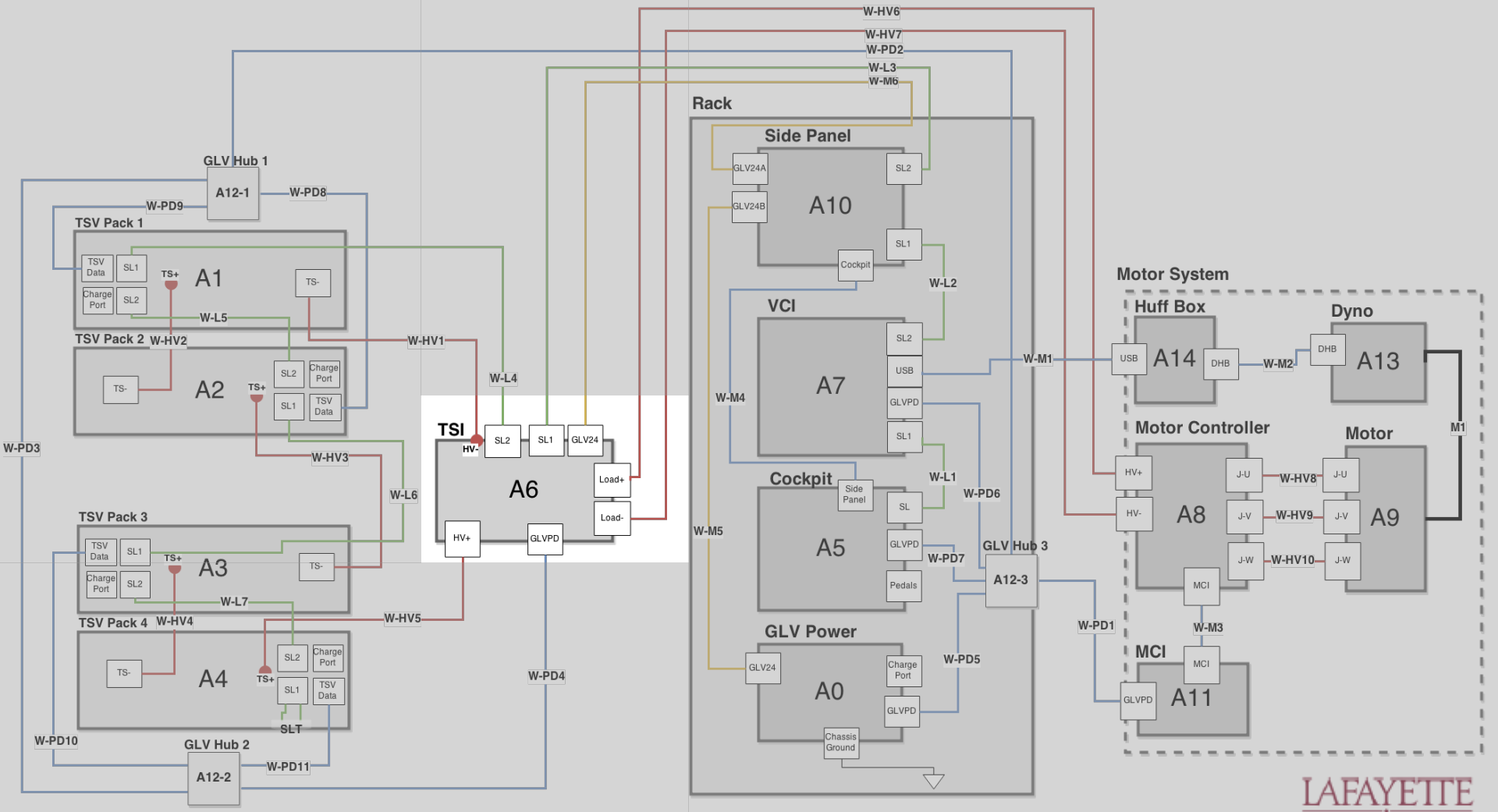
Tractive System Interface (TSI)



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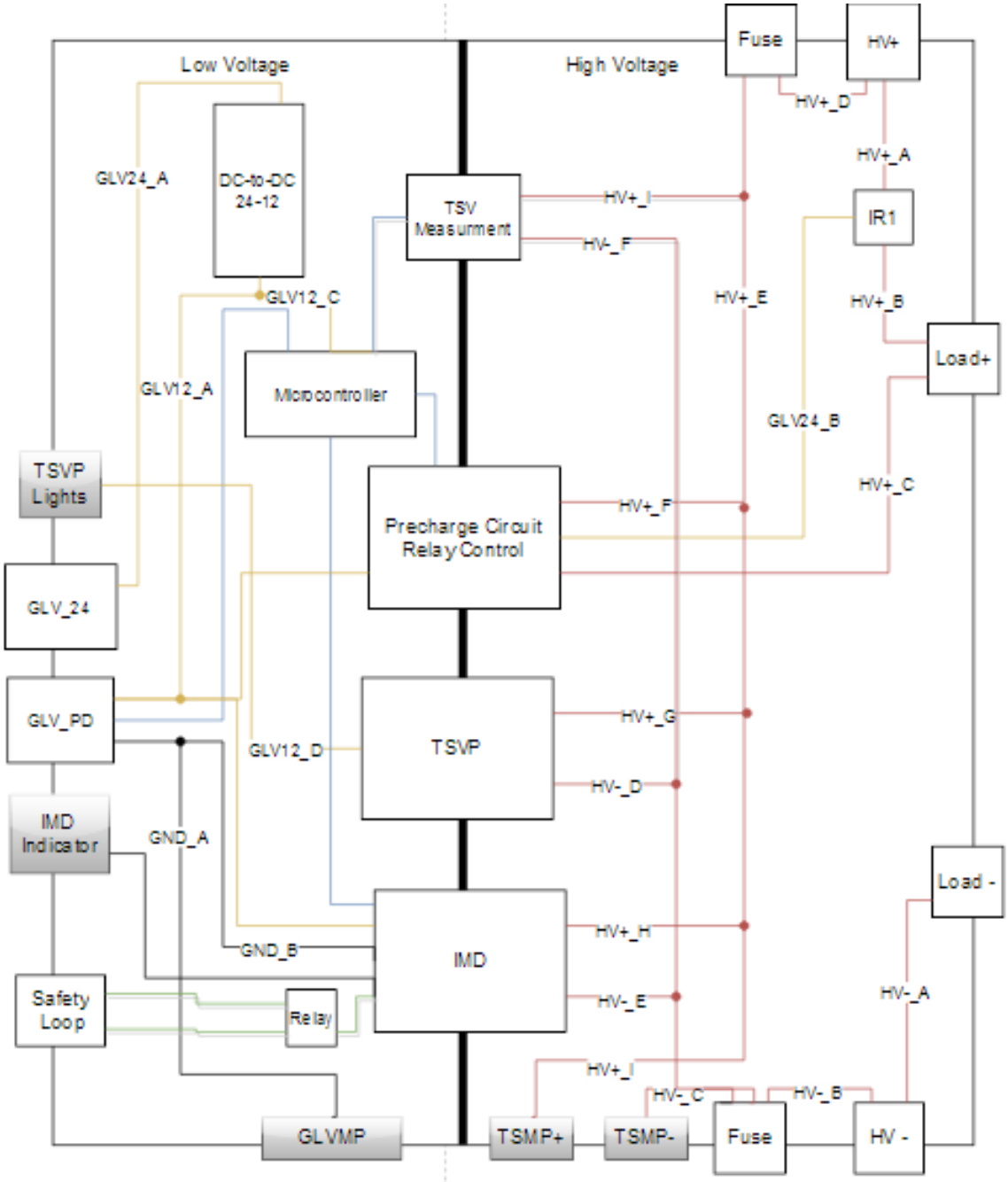
TSI - Overview

- High Voltage Relay Control
- Precharge Protection
- Tractive System Voltage Present Light (TSVP)
- Insulation Monitoring Device (IMD)
- GLV PD 24 to 12 stepdown
- TSMP

TSI



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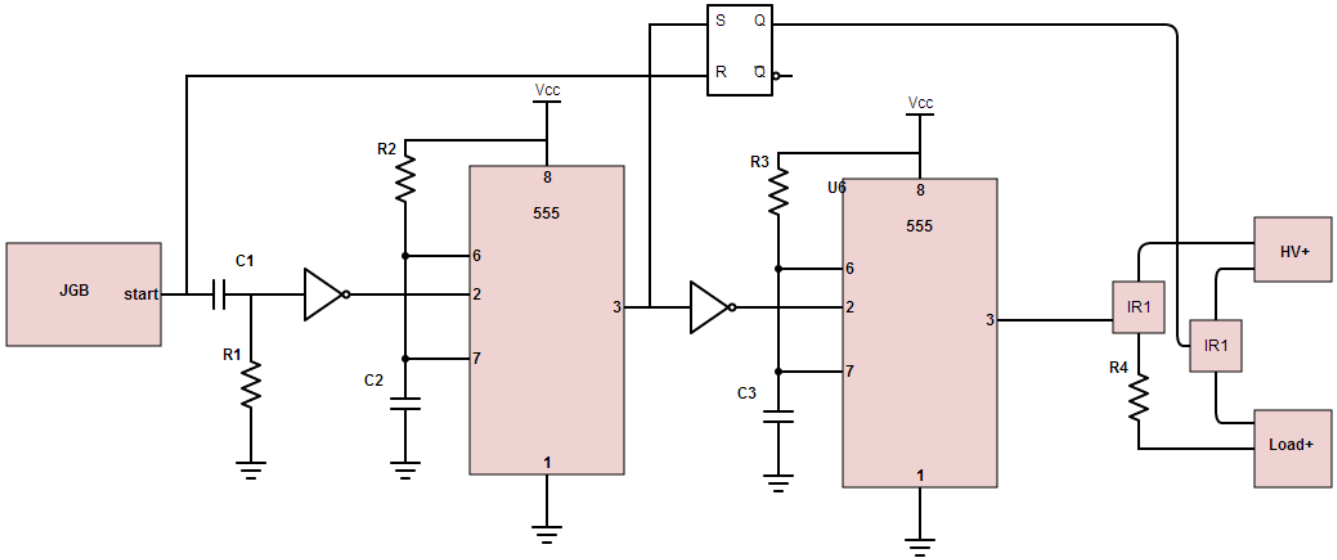
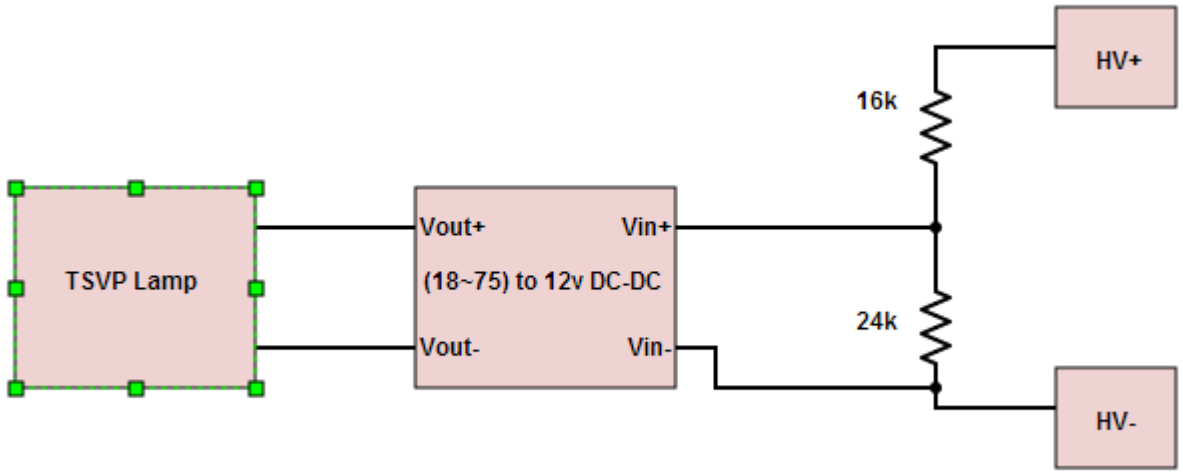
TSI - Pre-Charge/Relay Control

- Precharge circuit prevents inrush current and damage to relay contacts
- This configuration will take about 4 seconds for the motor controller to reach 96V

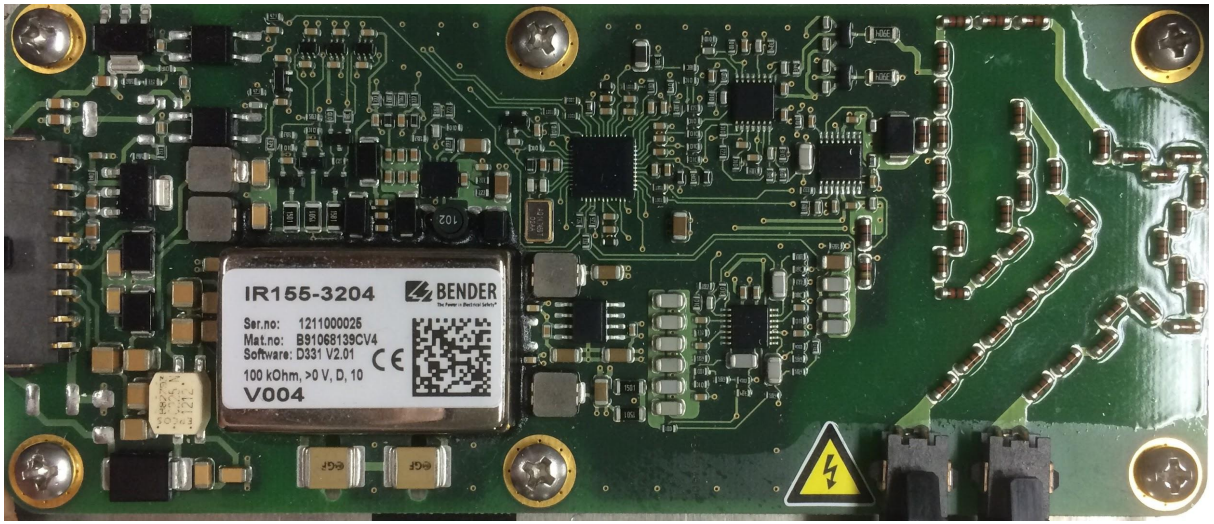


TSI - TSVP

- Must be powered by TSV and grounded to GLV ground
- Use a DC DC converter to satisfy this requirement and maintain isolation



TSI - IMD



- Pin 8 - Status Output High
- Feeds directly to a relay on Safety Loop
- Pin 8 output change opens Safety Loop (High → Low)

TSI - Other Components

- GLV Power
  - 24V to 12V DC-DC converter steps down the voltage from GLV24 to power the GLVPD at 12 Volts
- TSMP
  - TSMP+ is a direct contact to the HV+ terminal
  - TSMP- is a direct contact to the HV- terminal
  - GLV GMP provides a reference to GLV ground

TSI - QA Configuration

- Connect high voltage terminals to a high voltage power source
- Connect the high voltage load terminals to the motor controller
- Connect the GLV24 terminal to a low voltage power supply
-

TSI - QA Test Plan

- TSVP Test
  - Apply 30 volts to high voltage power supply and check the TSVP output with a multimeter
- Pre-charge/Relay Test
  - Put start signal high and measure time it takes relays to close
- IMD Test
  - Using a multimeter, check for connection across the relay after shorting the ground

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GLV Bill of Materials

Description	Vendor Part Name	Quantity	Unit Price	Total Price
Te-Connectivity 2 pin/1 row parallel	1-480699-0	4	$0.28	$1.12
Te-Connectivity 2 pin/1 row free	1-480698-0	4	$0.28	$1.12
Te-Connectivity 3 pin/1 row parallel	1-480701-0	6	$0.28	$1.68
Te-Connectivity 3 pin/1 row free	1-480700-0	6	$0.27	$1.62
Te-Connectivity 8 pin/2 row parallel	794954-8	4	$0.25	$1
Te-Connectivity 8 pin/2 row parallel	794953-8	4	$0.25	$1
Te-Connectivity pin	350561-3	10	$0.14	$1.38
Te-Connectivity socket	350570-3	10	$0.13	$1.32
24V DIN Rail DC/DC Converter	TCL 060-124 DC	1	$80.62	$80.62
DIN Rail DC/DC Converter	STMGFS152405-N2	1	$69.05	$69.05
36vdc PFC Power Supply	HRP-200-36	1	$64.80	$64.80
DIN Rail	277-2064-ND	1	$9.82	$9.82
DIN Rail Terminal Blocks	APC1281-ND	50	$1.33	$66.63
SWITCH PUSH SPST-NO	CWI282-ND	1	$4.12	$4.12
SWITCH KEYLOCK SP3T	KO129B606-ND	1	$9.80	$9.80
DIODE SCHOTTKY 45V 7A	SB15H45-E3/73GITB-ND	5	$0.81	$4.05
LED RED 1/4" HOLE 5V	L10021-ND	5	$2.17	$10.85
Relay 5A 5V	Z2774-ND	10	$1.18	$11.78
			Grand Total	$341.76

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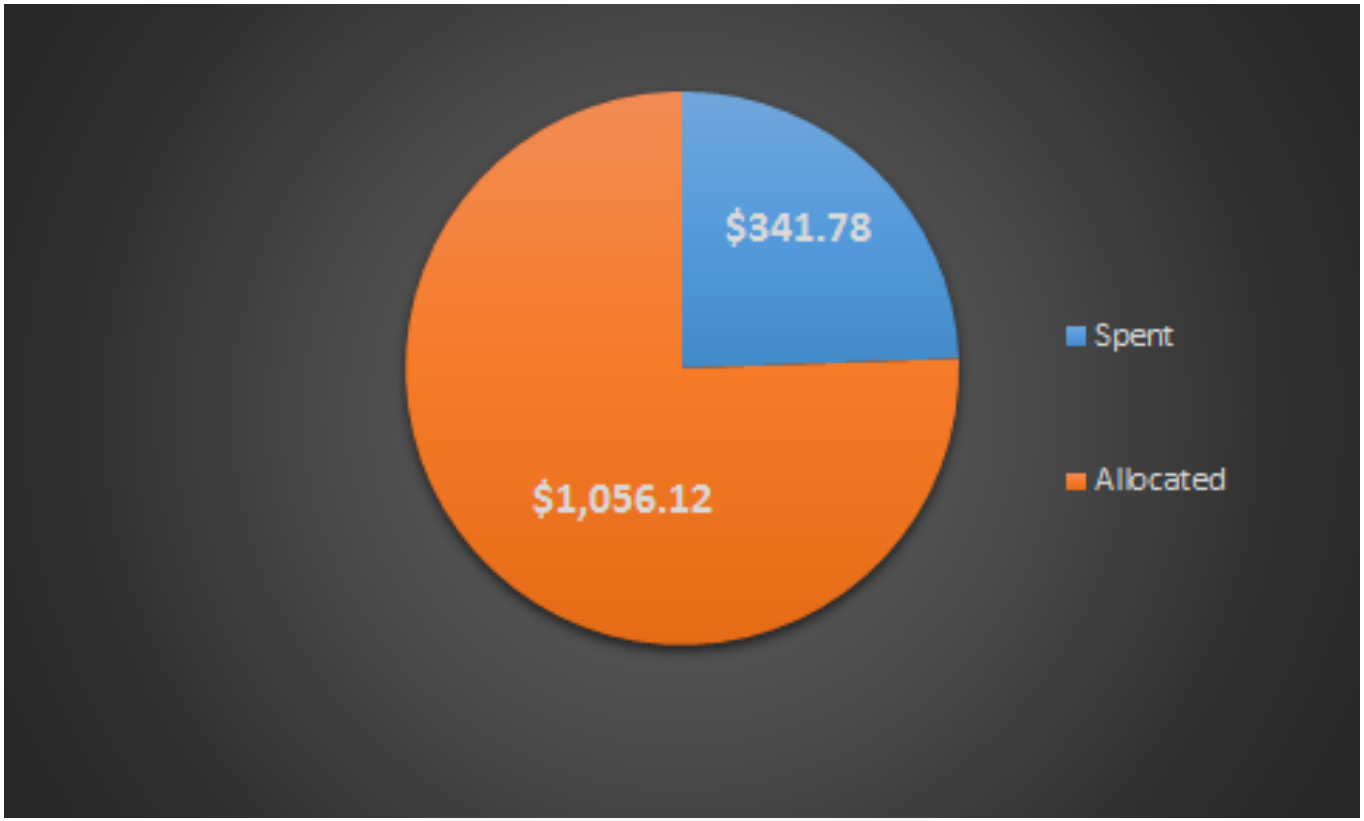
GLV Budget

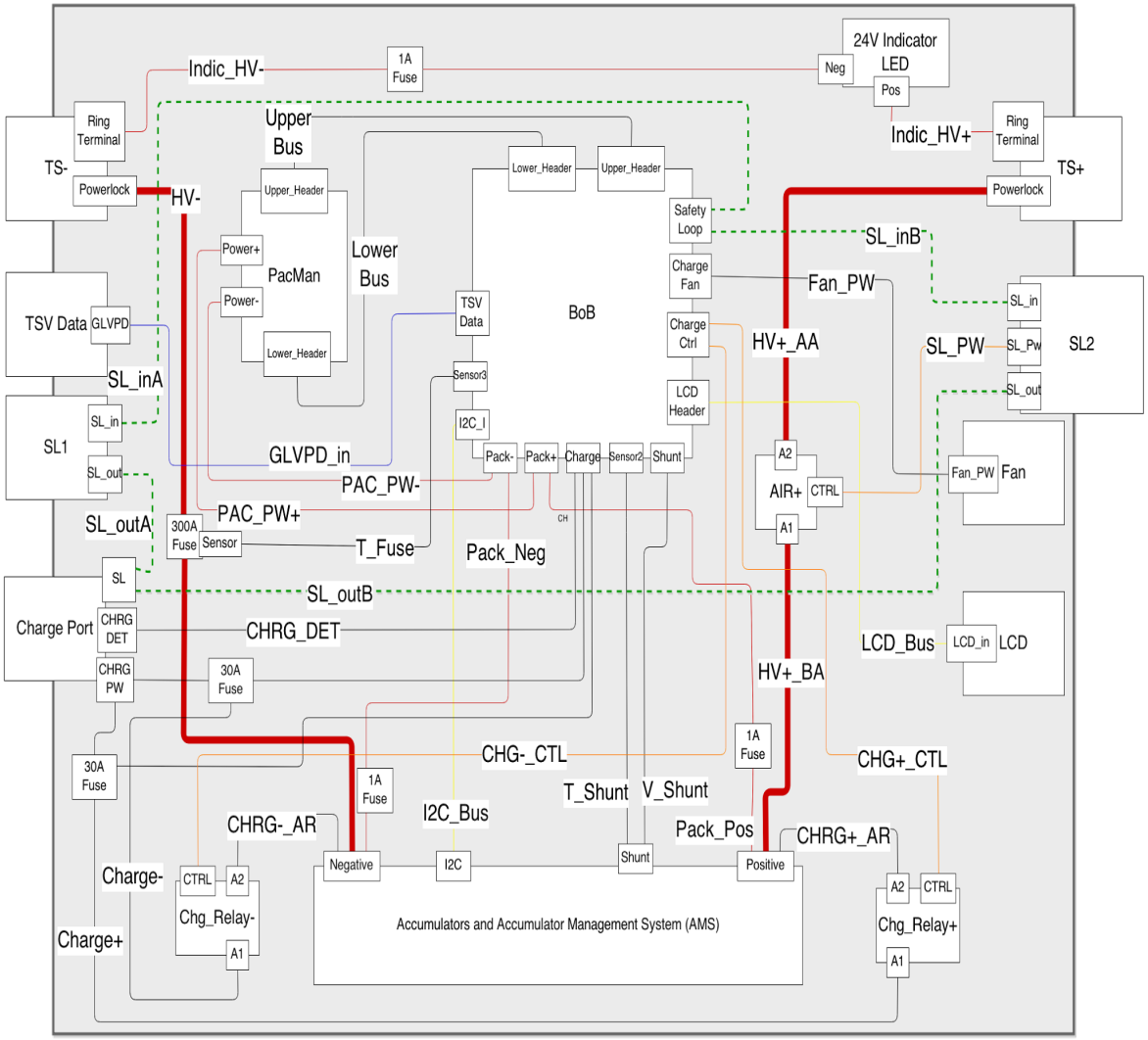


Total Allocated Funds - $1397.90

Roadmap Cont.

5. **Tractive System Voltage (TSV)**
    a. **Overview**
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Tractive System Voltage



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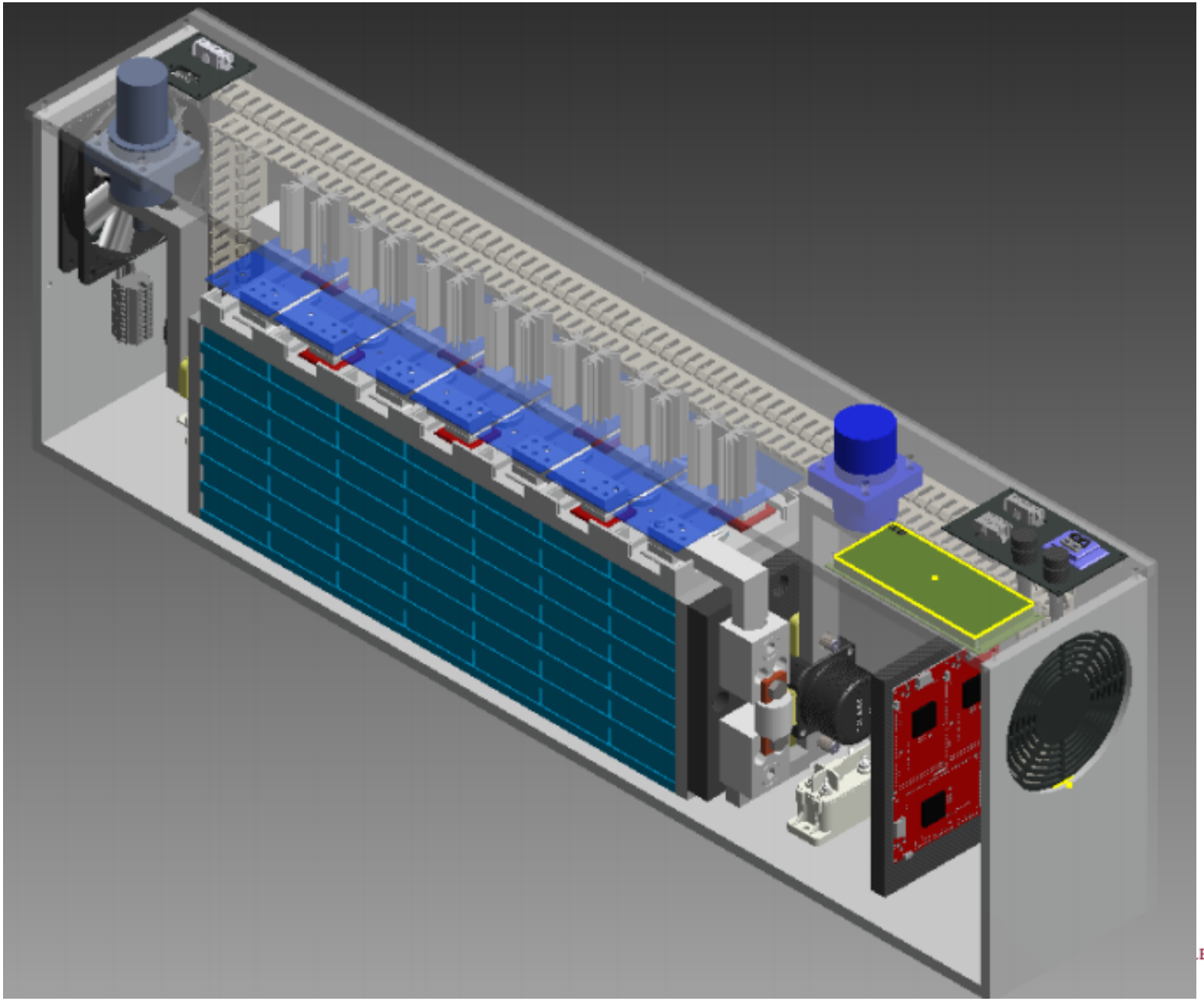
Main subsystems

- Accumulator Managment System (AMS)
- Breakout Board (BoB)
- Pack Manager (PacMan)
- 7 3.2V 60A-hr LiFePO4 Cells



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Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
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    c. Mechanical
    d. PacMan System
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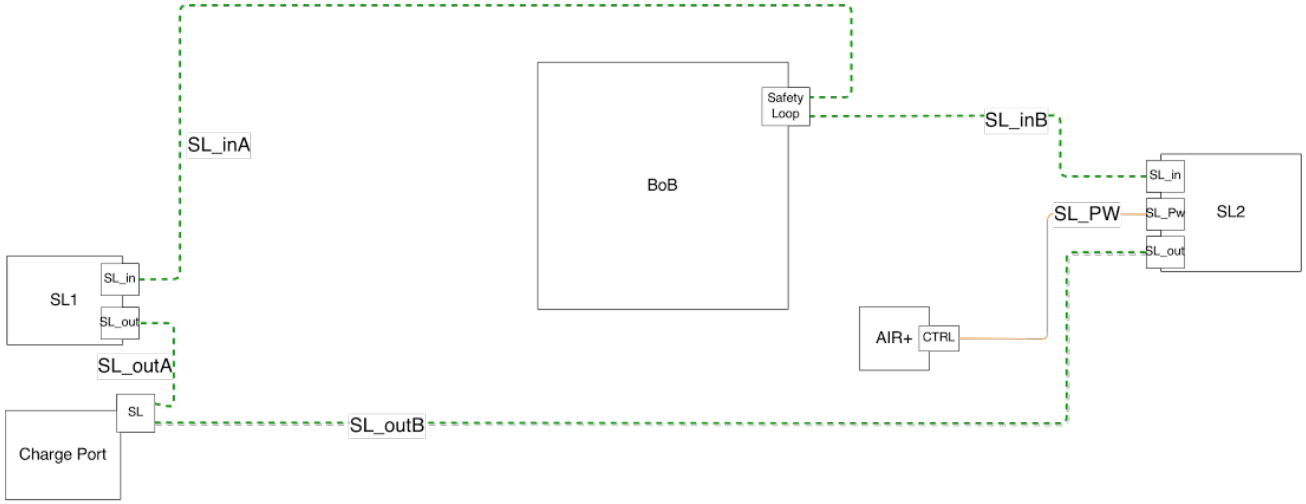
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

TSV - Safety

- Fusing
  - 2 fuses for BoB
  - 1 fuse for voltage present LED
  - 1 large fuse for pack main current path
  - 2 fuses for charge relay
- Voltage present LED
  - turns on when voltage > 20V DC present at poles
  - can sustain voltage up to 96V
  - works even when a cell fails with all other packs connected
- Safety protocols

Pack Safety Loop

- One port at each end of the pack
- Each contains safety loop and SL 24V/GND
  - SL 24V/GND used to power AIR
- Safety path:



High Voltage Interfaces

- 4 “Danglies” one per pack
  - 400A rated Newark 44W4352
  - Source Hangs off of pack with cable to + terminal
- 4 Panel mount female connectors
  - 400A rated Newark 44W4361
  - Connected to - terminal bus bar

http://www.newark.com/itt-cannon/nls-3-gy-s120-m40a/line-source-line-3-grey-400a/dp/44W4352

http://www.newark.com/itt-cannon/npdft-3-gy-l-t4/panel-drain-line-3-grey-400a/dp/44W4361

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
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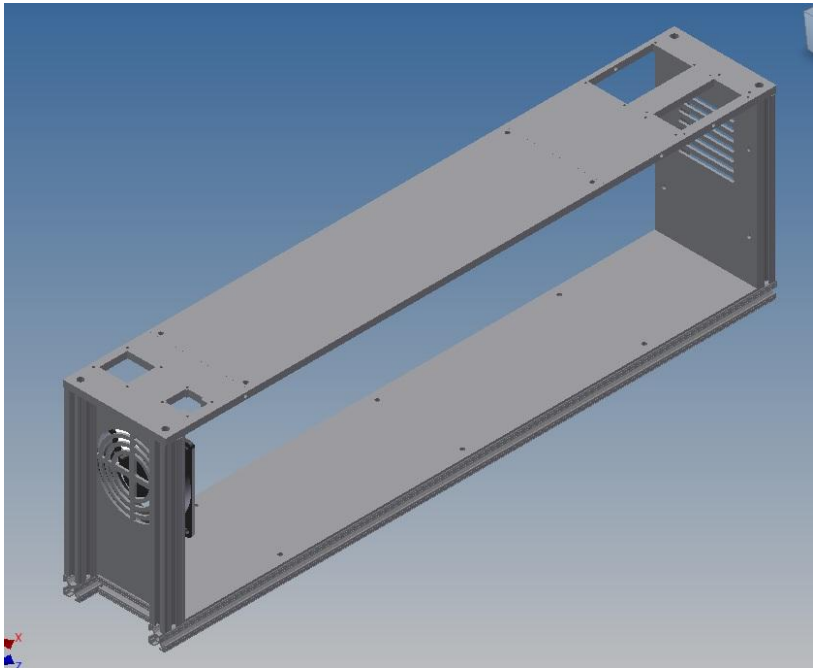
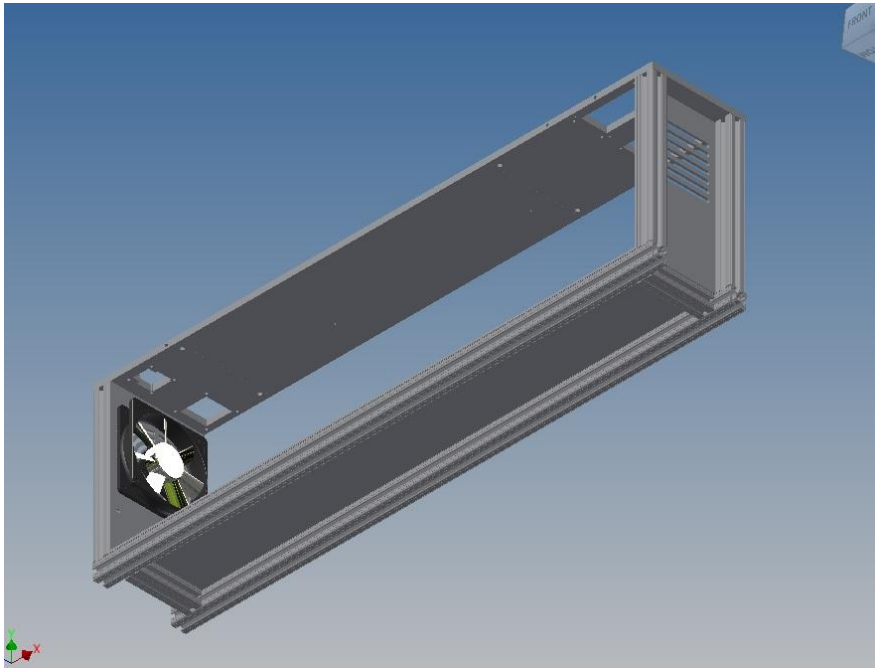
Mechanical Objectives

- acceleration requirements
- splash proof
- internal wall
- vibration
- galvanic isolation

Mechanical- Frame/External Casing

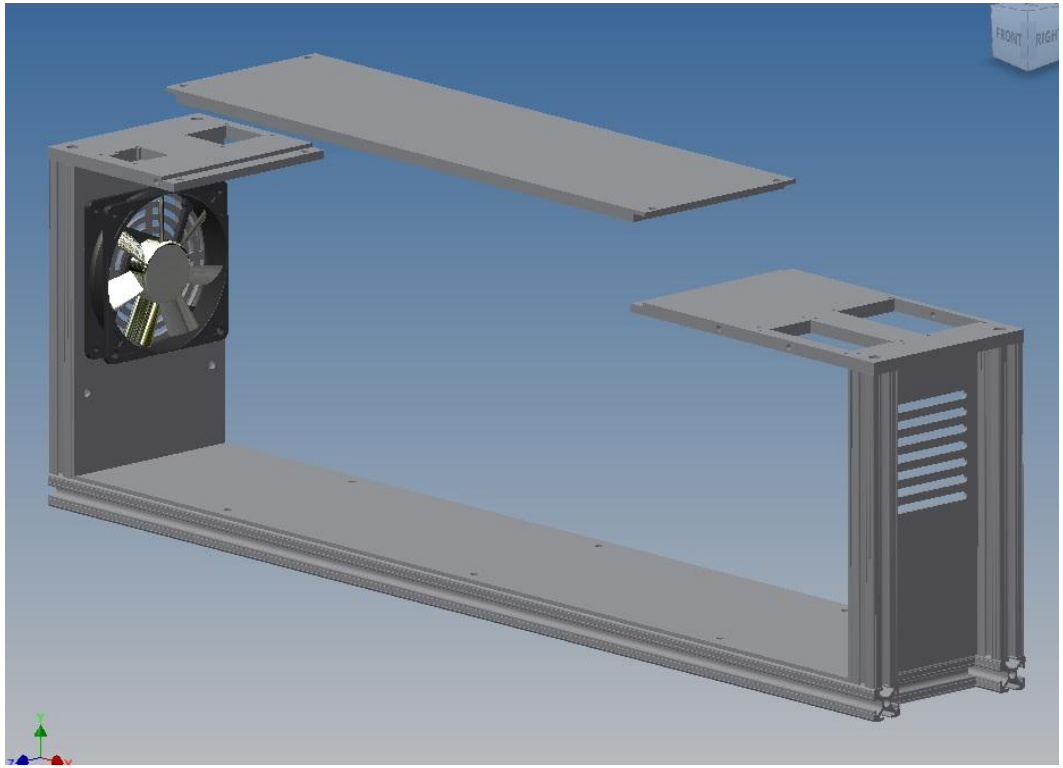
- Rigid 8020 Aluminum External Frame





Mechanical- Frame/External Casing

-Removable Top For Quick Battery/BMS Access



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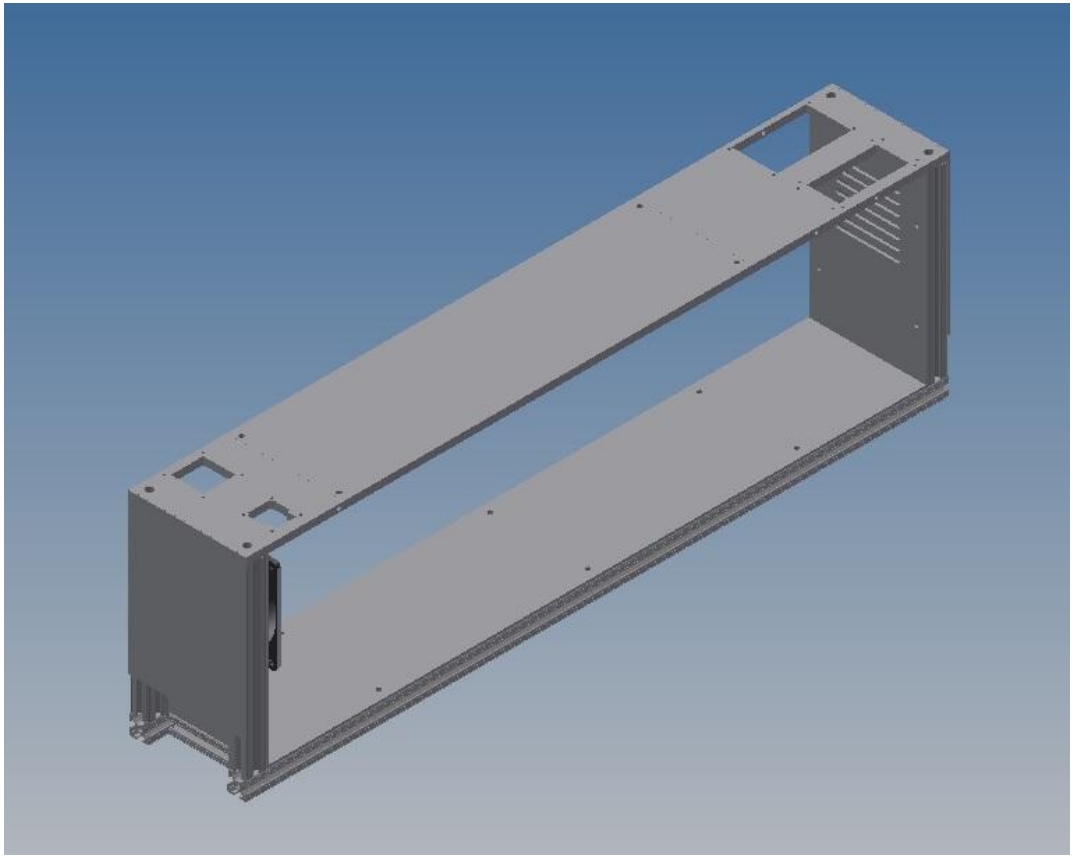
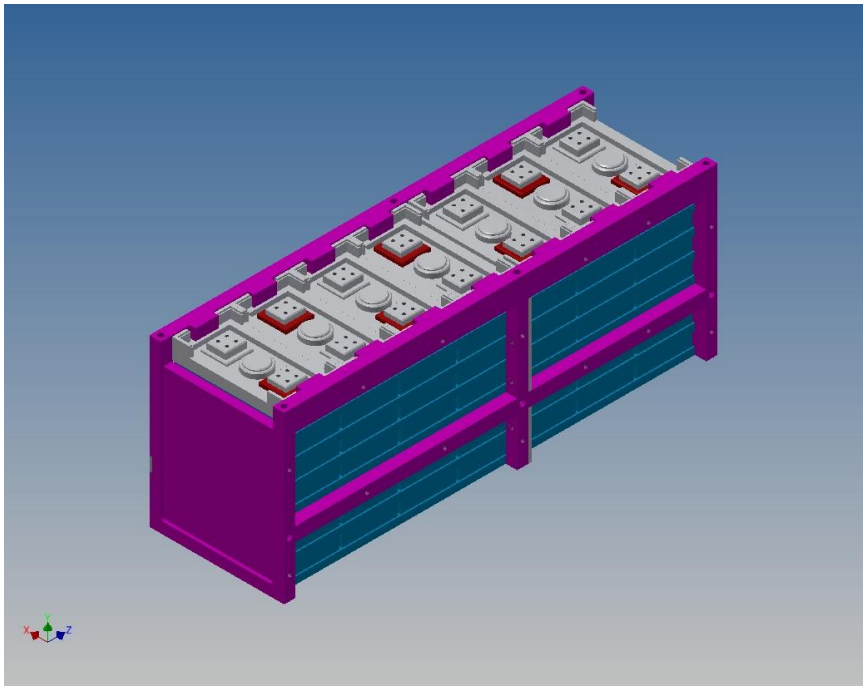
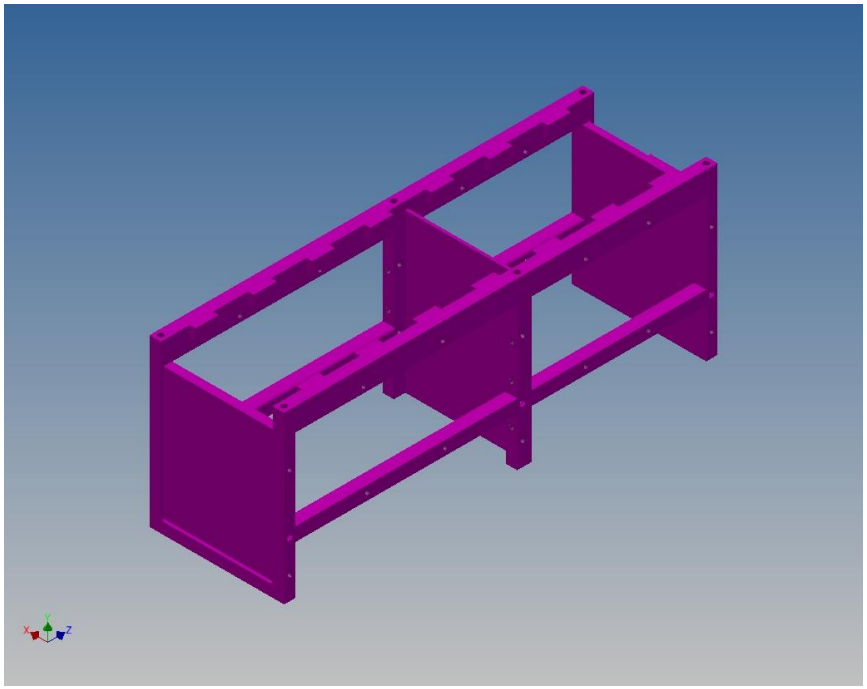
Mechanical- Frame/External Casing

-Splash Resistant Ventilation

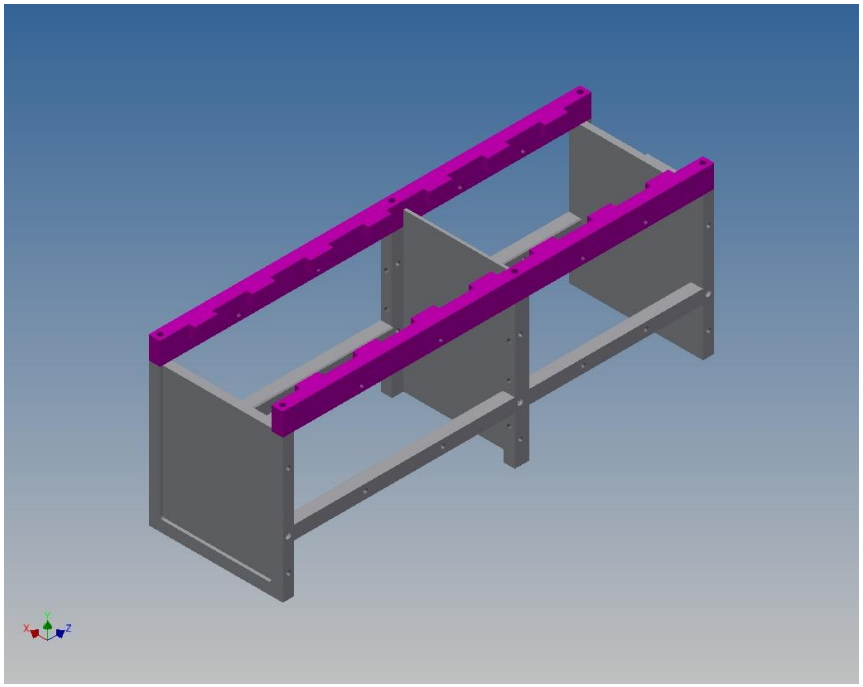


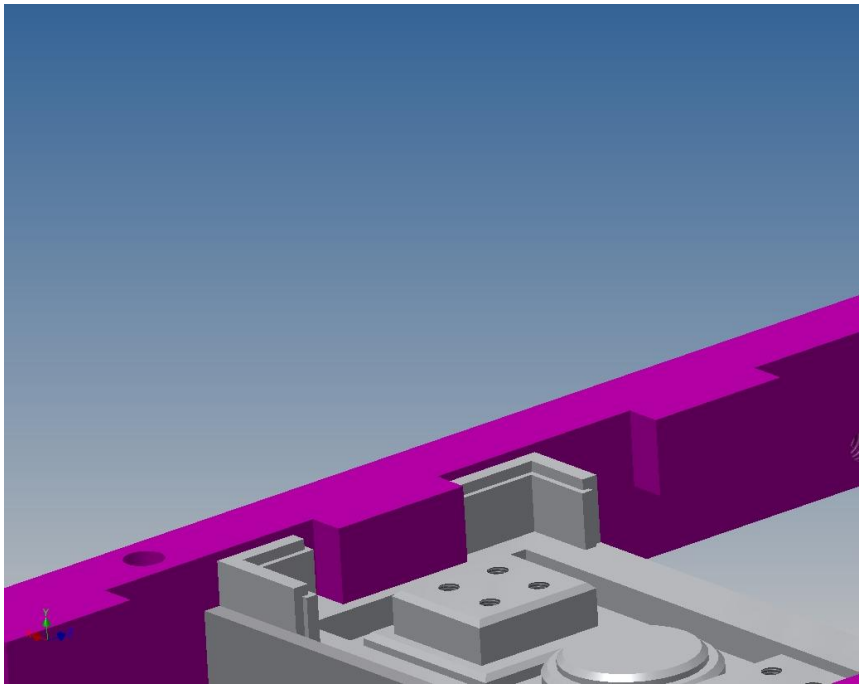
Cell Restraint



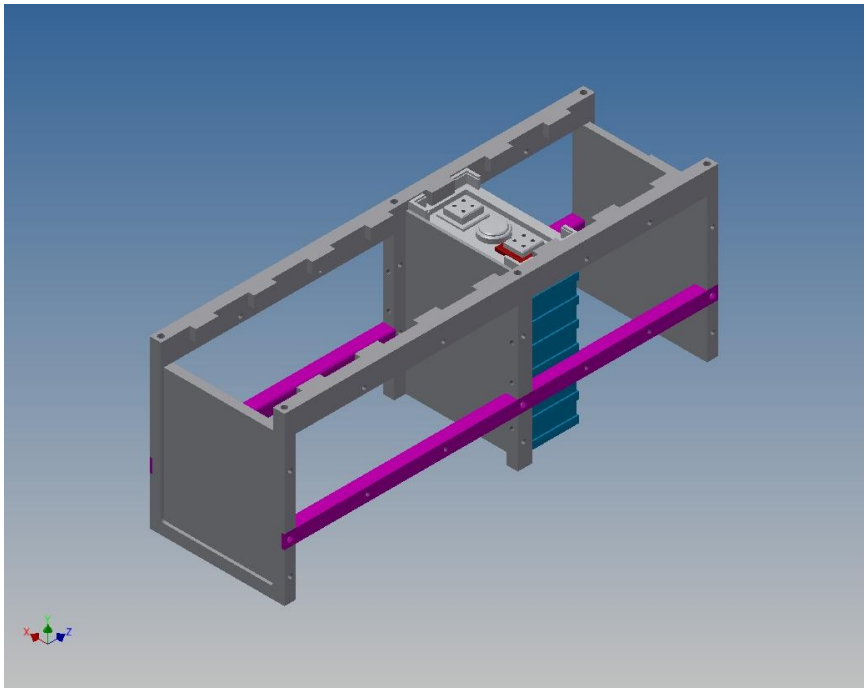


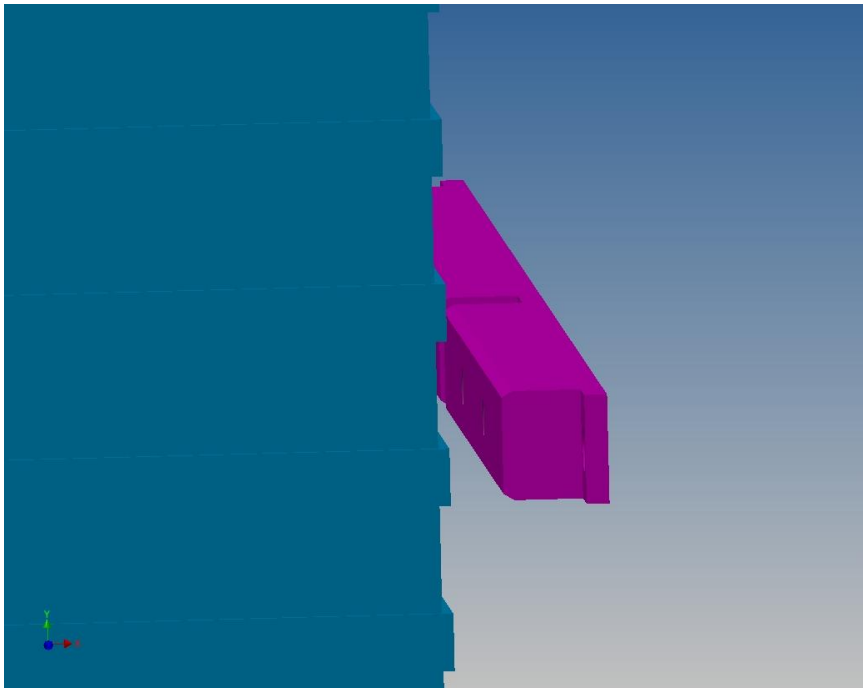
Top Bars



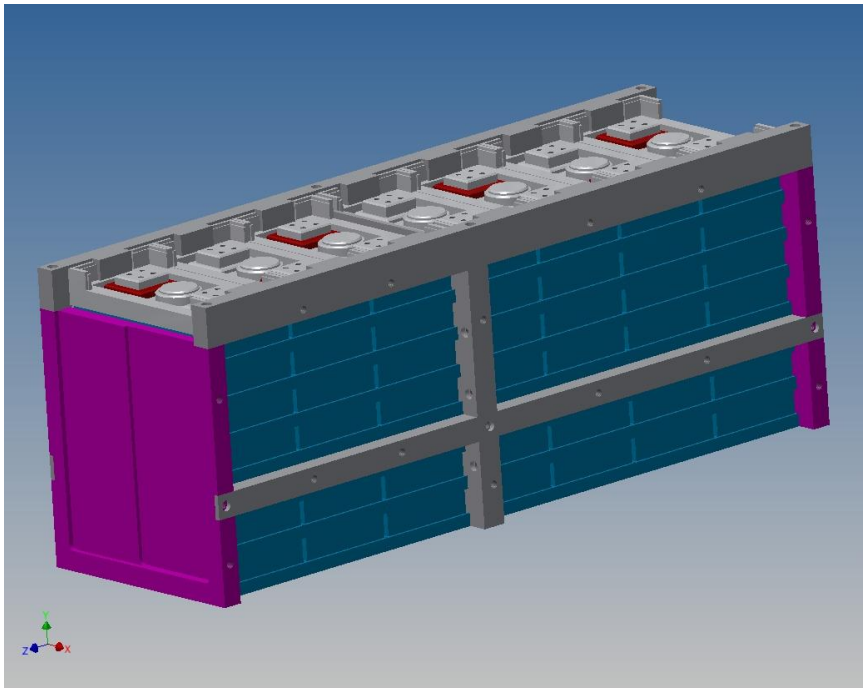


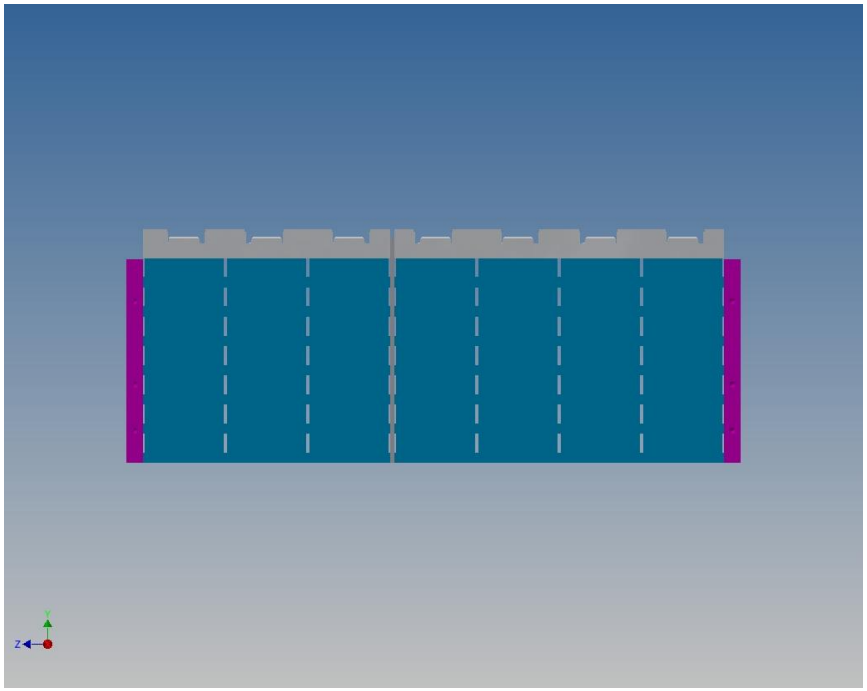
Side Bars



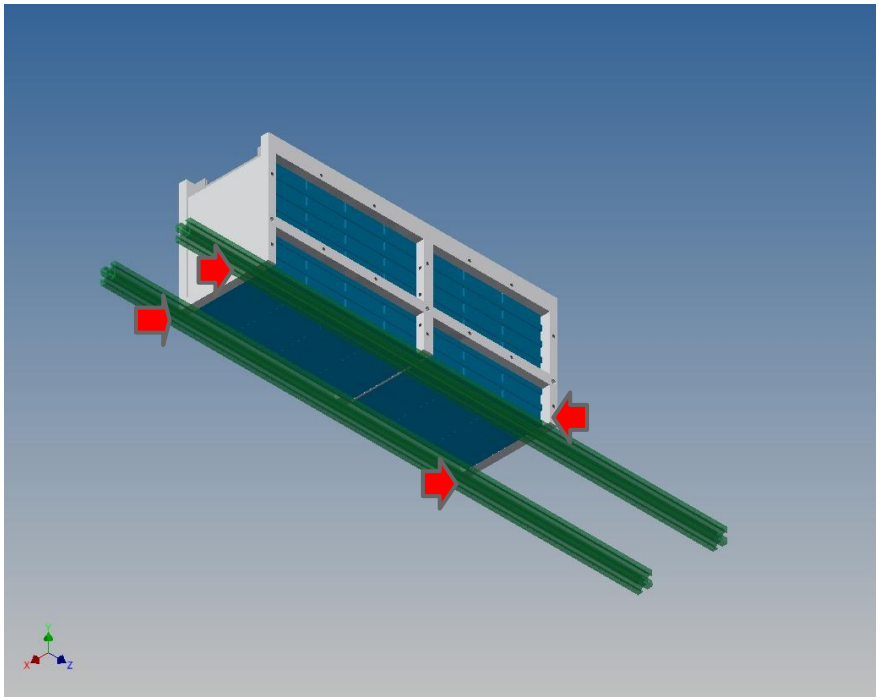


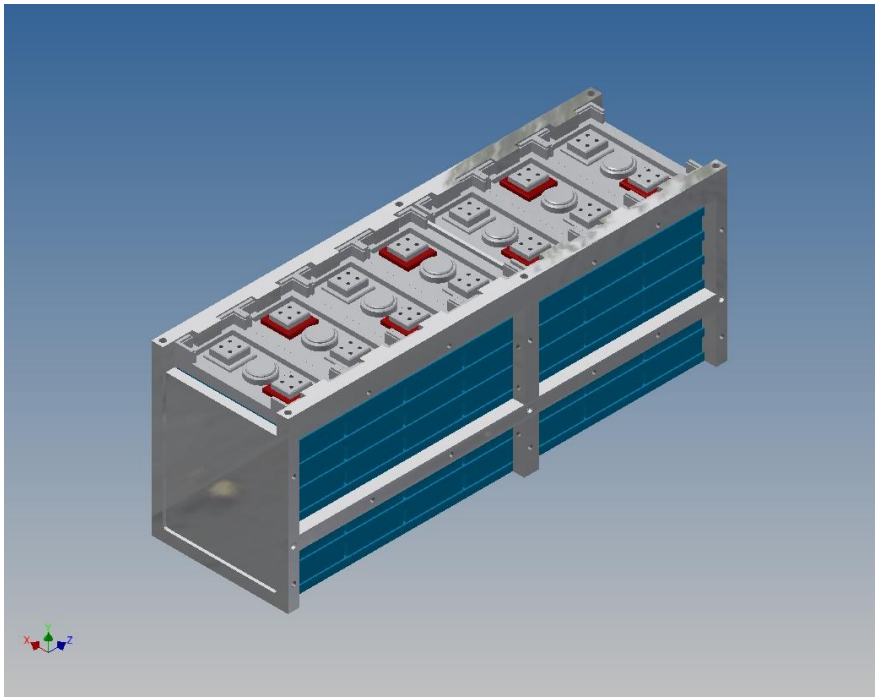
End Plates



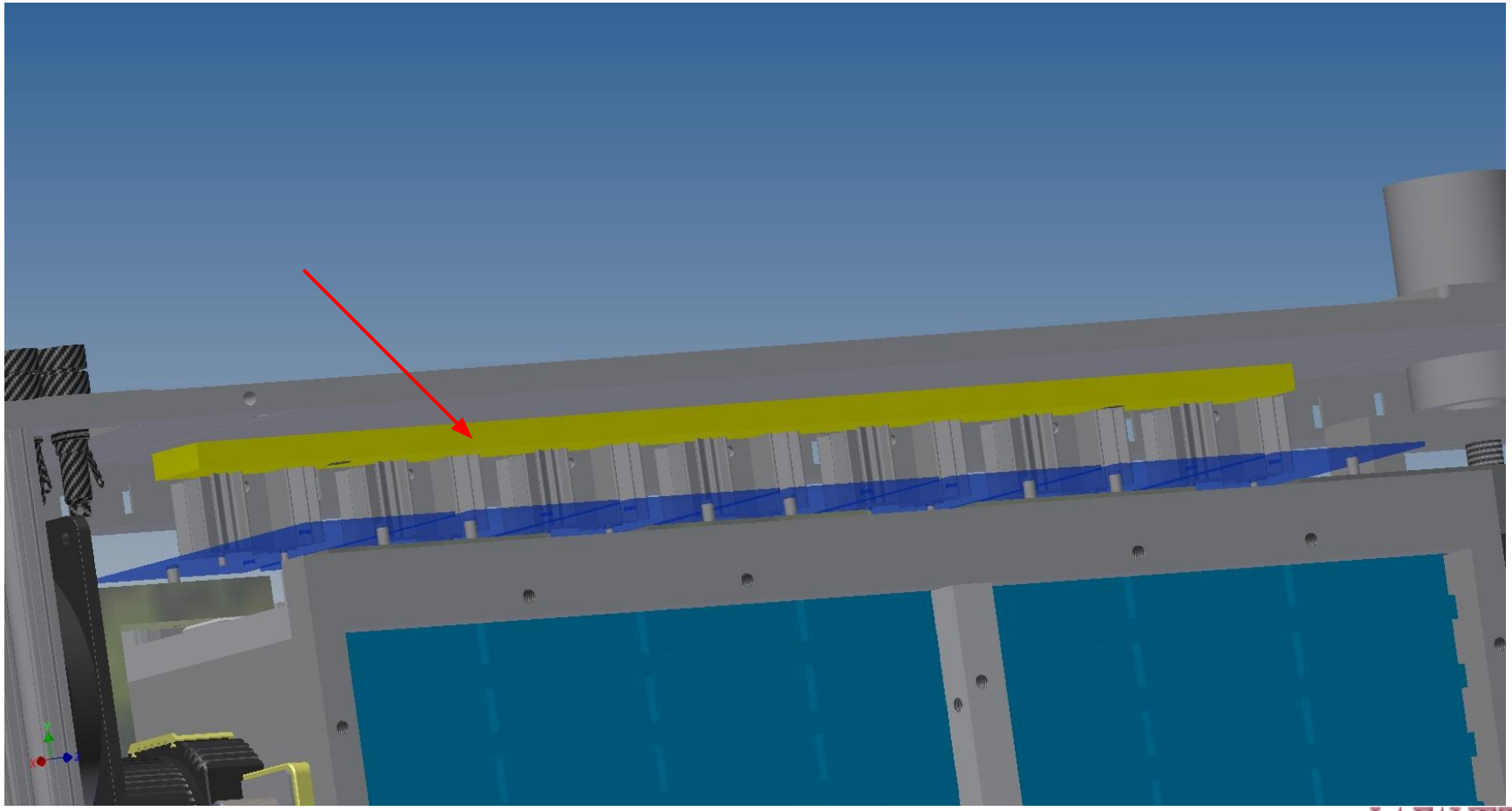


Integration with Container





BMS Restraint



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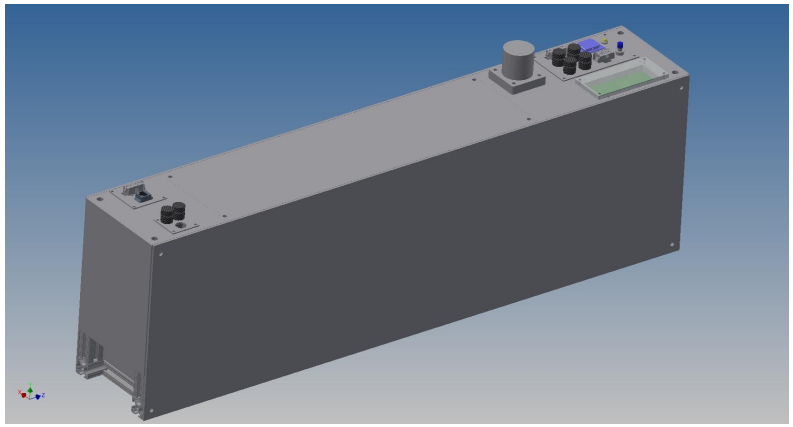
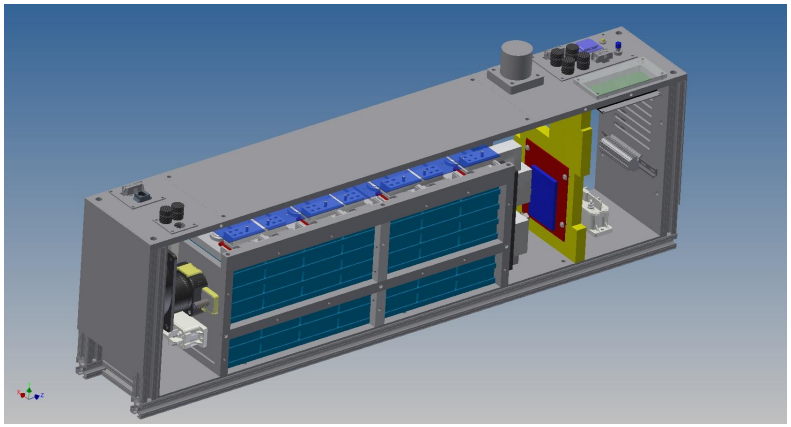
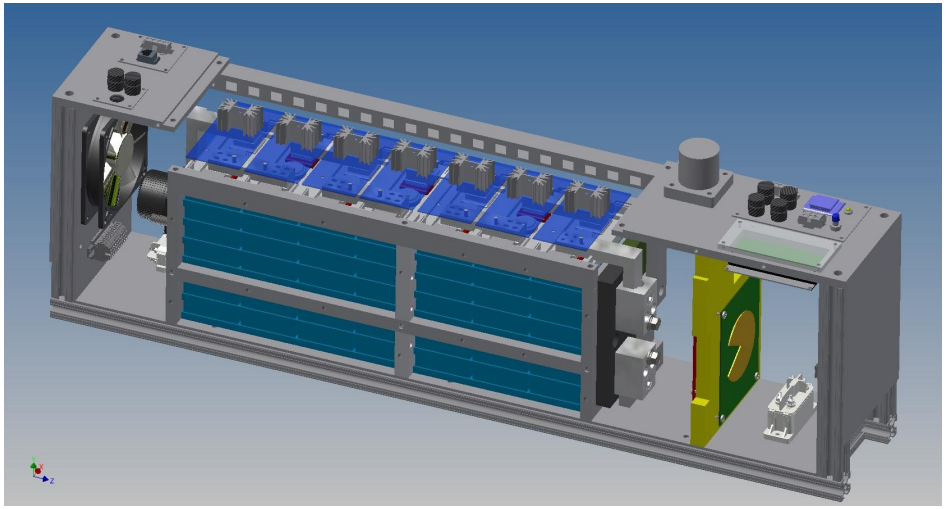
BMS Removal







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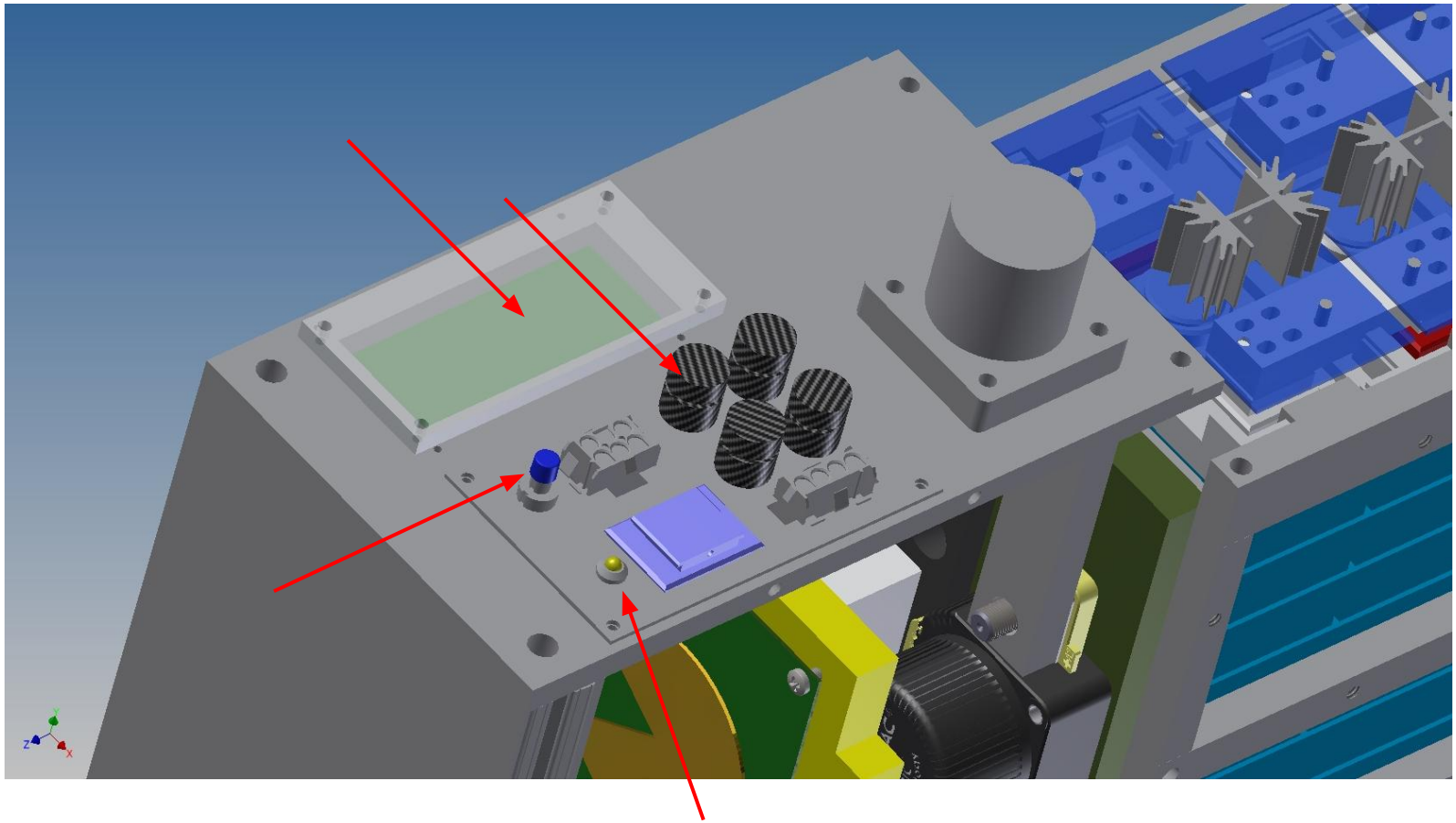
Added Components



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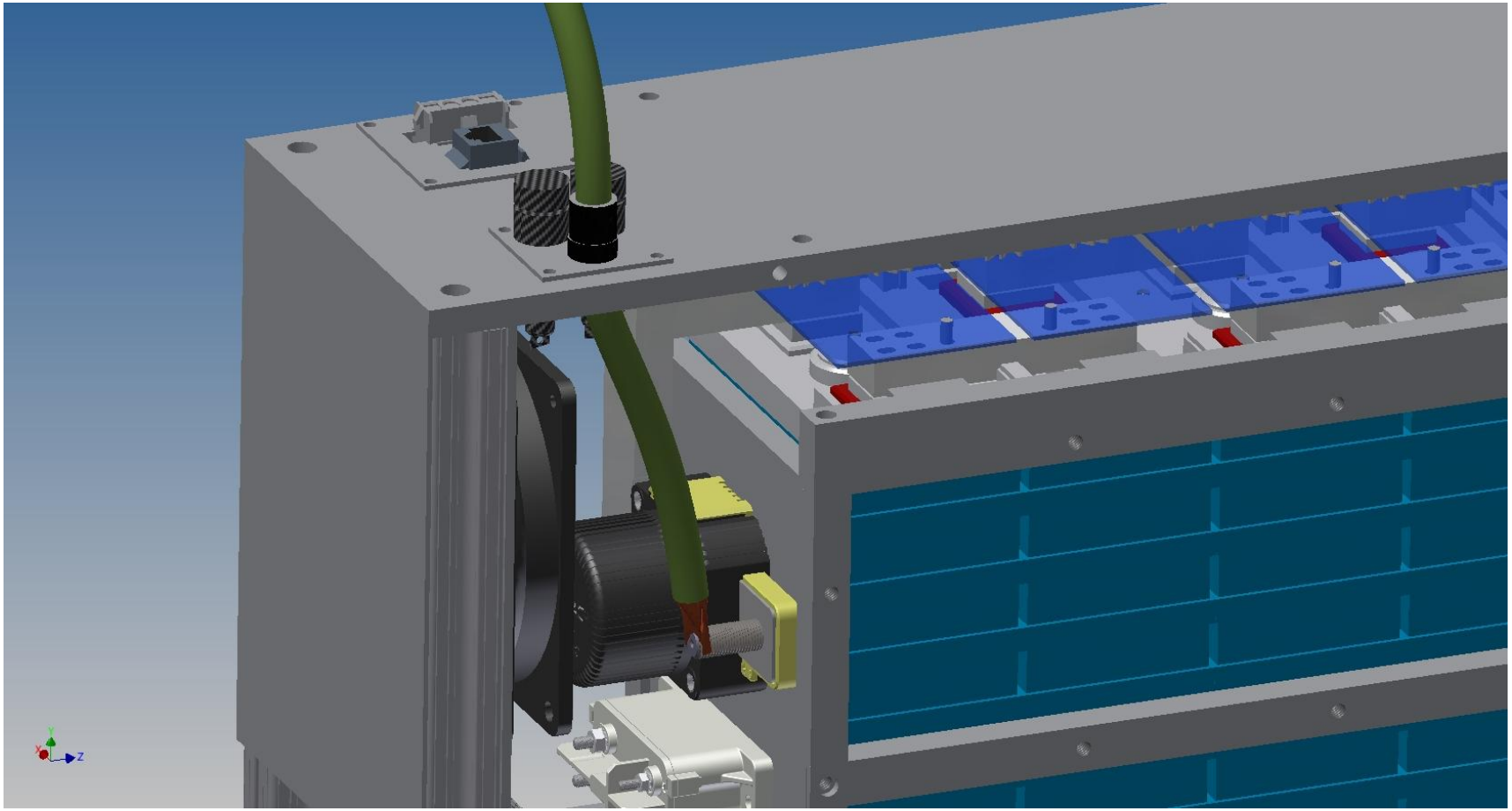
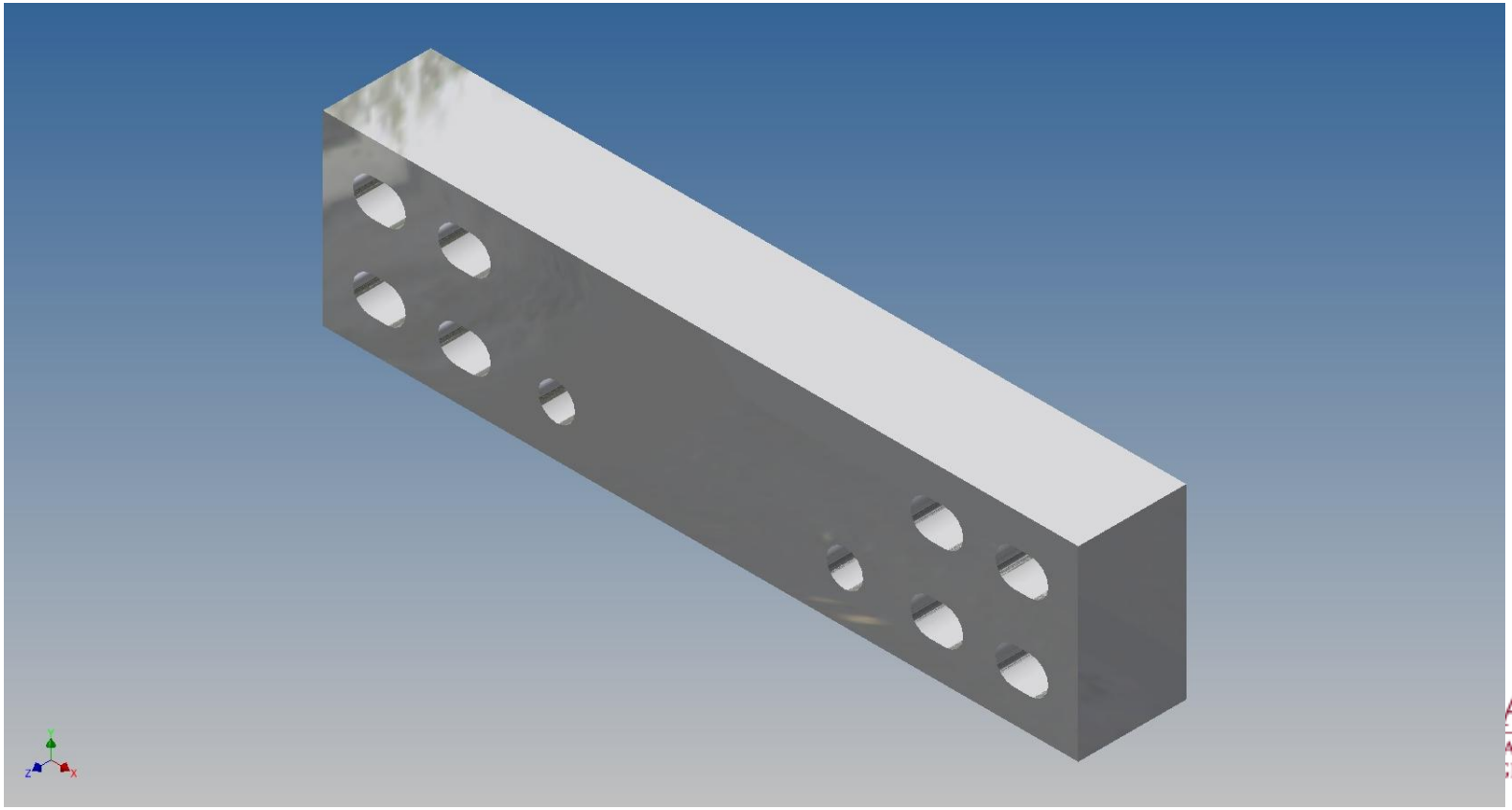
Free Terminal



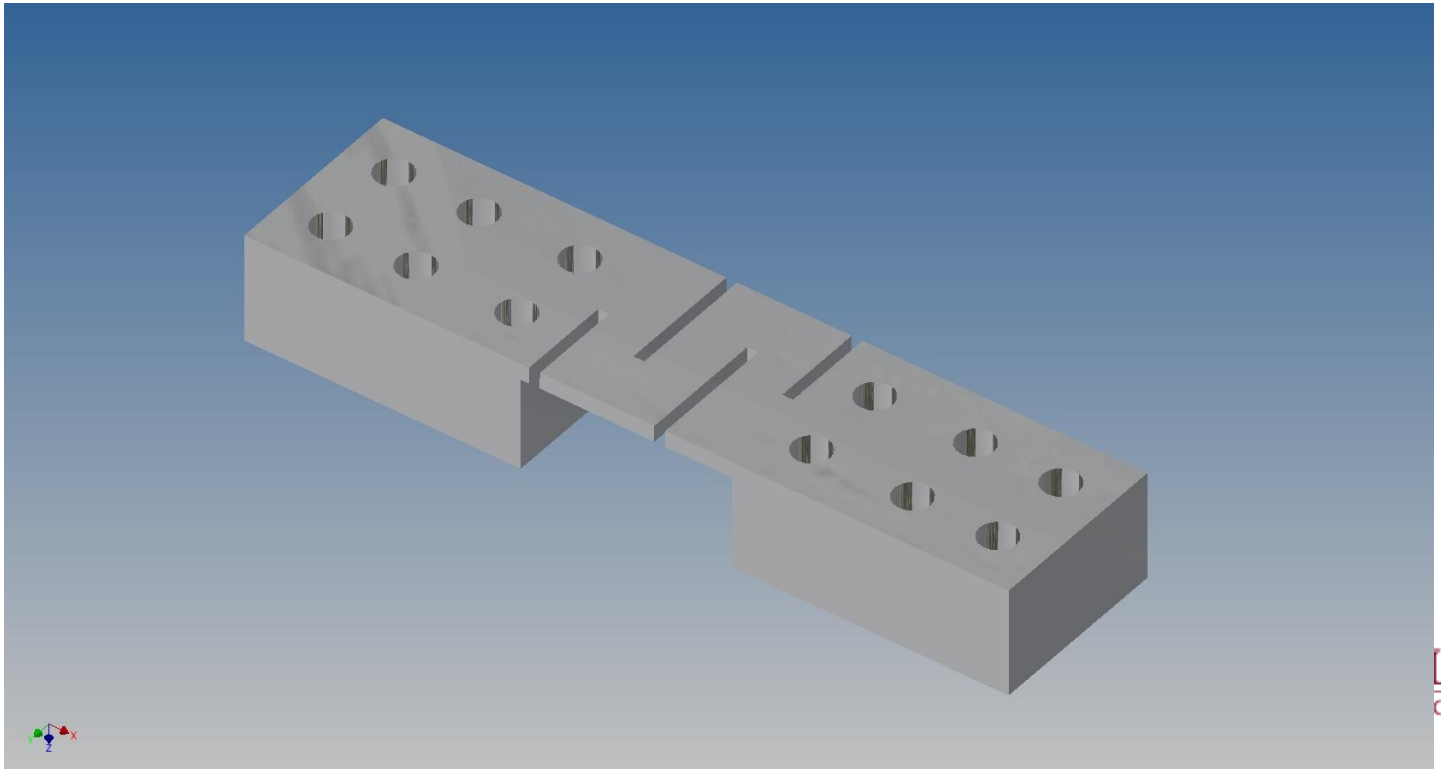
Mechanical - Conductor Bars

- Carries large current
- Low resistance



Mechanical - Current Measuring Shunt

- Special conductor used to measure current
- 118μΩ at STP



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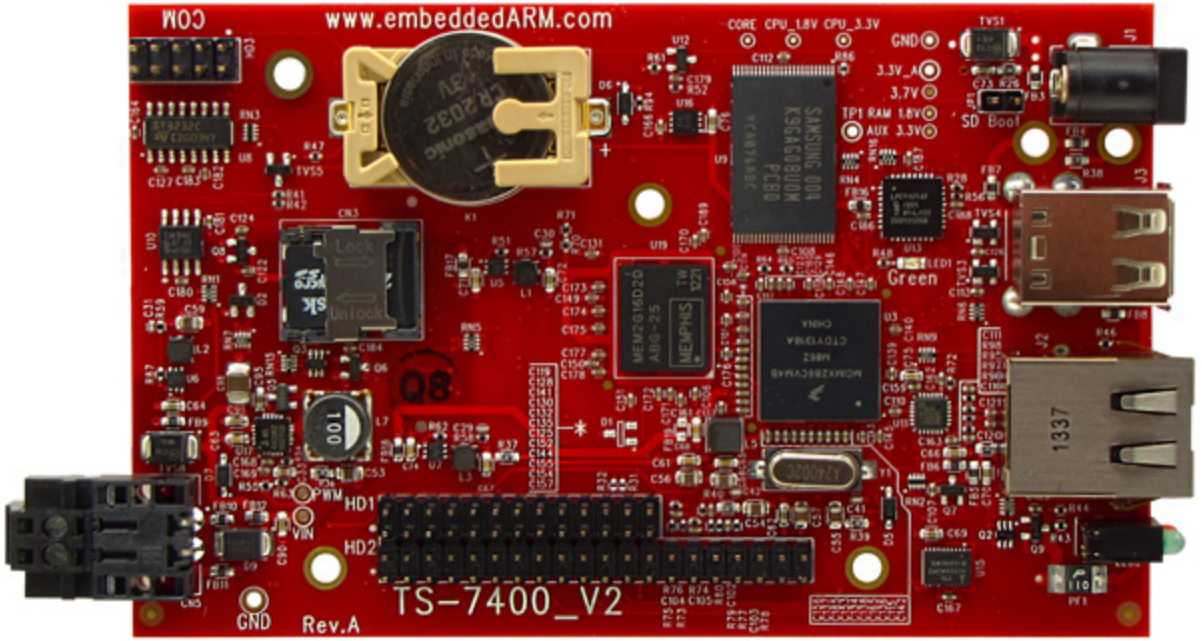
PacMan System

- Receives and processes data from AMS
- Receives and processes pack sensor data
- Opens BoB safety loop
- CAN communication with VSCADA and LCD
- Implement charge and forget charging

PacMan Computer



https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

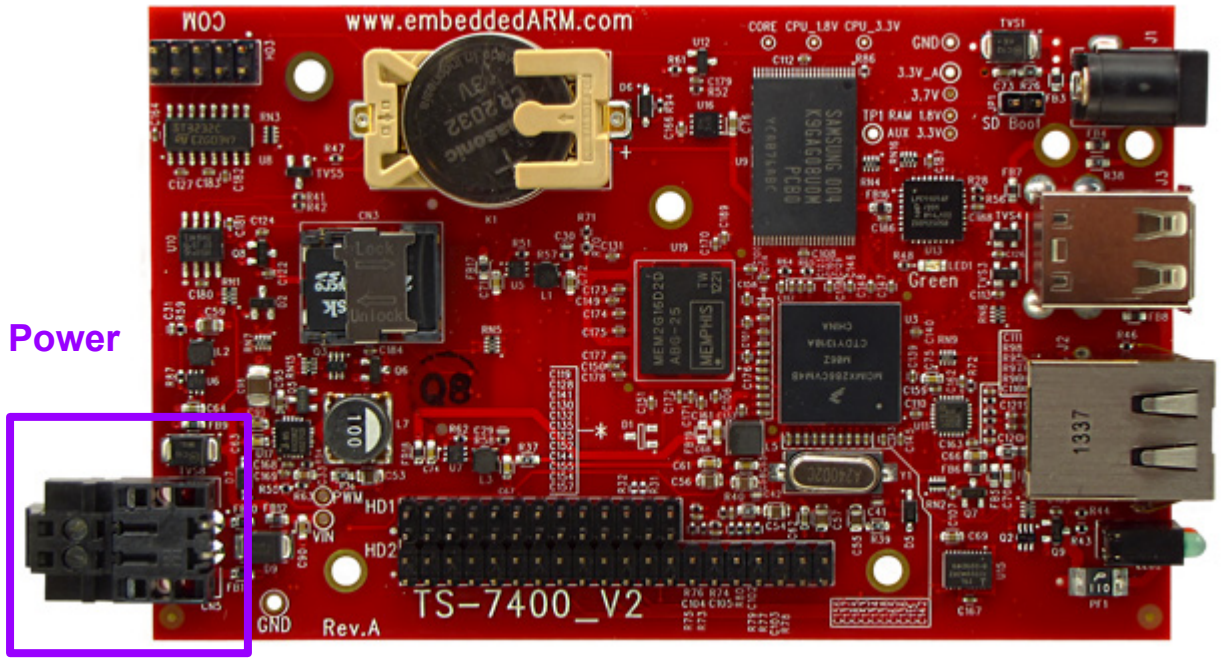
Technologic Systems TS-7400-V2

PacMan Computer Hardware Specs

- 1.2W Typical power usage
  - 6.67 Weeks for each pack
- 10mW sleep mode
  - 15.35 years for each pack
- I2C bus for AMS and LCD communication
- CAN bus for VSCADA interface
- 4 ADC inputs for pack sensors
- 39 DIO ports for logic functions

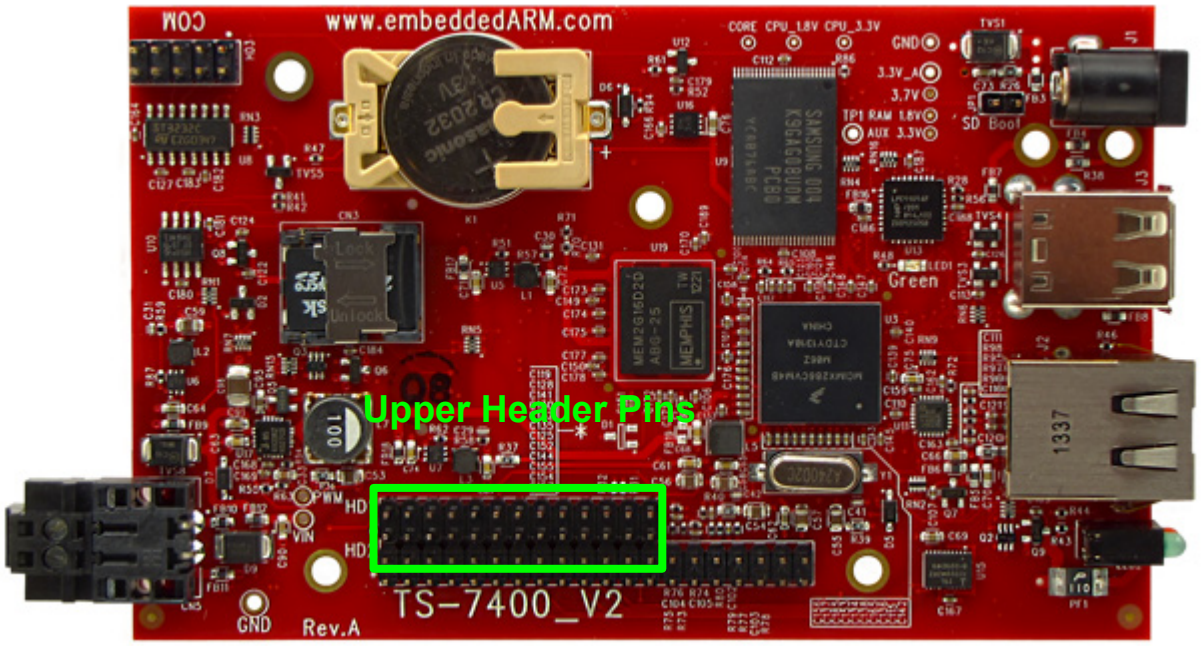
PacMan Computer - Connections

5-28V DC Power

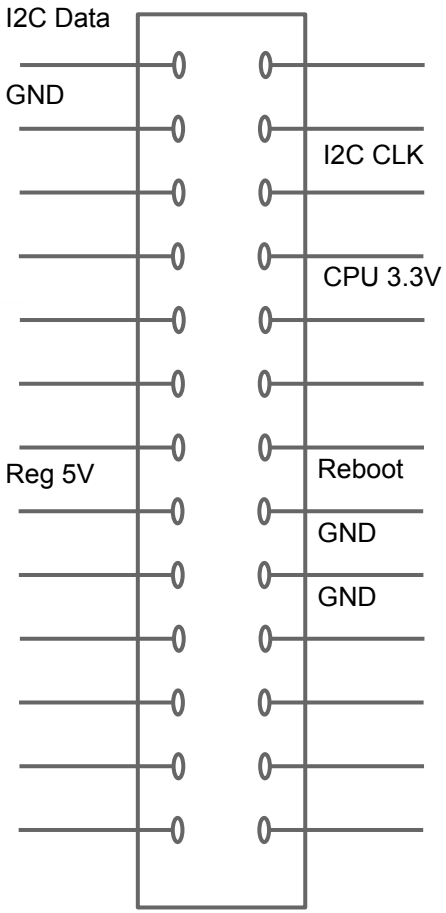


https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2

PacMan Computer - Connections



https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2



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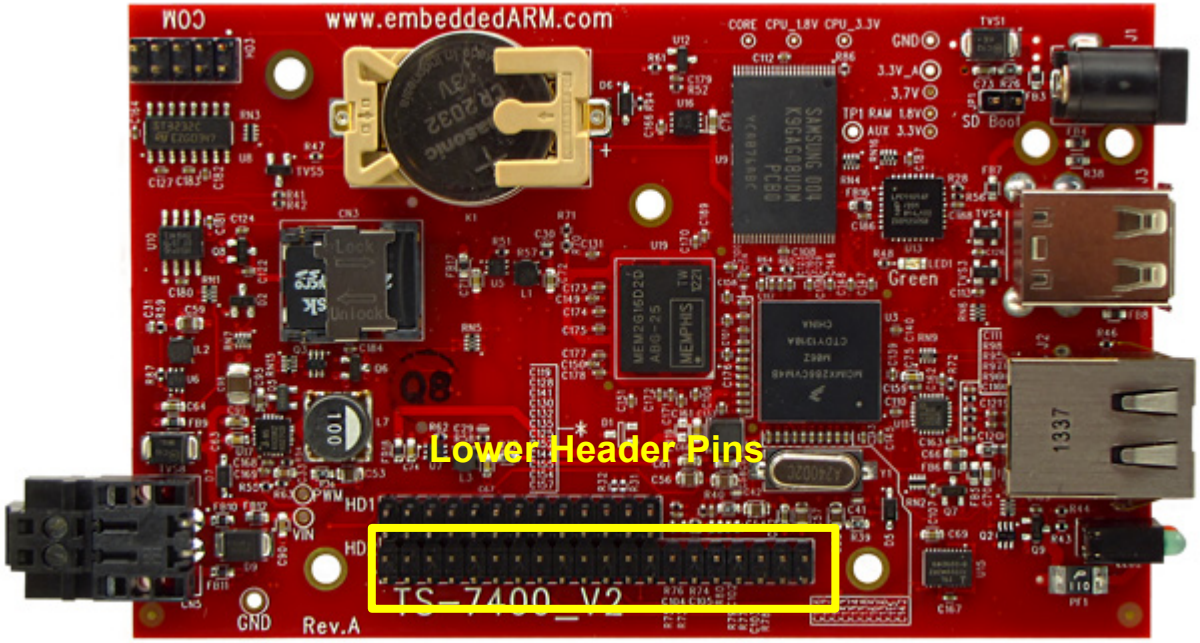
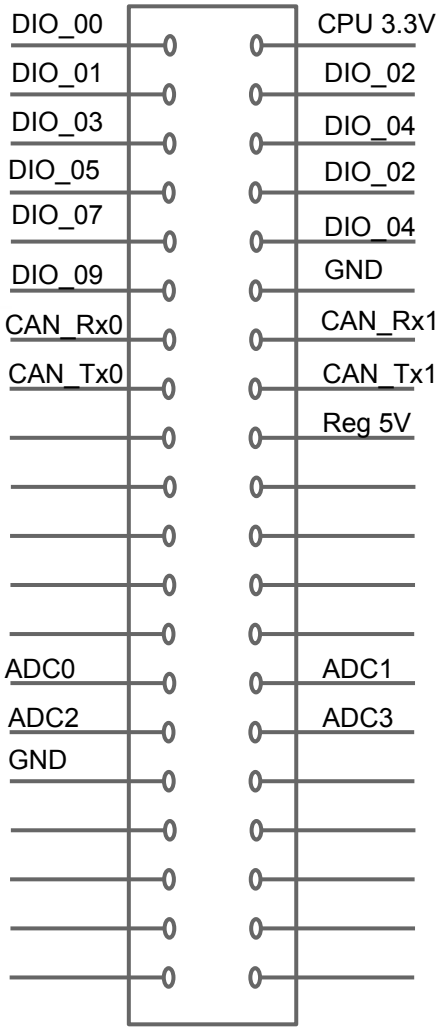
PacMan Computer - Connections



https://www.embeddedarm.com/products/board-pictures.php?product=TS-7400-V2



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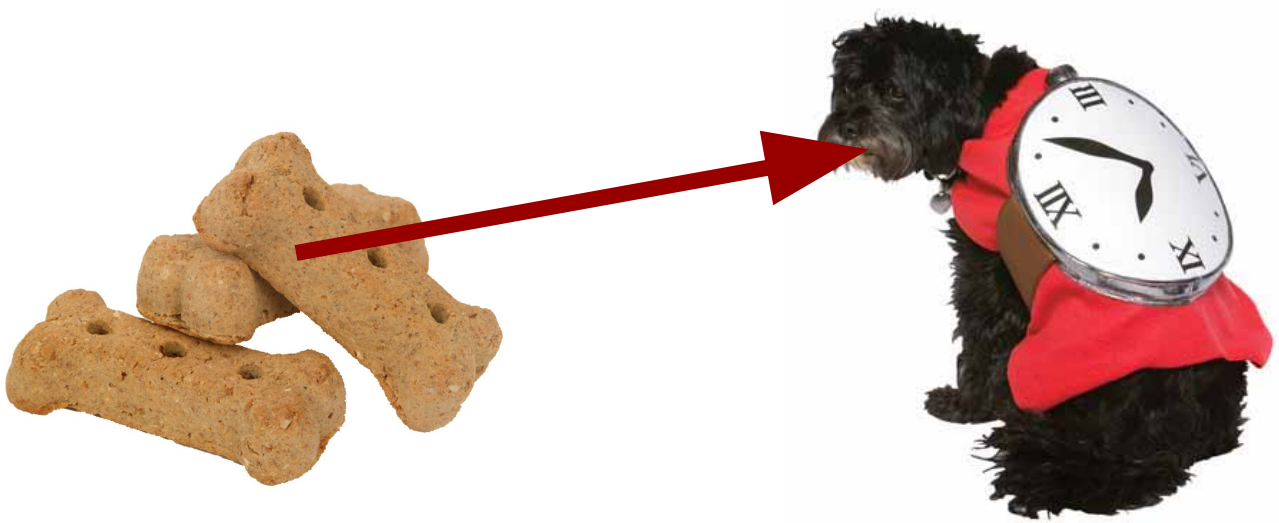
PacMan Software

- Debian 'Wheezy' Linux (Kernel 2.6.36)
- Updates from 2014 team’s code
  - Correct State of Charge algorithm
  - Reboot should not invalidate state of charge
  - Temperature adjustment for current-measuring shunt
- CAN communication with VSCADA

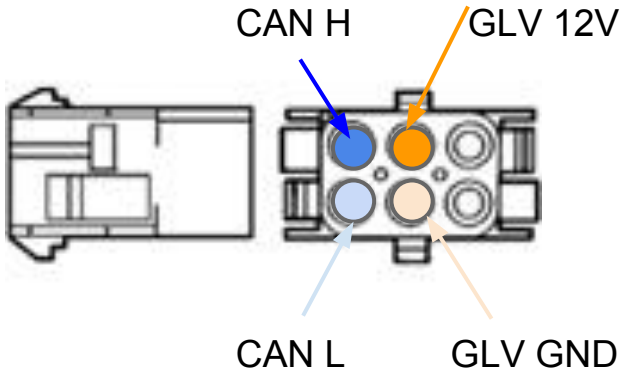
PacMan Safety Loop Control

- Safety loop opened in 3 different ways
  - Charger plugged
  - Watchdog timeout
  - CPU DIO02 pin for software control
- Watchdog fed by CPU DIO03 pin



VSCADA CAN Interface

- No longer RS-485, new isolated chip
- All 4 packs on the same main CAN line
- When address prompted, will return all relevant data to VSCADA



http://www.mouser.com/ProductDetail/TE-Connectivity-AMP/1-480705-0/?qs=OSEowtgdlxJxrUuPTLeZpA%3D%3D

Roadmap Cont.

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Charger-GENESYS 750W Half-Rack

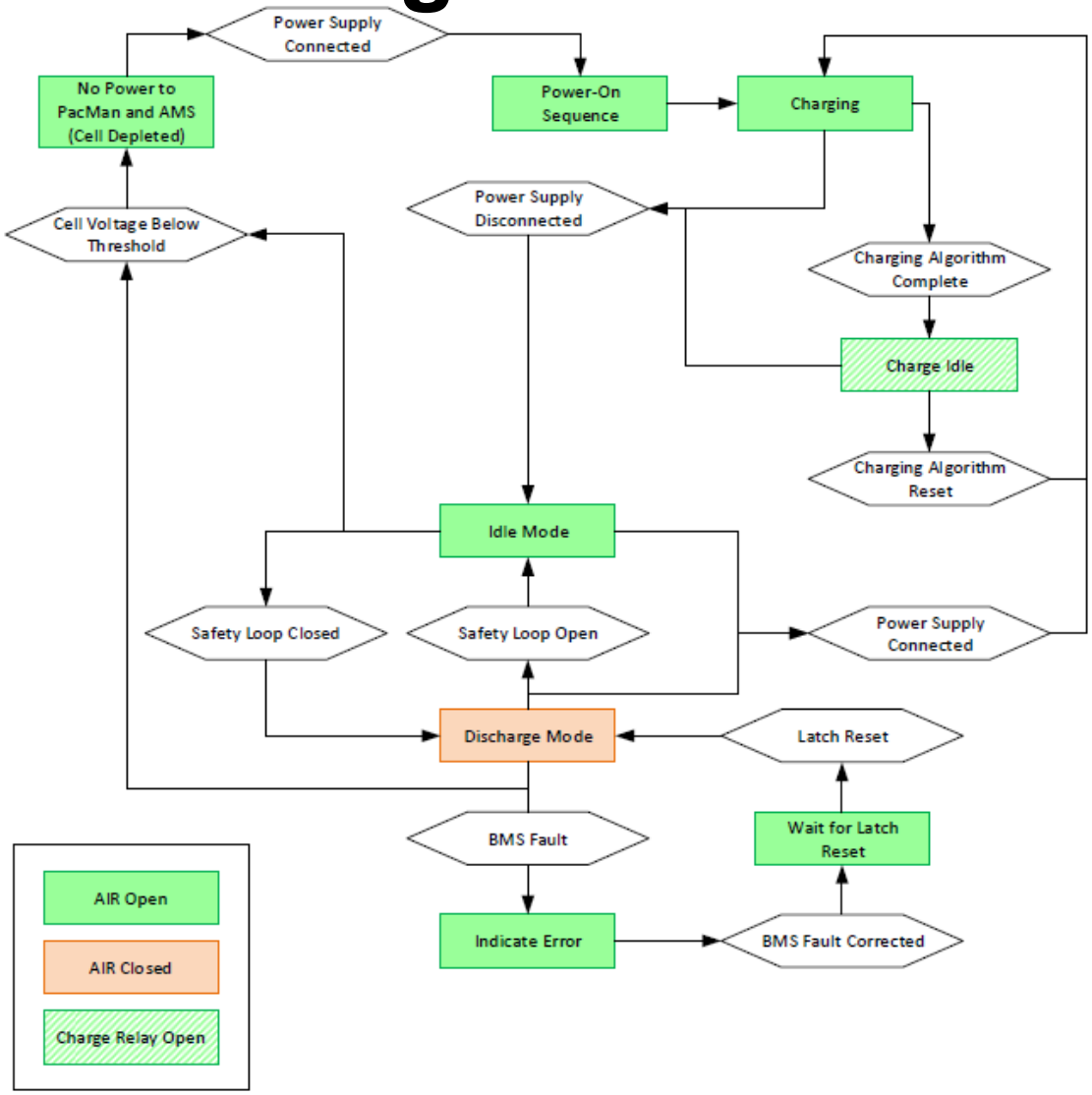
http://www.testoon.com/images_produit/009789-full.jpg

http://sites.lafayette.edu/ece492-sp14/files/2014/02/LFEV-ESCM-2014-UsersManual.pdf

Charging

- Anderson PowerPole connector used
  - Charge Detect
    - Charge Detect goes to BoB ends at PacMan
  - Charge +/-
    - Charge +/- go to charge relays
  - Safety Loop
    - Open when charging plug is plugged in
    - Closed when dummy plug is in charge port

Pack State Diagram



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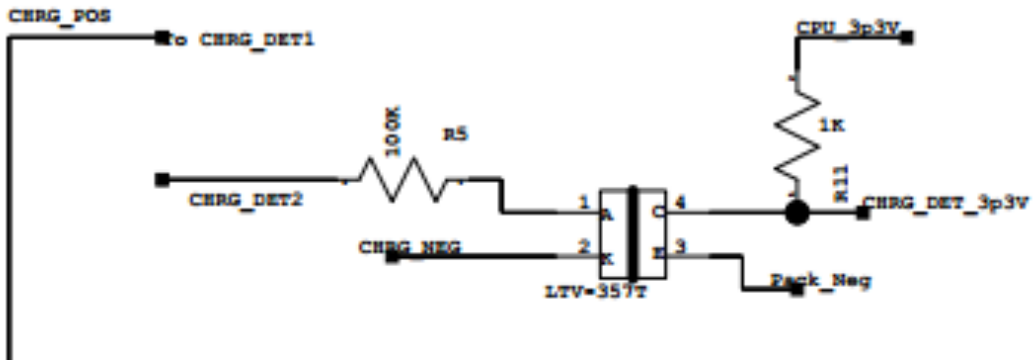
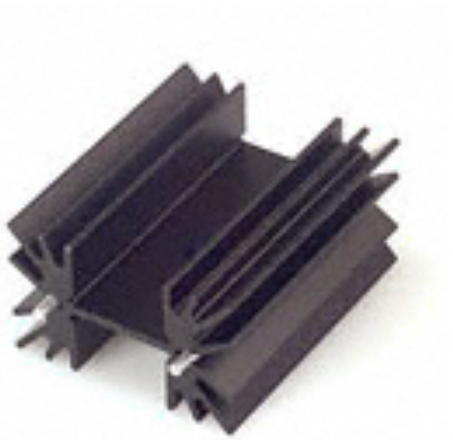
Charge Detect



- Charger creates electrical connection between CHRG_DET1 and CHRG_DET2
  - Pulls CPU DIO06 pin high through optoisolator

Cooling

- When bypassing cells, they get HOT
- When charger is plugged, fan switches on
  - Fan powered by charger to not deplete batteries
- Reducing heat sink to half height
  - Thermal resistance now 3.7 ℃/W @ 200 LFM
  - With 10.2W power, 37.74 ℃ rise



http://www.mouser.com/ProductDetail/ebm-papst/4414F/?qs=sGAEpiMZZMt8mcbdCMUjUxEnE1a%2fhD2SdPrUzYqJg8M%3d

http://www.digikey.com/product-detail/en/657-20ABP/345-1035-ND/340333?WT.z_cid=ref_octopart_dkc_buynow&site=us

Charge Relays

- We will be using a normally closed charge relay
  - This fixes previous error where pack was unchargeable when depleted
- Charging is finished when all AMS bypass
  - CPU DIO00 pin signals CHRG_TRIG to optoisolator for charge relays to open when charging is finished
- Using relay - OMRON MGN1C-DC24
  - SPDT - can wire to be NO or NC
  - 24V DC 30A

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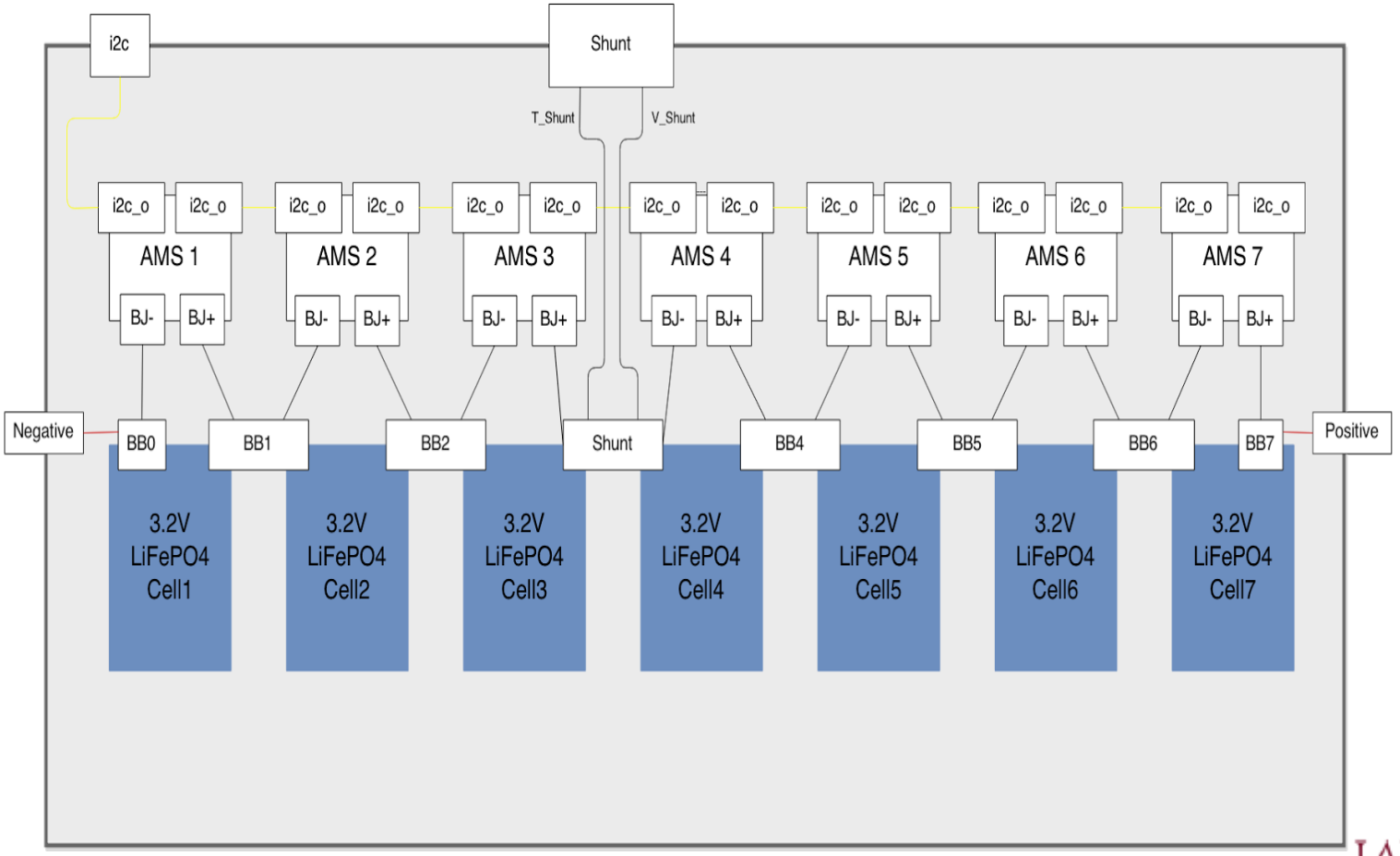
Accumulators and AMS



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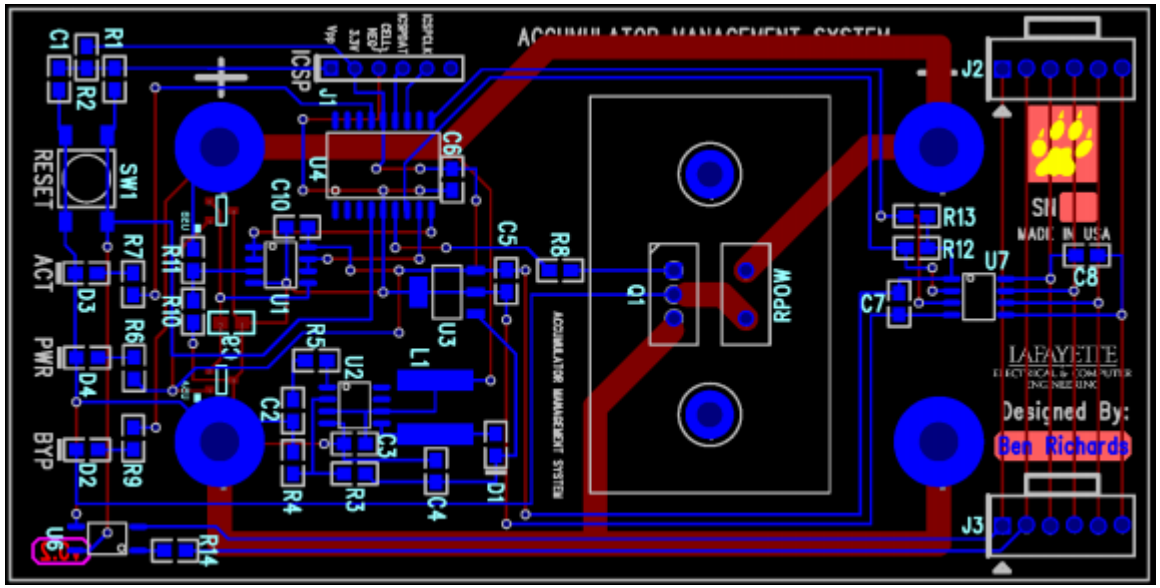
Accumulator Management System Board

- Boards monitor attributes of each assigned cell
  - Voltage levels
  - Current levels
- Ability to bypass cell during charging
- Reports back to PacMan through I^2C
- Board Reset
  - Software
  - Remote/Manual



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AMS Command List

Command #	Description	#Bytes Returned
0x 10	Gets the cell voltage	2
0x 11	Gets the cell temperature	2
0x 12	Gets the pack charging current	2
0x 13	Gets the pack discharging current	2
0x 14	Gets the bypass resistor switch state	2
0x 15	Gets the slave/board address	2
0x 16	Gets the software version	2
0x 17	Gets 0x0042(test command)	2
0x 18	Gets the bypass time in minutes	2
0x 19	Gets charging coulomb count as well as the number of times the charging current was summed	8*
0x 1A	Gets discharging coulomb count, as well as the number of times the discharging current was summed	8*
0x 1B	Gets cell voltage and temperature	4
0x1C	Gets the voltage, temperature and charging current of the cell	6
0x 1D	Gets the voltage, temperature and discharging current of the cell	6
0x 1E	Gets the time elapsed since the bypass switch has been set	6**
0x00	Sets the bypass switch state	n/a
0x 01	Sets the board address	n/a
0x 02	Sets the bypass time in minutes	n/a
0x 03	Calls the function to test the watchdog timer	n/a

Designed by 2013 Team.

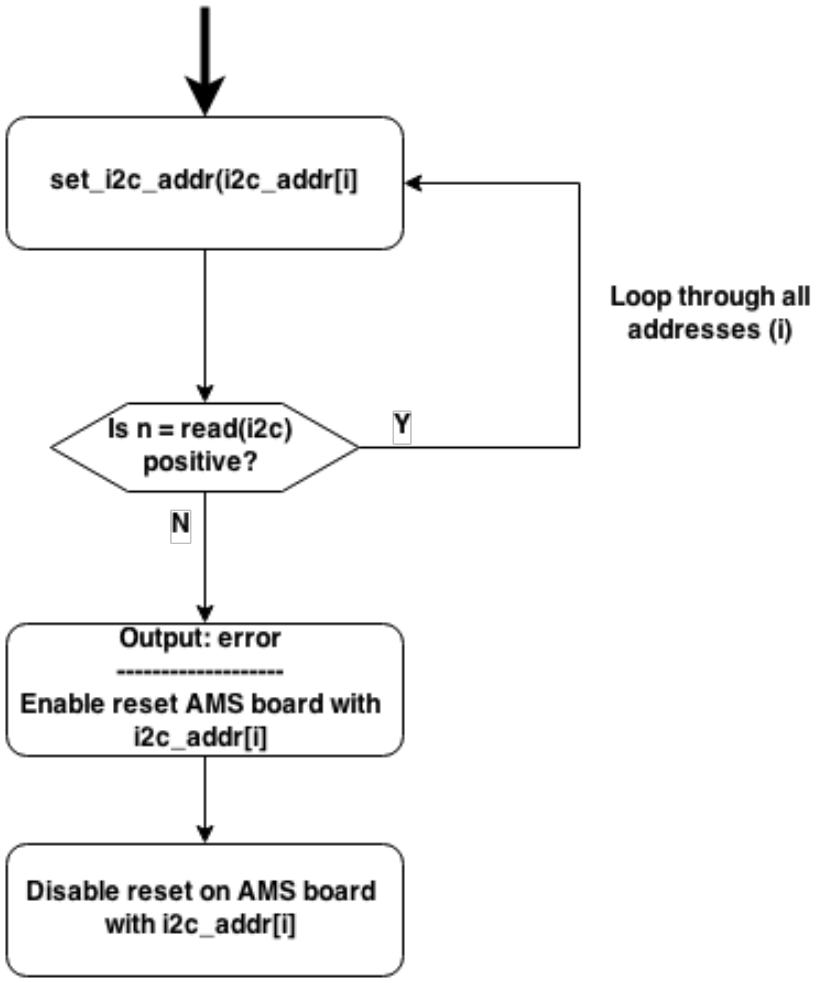
AMS Software Bug

- Bugs documented by LFEV-2013
  1. No constraint to force PacMan to wait until the AMS board has processed a request
     - Results: incorrect data readings on the first response
  2. Concurrency issues in memory: read/write collisions
     - Results: possible retrieval of unwanted data

- LFEV-2015 Goals
  1. Manipulate clocks so that no additional requests could be sent by PacMan until original request is processed.
  2. Implement constraints so that data cannot be read and written at the same time

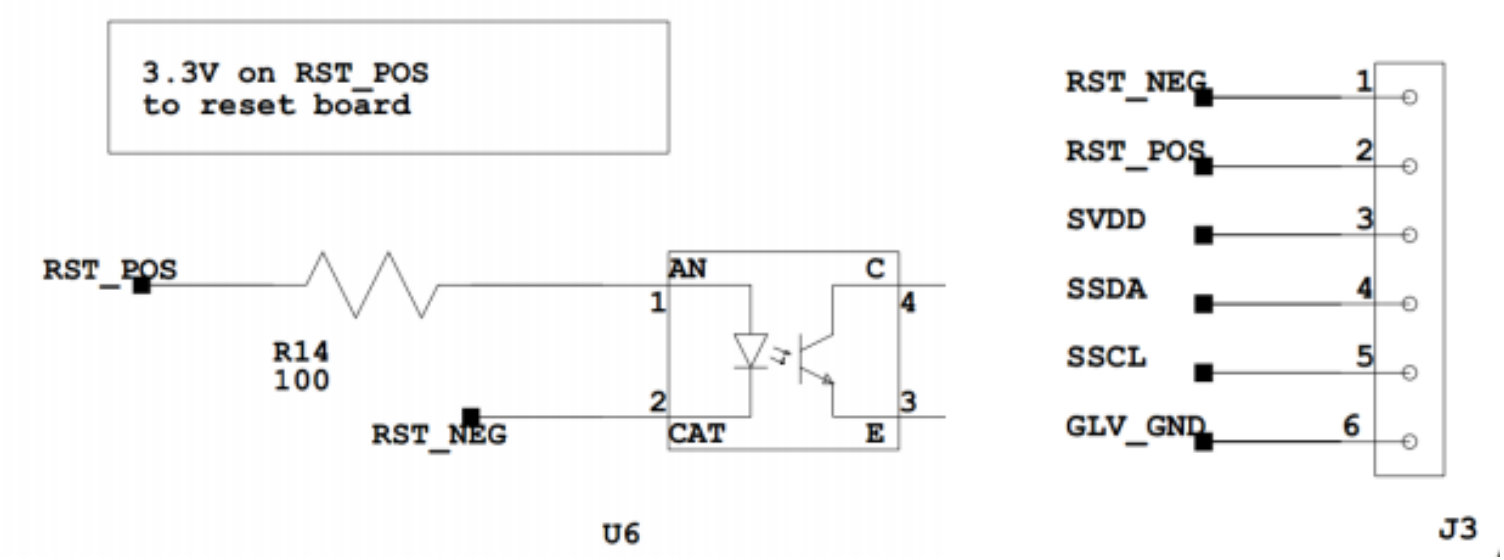
AMS Software Reset

- Initialization: PacMan will attempt to communicate with each board
  - Failed attempt → reset of that board
  - Error & Reset will display on Pack LCD



AMS Remote Reset

- LFEV 2014's Design → LFEV 2015 utilizing it
- Asserted by manual reset button through PacMan BoB



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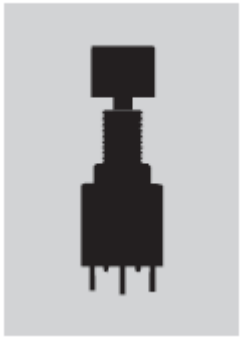
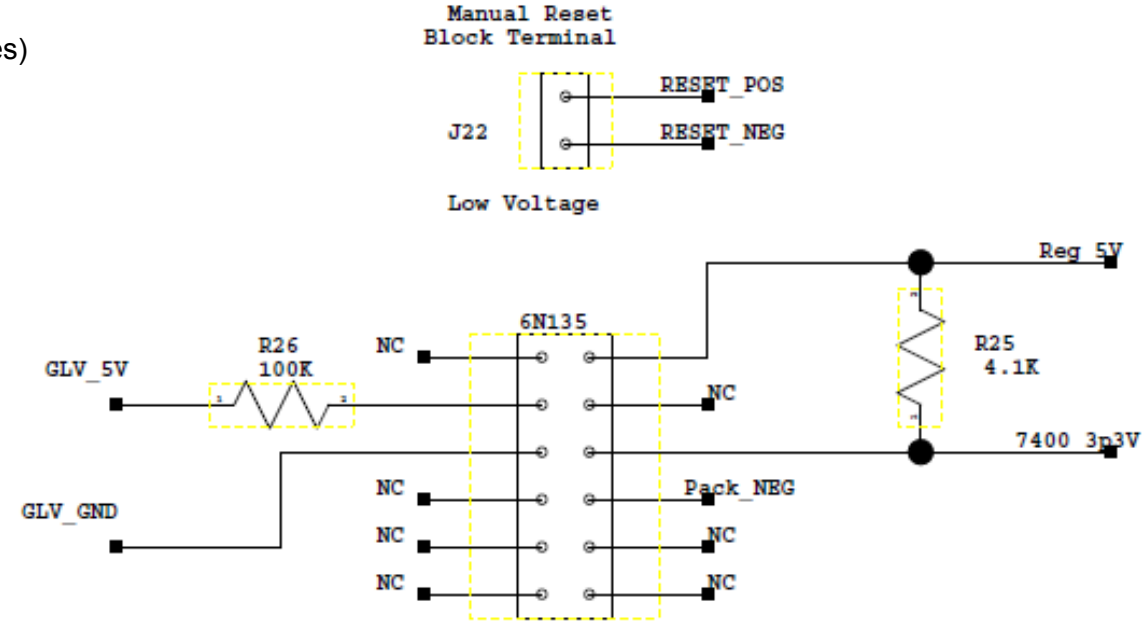
PacMan Breakout Board

- Acts as connector between TS-7400-V2 and the AMS boards and proper sensor relays
- Contains circuitry used for current, temperature, and pack voltage measurements
- Includes isolation chips to provide galvanic isolation between low and high voltage circuits

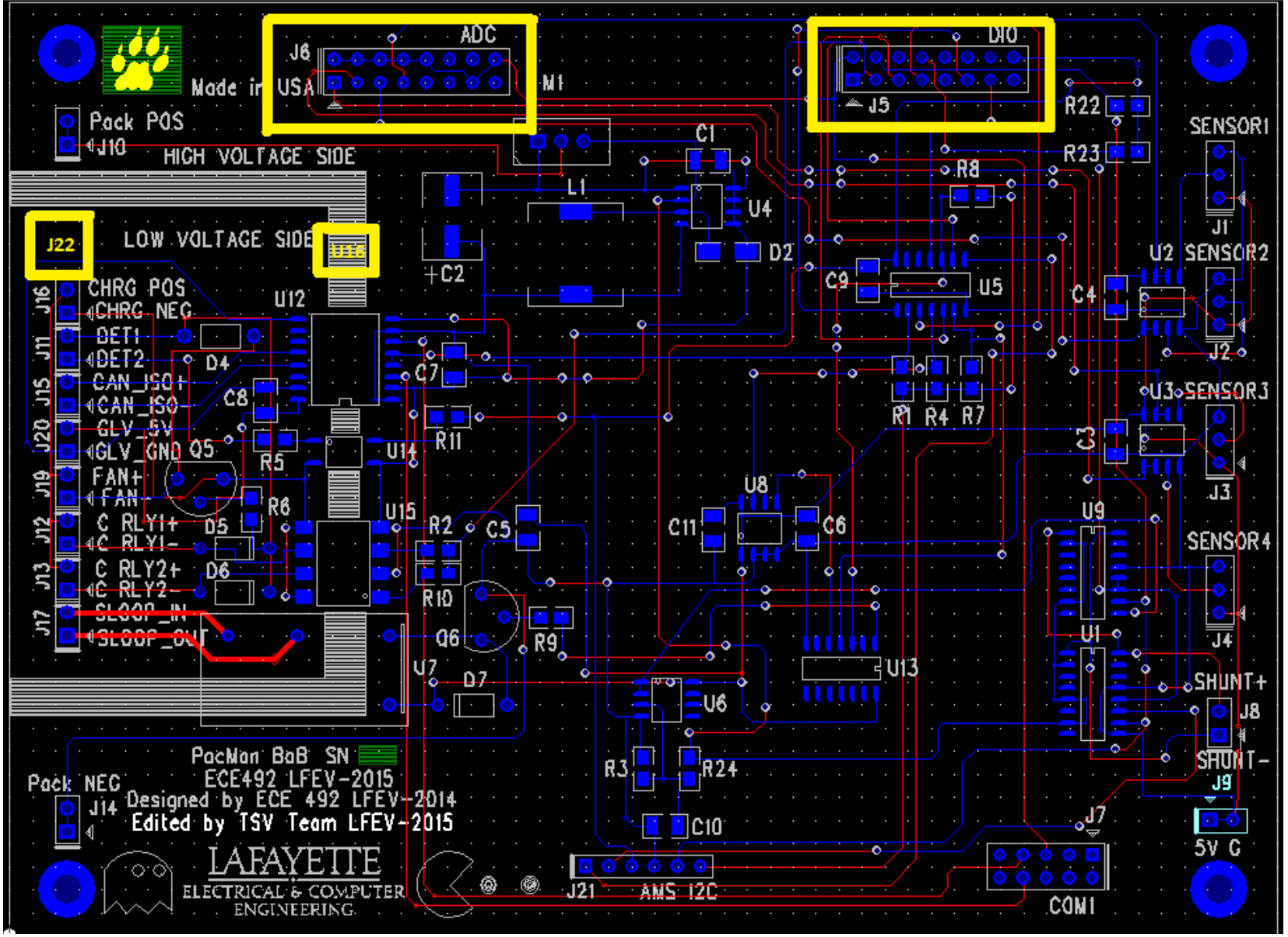
PacMan BoB Manual Reset

- MB2000 series switch pushbutton (NKK Switches)
  - RESET_POS
  - RESET_NEG
  - J22





- 6N135 high-speed optocoupler (Vishay Semiconductors)
  - U16



PacMan BoB Layout Errata

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Roadmap Cont.

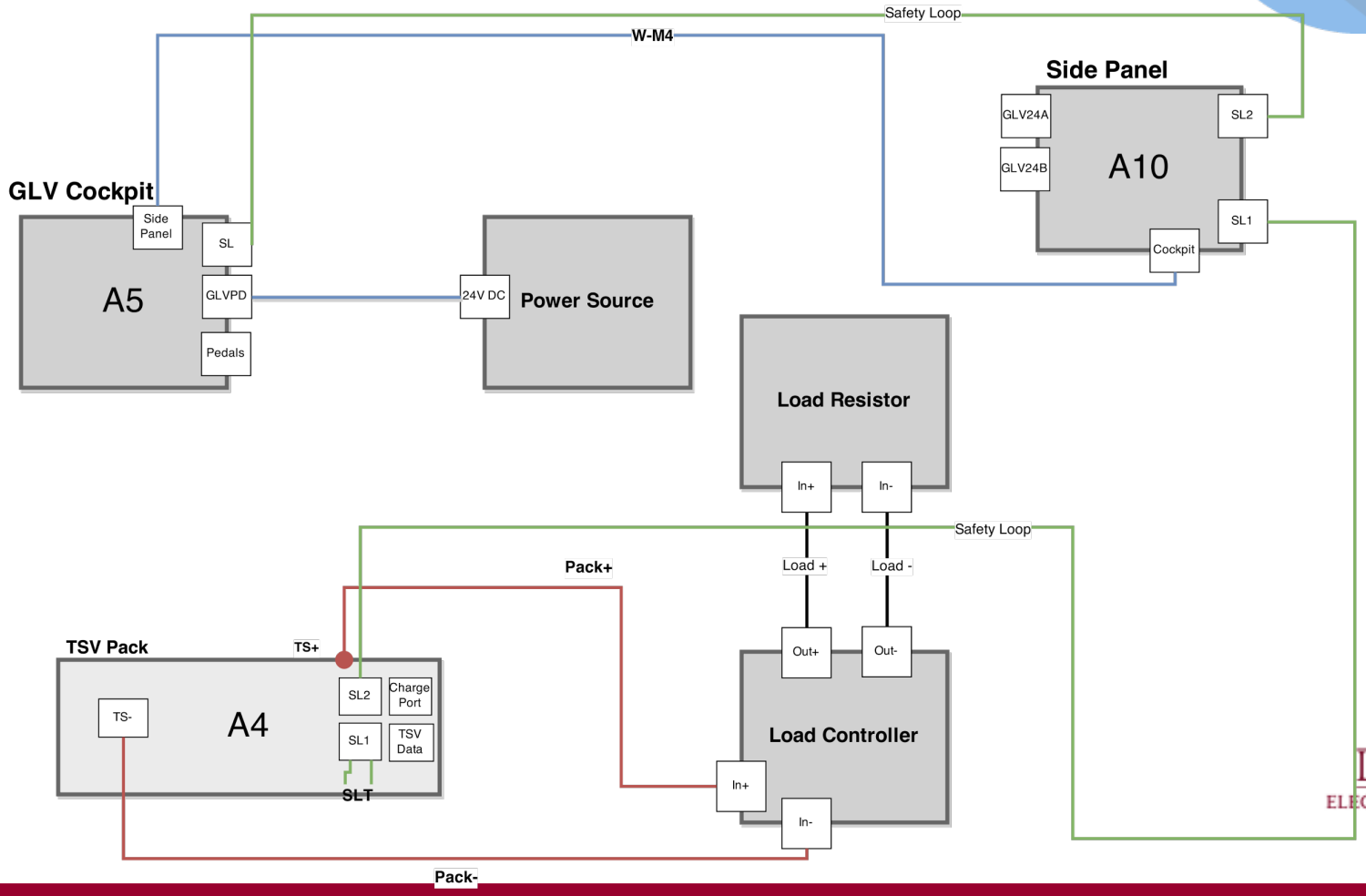
5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
    c. Mechanical
    d. PacMan System
    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. Out of Scope: LFEV-2016
7. Conclusion

Acceptance Testing

- Overview
  - Designed around requirements
  - Minimizing time and charge cycles needed
  - Repeatable for individual packs
- Focus
  - Safety
  - Plug-and-forget charging
  - Accuracy of measurands
  - New SoC algorithm

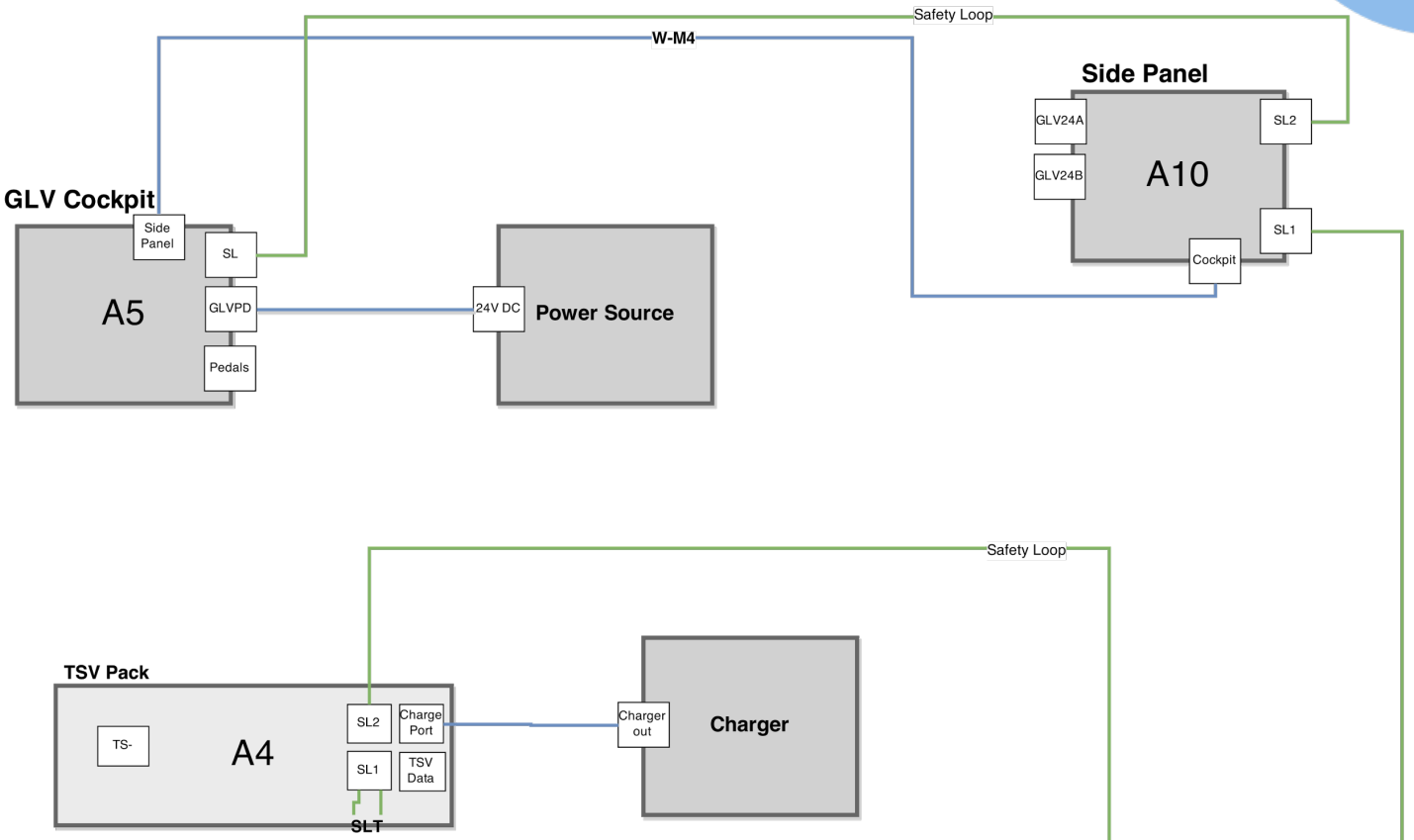
Acceptance Testing Cont.

- Test configuration A



Acceptance Testing Cont.

- Test configuration B



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Acceptance Testing Cont.

- T000: Pack Display and Safety Qualification
  - Prerequisite for all other tests
  - Configuration A
  - No active load
  - Measurement accuracy verification
  - Safety checks (isolation, sensor readings)
  - Controls/reset tests

Acceptance Testing Cont.

- T001: Low Current Discharge Test
  - Discharge cycle
  - Configuration A
  - Safety features tested (safety loop, low-voltage protection, temp/voltage sensors)
  - Un-balances cells for subsequent tests
  - Measurement accuracy verification
  - SoC tested

Acceptance Testing Cont.

- T002: Charge Cycle Test
  - Complete charge cycle
  - Configuration B
  - Charges at two different rates to test SoC
  - Safety loop tested
  - Measurement accuracy verification
  - Cell-balancing tested
  - Plug-and-forget feature tested

Acceptance Testing Cont.

- T003: High/low Current Discharge Test
  - Discharge cycle
  - Configuration A
  - Discharge at 3 different rates (high/low/paused)
  - Max current performance tested
  - Measurement accuracy verification
  - Safety features tested
  - SoC tested
  - Simulates real-life use case

Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
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Maintainability

- Hardware
  - MTTR = 1 day for most parts when spare parts on hand
  - MTTR < 8 days for most parts when no spare parts available
  - Full analysis in maintainability plan

Maintainability Cont.

- Software
  - PacMan software and AMS firmware
  - Source control
  - Backup/restore
  - Instructions for programming
  - Compatibility with VSCADA

TSV BOM & Budget

Total TSV Budget Required				
AMS	PacMan	BOB Parts	Pack Electrical Parts	Grand Total Budget
$430.38	$674.15	$223.75	$1,263	$2,590.95

Total Given Budget:	$2,739.10
Spent So Far:	$1,026.03
Remaining Budget:	$1,713.07

AMS

AMS (Accumulator Management System)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
1048778	Advanced Circuits PCB 30 AMS Boards	$8.32	30	$249.46
Mouser				
538-70543-0040	6-PIN SL Locking Header, tin-plate (J2, J3)	$0.74	20	$14.80
538-50-57-9706	6-PIN SL Locking Plug w/TPA (for J2, J3)	$0.75	20	$15.00
538-73838-0006	6-PIN SL TPA Piece (for J2, J3)	$0.26	20	$5.20
538-16-02-0096	SL Socket 24-30 AWG	$0.06	100	$6.00
567-657-15ABPN	TO-220 Vertical Board Mount Heatsink	$1.31	10	$13.10
652-PWR220T-20-R750F	TO-220 Resistor 20watt 0.75ohms 1% (RPOW)	$4.00	10	$40.00
567-173-7-220P	Thermal Interface Pad TO-220 .007" GRAY (for Q1, RPOW)	$0.42	17	$7.14
532-7721-7PPS	Insul Shoulder Washer (for No. 4 screw)	$0.18	15	$2.70
579-PIC16LF1827-I/SO	PIC16LF1827 8-bit Microcontroller (U4)	$1.72	8	$13.76
652-SRN8040-100M	SMD Inductor 10uH 20% (L1)	$0.39	20	$7.80
859-LTV-357T	Transistor Output Isolator (U6)	$0.19	20	$3.80
634-SI8600AB-B-IS	Silicon Labs Dual I2C Isolator Interface (U7)	$3.18	8	$25.44
579-MCP1825S-3302E DB	LDO Voltage Regulators 500 mA 3.3V (U3)	$0.51	9	$4.59
Digikey				
LT1307BCS8#PBF-ND	LT1307B	$2.75	4	$11.00
TIP102TU-ND	TRANS NPN DARL 100V 8A TO-220 (U2)	$0.73	1	$0.73
MCP9700AT-E/TTCT-ND	IC Sensor Thermal 2.3V SOT-23-3 (U5A, U5B)	$0.25	11	$2.75
MBR0520LCT-ND	Diode Schottky 20V 500MA SOD123 (D1)	$0.23	2	$0.46
MCP6242-E/SN	IC Opamp GP 550KHz PRO 8SOIC (U1)	$0.30	5	$1.50
655K-ND	Banana Plug	$1.72	3	$5.16
RMCF0805FT20K0CT-ND	20K 0805 SMD Resistor 1% 1/8W	$0.016	50	$0.81

AMS Total:	$430.38

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PacMan & BOB

PacMan (Pack Manager)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
TS-1400-V2-256-2048F-I-Dev	MicroComputer TS-7400-V2	$156	4	$663.00
908-MSD04GCS4P-1TM	Micro SD Card 4GB Class 10 Industrial	$10.54	4	$42.15
PacMan Total:	**$674.15**			

BOB (Breakout Board)				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
N/A	PCB for BOB boards	$10	6	$60
998-MIC4680-5.0YM	Switching Regulators 1.3A SuperSwitcher in SO-8 (Lead Free)	$4.23	3	$12.69
LTC4151CS-2#PBF-ND	IC CURRENT MONITOR(12BIT) 16SOIC	$5.55	4	$22.20
MCP6242-E/SN	Switching Regulators 1.3A SuperSwitcher in SO-8 (Lead Free) (also in AMS)	$4.23	5	$21.15
859-LTV-357T	Transistor Output Optocouplers (also in AMS)	$0.19	2	$0.38
584-ADM1232ARN	ADM1232 Watchdog Timer SOIC-8	$2.53	2	$5.06
849-LDA210S	LDA210 Dual Optoisolator/Darlington Pair SIP-8	$1.83	2	$3.66
771-HCT4002D118	Single 4 Input NOR/OR Gate SOIC-8	$0.50	2	$1.00
653-G6B-1114P-DC5	SPST 5V PCB Relay	$5.16	2	$10.32
ADM2483BRWZ	Half Duplex RS-485 Isolator	$6.84	2	$13.68
511-74LCX07YMTR	M74HC07 Hex Open-Drain Buffer SOIC-14	$0.52	2	$1.04
652-SRU1028-680Y	SMD Inductor 68uH 30%	$0.75	2	$1.50
P2N2222AGOS-ND	P2N2222A NPN BJT Transistor 600ma	$0.50	2	$1.00
621-B260A-F	B260A Schottky Diodes	$0.47	2	$0.94
512-1N4148	D1N4148 Diode Through Hole	$0.10	6	$0.60
810-C3216X5R1V226M	22uF SM Ceramic Capacitor 1206	$1.26	2	$2.52
598-AVE227M16X16T-F	220uF Electrolytic Capacitor Surface Mount 16V	$0.51	2	$1.02
538-70543-0013	Headers & Wire Housings 14 POS SHROUD HDR	$3.50	5	$17.50
538-50-57-9414	Headers & Wire Housings HSG 14P SINGLE ROW POSITIVE LATCH	$0.87	10	$8.70
517-D3408-6202-AR	16-PIN Shrouded Header	$1.99	3	$5.97
517-3452-6000	16-PIN Plug	$3.23	6	$19.38
517-D3793-6202-AR	10-PIN Shrouded Header	$1.44	2	$2.88
517-3473-6000	10-Pin Plug	$2.64	4	$10.56
BOB Total:	**$223.75**			

Pack Electrical Parts (page 1)

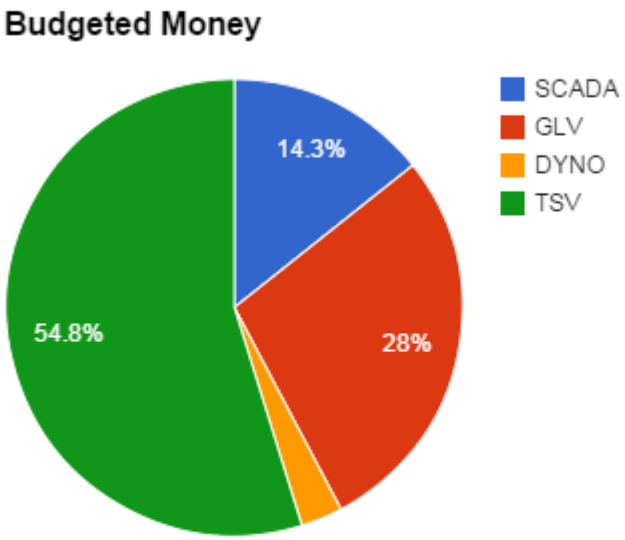
Pack Electrical Parts				
Vendor Part# / Order#	Description	Unit Price	QTY	Total Price
G3475534	Fuse, 200A, Class T, A3A, 300VAC/160VDC	$28.34	2	$56.68
G1878003	Fuse Holder, 200A AC, 300V, 1 Pole, Molded	$68.99	2	$137.98
504-BK/HKP-R	Cooper Bussmann AGC 30A/250V Fuse Holder	$4.72	6	$28.32
504-C10G0.5	Fuse, Bussman .5A/500V	$13.26	6	$79.56
5912-4414F	Fans 119x25 24DC 100CFM 5W 2900RPM 43dBA BB	$33.58	2	$67.16
562-0945030	Fan Accessories BLK FLTR ASSM 4.65"	$2.08	2	$4.16
562-09123-G	Fan Accessories PLASTIC GUARD 120MM	$1.21	3	$3.63
GX14CB	AIR - 350A Contractor, 24VDC coil, 24-in flying leads, no auxiliary contact	$94.35	1	$94.35
Waytek 124-903 124-11411	POWER RELAY CONTACTOR 24V 100A SPNO WHITE-RODGERS 124-903	$34.96	3	$104.88
Newark 44W4342	Panel Drain, Line 3, Grey	$74.10	2	$148.20
Newark 44W4365	Panel Source, Neutral, Blue	$50.62	2	$101.24
~~OFR0184~~	~~LCD Character Display Module STN Y/G~~	~~$23.00~~	~~4~~	~~$92.00~~
571-14807030	Pin & Socket Connectors CAP HOUSE 4 POS	$0.20	50	$10.00
571-14807050	Pin & Socket Connectors CAP HOUSE 6 POS	$0.32	50	$16.00
571-32950	Insul. Ring Terminal, 18 AWG, #6/M3 stud	$0.29	25	$7.25
538-19070-0121	Insul. Ring Terminal, 10-12 AWG, #8/M4 stud	$0.20	25	$5.00
571-35492	Insul. Ring Terminal, 12-10 AWG #1/4 /M6 stud	$0.56	10	$5.60
579-MCP9700A-E/TO-ND	Board Mount Temperature Sensors Lin Active Therm	$0.37	4	$1.48
517-9602207102AR	Headers & Wire Housings 20P SIDE ENT DR SKT	$3.18	3	$9.54
517-9602406303AR	Headers & Wire Housings 40P STR SR BDMNT SKT 3.5MM TAIL/8.5MM BODY	$4.85	3	$14.55
879-1470G1	Heavy Duty Power Connectors PP PAK 2-4P HSG SNAP-IN RECEPT	$2.10	4	$8.40
879-1327FP	Heavy Duty Power Connectors PP15/45 FINGERPROOF HOUSING ONLY, RED	$0.85	3	$2.55
879-1327G6FP	Heavy Duty Power Connectors PP15/45 FINGERPROOF HOUSING ONLY, BLACK	$0.82	3	$2.46
879-269G1-LPBK	Heavy Duty Power Connectors PP30 HD LOOSE CONT #12-16 AWG	$0.70	3	$2.10
879-4827G6	Heavy Duty Power Connectors PPMX 2-PIECE BLACK HOUSING ONLY	$0.80	3	$2.40
879-261G2	Heavy Duty Power Connectors PP45 REELED CONTACT #10-14 AWG, TIN	$0.16	25	$4.00

Pack Electrical Parts (page 2)

571-5550521	Ethernet Connectors 8 COUPLER IN-LINE	$7.02	2	$14.04
651-5602099	15mm DIN Rail Perf	$9.64	1	$9.64
651-3100305	MT1.5 Feed-Thru DIN Rail Terminal Block	$2.62	20	$52.40
651-3001682	MT1.5 Twin DIN Rail Terminal Block	$4.62	3	$13.86
651-3100318	MT1.5 PE Ground Din Rail Terminal Block	$8.42	1	$8.42
651-3100321	MT1.5 End Plate	$0.78	3	$2.34
651-3002979	MT1.5 Twin End Plate	$1.34	3	$4.02
651-1402940	MBK5/EZ Feed-Thru DIN Rail Terminal Block	$3.15	6	$18.90
651-1415021	MBK5/EZ End Plate	$0.97	2	$1.94
651-1421659	DIN 15 End Clamp	$1.28	4	$5.12
298-G75X75LG72-ND	Wire Ducting TYPE G .75 X .75 6-FOOT SECTION	$28.56	1	$28.56
651-1725711	Fixed Terminal Blocks 8P 2.54mm 90DEG	$5.40	2	$10.80
651-1725656	Fixed Terminal Blocks 2P 2.54mm 90DEG	$1.42	3	$4.26
651-1725669	Fixed Terminal Blocks 3P 2.54mm 90DEG	$2.16	4	$8.64
571-3506891	Pin & Socket Connectors SOCKET 24-18 AWG	$0.085	100	$8.50
571-3506901	Pin & Socket Connectors PIN 24-18 AWG	$0.088	100	$8.80
538-16-02-0096	SL Socket 24-30 AWG	$0.10	100	$10.00
651-3001624	FBRN 10-4 N Fixed Bridge (10 Position)	$7.90	1	$7.90
298-C75LG72-ND	Wire Ducting COVER 3/4" 6-FOOT SECTION	$8.46	1	$8.46
651-0203250	FBI10-6 Fixed Bridge for 6.2mm DIN blocks	$9.86	1	$9.86
782-ILD755-1X017	Transistor Output Optocouplers Photodarlington	$2.77	4	$11.08
156-1409-E	D-SUB CRIMP FEMALE 9P	$0.56	2	$1.12
156-1401-E	D-SUB CRIMP PIN FM	$0.10	20	$2.00
164-9007-E	IDC SOCKET 14 PIN W/STRAIN RELIEF	$0.65	2	$1.30
164-9008-E	IDC SOCKET 16 PIN W/STRAIN RELIEF	$0.61	2	$1.22
Pack Electrical Total:	**$1,262.67**			

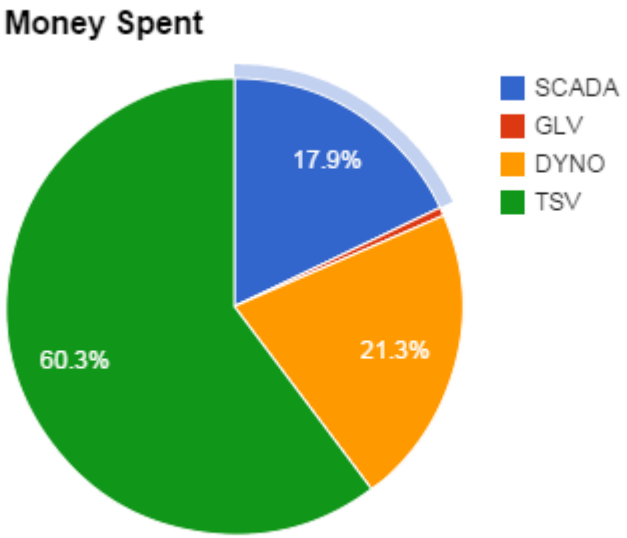
Budget

- Initially allocated money:
  - Dyno - $148
  - SCADA - $715
  - GLV - $1397.90
  - TSV - $2739.10



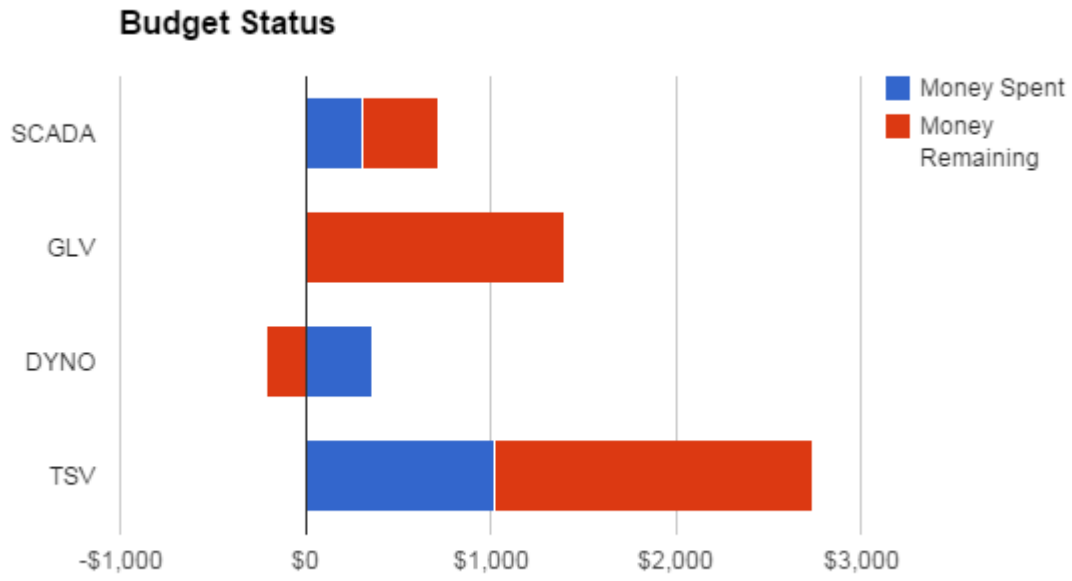
Budget

- Money Spent so far
  - Dyno - $362
  - TSV - $1026.03
  - SCADA - $304.26
  - GLV - $10.24



Budget

Current status of money:



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Roadmap Cont.

5. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
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    e. Charging
    f. AMS
    g. BoB
    h. Acceptance Testing
    i. Maintenance
6. **Out of Scope: LFEV-2016**
7. Conclusion

Out of Scope: LFEV-2016

- GLV
  1. Implement AIR failure sensors
  2.

Out of Scope: LFEV-2016 Cont.

- TSV
  1. Implement AIR failure sensors
  2. Low voltage indicator light
  3. Building 4 complete packs

Roadmap

6. Tractive System Voltage (TSV)
    a. Overview
    b. Safety
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6. Out of Scope: LFEV-2016
7. **Conclusion**

Conclusion