

LFEV FSAE Electrical Systems

Acceptance Test Plan v0.2

ECE 492 - Spring 2020

Latest Submission: 1/22/2020

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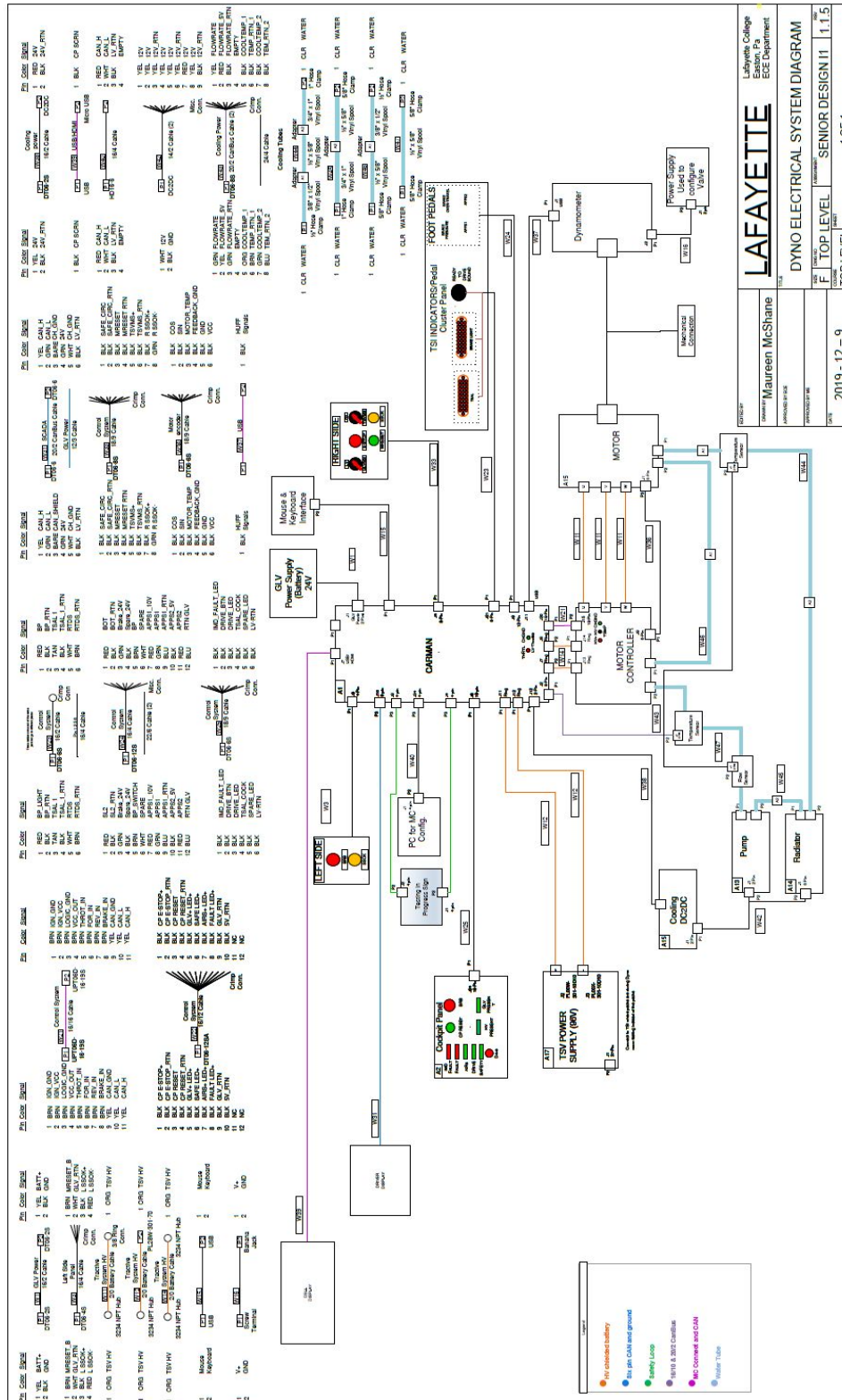
Abstract: Document designed to outline the tests needed to deliver the 2020 LFEV. Follows requirements stated in the Statement of Work.

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System Block Diagram



Compliance Matrix

Table numerically listing design documents for systems, the test procedure used to prove rule compliance, the analysis document if needed, and inspection reports. All of which are provided in the Acceptance Test Report.

Requirement Prefixes:

GPRXXX - General Requirement from the Statement of Work

TX.X.X - FSAE Rule in Part T - General Technical Requirement

ICX.X.X - FSAE Rule in Part IC - Internal Combustion Engine Requirement

EVX.X.X - FSAE Rule in Part EV - Electrical Powertrains and Systems

SX.X.X - FSAE Rule in Part S - Static Events

DX.X.X - FSAE Rule in Part D - Dynamic Events

Requirements	Design Document	ATP Test Procedure	Analysis Document	Inspection Report
T7.3 (Brake Over-Travel)	Safety Loop Diagram	1.6		
T7.4 (Brake Light)	TSI Manual	1.2		
T8.1 (Cooling Fluid)	Cooling Manual			
T8.2.1 (Cooling Sealing)	Cooling Manual			
T11 (Fasteners)			CarMan Enclosure Manual Pack Enclosure & Testing Document	
T12 (Transponder)				
EV1.2.1 (Max System Voltages)	ESF	-		
EV2.1.1 & EV2.1.3 (Permitted Cells)	ESF	-		

EV2.2 (Segment Firewall)		-	Pack Testing Document	
EV2.3.1-EV2.3.4 (Accumulator Visual)		Visual Inspection of Accumulator, Sticker Measurement	Pack Testing Manual	
EV2.4 (Physical Pack Design Reqs.)			Pack Testing Manual	
EV2.6 (Accumulator Fusing)		-	Pack Testing Manual	
EV2.7 (Accumulator SMD)		2.6	Pack Testing Manual	
EV2.8.1 EV2.8.2 EV2.8.5-EV2.8.6 (AIR's user manual)	TSI Manual	2.7	Pack Testing Manual	
EV2.8.3 (AIR's TS voltage Discharge Test)		2.7		
EV2.8.4	TSI Manual	1.5, 2.7		
EV2.9.1-2.9.4 (HVD)		2.4, 2.6		
EV2.9.5-2.9.7 (HVD Label / Lockout Tagout)		-	Pack Testing Manual	
EV2.9.8 (HVD Location)		-	Pack Testing Manual	
EV2.10.1-2.10.3 (Precharge Circuits)		1.3, 1.5		
EV2.10.4, 2.10.6, 2.10.7 (Discharge)	TSI Manual			
EV2.10.5	TSI Schematic			

EV2.11.1 (If TS on- AMS on)		1.1,1.2,1.3	Pack Testing Manual	
EV2.11.2 (AMS volts & temps)		2.1,2.3, 1.11, 1.12		
EV2.11.3 (TS disabled)		1.9,1.10, 1.11, 1.12		
EV2.11.4 (TS voltage measurement)		2.1,2.3		
EV2.11.5 (TS cell measurement)		2.2	Pack Testing Manual	
EV2.11.6 (TS voltage sense wires fused)			Pack Testing Manual	
EV2.11.7 (TS inputs isolated)		-	Pack Testing Manual	
EV2.11.8 (GLV galvanic isolation)	PacMan schematic	-		
EV2.11.9 (AMS Microcontroller)	PacMan, CellMan schematic	-		
EV3.1.3 (Finger Probe)		3.1		
EV3.1.4 (Container Minimum Resistance)		3.2		
EV3.1.5 (High Voltage Sticker)		5.1		
EV3.2.1-EV3.2.5 (TS Wiring) EV 3.2.9 (Shielded Dual Insulated)		-		Cable, Wiring and Connector Inspection Document
EV3.2.2		-		Cable, Wiring and

(Soldering in High Current Path)				Connector Inspection Document
EV3.3 (Cable Strain Relief)		-		Cable, Wiring and Connector Inspection Document
EV3.4 (TS Electrical Connections)		Motor Connections	Pack Testing Manual CarMan Enclosure Manual	Cable, Wiring and Connector Inspection Document
EV3.5.1 (Motor Controller)	TSI/TSV schematic	-		Cable, Wiring and Connector Inspection Document
EV3.5.4 & EV3.5.5 (Acceleration error checking)	Drive State FSM, TSI Schematic, TSI QA Testing	1.4		
EV3.5.6 (Accelerator Limit Shutoff)	TSI Schematic	1.4		
EV3.5.7-EV3.5.8 (MC inputs isolation)		-		Cable, Wiring and Connector Inspection Document
EV3.5.9 (Motor Free Spinning)		1.7,1.8,1.9,1.10		
EV4.1.1 (Lower GLV Voltage)	GLV schematic	-		
EV4.1.3 (Insulated Battery Terminal)	GLV schematic	-		
EV4.1.8 (No Orange GLV wiring)		-		Cable, Wiring and Connector Inspection Document

EV5.1 (Galvanic Isolation)		-		Isolation Inspection Document
EV5.2.2 (No TS & GLV wiring in same connector)		-		Cable, Wiring and Connector Inspection Document
EV5.2.4 (No TS wiring in panel)		-		Cable, Wiring and Connector Inspection Document
EV5.3 (TS & GLV spacing) EV5.4 (Insulation)		Measure each close point put in spreadsheet		Isolation Inspection Document
EV5.5 (PCB layout)	TSI PCB Layout, CellMan Layout, PacMan Layout	-		Isolation Inspection Document
EV6.1 (Fuse Inventory)	TSI Diagram Charging Diagram	-		Fuse Inventory Document
EV7.1.1 - EV 7.1.3 (Safety Loop)	Safety Loop Diagram	1.1, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12		
EV7.1.4 (Rated for max current)	TSI Manual, Safety Loop Diagram	-		
EV7.1.5 (AMS, IMD, O-T Fault)		1.9, 1.10, 3.1		
EV7.1.6 (No Feeding Power Back)	TSI Schematic, GLV Schematic			
EV7.2 (Master Switches) EV7.3.4 (GLV Switch Identifier)	Safety Loop Diagram	1.7		Indicator Inspection Document

EV7.3.1 (GLVMS)		1.1, 1.7		
EV7.3.2 (GLVMS current)	Safety Loop Diagram	-		
EV7.3.3 (GLV charging isolation)	GLV Schematic	-		
EV7.4.1 (TSMS)		1.8		
EV7.4.3 (TSMS AIRs)	Safety Loop Diagram	1.8		
EV7.5 (SMSB)	Safety Loop Diagram	1.1		
EV7.6 (CSB)		1.5, 1.8, 1.9		
EV7.7 (Vehicle Start Button)	Safety Loop Diagram	1.1, 1.2		
EV7.8 (Shutdown System Sequencing)		1.1, 4.1, 4.2, 4.3		
EV7.9.1-7.9.3 (IMD, TSI QA)	TSI Testing	1.9		
EV7.9.4 (Shutdown all Electrical Systems)	Safety Loop Diagram	1.9		
EV7.9.5 (Manual Reset)		1.9		
EV7.9.6 (Latching electro-mechanical relay)	TSI Schematic	1.9		
EV7.9.7 (IMD Indicator Light)	TSI Schematic	1.9		

EV7.9.8 (IMD wiring)		-		Cable, Wiring and Connector Inspection Document
EV8.1 (General Grounding)		3.2		
EV9.1.1 (TSAL on with AIR)	TSI Schematic	1.3, 1.4		
EV9.1.3 (TSAL Flashes)		1.3		
EV9.1.8 (50% nominal accumulator voltage)	TSI Schematic	5.2		
EV9.1.9 (TSAL powered by TS)	TSI Schematic	5.2		
EV9.1.10 (TSAL no TS wires)	TSI Schematic	5.2		
EV9.2 (R2D sound)		1.4		
EV9.3.1-9.3.2 ("SSOK")		1.2, 1.3, 1.4		Indicator Inspection Document
EV9.3.3 (SSOK Safety Loop Closed)		1.2, 1.3, 1.6, 1.7, 1.9, 1.10, 1.11, 1.12, 3.1		Safety Loop Document
EV9.3.4 (SSOK CSB, TSMS)		1.5, 1.8, 3.1		
EV9.4 (IMD status light)		1.9		
EV9.5 (Accumulator voltage light)		2.6, 2.7, 2.8		
EV9.6 (AMS CP indicator light)		1.10, 1.11, 1.12		

EV10.1 (IMD resistance test)		1.9		
EV10.2 (Insulation resistance between control system ground)		-		
EV10.3 (TSMP's)		2.7		
EV10.4 (AMS MP's)		1.10, 1.11, 1.12		
EV 13 (ESF)		-		

Non-Applicable Requirements

These requirements are not included in the test plan because they are unrelated to full system electrical testing. The rule is included along with a short indication of its content and why it is unrelated or is not required.

Waived Rules	
T1	Dyno room testing form - no applicable electrical requirements
T2	Vehicle mechanical requirements - no applicable electrical requirements
T3	Vehicle frame mechanical requirements - no applicable electrical requirements
T4	Cockpit mechanical requirements - no applicable electrical requirements
T5	Drive equipment requirements - no applicable electrical requirements
T6	General chassis rules and requirements - no applicable electrical requirements
T7.1	General brake system - no applicable electrical requirements
T7.2	Brake test - no applicable electrical requirements
T8.2.2-8.2.6	Cooling mechanical support - no applicable electrical requirements
T8.3	Transmission and drive - no applicable electrical requirements

T8.4	Drivetrain shields and guards - no applicable electrical requirements
T8.5	Tilting test not possible in Dyno Room, no applicable electrical requirements
T9	Aerodynamic Devices - no applicable electrical requirements
T10	Compressed Gas Systems and High Pressure Hydraulics - no applicable electrical requirements
T13	Vehicle Identification - no applicable electrical requirements
T14	Driver Equipment - no applicable electrical requirements
T15	Safety Equipment - no applicable electrical requirements
T16	Not using on board cameras
Part IC	No IC engine
EV2.1.2	No Pouch Cells
EV2.3.5	No Spare Accumulators
EV2.4-2.5	Container will not be finished
EV2.12	Virtual Accumulators will not be used
EV3.1.1-3.1.2	Container will not be finished
EV3.1.6-3.1.10	Vehicle Frame not tested, similar with accumulator container for rain test
EV3.2.6-3.2.7	Will not be using conduit
EV3.2.8	No outboard wheel motor
EV3.5.2-3.5.3	Will not be testing foot pedal
EV4.1.2, EV4.1.4, EV4.1.5	Battery will not be attached to chassis
EV4.1.7	Battery is commercially made
EV5.2.1	No conduit used
EV5.2.3	No Firewall component
EV7.4.2	Deleted
EV8.1.3	No heat sinks

EV9.1.2	Using Amber TSAL in Dyno
EV9.1.4-9.1.7	Not testing TSAL on car
EV10.5	Car will not be complete
EV11	No pouch type cells

State Transitions

The following tests aim to verify that the System Shutdown Circuit behaves according to the State Transition Diagram described in EV 7.8.1:

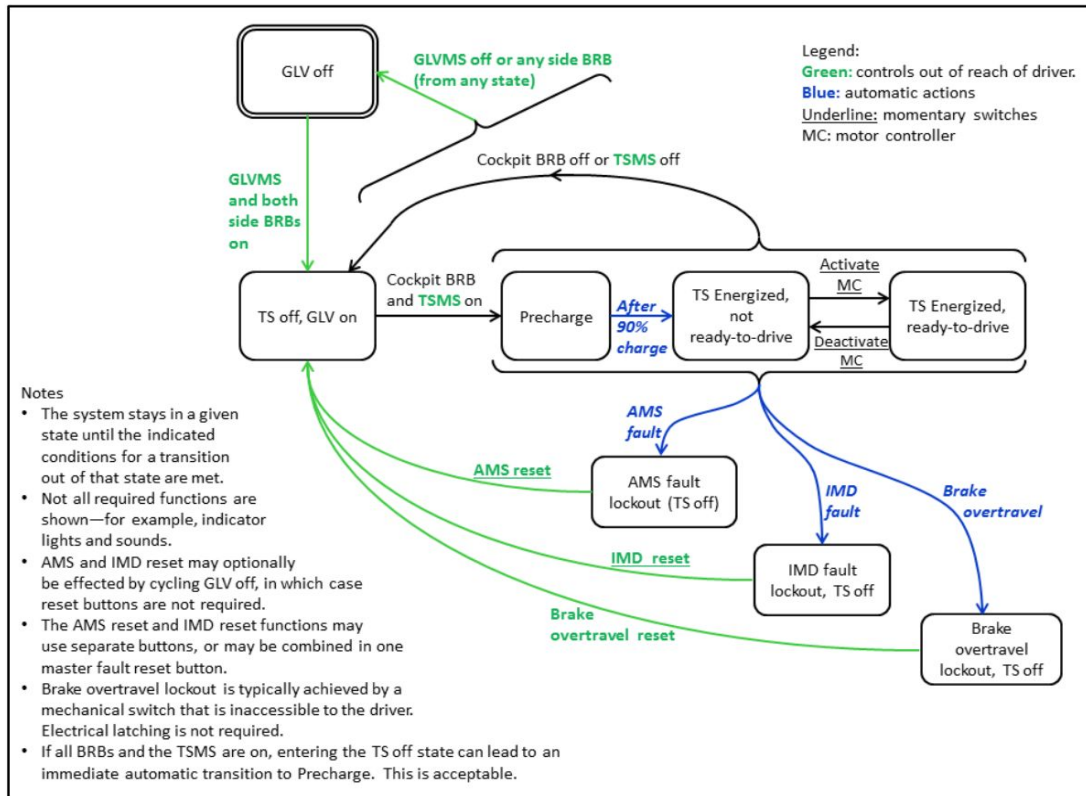


Figure 41 - Example Shutdown State Diagram

1.1 Startup Procedure to GLV on

- **Summary:** Starting with both BRB's open. Put each switch in the respective position and see if the system turns on.
- **Requirements:** EV2.11.1, EV7.1.1, EV7.3.1, EV7.5, EV7.6.3, EV 7.8
- **Materials:**
- **Pass Criteria:**
 - GLV system only activates when all are closed.
 - AMS Active Light is not on ever
- **Results:**

GLVMS	R. BRB	L. BRB	SCADA Screen	GLV Light	GLV	System On
Open	Open	Open				
Open	Open	Closed				
Open	Closed	Open				
Open	Closed	Closed				
Closed	Open	Open				
Closed	Open	Closed				
Closed	Closed	Open				
Closed	Closed	Closed				

A. PASS / FAIL

B. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.2 GLV on to Drive Mode

- Summary: Starting with GLV system on, put the system into drive mode. Close the safety loop with the IMD/AMS Master Reset. Verify the L&R BRBs de-energize the system. Verify the system only goes into drive mode while the brake is being pressed.
- Requirements: T7.4, EV 9.3
- Materials:
- Pass Criteria:
 - In precharge state the LBRB & RBRB De-energize system
 - AIRs close using the TSMS and cockpit reset
 - Drive light stays off if drive button is pressed and brake is not pressed while in precharge or GLV on.
 - System does not move into drive mode if TSMS is off
 - TSAL and AIRs lights remain off after Cockpit BRB is closed if the Cockpit Reset button has not been pressed
 - While pressing the brake, the brake light turns on
 - When TSAL turns on AMS Active Light turns on.
- Results:

Test Observed By: _____ **Date:** _____

1.3 Non-Drive State Throttle

- Summary: Follow the start up procedure, but do not press the drive button. Slowly increase the throttle to observe if the motor spins
- Requirements Met: EV9.1.3, EV9.3
- Observations:
- Materials:
- Pass Criteria:
 - SCADA reports state
 - SSOK's illuminated
 - TSAL illuminated
 - TSAL flashes between twice and five times per second
 - Motor does not spin when throttle is increased
 - AMS Active Light is on

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL
- E. PASS / FAIL
- F. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.4 Drive State Throttle

- Summary: Follow the start up procedure and press the drive button. Observe the Ready To Drive Sound at a distance of 2 meters. Slowly increase the throttle to observe if the motor spins. Cause the throttle to be implausible, observe the motor stop, and time how long it takes
- Requirements Met: EV3.5.9, EV9.3
- Observations:
- Materials: Meter Stick or Tape Measure, Sound Meter, Stopwatch
- Pass Criteria:
 - SCADA reports state
 - SSOK's illuminated
 - TSAL illuminated
 - Motor spins when throttle is increased
 - Motor stops when throttle goes to original position
 - Motor stops spinning when Throttle Implausible
 - Ready to drive sound is at least 80dB from 2M

Results

- A. PASS / FAIL
- B. PASS / FAIL

- C. PASS / FAIL
- D. PASS / FAIL
- E. PASS / FAIL
- F. PASS / FAIL
- G. PASS / FAIL

Trial	Sound Level (Db)	Time to Stop Motor (Sec)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Test Observed By: _____ **Date:** _____

1.5 Precharge

- **Summary:** Verify that pre-charge circuitry will reach at least 90% of TSV before the Precharge Relay is closed by passing the pre-charge resistors. Verify the behavior described in the competition inspection procedure by following the start up procedure. Do not press Cockpit Reset to turn on high voltage. Begin precharge by pressing the Cockpit Reset and observing the voltage rise on an oscilloscope. Record the TS voltage rising and the precharge relay closing event on the oscilloscope. Reset the system and follow the start up procedure and open the Cockpit BRB during precharge before 90% TSV is reached. Ensure that precharge is not continued after the BRB is pressed and does not reach the 90% TSV mark and discharges the system.
- **Requirements Met:** EV7.6, EV2.8.4, EV2.10.1-2.10.3, EV9.3.4
- **Measurement:** Plot of voltage across R33 of TSI PCB versus Time. Plot of Pre_Charge_Ready signal on TSI PCB versus time. Tractive System Voltage (to determine 90% mark). Output voltage of Precharge relay (K1 on TSI schematic).
- **Materials:** Oscilloscope(s), Isolated Differential Probe

- Pass Criteria:
 - AIRs open when pressing Cockpit BRB
 - Precharge is not allowed to reach completion when Cockpit BRB is opened during Precharge process
 - Precharge is allowed to reach completion when Cockpit BRB is not opened during Precharge process
 - The Pre_Charge_Ready signal intersects with the VR33 signal above 90% TSV
 - 24 V present at Precharge Relay after 90% TSV charged
 - SSOK Lights remain on after hitting cockpit shutdown

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL
- E. PASS / FAIL
- F. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.6 Drive State Over-Travel Switch

- Summary: Follow the start up procedure, move the motor using the throttle, and flip the brake over-travel switch. Wait 10 seconds and flip the switch again to make sure TS does not reactivate.
- Requirements Met: T7.3, EV3.5.9, EV7.1.1, EV9.3.3
- Materials: N/A
- Pass Criteria:
 - SSOK's are not illuminated
 - AIRs are open after switch is flipped
 - Motor spins freely
 - TS stays inactive after flipping Brake OT back

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.7 GLVMS During Drive State

- Summary: Follow the start up procedure, move the motor using the throttle, and turn the GLVMS.

- Requirements Met: EV7.1.1, EV7.2.1, EV7.3.1, EV9.3.3
- Materials: N/A
- Pass Criteria:
 - SSOK's are not illuminated
 - AIRs are open after switch is flipped
 - Motor spins freely
 - TS stays inactive after flipping GLVMS back

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.8 TSMS During Drive State

- Summary: Follow the start up procedure, move the motor using the throttle, and turn the TSMS.
- Requirements Met: EV7.1.1, EV7.4.1, EV7.4.3, EV 7.6.5, EV9.3.4
- Materials: N/A
- Pass Criteria:
 - SSOK's remain illuminated
 - AIRs are open after switch is flipped and AIRs light turns off
 - Motor spins freely, but stops after 60 seconds

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.9 IMD Fault Drive State Test

- Summary: Using two resistors in parallel, short the TSMP to ground, measure resistance, and time how long it takes to induce an IMD Fault. After the fault, try to re-energize the system using the cockpit reset.
- Requirements Met: EV2.11.3, EV7.1.1, EV7.1.5, EV7.9.1, EV7.9.4, EV 7.9.5, EV7.9.6, EV 7.9.7, EV9.3.3, EV9.4.1, EV 9.4.2, EV10.1
- Materials: Stopwatch, Resistors, Ohmmeter
- Pass Criteria:
 - High Voltage shuts off within 30 seconds of causing the short on the HV+ TSMP
 - IMD Fault Illuminates when the fault is induced on the HV+ TSMP

- After the resistor is removed from the HV+ TSMP the system does not re-energize.
- High Voltage shuts off within 30 seconds of causing the short on the HV- TSMP
- IMD Fault Illuminates when the fault is induced on the HV- TSMP
- After the resistor is removed from the HV- TSMP the system does not re-energize.
- SSOK's turn off when IMD Fault Light turns on
- High Voltage shuts off with a fault resistance of 250 ohm/volt
- One cannot re-energize the system using the cockpit reset.
- IMD Fault should open the AIRs

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL
- E. PASS / FAIL
- F. PASS / FAIL
- G. PASS / FAIL
- H. PASS / FAIL
- I. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.10 AMS Fault Simulation- Connector

- Summary: Follow the start up procedure, put the car in drive mode. Remove the AMS test connector wiring demonstrating an AMS shutdown. Press Cockpit reset.
- Requirements Met: EV2.11.1, EV2.11.2, EV2.11.3, EV7.1.1, EV7.1.5, EV9.3.3, EV9.6, EV10.4
- Materials: N/A
- Pass Criteria:
 - SSOK's turn off
 - AMS fault light illuminates within 60 seconds
 - AIRs open when jumper is removed
 - Nothing happens when pressing cockpit reset

Results

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.11 AMS Fault Simulation- Software Manipulation

- Summary: Follow the start up procedure, put the car in drive mode. Vary AMS software setpoints so that actual cell voltage is above or below the trip limit. Press Cockpit reset.
- Requirements Met: EV2.11.1, EV2.11.2, EV2.11.3, EV7.1.1, EV7.1.5, EV9.3.3, EV9.6, EV10.4
- Materials: N/A
- Pass Criteria:
 - SSOK's turn off
 - AMS fault light illuminates within 60 seconds
 - AIRS open when jumper is removed
 - Nothing happens when pressing cockpit reset

Results

- E. PASS / FAIL
- F. PASS / FAIL
- G. PASS / FAIL
- H. PASS / FAIL

Test Observed By: _____ **Date:** _____

1.12 AMS Fault Simulation- Vary Cell Sense Voltage

- Summary: Follow the start up procedure, put the car in drive mode. Vary the cell sense voltage using the potentiometer in the test. Press Cockpit reset.
- Requirements Met: EV2.11.1, EV2.11.2, EV2.11.3, EV7.1.1, EV7.1.5, EV9.3.3, EV9.6, EV10.4
- Materials: N/A
- Pass Criteria:
 - SSOK's turn off
 - AMS fault light illuminates within 60 seconds
 - AIRS open when jumper is removed
 - Nothing happens when pressing cockpit reset

Results

- I. PASS / FAIL
- J. PASS / FAIL
- K. PASS / FAIL
- L. PASS / FAIL

Test Observed By: _____ **Date:** _____

Accumulators

2.1. TS Active Cell Voltage

- Summary: Read at least 5 cell voltages from each pack on pack display, verify with voltmeter
- Requirements Met: EV2.11.4
- Materials: Voltmeter
- Pass Criteria:
 - Can read at least 5 cell voltages on the Pack Display within some % uncertainty
- Results:

Actual Voltage Reading (V)	Pack Display Voltage (V)

A. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.2. TS Active Cell Temperature

- Summary: Read at least 5 cell temperatures from each pack on pack display, verify with fluke temperature sensor
- Requirements Met: EV2.11.5
- Materials: Fluke Temperature Sensor
- Pass Criteria:
 - Can read at least 3 cell temperatures on the Pack Display within some % uncertainty

Results

Fluke Temperature (°C)	Pack Display Voltage (°C)

A. PASS / FAIL

B. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.3. TS Charging Temperature and Voltage

- Summary:
 - Read at least 3 cell voltages from each pack on pack display, verify with voltmeter
 - While the packs are charging read at least 3 cell temperatures from each pack on pack display, verify with fluke temperature sensor
- Requirements Met: EV2.11.4
- Materials: Multimeter
- Pass Criteria:
 - Can read at least 3 cell voltages on the Pack Display within some % uncertainty
 - Can read at least 3 cell temperatures on the Pack Display within some % uncertainty
- Results:

Actual Voltage Reading (V)	Pack Display Voltage (V)

Fluke Temperature (°C)	Pack Display Temperature (°C)

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.4. High Voltage Disconnect (HVD)

- Summary: Time how long it takes to disconnect the high voltage disconnect using the HVD without tools.
- Requirements Met: EV2.9.1, EV2.9.2, EV2.9.3, EV2.9.4

- Materials: Stopwatch
- Pass Criteria:
 - Time to disconnect takes less than 10 seconds
 - No tools used
- Results

Trial	Time to Disconnect (Sec)
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

- A. PASS / FAIL
- B. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.5. Cell Number Reading

- Place a dead cell in a charged segment and see if the pack display and SCADA correctly read which cell it is.
 - Materials: Dead Cell
 - Pass Criteria:
 - Cell is read by pack display
 - Cell is read by SCADA
 - Results:
- A. PASS / FAIL
 - B. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.6 SMD Test

- When the tractive system is active, put the SMD in the open position and make sure the segments are disconnected
- Requirements Met: EV2.7, EV 2.9, EV 9.5
- Materials: Voltmeter
- Pass Criteria:
 - SMD can be operated without tools
 - SMD opening disconnects the segments
 - There are no conductive removable parts from the SMD
 - SMD functions as the HVD.
- Results:
 - A. PASS / FAIL
 - C. PASS / FAIL
 - D. PASS / FAIL
 - E. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.7 Accumulator AIRS

- Using the GLV safety loop, open the Accumulator AIR's and make sure TS voltage drops below 30V in less than 5 seconds.
- Requirements Met: EV2.8.1, EV2.8.2, EV2.8.4-2.8.6, EV9.5
- Materials: Voltmeter, Stopwatch
- Results:

Trial	Time For Voltage Drop (Seconds)
1	
2	
3	

A. PASS / FAIL

Test Observed By: _____ **Date:** _____

2.8 Pack Indicator Lights

- Summary: Ensure that the Pack indicator lights are active when charging and when TS Active
- Requirements Met: EV9.5
- Pass Criteria:
 - Charging Light is active when the packs are charging and TS active light is inactive.

- TS Active Light is on when the Tractive System is active
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL

Test Observed By: _____ **Date:** _____

Grounded Low Voltage & Safety Loop

3.1 Finger Probe Test

- Summary: All TS electrical connections must not be able to be touched by a 10cm long, 0.6 cm diameter non-conductive test probe.
- Requirements Met: EV3.1.1, EV3.1.2, EV3.1.3
- Materials: Finger Probe
- Pass Criteria:
 - The probe does not touch the TS connections on the AIRs
 - The probe does not touch the TS connections on the TSI board.
 - The probe does not touch the TS connections on the Amphenol connectors
 - The probe does not touch the TS connections inside the CarMan enclosure
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL
 - C. PASS / FAIL
 - D. PASS / FAIL

Test Observed By: _____ **Date:** _____

3.2 Grounding Test

- Summary: Verify the metal parts of the system that need to be integrated to the car have a resistance below 300 mΩ to GLV system ground. Verify non-metal components that contain a conductive material have a resistance below 100 Ω to GLV system ground
- Requirements Met: EV3.1.4, EV8.1.1, EV8.1.2, EV8.1.5
- Materials: Ohm Meter
- Pass Criteria:
 - Resistance measurement between the CarMan enclosure and chassis ground is less than 300 mΩ
 - Resistance measurement between the TSI PCB mounting plate and chassis ground is less than 300 mΩ
 - Resistance measurement between the MCS mounting plate and chassis ground is less than 300 mΩ
 - Resistance measurement between the GLV panel and chassis ground is less than 300 mΩ

- Resistance measurement between the Accumulators and chassis ground is less than 300 mΩ
- Resistance measurement between the TSI high voltage plate and chassis ground is less than 100Ω
- Resistance measurement between the Left Side panel and chassis ground is less than 100 Ω
- Resistance measurement between the Right Side panel and chassis ground is less than 100 Ω
- Resistance measurement between the Cockpit panel and chassis ground is less than 100Ω
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL
 - C. PASS / FAIL
 - D. PASS / FAIL
 - E. PASS / FAIL
 - F. PASS / FAIL
 - G. PASS / FAIL
 - H. PASS / FAIL
 - I. PASS / FAIL

Test Observed By: _____ **Date:** _____

Tractive System Interface

4.1 Over-Current Error

- Summary: Enter drive mode and drive the motor such that an over-current error should occur. Verify that the over-current state is not left until the current is below the TSI overcurrent threshold and that the throttle is below 0.5V. Demonstrate that the TSI overcurrent threshold can be changed without recompiling any firmware. Repeat testing above for the new threshold.
- Requirements Met: EV7.8.1, EV7.8.2
- Materials:
- Pass Criteria:
 - The motor stops spinning when in the over-current state
 - The Drive Light in the cockpit flashes while in the over-current state.
 - The drive state field on the SCADA display shows that the system is in the over current state.
 - The system does not leave the overcurrent state until the current is under the TSI overcurrent threshold and the throttle is less than 0.5 V.
 - The TSI overcurrent threshold is not set by re-compiling and uploading firmware to the TSI microprocessor

- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL
 - C. PASS / FAIL
 - D. PASS / FAIL
 - E. PASS / FAIL

Test Observed By: _____ **Date:** _____

4.2 Return to Drive & Idle Transitions

- Summary: Breaking the Safety Loop in any state returns to Idle state
- Requirements Met: EV7.8.1, EV7.8.2
- Materials: N/A
- Pass Criteria:
 - The drive state field on the SCADA display shows that the system is in the Idle State when the safety loop is broken.
 - The drive light turns off when the safety loop is broken
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL

Test Observed By: _____ **Date:** _____

4.3 Drive to Drive Setup

- Summary: Put the system into drive state. Check that throttle implausibility, pressing the drive button, pressing the throttle and brake at the same time, or turning off the motor controller will return the system to the Drive Setup State
- Requirements Met: EV7.8.1, EV7.8.2
- Materials: N/A
- Pass Criteria:
 - The drive light turns off when in Drive Setup state
 - SCADA displays the current state as Drive Setup after the throttle is implausible
 - SCADA displays the current state as Drive Setup after turning off the motor controller
 - SCADA displays the current state as Drive Setup after pressing the drive button
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL
 - C. PASS / FAIL
 - D. PASS / FAIL

Test Observed By: _____ **Date:** _____

Indicators

5.1 High Voltage Stickers

- Summary: Ensure all enclosures with High Voltage Components have a HV sticker
- Requirements: EV 3.1.5
- Materials: N/A
- Pass Criteria:
 - CarMan enclosure has high voltage sticker
 - Pack Prototype has a HV sticker
 - Pack Prototype has an accumulator always energized sticker
- Results:
 - A. PASS / FAIL
 - B. PASS / FAIL
 - C. PASS / FAIL

Test Observed By: _____ **Date:** _____

5.2 High Voltage Indicator Lights

- Summary: Slowly increase power supply voltage until cockpit HVPL and TSAL are active. Record each voltage. Turn up to full nominal voltage. Reduce voltage until both turn off and record the voltage that each turns off.
Connect to HV power supply at 50V and make sure TSAL is active
- Requirements: EV 9.1.8, EV 9.1.9, EV 9.1.10
- Materials: Power supply
- Pass Criteria:
 - TSAL turns off when the power supply is less than 40V
 - HVPL turns off when the power supply is less than 40V
 - The difference between the voltages when the TSAL and HVPL turn off is less than 2V
 - TSAL is on when the power supply is greater than 60 V
 - HVPL is on when the power supply is greater than 60 V
 - The difference between the voltages when the TSAL and HVPL turn on is less than 2V
- Results:

Voltage TSAL turns off	
Voltage HVPL turns off	
Voltage TSAL turns on	
Voltage HVPL turns on	

- A. PASS / FAIL

- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL

Test Observed By: _____ **Date:** _____

Reliability

6.1 24 Hour Test

- Summary: Run the system for 24 hours then run the motor.
 - Pass Criteria:
 - Motor runs
 - Results
- A. PASS / FAIL

Test Observed By: _____ **Date:** _____

6.2 Cooling System Test

- Summary: Spin the motor torque up to 70 Nm for 30 seconds and verify the motor and motor controller remain below 60°C, in a different run spin the motor for up to ~3000RPM for 30 seconds and verify the motor and motor controller remain below 60°C
 - Pass Criteria:
 - After torque test motor is less than 60°C
 - After torque test motor controller is less than 60°C
 - After RPM test motor is less than 60°C
 - After RPM test motor controller is less than 60°C
 - No Cooling Leaks are observed
 - Results:
- A. PASS / FAIL
B. PASS / FAIL
C. PASS / FAIL
D. PASS / FAIL

Test Observed By: _____ **Date:** _____

SCADA

7.1 Accumulator Data Test

- **Summary:** Verify ambient temperature, pack current, at least five cell voltages, and at least five cell temperature values displayed on SCADA. Measure ambient temperature near PacMan with thermometer. Measure pack current with ammeter. Measure voltage values of each cell with voltmeter. Measure temperature values of each cell with probe. Collect at least data points from each measurement, perform statistical analysis outlined in Appendix 1.
- **Materials:** Fluke Temperature Sensor, Ammeter, Voltmeter
- **Pass Criteria:**
 - Value for ambient temperature displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for pack current displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Values for cell temperatures displayed on SCADA are as expected, given the level of uncertainty found in the statistical analysis.
 - Values for cell voltages displayed on SCADA are as expected, given the level of uncertainty found in the statistical analysis.

Actual Voltage Reading (V)	SCADA Voltage (V)	Actual Temp Reading (C)	SCADA Temp (C)

- A. PASS / FAIL
- B. PASS / FAIL
- C. PASS / FAIL
- D. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.2 Cooling Data Test

- Summary: Verify cooling system temperature values displayed on SCADA by comparing them to measured values. Measure water with a fluke thermometer at a minimum of ten data points, perform statistical analysis outlined in Appendix 1.
- Materials: Fluke Thermometer
- Pass Criteria:
 - Value for cooling temperature displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.

A. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.3 Motor Data Test

- Summary: Verify motor temperature, motor controller temperature, rotations per minute (RPM), and motor controller voltage values displayed on SCADA. Measure motor and motor controller temperatures with fluke sensor. Measure RPM with tachometer. Measure motor controller voltage with voltmeter. Collect at least data points from each measurement, perform statistical analysis outlined in Appendix 1.
- Materials: Fluke temperature sensor, Tachometer, Voltmeter
- Pass Criteria:
 - Value for motor temperature displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for motor controller temperature displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for RPM displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for motor controller voltage displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.

A. PASS / FAIL

B. PASS / FAIL

C. PASS / FAIL

D. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.4 TSI Data Test

- Summary: Verify TSI max voltage and high voltage current values displayed on SCADA. Measure current and voltage with multimeter. Collect at least data points from each measurement, perform statistical analysis outlined in Appendix 1.
- Materials: Multimeter

- Pass Criteria:
 - Value for TSI max voltage displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for TSI high voltage current displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
- A. PASS / FAIL
B. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.5 GLV Data Test

- Summary: Verify GLV current, voltage, temperature, and power values displayed on SCADA. Measure current and voltage with multimeter and calculate power. Measure temperature with fluke sensor. Collect at least data points from each measurement, perform statistical analysis outlined in Appendix 1.
 - Materials: Multimeter, Fluke Temperature Sensor
 - Pass Criteria:
 - Value for GLV voltage displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for GLV current displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for GLV temperature displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
 - Value for GLV power displayed on SCADA is as expected, given the level of uncertainty found in the statistical analysis.
- A. PASS / FAIL
B. PASS / FAIL
C. PASS / FAIL
D. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.5 SCADA Relay

- Summary: If a sensor reading is out of the range specified by the SCADA configuration file, the SCADA relay will open the safety loop. This will be tested at a minimum of 2 different thresholds set in configuration file.
- Materials: Oscilloscope, Voltmeter, Thermometer
- Pass Criteria:
 - SSOKs turn off when throttle voltage exceeds programmed threshold, specified in configuration file.

- Observe the SSOKs turn off when the GLV temperature sensor exceeds threshold, specified in configuration file.
 - Observe the SSOKs turn off when the Motor RPM exceeds programmed threshold, specified in configuration file
- A. PASS / FAIL
B. PASS / FAIL
C. PASS / FAIL

Test Observed By: _____ **Date:** _____

7.6 SCADA Drive State Logging

- Summary: Put the car into drive state and induce a fault. SCADA should log what state you were in as well as what fault was induced.
- Pass Criteria:
 - SCADA produces real time data of what drive state and resulting errors.
- Results:

A. PASS / FAIL

Motor Characterization

- Summary: Spin the new motor and using SCADA produce a .csv file of, RPM, Torque, TS Current and TS Voltage. Use this data to produce graphs of the motor performance. Manually record Pump Voltage during each trial or use SCADA to read pump voltage.
- ***When ran by packs SCADA should also deliver pack performance analysis during motor operation**
- Pass Criteria: SCADA produces said .csv, (attach graphs in appendix)
- Results:

A. PASS / FAIL

Appendix A- Statistical Method

All hypothesis testing for the ATP is done at the 90% confidence level as required by statement of work.

Calibration Verification Procedure: Sensor calibration will be verified by comparing the observed uncertainty of a sensor to the expected uncertainty from analysis. We hypothesize that these two values are the same.

Expected sensor uncertainty is derived through analysis using Type B methods. Errors from datasheets of components will be considered.

Observed sensor uncertainty will be approximated by Type A methods. The observed sensor uncertainty will be approximated by the root mean square (RMS) of the measurement errors.

In the case of a set of n values $\{x_1, x_2, \dots, x_n\}$, the RMS is

$$x_{\text{rms}} = \sqrt{\frac{1}{n} (x_1^2 + x_2^2 + \dots + x_n^2)}.$$

90% confidence interval of standard uncertainty will be created from the RMS of measurements errors.

If more than 30 measurements are taken, the 90% confidence interval should be constructed assuming that the distribution of measurements follows a normal distribution. Standardized statistics (Z-scores) should be used.

If less than 30 measurements are taken, the 90% confidence interval should be constructed using the t-statistic.

If the confidence interval of sensor uncertainty does not contain the expected sensor uncertainty, the sensor does not pass calibration verification.

Testing Involving the Use of Measurements: All system measurements have standard uncertainty. The standard uncertainty used in this section is derived through analysis using Type B methods. Errors from datasheets of components will be considered. (Expected sensor uncertainty from the calibration verification procedure.)

A hypothesis test should be conducted assuming normality of all sensor measurements.

Safety

Deliverables

D000: PDR

D001: CDR

D002: Project Web Site

D003: Competition and Final Delivery

D004: Project Posters

D005: Purchasing Report

E001: User Manuals

E002: Final Report Maintenance Manuals, and Errata

Final Report

Maintenance Manuals

Errata

E003: Electrical ATP

E004: Electrical ATR

M000: WBS

M001: Gantt Chart

M002: Budget