Electric Formula SAE 2020-21

Easton, Pennsylvania 18042-1775

LAFAYETTE COLLEGE

Lafayette College 2020-2021 FSAE Formula One Hybrid Team

TD015 Top-Level Laboratory Test Plan

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Electrical System Specifications

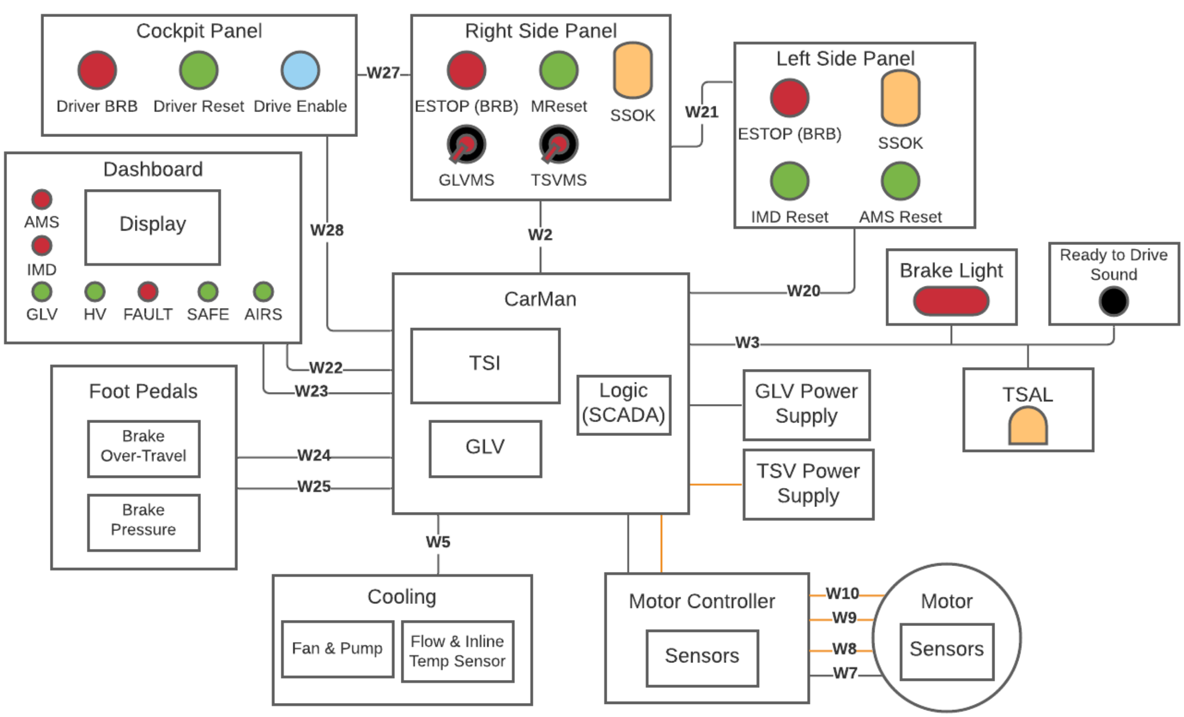
This Laboratory Test Plan is intended to be performed on the 2020-2021 Lafayette Motorsports completed electrical systems within the Dyno Room. This electrical system consists of the Battery Packs, CarMan (Car Manager), SCADA (Supervisory Control and Data Acquisition), EPAL (External Panels and Lights), Interconnect, and Cooling subsystems. The system is powered by two Accumulator Packs fit with 16 cells in each. The TSV from the Battery Packs is distributed by CarMan throughout the car to the motor, motor controller, and throughout the safety loop. All dashboard indicators, external lights, and SCADA are powered through the GLV battery provided by CarMan. The CarMan contains the safety loop which sets off indicators within the Dashboard to indicate what error occurred within the electrical system. SCADA helps monitor all electrical components of the electrical system to track and report any errors or warnings and communicate with each subsystem. The electrical system will operate a EMRAX 208 motor with an emDrive 500 motor controller, both of which are water cooled.

Test Setups

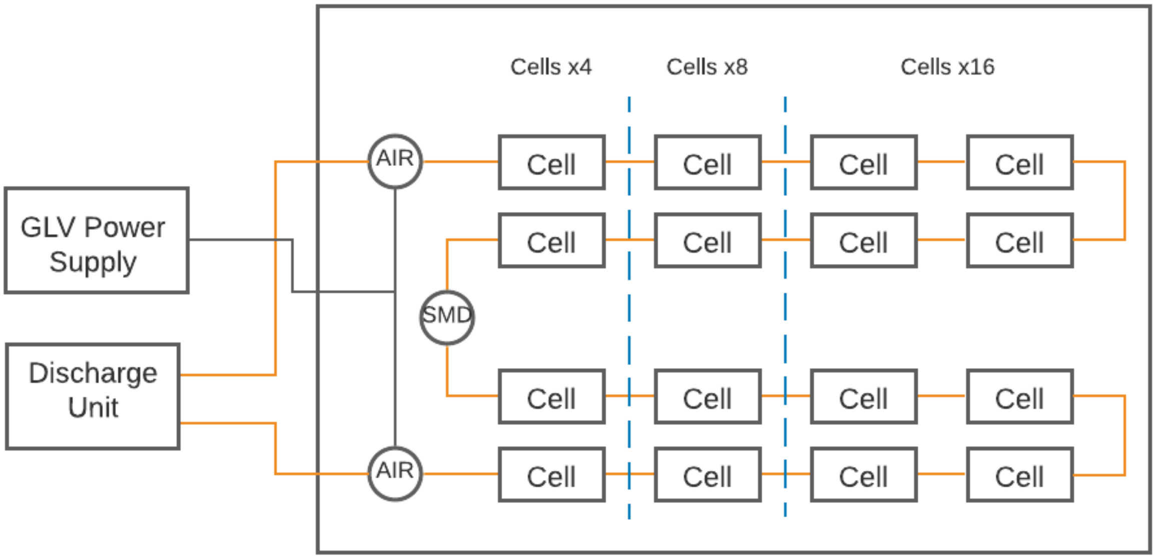
Dyno Setup

Test Procedures: 1.1-1.11, 3.2-3.5, 5.1-5.7, 6.1-6.3

Equipment Needed: CarMan Boards, SCADA, Side Panels, Cockpit Panel, Dashboard, Motor, Motor Controller, Cooling, Foot Pedals, Brake Lights, RTDS, TSAL, GLV Power Supply, TSV Power Supply, Voltmeter, Thermometer, Ohmmeter, W2,3,5,7,8,9,10,20,21,22,23,24,25,27,28

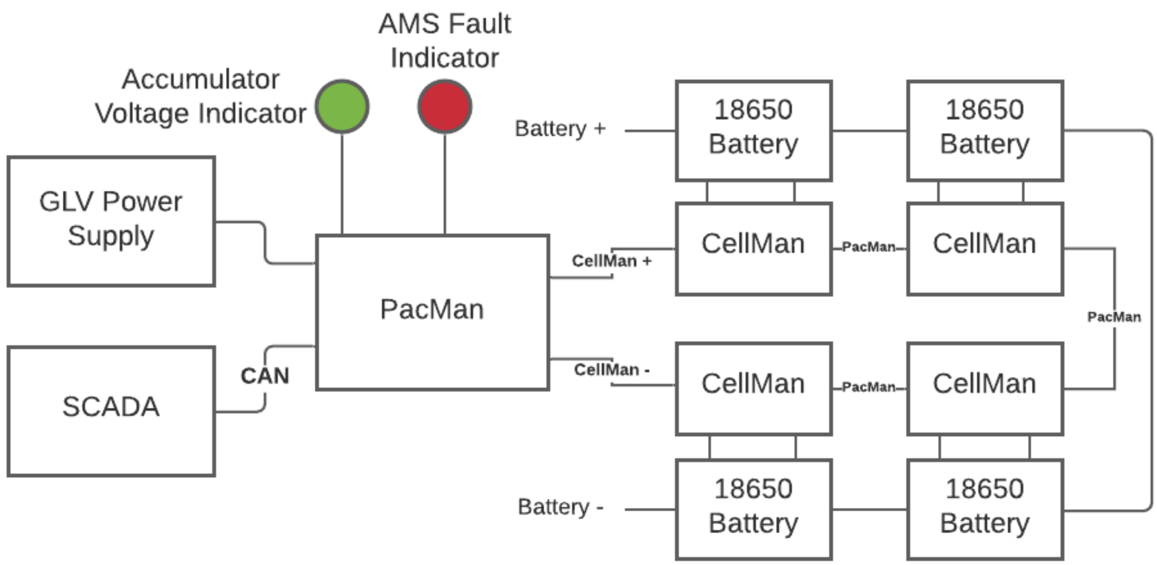


Mechanical Prototype Test Setup
Test Procedures: 2.2,2.6
Equipment Needed: Mechanical Pack, GLV Power Supply, Discharge Unit, multimeter



*Blue dividing lines for test setup of 4, 8, and 16 cells

Electrical Prototype Test Setup
Test Procedures: 2.1,2.3,2.4,2.5,2.7,2.8
Equipment Needed: PacMan, CellMen, Voltmeter, Thermometer, GLV Power Supply



Rules & Procedures Summary

This document outlines all requirements outlined by the SOW (Statement of Work) as well as the FSAE Competition Rules Document (General Technical Requirements, Electrical Powertrain and Systems Rules). Each test indicates the test number that fulfills and checks these requirements. If the requirement is not tested within the ATP, explanation within another document or manual is required. Inspection should be shown in the Inspection Report (IR), linked below. This is where any photographs or explanation of how an inspection meets the requirement. Failed requirements are also noted so that future teams can understand what needs to be accomplished. Any measurements must have their uncertainty evaluated through NIST 1297 Type A uncertainty. Below is the calculation of the standard deviation as well as standard deviation of the mean.

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

Standard Deviation

$$u(x_i) = s(\bar{X}_i) = \left(\frac{1}{n(n-1)}\sum_{k=1}^{n}(X_{i,k} - \bar{X}_i)^2\right)^{1/2} .$$

Standard Deviation of the Mean

Example:

X.X Example Test
Description: This is an example to show where the rules will be within each test procedure.
Requirements Met: TX.X.X, EVX.X.X
Pass Criteria & Results:

A. "Requirements Met" houses all applicable rules and requirements P/F

Test Conducted By:____ Date:________________

Inspection Report:
https://docs.google.com/document/d/1OLuwVKZNTRxtrKJslT_GB_C_6Rzoiq5asJ-xIGFwSZM/edit

Requirement Prefixes

TX.X.X - FSAE General Technical Requirements
EVX.X.X - FSAE Electrical Powertrain and Systems

Failed Requirements & Notes

These requirements will not be passed this year or these are notes to future teams.

Requirement	Reasoning
EV2	Must be rechecked with fully integrated pack
EV3.2.3	Wires in CarMan not marked
EV9.5	Not completing rain testing
EV11.3	Look at battery removability plan

Metzgar Test Plan

This document is for any test that could not be completed within the Dyno, however can on the integrated car.

Link:
https://docs.google.com/document/d/1Q5tANatClfTDh0CODmMlxrENsk0gJ19ARNh7J0ACNaU/edit

Laboratory Test Procedures

1. State Transitions

Test state transitions and safety loop to ensure car startup and shutdown is safe.

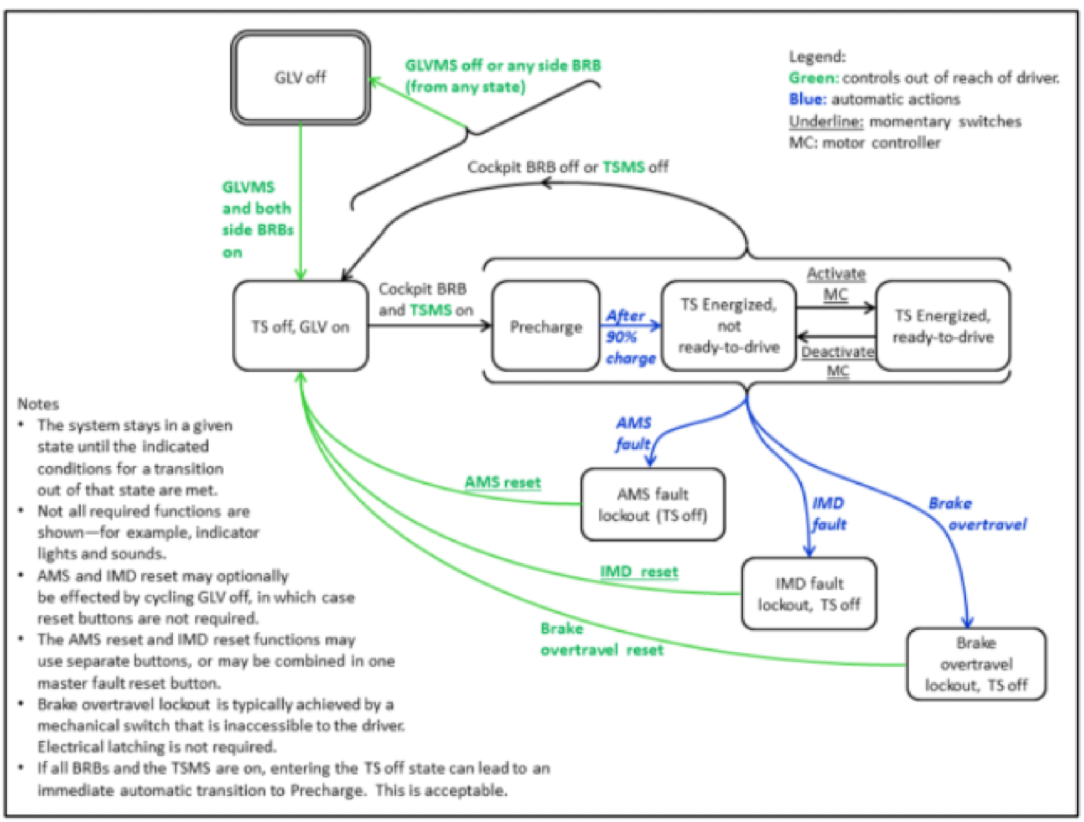


Figure 41 - Example Shutdown State Diagram

1.1 GLV Startup (GLV off and TSV off, to GLV on)
Description: Starting with everything open, close both BRBs and GLVMS. Ensure that the 3 circuit breakers on the carman enclosure are closed. For the GLV measurement STD is calculated in procedure 3.4.
Requirements Met: EV2.8.1,EV2.10.1,EV,2.11.1,EV6.4.2,EV6.8.1,EV6.8.2, EV6.9
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. GLV light, screens, Fault light activates if only both BRBs and GLVMS are closed P/F
B. GLV voltage reads 20V-24V on the CarMan Voltmeter* P/F
C. TSV not activated (reads 0V on voltmeter) P/F
D. Throttle does nothing P/F

*Calculations done based on length of safety loop indicate 18V would be okay, but 20V is safe minimum

Test Conducted By:____ Date:________________

1.2 Precharge to TS Energized (not ready to drive)
Description: After TSMS is on, MC+ should reach at least 95% TSV before the precharge circuit is closed. Begin with start up procedure 1.1, and after GLV is confirmed on and operational, put the system into precharge and then into TS energized (not ready to drive). Press the IMD/AMS reset buttons, then close the Side Panel MReset, CPBRB, CP Reset, and lastly the TSMS. Record voltage over time for the tractive system and motor controller.
Requirements Met: EV2.10, EV2.11.1, EV6.8.2, EV8.1, EV8.3.4, EV6.9
Measurement: Make plot of voltage over time within the precharge circuitry. Use an oscilloscope to measure TSV via the TSMPs and on the second channel, measure MC+ by connecting directly to the motor controller.
Pass Criteria & Results:

A. MC+ reaches 95% TSV P/F
B. Precharge Relay closes once MC+ reaches 95% of TSV, and then MC+ reaches TSV P/F
C. Opening cockpit BRB does not allow MC+ to be at least 95% TSV P/F
D. Opening TSMS does not allow MC+ to be at least 95% TSV P/F
E. SSOK & Dashboard SAFE light stays on after shutdown via cockpit BRB/TSMS P/F
F. Throttle does not activate motor P/F

Test Conducted By:____ Date:________________

1.3 TS Energized NRTD to Ready to Drive
Description: Conduct Procedure 1.3. Press down brake pedal (90% to not trip overtravel) and hold the drive button for one second at the same time as the break. The system should enter drive mode which means the car is ready to drive and motor activatable.
Requirements Met: T7.4, EV2.10.4, EV6.8.2, EV6.9, EV8.2
Pass Criteria & Results:

A. SCADA indicates on Pi display in RTD P/F
B. Brake light turns on when brake pressed P/F
C. Drive button light turns on after pressed P/F
D. System should enter drive mode (throttle can move motor) P/F
E. Ready to drive sound plays (Procedure 1.11 for details) P/F

Test Conducted By:____ Date:________________

1.4 Ready to Drive to Not Ready to Drive

<u>Description:</u> After the system is ready to drive (Procedure 1.4), pressing the brake and drivers button should transition the car into not ready to drive mode. The driver should not be able to run the motor at this time.

<u>Requirements Met:</u> T7.4, EV6.8.2, EV6.9,

<u>Pass Criteria & Results:</u>

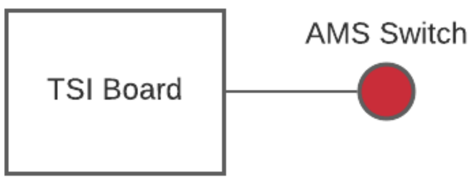
A. Pressing the brake pedal turns brake lights on P/F
B. Pressing the drivers button turns driver button light off P/F
C. System transitions into not ready to drive (throttle cannot move motor) after both the brake and drive button are pressed P/F

Test Conducted By:____ Date:________________

1.5 AMS Fault (SLOOP)

<u>Description:</u> Complete car startup procedure. Using the methods listed below, simulate an AMS fault using the attached switch. Pressing the CPReset does not reactivate TSV. This should be tested in all energizing states. This test will be completed in the Dyno without the AMS, however a fault will be simulated through a switch. The switch is connected to TSI's J12.3 and J12.4.

<u>Test Setup:</u>



This switch will simulate the signal from the PacMan board, as the PacMan will not be connected to the Dyno to complete this test. The AMS testing can still be completed as these tests are what the system does in response to the fault.

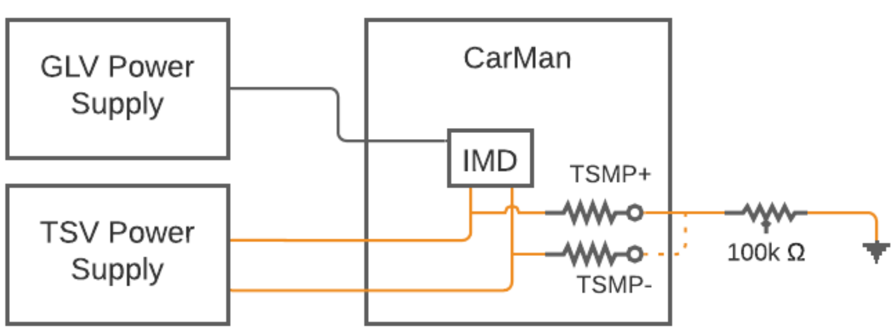
<u>Requirements Met:</u> EV2.8.2, EV2.11.2, EV2.11.3, EV2.11.10, EV6.2.5, EV6.9, EV8.3.3, EV8.6, EV9.4

Equipment Needed: Voltmeter
Pass Criteria & Results:

A. AMS Fault In TS Energized NRTD — P/F
   a. AIRs open after fault trip (AIRs indicator is off) — P/F
   b. AMS fault light turns on and must be manually reset — P/F
   c. SSOKs & Dashboard SAFE light turn off when tripped — P/F
   d. Nothing occurs when pressing CPReset — P/F
   e. TS deactivated after fault — P/F
   f. TS shutdown (TSAL off) & GLV lights must occur within 60 sec — P/F
B. AMS Fault In TS Energized Drive State — P/F
   a. AIRs open after fault trip (AIRs indicator is off) — P/F
   b. AMS fault light turns on and must be manually reset — P/F
   c. SSOKs & Dashboard SAFE light turn off when tripped — P/F
   d. Nothing occurs when pressing CPReset — P/F
   e. TS deactivated after fault — P/F
   f. TS shutdown (TSAL off) & GLV lights must occur within 60 sec — P/F

Test Conducted By:_______________________________________ Date:________________

1.6 IMD Fault
Description: Complete car startup procedure. Connect 100k potentiometer between TSMPs (Tractive System Measuring Points) and ground to trigger an IMD fault. Identify the IMD trip point. Verify that it does not exceed 500Ohm/Volt. See Figure 43 in EV 9.1 for further clarification. This shall be tested in every state. The standard deviation of the mean shall be calculated here over all test points.
Requirements Met: EV2.8.2, EV2.11.3 EV6.2.5, EV6.9, EV6.10, EV8.3.3, EV8.4, EV9.1
Equipment Needed: Voltmeter, 100k Potentiometer
Test Setup:



Pass Criteria & Results:

A. TS Energized NRTD:
   a. HV+ TSMP

i. Trip point >=29k P/F
ii. TS shuts down within 30 seconds of fault on P/F
iii. IMD fault light turns on P/F
iv. Tractive System does not reenergize after removing resistor P/F
v. SSOKs & Dashboard SAFE light turn off P/F
vi. AIRs Open (Voltage Across AIRs reads 0V on voltmeter and AIRs indicator is off) P/F

b. HV- TSMP
   i. Trip point >=29k P/F
   ii. TS shuts down within 30 seconds of fault on P/F
   iii. IMD fault light turns on P/F
   iv. Tractive System does not reenergize after removing resistor P/F
   v. SSOKs & Dashboard SAFE light turn off P/F
   vi. AIRs Open (Voltage Across AIRs reads 0V on voltmeter and AIRs indicator is off) P/F
c. Cockpit Reset cannot reenergize tractive system P/F

B. TS Energized RTD:
   a. HV+ TSMP
      i. Trip point >=29k P/F
      ii. TS shuts down within 30 seconds of fault on P/F
      iii. IMD fault light turns on P/F
      iv. Tractive System does not reenergize after removing resistor P/F
      v. SSOKs & Dashboard SAFE light turn off P/F
      vi. AIRs Open (Voltage Across AIRs reads 0V on voltmeter and AIRs indicator is off)
      P/F
   b. HV- TSMP
      i. Trip point >=29k P/F
      ii. TS shuts down within 30 seconds of fault on P/F
      iii. IMD fault light turns on P/F
      iv. Tractive System does not reenergize after removing resistor P/F
      v. SSOKs & Dashboard SAFE light turn off P/F
      vi. AIRs Open (Voltage Across AIRs reads 0V on voltmeter and AIRs indicator is off)
      P/F
   c. Cockpit Reset cannot reenergize tractive system P/F

Test	Resistance 1	Resistance 2	Resistance 3	Resistance 4	Resistance 5
Precharge +					
Precharge -					

NRTD +					
NRTD -					
RTD +					
RTD -					

Standard Deviation of the Mean Calculation:

Test Conducted By:______________________________________ Date:________________

1.7 Brake Overtravel Fault
Description: Follow car startup procedure. Flip the brake overtravel switch in every state. Wait 10 seconds and flip switch again, TS should not reactivate.
Requirements Met: T7.8, EV2.8.2, EV2.11.3, EV3.5.9, EV6.2.5, EV6.9, EV8.3.3
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. TS Energized NRTD:
   a. SSOKs & Dashboard SAFE light turn off after fault trip P/F
   b. AIRs open (AIRs indicator is off) after fault tripped P/F
   c. TS remains inactive after switch back on (TSAL Off) P/F
B. TS Energized RTD:
   a. SSOKs & Dashboard SAFE light turn off after fault trip P/F
   b. AIRs open (AIRs indicator is off) after fault tripped P/F
   c. TS remains inactive after switch back on (TSAL Off) P/F
   d. Motor free spinning after fault P/F

Test Conducted By:______________________________________ Date:________________

1.8 GLVMS/Side BRBs
Description: In any state, opening the GLVMS or Side BRBs will shut down the entire electrical system including GLV and TSV.
Requirements Met: EV2.11.1, EV2.11.3, EV 6.2.2, EV6.4.1, EV6.6.4
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. GLV On, TS Deactivated:
   a. GLV deactivated (screens turn off, GLV light off) P/F
B. TS Energized NRTD:
   a. GLV deactivated (screens turn off, GLV light off) P/F
   b. AIRs Open (AIRs indicator is off) P/F
   c. SSOK & Dashboard SAFE light,TSAL Light Off P/F
C. TS Energized RTD:
   a. GLV deactivated (screens turn off, GLV light off) P/F

b. AIRs Open (AIRs indicator is off) P/F
c. SSOK & Dashboard SAFE light,TSAL Light Off P/F

Test Conducted By:_______________________________________ Date:_______________

1.9 TSMS/Cockpit Reset

Description: In any TSV active state, opening the TSMS or Cockpit Reset will shut down the TS.
Requirements Met: EV2.11.1, EV2.11.3, EV 6.2.2, EV6.5.1, EV6.6.4, EV6.7.3, EV6.7.4
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. TS Energized NRTD:
    a. SSOK & Dashboard SAFE light light stays on P/F
    b. TSAL,AIRs light turns off P/F
    c. AIRs Open (AIRs indicator is off) P/F
    d. TSV voltage reads 0V with Voltmeter P/F
B. TS Energized RTD:
    a. SSOK & Dashboard SAFE light light stays on P/F
    b. TSAL,AIRs light turns off P/F
    c. AIRs Open (AIRs indicator is off) P/F
    d. TSV voltage reads 0V with Voltmeter P/F

Test Conducted By:_______________________________________ Date:_______________

1.10 Master Reset

Description: After a fault is tripped, pressing the master reset, IMD reset, and AMS reset buttons should return the system to GLV on state. Cockpit reset must also not be able to reset IMD,AMS, brake overtravel fault.
Requirements Met: EV2.11.3, EV6.2.5, EV6.9, EV6.7.10
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. AMS Fault
    a. TSV remains off (TSAL Off) P/F
    b. CPReset does not reset system P/F
    c. AMS light turns off P/F
    d. Reset buttons reactivate system P/F
B. IMD Fault
    a. TSV remains off (TSAL Off) P/F
    b. CPReset does not reset system P/F
    c. IMD light turns off P/F
    d. Reset buttons reactivate system P/F
C. Brake Overtravel
    a. TSV remains off (TSAL Off) P/F

b. CPReset does not reset system P/F
c. Reset buttons reactivate system P/F

Test Conducted By:____ Date:________________

1.11 Ready to Drive Sound
Description: When the RTDS sounds it must generate a tone between 1000-3500Hz, and have 80dB loudness at 2m away.
Requirements Met: EV8.2.2
Equipment Needed: Frequency & Loudness Meter Phone App
Pass Criteria & Results:

A. Tone is between 1000-3500Hz P/F
B. At 2m away it is at least 80dB P/F

Test Conducted By:____ Date:________________

2. Accumulator Test Procedures

The accumulator will be tested out of the dyno room separately from the rest of the system. This will be broken down into the Mechanical Prototype and the Electrical Prototype. This is the level of progress we hope to achieve by the end of the semester.

2.1 Opening Accumulator AIRs (Electrical Prototype)
Description: Whenever the AIRs are opened the TS must drop to under 30V in less than 5 seconds. AIRS will be opened by turning off the GLV power supply.
Requirements Met: EV2.8.3
Equipment Needed: Voltmeter
Pass Criteria & Results:

A. TS voltage drops below 30V (measured with voltmeter) in less than 5 seconds P/F

Test	Time to Drop Below 30V (sec)
1	
2	
3	

Test Conducted By:____ Date:________________

2.2 HVD Test (Mechanical Prototype)
Description: It must be possible to disconnect HVD without the use of tools.
Requirements Met: EV2.9.1-EV2.9.4
Pass Criteria & Results:

A. No tools used P/F
B. Current path interrupted P/F

Test Conducted By:____ Date:________________

2.3 AMS Voltage Measurements (Electrical Prototype)

Description: Use a power supply bench as a voltage input. Conduct trials with supplied voltages ranging from 0-7.7V* with an increment of 1V.

Repeat trials twice for each board tested under every voltage supplied and calculate standard deviations in all sets of trials using standard deviation equation in the Rules & Procedures.
Compare the calculated sample means in all sets of trials with readings from a voltmeter.
Voltage readings can be verified by SCADA as well.

Requirements Met: EV1.2, EV2.11.4

Equipment Needed: Power Supply Bench, Voltmeter.

Pass Criteria & Results:

A. AMS voltage reading has an error of ∓____mV at 1st standard deviation within ____V voltage testing range.

Results:

Supplied Voltage (V)	**CellMan Voltage Reading(V)**				**CellMan Voltage Reading Mean(V)**	**Voltmeter Reading (V)**	**Voltage Error (mV)**	**1st STD Dev Error (mV)**
	Serial Num: 103	Serial Num: 104	Serial Num: 105	Serial Num: 106				
0								
1								
2								
3								
4								
5								

6								
7								
7.7								

*Theoretical Calculations done based on amplifier gain, bias, pin, adc limitation specifications. Narrow down the range according to actual test results if only dramatic error appears at boundary conditions.

Test Conducted By:____ Date:________________

2.4 AMS Temp Measurements (Electrical Prototype)

Description: Use a heating device to create different ambient temperatures, and attach a thermometer to reach desired ambient temperatures. Conduct trials with supplied temperatures ranging from 25-65℃ with an increment of 10℃. Repeat trials twice for each board tested under every temperature supplied and calculate standard deviations in all sets of trials using standard deviation equation in the Rules & Procedures.

Compare the calculated sample means in all sets of trials with readings from a thermometer, and record the errors. Temperature readings can be verified by SCADA as well.

Requirements Met: EV2.11.5

Equipment Needed: Heating Device, Thermometer.

Pass Criteria & Results:

A. AMS temperature reading has an error of ∓____℃ at 1st standard deviation within ____℃ temperature range.

Results:

Supplied Temp (℃)	**CellMan Temp Reading(℃)**				**CellMan Temp Reading Mean (℃)**	**Thermo meter Reading (℃)**	**Temp error (℃)**	**1st STD Dev Error (℃)**
	Serial Num: 103	Serial Num: 104	Serial Num: 105	Serial Num: 106				
25								
35								
45								

55								
65								

Test Conducted By:____ Date:_________________

2.5 Accumulator Voltage Indicator (Electrical Prototype)

<u>Description:</u> When in a state of greater than 30VDC on the vehicle side of the AIRs (measured with a voltmeter), the AVI must be lit.

<u>Requirements Met:</u> EV8.5

<u>Equipment Needed:</u> Voltmeter

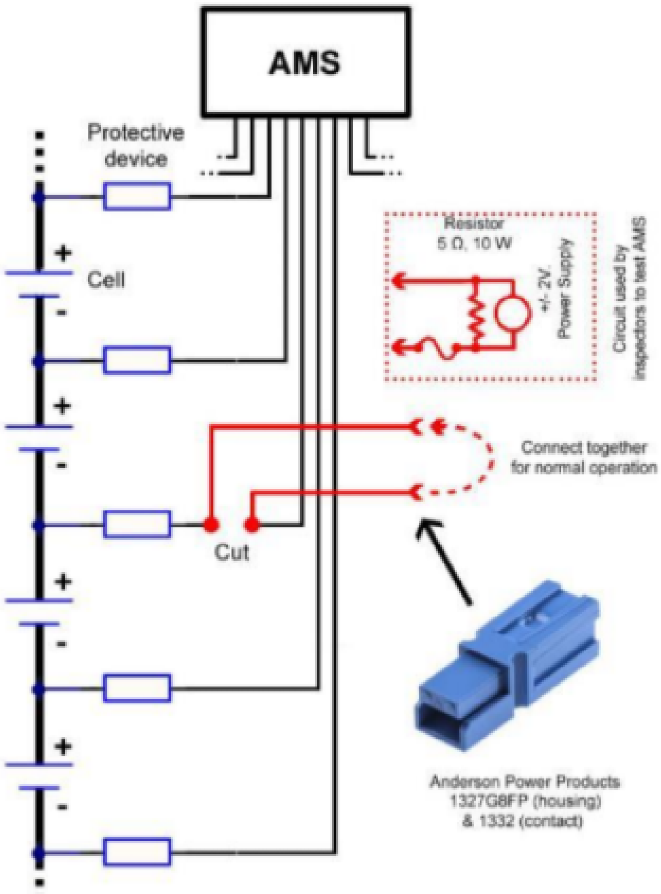
<u>Pass Criteria & Results:</u>

A. When greater than 30VDC on vehicle side of AIRs AVI is lit P/F
B. AVI is not lit whenever vehicle side of AIRs is below 30VDC P/F

Test Conducted By:____ Date:_________________

2.6 AMS Shutdown (Electrical Prototype)

<u>Description:</u> This is the supplemental AMS test with the real AMS. After detecting a critical voltage or temperature through simulation, the AMS can send a signal to shut down the TS. This signal will light an LED. This will ensure that the signal would be sent to CarMan if triggered. The test method used will be varying AMS software setpoints so that actual cell voltage is above or below the trip limit.



Requirements Met: EV2.11.2
Equipment Needed: LED (For signal)
Pass Criteria & Results:

A. LED turns on after a fault is detected P/F

Test Conducted By:____ Date:________________

2.7 Watchdog Timer Functionality (Electrical Prototype)

Description: This test will demonstrate that the watchdog timer functions properly. A crash of the microcontroller will trigger the watchdog timer, such as the crash caused by no I2C device detected by the microcontroller. The watchdog will automatically reset the ESP32 after a certain period of time.
Requirements Met: EV2.11.9
Pass Criteria & Results:

A. After microcontroller detects no I2C, microprocessor is reset P/F

Test Conducted By:____ Date:________________

2.8 Total Pack Voltage (Mechanical)

Description: Measure the total pack voltage over all cells. This will be done in the mechanical prototype without the AMS. Make sure all limits in the table are not exceeded.

Formula Hybrid voltage and energy limits	
Maximum operating voltage[9] (TSV)	300 V
Maximum GLV	30 VDC or 25 VAC
Maximum accumulator segment voltage	120 V
Maximum accumulator segment energy[10]	6 MJ

Equipment Needed: High Voltage Voltmeter, Discharge Unit

Pass Criteria & Results: EV1.2

A. Maximum operating voltage does not exceed 300V P/F
B. Maximum accumulator segment voltage does not exceed 120V P/F
C. Maximum accumulator segment energy does not exceed 6 MJ P/F

Test Conducted By:____ Date:________________

2.9 Total Pack Current (Mechanical)

Description: Measure the total pack current over all cells with a 2C discharge rate. This will be done in the mechanical prototype without the AMS. The standard deviation of this value will be calculated. (Discharge of 2C is used within ESF-2)

Equipment Needed: High Voltage Ammeter, Discharge Unit

Pass Criteria & Results:

A. Total pack current 60A at 2C P/F

Test #	Current (A)
1	
2	
3	
4	
5	
Standard Deviation	

Test Conducted By:____ Date:________________

3. TSV/GLV Test Procedures

3.1 Grounding Test

Description: Any metal part of the car must have a resistance below 300mΩ to GLV ground. This will be measured using an ohmmeter. Non-metal parts containing conductive material components must have a resistance below 100Ω to GLV ground. If the two-wire meter does not meet requirements, use a four-terminal setup. Standard deviation must be calculated for each location.

Requirements Met: EV2.4.5, EV7.1.1, EV7.1.2

Equipment Needed: Ohmmeter

Pass Criteria & Results:

A. Conductive Parts < 300mΩ to GLV System Ground
   a. Carman Enclosure P/F
   b. Left Side Panel P/F
   c. Right Side Panel P/F
   d. Accumulator Enclosures P/F
   e. Pedals P/F
B. Non-Conductive Parts < 100Ω to GLV System Ground
   a. TSI PCB P/F
   b. GLV PCB P/F
   c. Logic PCB P/F

Location	Resistance 1	Resistance 2	Resistance 3	STD	Test Used
CarMan Enclosure					
Left Side Panel					
Right SIde Panel					
Accumulator Enclosure					
Pedals					
TSI PCB					
GLV PCB					
Logic PCB					

Test Conducted By:______________________________________ Date:________________

3.2 Insulation Measuring Test

Description: TSMP and Ground MP are connected together via a resistor
Requirements Met: EV9.1, EV9.2
Equipment Needed: Resistors
Pass Criteria & Results:

A. IMD Test: Measure TSV. A fault resistance of at most TSV x 250ohm/volt causes the tractive system to shutdown within 30 seconds from when the fault resistance was applied P/F
B. Insulation Test: Measure the tractive system with 250V. The measured insulation resistance between TSV and control system ground must be at least 125K Ohms (500ohm/volt x 250V) P/F

Test #	Resistance
1	
2	
3	
4	
5	
STD	

Test Conducted By:____________________________________ Date:_______________

3.3 Acceleration Error Checking & Torque Control

Description: Verify torque control via the motor controller is disabled if a fault in throttle plausibility is detected. Any fault should move the car out of the DRIVE state in less than one second.
Requirements Met: EV3.5.4, EV3.5.5
Pass Criteria & Results:

A. Detection of open and short circuits across both accelerator pedal sensors P/F
B. Ensure both accelerator pedal sensors are within 90% of their range of travel. (Turn the Apps1 and Apps2 pots. Have jumpers on the “auto” pins. Use the meter for Apps2 to ensure that it is within 90%-0.24V to 4.76V) P/F
C. Ensure both accelerator pedal sensors are within 5 volts of each other (throttle plausibility board has jumpers on the “auto” pins) P/F
D. Ensure torque control is stopped less than one second after an error is detected P/F

Test Conducted By:____________________________________ Date:_______________

3.4 Maximum Voltage

Description: Through analysis, show the max TSV is under 300V and the GLV is under 30VDC or 25VAC. This should be shown in the Inspection Report. Standard Deviation should also be examined.

Requirements Met: EV1.2, EV4.1.1

Equipment Needed: High Voltage Voltmeter

Pass Criteria & Results:

A. TSV is under 300V P/F

B. GLV is under 30VDC P/F

# Test	GLV Voltage (V)
1	
2	
3	
4	
5	
STD	

# Test	TSV Voltage (V)
1	
2	
3	
4	
5	
STD	

Test Conducted By:____ Date:_________________

3.5 Closing AIRS

Description: The GLV must be capable of closing the AIRS under a full GLV load. A full GLV load consists of GLV powering CarMan, the dashboard, SCADA, cockpit panel, PacMan boards, CellMan boards, brake lights, TSAL, and Cooling. The voltage drop versus time as the AIRS are

closing should also be measured utilizing a scope and be plotted. This must be tested first with the GLV power supply then the actual GLV battery.
Requirements Met:
Equipment Needed: Voltmeter, Timer, Oscilloscope
Pass Criteria & Results:

A. AIRS close at full GLV load P/F
B. GLV Voltage remains 24V +-2V* P/F

Plots at Locations:
AIRs:
Positive Terminal of GLV Battery:
SL Circuit Breaker:
General Circuit Breaker:
Cooling Circuit Breaker:

*This standard deviation is calculated in procedure 3.4

Test Conducted By:____ Date:________________

3.6 TSV Path Resistances

Description: Resistances along bolted paths of TSV must be under 100u Ohms. Overall TSV system resistance must also be measured. This will be accompanied with photographs of measured locations in the inspection report and a spreadsheet to calculate resistance. Standard deviation of the mean should be calculated in this instance.
Requirements Met: EV3.4
Equipment Needed: Ohmmeter
Pass Criteria & Results:

A. All resistances are under 100u Ohms P/F

Resistance Spreadsheet:
https://docs.google.com/spreadsheets/d/1jLFoGKBQibfCwU41cMZMI9bL-WNEOhqNEI2KPa5X9mI/edit#gid=0

Test Conducted By:____ Date:________________

3.7 Brake Electronics

Description: Verify that the foot pedal electronics operate correctly and accurately. This test will be completed with potentiometer linkages.
Equipment Needed: Power Supply, Multimeter
Pass Criteria & Results:

A. Resistance of foot pedal matches potentiometer, no give in the linkages P/F

Test Conducted By:____ Date:________________

4. SCADA

General Dyno Room SCADA Test Procedures:

The following are steps the user should follow or look out for when running the SCADA software on the Dyno Room Raspberry Pi.

1. Power on the Dyno Room Pi which should already have the SCADA software installed on it and verify that the Graphical User Interface (GUI) which displays the real time sensor information starts up on boot.
2. By default the sample rate of the slowest sensor is five seconds, so it's advised to wait at least for 10 seconds upon boot to allow for each sensor to display live information.
3. To allow for faster sampling for sensors defined in the configuration file, SSH into the Dyno Room Pi, change the directory to `~/SCADA_2021/config/` and execute the command `sudo nano config.yaml` and change all the sensor period declarations to 2 seconds . `Ctr + X` and save to buffer . Run the `sudo bash make` file to update the binary files with the newly updated configuration file and run the GUI by running the following bash command in terminal :
   ```
   cd ~/SCADA_2021/GUI
   Python3 MainGUI.py
   ```
4. Sensor values should be updating on the real time GUI within the newly specified sensor period. The Real Time Clock (RTC) can also be seen ticking on the GUI along with the other sensors.
5. To test if the data pipeline is functioning correctly, verify that the two redis channels storing raw and calculated data are being populated with values. Open up two terminals and run the following bash commands each.

   Terminal 1 :
   ```
   $ redis-cli
   SUBSCRIBE raw_data
   ```
   Terminal 2:
   ```
   $ redis-cli
   SUBSCRIBE calculated_data
   ```
6. Verify that the PostgreSQL database is populated with calibrated information for each scada session. Type the following bash commands in a new terminal:
   ```
   psql test
   select * from data order by timestamp desc;
   ```
   This will show all calibrated sensor data from newest to oldest
7. Shut down the system and verify that it successfully does so.

Detailed Dyno Room SCADA Test Procedures:

Before running the following tests, properly install and set up the SCADA system on a Raspberry Pi 3B using the installation procedure described in GPR-007.

4.1 SCADA System Start on Boot Test
Description: Check if the system starts on boot and all files are appropriately functioning
Pass Criteria:

A. SCADA GUI and EPAL dashboard start on respective displays on boot
B. Measure time between GLV power on and full availability of SCADA and check that it is less than 1 minute 30 seconds (estimated max. time for SCADA startup).

Results:

A. Pass/Fail
B. Pass/Fail

Test Conducted By:____ Date:________________

4.2 SCADA System Kiosk Mode Test
Description: The System should be taking up the full display and the OS should not be visible or accessible.
Pass Criteria:

A. No system alerts, screensavers, or OS dialog boxes should be displayed while using SCADA. Test for 30 minutes of active use.
B. The user should be unable to exit the GUI on the Carman enclosure without the use of a keyboard. If a keyboard is plugged into the SCADA Raspberry Pi, the user can press ctrl + alt + F1 to exit the GUI.
C. The entire carman enclosure display and the driver display should be covered by the system GUI for SCADA and EPAL respectively.

Results:

A. Pass/Fail
B. Pass/Fail
C. Pass/Fail

Test Conducted By:____ Date:________________

4.4 SCADA GUI Live Sensor Data Display Test
Description: The GUI should display CAN and I2C data on the screen
Pass Criteria:

A. All sensor data is displayed with the values on the screen being identical to the ones in the database calculated from the sensor verification table included in the section below.
B. Sensors displayed on the GUI should display “No Data” when no data is available if the connection to the bus is removed. The test will check if “No Data” is displayed when RTC, IMU, or CANbus connections are removed where there is otherwise valid data present. There should be valid data present for the sensors that depend on these bus connections when they are properly connected.

C. Sensors displayed on the GUI should display “Error in Datapath” when there is no data in the database or there is a connection error with Postgres. This test will check if “Error in datapath” is displayed when no data is sent from connected RTC, IMU, or CANbus, as well as if SCADA is disconnected from Postgres.

Results:

A. Pass/Fail
B. Pass/Fail
C. Pas/Fail

Test Conducted By:_______________________________________ Date:________________

4.5 SCADA Configuration Test

Description: The GUI config file should change various parameters for the SCADA display. Before testing this, ensure that the data display GUI is currently running and visible on the Carman enclosure display.

Pass Criteria:

A. Check if individual sensors are displayed in the correct format as per their configuration
    a. Change the “display_variable”, “unit”, “description”, and/or “precision” values under a sensor’s configuration in the config.yaml file
    b. Click the RESET button on the GUI display and check if the formatting of the sensor on the GUI display after reset reflects these changes.
B. All sensor data should match config calibration functions including virtual sensors
    a. Change the cal_function attribute under a sensor’s configuration in the config.yaml file
    b. Click the RESET button on the GUI display and check if the value (numerical or state) of the sensor on the GUI display after reset reflects these changes.
C. Test to check if user can select the sensors displayed on GUI
    a. Change the “Pages” values under the “Display” configuration in the config.yaml file
    b. Add sensors to the various “Groups” to be displayed on specific pages
    c. Click the RESET button on the GUI display and check if the sensor appears under these groups on the pages defined.
D. User should be able to define virtual sensors
    a. Create a new sensor configuration using “VIRTUAL” as the value for its “bus_type” attribute. The “inputs” under “cal_function” should use another sensor (can be real or virtual) for input data.
    b. Add this new virtual sensor to a sensor group under “Groups” in “Display” in the config.yaml file and ensure this sensor group is listed under one of the “Pages”
    c. Click the RESET button on the GUI display and check if the sensor appears on the GUI where defined displaying the desired data.
E. User should be able to change the refresh rate for sensors.
    a. Change the “sample_period” value under a sensor’s configuration in the config.yaml file

        b. Click the RESET button on the GUI display and check if the sensor is updated as frequently as defined.
F. User should be able to change the default values for sensors and test if sensors with no specified fields reflect defaults declared in the config.yaml file
    a. Change “units”, “precision”, “display_variable”, “sample_period”, and “description” under “Defaults” in the config.yaml file
    b. Click the RESET button on the GUI display and check if the formatting of the any sensors without these values specified reflects the changes in the GUI

Results:

A. Pass/Fail
    a. Pass/Fail
B. Pass/Fail
C. Pass/Fail
D. Pass/Fail
E. Pass/Fail
F. Pass/Fail

Test Conducted By:_______________________________________ Date:________________

4.6 SCADA Live Action Test

Description: The SCADA system should be able to respond to inputs with actions such as logging, displaying warnings on the EPAL display, and writing values to sensors or bus nodes

Pass Criteria:

A. Logs are written to when conditions specified in the config file are met
    a. Test to check if the Watcher logs are accessible on the final page of the SCADA GUI.
    b. Test to check if Watcher logs and errors are accessible through the post-processing system for a specified session
B. Actions are taken by writing to specific sensors when certain conditions specified in the config file are met
    a. Use data display GUI to verify TSI drive mode is correctly switched out of DRIVE for a qualifying condition
    b. Use data display GUI to verify safely loop has been opened for a qualifying condition
C. Warnings are displayed on the EPAL display when specific conditions in the config file are met for a known warning-type Watcher control
    a. Use EPAL dashboard display to verify driver is warned when the car is about to be switched out of DRIVE mode unless action is taken
    b. Use EPAL dashboard display to verify driver is notified when the car is about to being switched out of DRIVE mode

Results:

A. Pass/Fail
    a. Pass/Fail

    b. Pass/Fail
B. Pass/Fail
    a. Pass/Fail
    b. Pass/Fail
C. Pass/Fail
    a. Pass/Fail
    b. Pass/Fail

Test Conducted By:_______________________________________ Date:________________

4.7 SCADA Post Processor Test

Description: TheSCADA system should be able to display stored data in GUI with sessions and summaries for post processing

Pass Criteria:

A. GUI displays cheap and expensive summaries of data with session delimiters
B. Data can be exported in a CSV format to be analyzed using Excel

Results:

A. Pass/Fail
B. Pass/Fail

Test Conducted By:_______________________________________ Date:________________

Traceability Matrix:

Requirement	Description	Met By	Pass/Fail
1	**SCADA system starts up at boot**		
2	**SCADA has a Kiosk Mode Functionality**		
3	**SCADA fresh install is successful**		
4	**GUI displays live data**		
5	**Displayed sensors can be configured with the configuration file**		
6	**SCADA can perform actions based on input values from sensors**		
7	**SCADA can present data “sessions” and postprocess/export a user-chosen session to Excel**		

SCADA Sensor Verification Test

Sensor Name	Sensor Test	P/F
Car Wheel Speed	Verify value displayed on GUI is the same as (rotational speed in rad/s)*(radius of tire). See 'Motor RPM' test for independent rotational speed verification	
Motor RPM	Run the motor at a slow enough speed to film a slow motion video of the motor shaft and time the video. Verify calculated RPM from video is the same as the value displayed on GUI while the test was run.	
Motor Controller Temperature	Check if temperature reading on GUI is within 10% of thermometer reading	
Dyno Torque	Hang a known weight from the arm on which the torque sensor is mounted, at a known distance from the torque sensor. The product of the weight and distance should match the difference in torque measurement	
Motor Controller TS Voltage	Check voltage using voltmeter and compare reading with displayed value on GUI	
Motor Throttle Voltage	Check voltage using voltmeter and compare reading with displayed value on GUI	
Throttle Plausibility State Vector	Vary Apps1 and Apps2 to create plausible and implausible scenarios. The GUI shall report on the status of throttle plausibility.	
Magnetic Compass Heading	Verify that magnetometer sensor values are within 10% of compass reading	
rtc_time	Check if system time matches the time displayed on the GUI	
linear acceleration	Check to see if sensors readings are close to 0 when at rest or within 10% of motor controller accelerometer reading	
Gravity	Vector sum of gravity_x, y, z should be approximately 9.81 m/s^2	
Dyno Torque	Hang a known weight from the arm on which the torque sensor is mounted, at a known distance from the torque sensor. The product of the weight and distance should match the difference in torque measurement	
TS Current(Relay Board Sensor)	Measurements are taken when the motor is idle and then	

	running. Vary the throttle voltage by increments of 1V until you get to 5V. Check if readings are within 10% of the TSV power supply.	
Coulomb Count in units of Amp-Hours (integrated TS Current)	Put the dyno configuration of the car into Drive state. Measure the current with a calibrated multimeter as you vary throttle voltage to drive the motor. As throttle voltage increases, the current shall increase linearly.	
TS Voltage (TSI)	Measurements are taken when the motor is idle and then running. Vary the throttle voltage by increments of 1V until you get to 5V. Check if readings are within 10% of the TSV power supply.	
GLV Voltage	Power just CarMan and SCADA with the dyno's GLV power supply and check if the GLV V/I sensor is within 10% of the supply's measurements. Add in Battery Packs, Cooling, and EPAL and cycle through the shutdown states of the car. Compare measurements.	
GLV Current	Power just CarMan and SCADA with the dyno's GLV power supply and check if the GLV V/I sensor is within 10% of the supply's measurements. Add in Battery Packs, Cooling, and EPAL and cycle through the shutdown states of the car. Compare measurements.	
Throttle Voltage (TSI)	Vary Apps1(5V-10V) and Apps2(0V-5V). As Apps2 increases, throttle voltage increases linearly. Reported measurement should be within 5% of a calibrated voltmeter's measurement.	
Carman Drive State	Cycle through the states of the car. (Engage safety loop, press brakes and drive button, wait for RTDS to finish, and then either disengage the safety loop or press the drive button and brakes again). Compare the reported drive state with TSI's drive state FSM diagram.	
Brake State	Press the brakes. Check that brake_pressed is True. Release the brakes. Check that brake_pressed is False.	
AIRs State	Disengage(AIRs open) and rengage(AIRs closed) the safety loop. The status of the AIRs shall be correctly listed(open/closed).	
Carman Temperature	Power CarMan with only GLV. Use a heat gun to heat up the TSI and Logic board. Reported temperatures are within 10%	

	of a thermometer's reading when it comes into contact with the boards.	
Cooling Temp	Use a heat gun to increase the temperature of the coolant. Reported temperatures are within 10% of a thermometer's reading when placed in the reservoir.	
Cooling System Flow Rate	Power the cooling system. Reported flow rate shall be within 10% of estimated flow rate (see https://koolance.com/pmp-500-pump-g-1-4-bsp).	
IMD Fault	Induce an IMD fault within the safety loop. Check that an IMD fault is reported.	
AMS Fault	Induce an AMS fault within the safety loop. Check that an AMS fault is reported.	
Battery Voltage	Charge the battery and measure the battery voltage check whether the measurement is the same as the reading	
Battery Current (each pack)	Charge the battery and measure the battery current check whether the measurement is the same as the reading	
Cell Voltage	Power the cellman with the voltage source check whether the cell voltage reading is accurate	
Cell Temperature	Power up the cellman and the pacman, use the heat gun to heat up the metal connected to the cellman board. Reported temperatures are within 10% of a thermometer's reading when it comes into contact with the boards.	
Safety Loop	Active Control Test- Monitor the cooling temperature while performing the Cooling Temp Sensor test, once temperature rises above 60C, check the state of safety loop (which should be open) as displayed on the SCADA GUI	
Watcher / Warnings	Monitor the cooling temperature while performing the Cooling Temp and ensure that config specification for cooling temp above 60C is specified in config. Once cooling temp does surpass the desired range, warning message should be generated in JSON file to be displayed on the Dashboard display	

5. Cooling

5.1 Sealing & Temperature Test

<u>Description:</u> Run the motor at 70Nm of torque for 30 seconds, make sure no coolant is leaked and the system stays under 55 degrees Celsius. The motor is air cooled in the dyno, this test will measure the temperature with only the motor controller. The standard deviation of the temperature should be looked at.
<u>Requirements Met:</u> T8.2
<u>Equipment Needed:</u> Thermometer
<u>Pass Criteria & Results:</u>

A. There are no visible coolant leaks P/F
B. Temperature does not exceed 55 C P/F

Test #	Temp (C)
1	
2	
3	
4	
5	
STD	

Test Conducted By:____ Date:________________

5.2 Tilt Test

<u>Description:</u> When the cooling system is tilted at an angle of 45 degrees no coolant should spill. The coolant system will be filled to its maximum capacity.
<u>Requirements Met:</u> T8.5
<u>Equipment Needed:</u> Protractor
<u>Pass Criteria & Results:</u>

A. Tilted at an angle of 45 degrees, no coolant leaks P/F

Test Conducted By:____ Date:________________

5.3 Cooling Watts
Description: Measure the amount of watts the cooling system dissipates through operation. This should be documented in the inspection report and shown as a function of time.
Pass Criteria & Results:

A. Watts dissipated recorded in inspection report P/F

Test Conducted By:______________________________________ Date:_______________

6. Inspection & System Requirements

This section is to outline any rules that specify what certain parts should or should not be, how parts should be manufactured or produced, as well as any overarching requirements the electrical system needs to meet. The Inspection Report will be used for proving these requirements. Procedures need annotated photos to prove rules compliance.

Link to Inspection Report (IR):
https://docs.google.com/document/d/1OLuwVKZNTRxtrKJsIT_GB_C_6Rzoiq5asJ-xIGFwSZM/edit

Equipment Needed: Camera

6.1 Labels Designated in Rules
Description: These labels must all be on their respective subsystems according to the rules. This test checks that they are all where they need to be and rules compliant. Photos need to be annotated and included in the Inspection Report.
Requirements Met: EV2.3.2, EV2.9.5, EV3.1.5, EV6.3, EV6.4.4, EV6.6.7, EV8.3.2, EV8.4.2, EV8.6.2
Pass Criteria & Results:

A. Accumulator labeled with 3”x9” red lettered white background: “Accumulator Always Energized” on all sides P/F
B. HVD labeled as HVD P/F
C. TS components are labeled with “Danger” or “High Voltage” with black lightning bolt in a yellow triangle (Battery Pack Mechanical Prototype, Motor & Controller, CarMan not in Dyno) P/F
D. GLVMS and TSMS Labeled as GLVMS and TSMS P/F
E. GLVMS labeled with red lightning bolt in blue triangle P/F
F. Side BRBs labeled with red lightning bolt in blue triangle P/F
G. SSOKs labeled as SSOK P/F
H. IMD light labeled as IMD P/F
I. AMD light labeled as AMS P/F

Test Conducted By:______________________________________ Date:_______________

6.2 Lights Requirements

Description: These lights must meet the requirements outlined within the rules. They must be bright enough to be seen in direct sunlight.

Requirements Met: T7.4, EV8.1,EV8.3-6

Pass Criteria & Results:

A. Brake Light: Red, black background and rectangular shape w/ shining surface 15cm^2, visible in bright sunlight P/F
B. Drive light visible in bright sunlight P/F
C. TSAL: Red, frequency of 2-5Hz, visible in direct sunlight P/F
D. SSOK: Amber, visible in direct sunlight P/F
E. IMD Fault: Red, visible in direct sunlight P/F
F. Accumulator Voltage Indicator: visible in direct sunlight P/F
G. AMS Fault: Red, visible in direct sunlight P/F
H. GLV: Green, visible in direct sunlight P/F
I. HV (TSAL): Green, visible in direct sunlight P/F
J. General Fault: Red, visible in direct sunlight P/F
K. SAFE: Green, visible in direct sunlight P/F
L. AIRs: Green, visible in direct sunlight P/F

Test Conducted By:____ Date:_______________

6.3 Accumulator Electrical Requirements

Description: Show that the Accumulators meet the electrical requirements outlined within EV2.1,2.2,2.3,2.6.,2.7,2.8,2.9.

Requirements Met: EV2.1, EV2.2, EV2.3, EV2.6, EV2.7, EV6.1

Pass Criteria & Results:

A. Batteries used meet requirements and is shown in IR P/F
B. Segments are separated with barrier requirements outlined, shown in IR P/F
C. Both accumulators contain at least one fuse meeting requirements, shown in IR P/F
D. Fuses used meet requirements in EV6.1 P/F
E. Both accumulators contain an SMD and meet requirements, shown in IR P/F
F. Accumulators do not contain any other circuitry not needed for Packs P/F
G. AIRS meet requirements outlined in EV2.8 P/F
H. HVD meets requirements outlines in EV2.9 P/F

Test Conducted By:____ Date:________________

6.4 Accumulator Mechanical Requirements

Description: Show that the accumulator housings meet each requirement outlined in EV2.4 and EV2.5 for construction and mounting respectively. Each of these must be shown in the IR.

Requirements Met: EV2.4,EV2.5

Pass Criteria & Results:

A. Housing material is robust, fire resistant P/F
B. All conductive elements are properly grounded and insulated P/F
C. All holes in enclosure are properly sealed P/F

D. Cells are properly secured inside P/F
E. Accumulator lies within surface envelope P/F
F. Mounting is rigid and can withstand deceleration forces in EV2.5.3 P/F
G. Attached to frame by at least 4 8mm 8.8 Metric Grade or 5/16in Grade 5 bolts P/F

Test Conducted By:____ Date:________________

6.5 AMS Requirements

Description: Show that the AMS meets the requirements within EV2.11. These must be shown in the IR.

Requirements Met: EV2.11.6 - EV2.11.9

Pass Criteria & Results:

A. Voltage sense wires to AMS are protected by fuses P/F
B. Input channels of AMD used for different segments are isolated from each other P/F
C. GLV connection to AMS galvanically isolated from TSV P/F
D. AMS microprocessor dedicated to AMS P/F
E. AMS circuit board must include watchdog timer P/F

Test Conducted By:____ Date:________________

6.6 TS Wiring & Connection Requirements

Description: TS wiring and related connections must meet the requirements listed under EV3.2, EV3.3, and EV3.4. These must be documented in the IR.

Requirements Met: EV3.2, EV3.3, EV3.4

Pass Criteria & Results:

A. No soldering in high current path unless SMD fuse P/F
B. Fuses mechanically supported P/F
C. Wires terminals etc match rating of fuse, these wires must be marked with gauge, temp rating, insulation voltage rating P/F
D. TS wiring min temp 90C, orange shielded dual insulated cable P/F
E. Conduit must meet requirements in EV3.2.6, must be one piece P/F
F. Cable or conduit exiting or entering enclosure must have adequate fitting P/F
G. TS connections must be copper or aluminum, no steel P/F
H. TS connections do not include compressible material P/F
I. Conductors or terminals not modified to fit P/F
J. Bolts with nylon or loctite are not used P/F
K. Bolted or threaded connections are torqued properly using contrasting indicator paste to indicate P/F

Test Conducted By:____ Date:________________

6.7 Motor Controller & Foot Pedal Requirements

Description: The motor controller must meet the requirements outlined in EV3.5 and be shown in the IR.

Requirements Met: EV3.5
Pass Criteria & Results:

A. Motor does not connect to accumulator directly P/F
B. Foot pedal is right foot operated and returns to original position when released P/F

Test Conducted By:____ Date:________________

6.8 GLV Requirements

Description: The GLV system must meet the requirements outlined in EV4.1 and EV6.2.6 and shown in the IR.
Requirements Met: EV4.1, EV6.2.6
Pass Criteria & Results:

A. GLV batteries attached securely to frame P/F
B. Ungrounded terminal of battery must be insulated P/F
C. One terminal on GLV battery is connected to chassis ground by at least 12AWG wire and must run to the nearest frame ground P/F
D. GLV batteries based on lithium not used P/F
E. No orange wire used in GLV wiring P/F
F. No power feedback into GLV system after GLV shutdown P/F

Test Conducted By:____ Date:________________

6.9 TSV Requirements

Description: The TSV system must meet the requirements outlined in the rules sections below and show that they do in the IR
Requirements Met: EV3.5.7, EV3.5.8, EV5.2-EV5.4
Pass Criteria & Results:

A. TS circuitry is not inside cockpit, motor controller inputs must be isolated P/F
B. TSV and GLV must be galvanically isolated, interaction between the two must be through galvanically isolated devices rated for twice the max TS voltage P/F
C. External connections to TSV must be isolated P/F
D. TSV & GLV do not run through the same conduit and are not present in same connectors P/F
E. TS wiring separated from drivers compartment by firewall, may not be present behind instrument panel or in cockpit unless in conduit and protected P/F
F. TS main components and TS circuits not protected by overcurrent devices must use spacing or isolation P/F
G. TS & GLV within same enclosure must meet spacing and barrier requirements outlined in EV5.3.2, these spacing must be clearly defined such that none move P/F
H. All insulation for TS/TS and TS/GLV must meet EV5.4.2 standards P/F
I. Materials must extend far enough to meet spacing and creepage requirements P/F
J. Thermoplastic materials are not used P/F

Test Conducted By:____ Date:________________

6.10 PCB Isolation Requirements

Description: Any PCBs containing both TS and GLV must meet the requirements outlined in EV5.5 and be documented in the IR.

Requirements Met: EV5.5

Pass Criteria & Results:

A. TSV & GLV areas of board must be clearly defined and marked P/F
B. Spacing must meet requirements in EV5.5.3 P/F
C. Accumulator boards with TS connections must be fused at 1A or lower, if fuses are on board must be spaced 3.2mm P/F

Test Conducted By:____ Date:________________

6.11 Fusing Requirements

Description: These requirements are for all fuses used throughout the entire car. The fuses that should be outlined include 4 fuses on Battery Pack Power+,-, as well as SEG- flex bus bar, fuse near GLV battery in safety loop, and fuses on the relay board that go to TSI and the IMD. All fuses used should be documented in the IR.

Requirements Met: EV6.1

Pass Criteria & Results:

A. Continuous current rating for fuses are not greater than any continuous current ratings of components they protect P/F
B. Rated for highest voltage in system they protect P/F
C. DC fuses must be rated for DC and must carry DC voltage rating equal to or greater than the max voltage in system they are used in P/F
D. All fuses have interrupt current rating higher than theoretical short circuit current P/F
E. Fuses located at end of wire closest to uncontrolled energy source P/F
F. Smaller branching circuits from main system must have fuses P/F

Test Conducted By:____ Date:________________

6.12 Shutdown Circuit & Safety Loop Requirements

Description: The requirements for the shutdown circuit and all of its components should be outlined here and shown in the IR.

Requirements Met: EV6.2.1, EV6.2.3, EV6.2.4, EV6.3, EV6.5.3, EV6.6, EV6.7.1, EV6.7.2, EV6.7.5, EV6.8.3

Pass Criteria & Results:

A. Shutdown Loop contains: GLVMS, TSMS, 2 Side Mounted BRBs, CP BRB, brake overtravel switch, N.O relay controlled by IMD, N.O. relay controlled by AMS, all required interlocks, IMD and AMS latching w/ manual reset button P/F
B. All devices must be in series, no logic or microcontrollers P/F
C. AIRs powered directly from current from loop P/F
D. All components rated for max current in circuit P/F

E. Master switches: right side of vehicle, rotary with red removable key, do not operate through relay, on position parallel to fore-aft axis of vehicle P/F
F. TSMS is last switch before AIRs P/F
G. Side BRBs: one located on each side of vehicle, red with min 38mm diameter, must be push rotate, not easily removable, many not act through logic P/F
H. CP BRB: accessible by driver with steering wheel in any position, push rotate, red with min 24mm diameter, may not act through logic P/F
I. Start button cannot be left in on position after shutdown P/F

Test Conducted By:______________________________________ Date:_______________

6.13 TSMP & GLV Ground MP Requirements

Description: TSMPs must follow the requirements outlined in EV9.3 and documented in the IR.

Requirements Met: EV9.3

Pass Criteria & Results:

A. 2 TSMPs located in easily accessible well marked locations P/F
B. Protected by non-conductive housing that can be opened with tools P/F
C. 4mm banana jacks that accept shrouded banana jacks used P/F
D. Connected directly to motor controller +,- lines P/F
E. Each protected with 10,000Ohm current limiting resistor P/F
F. GLV ground measuring point must be next to TSMPs P/F