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 Specifications

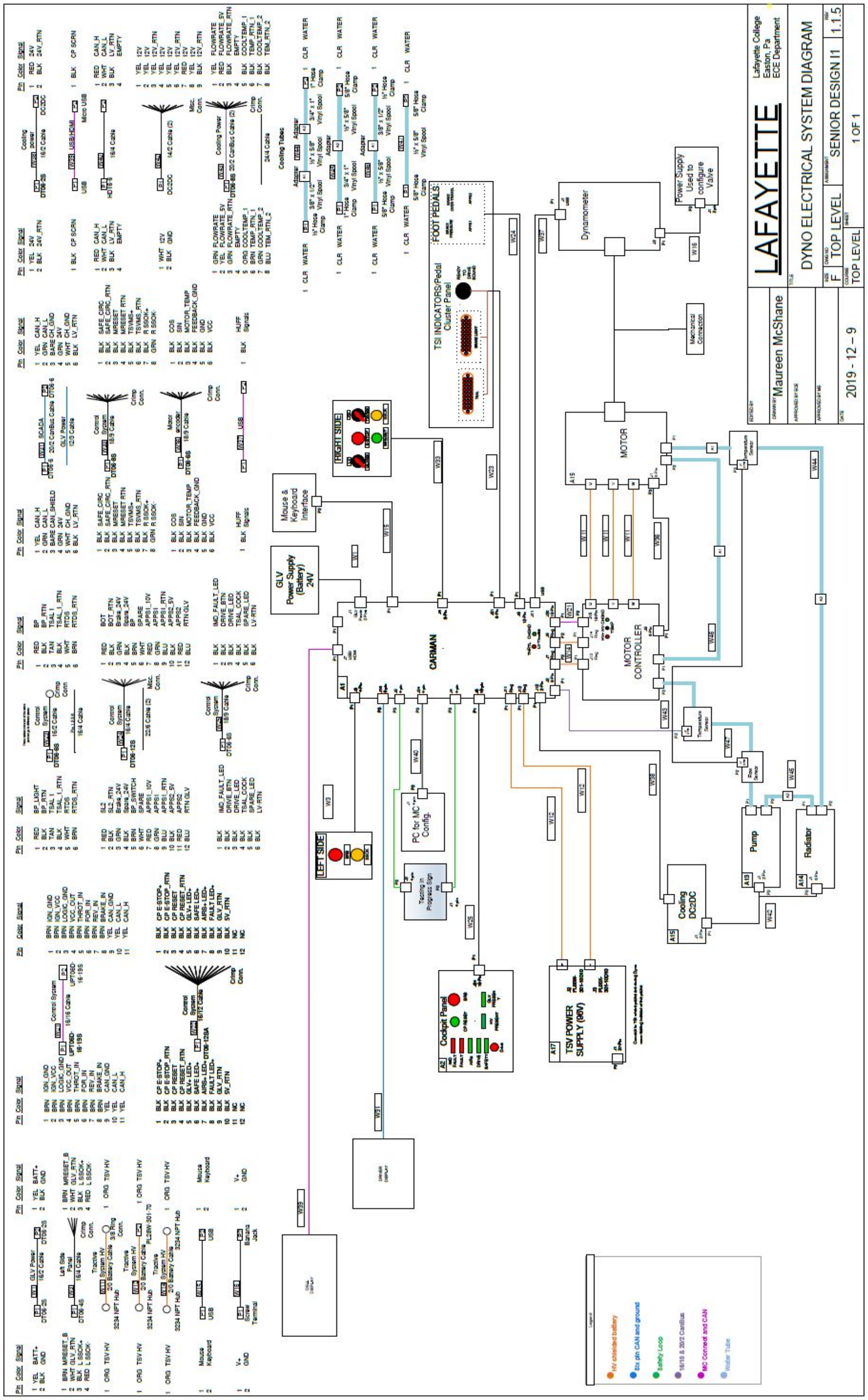
This ATP is proposed for the Lafayette Motorsports system as it is intended to exist in the Dynamometer Room at Lafayette College. This ATP is designed to test a system with two Accumulator Packs complete with displays, that are capable of powering the system defined here: The system that is operating in the dyno room will be our fully integrated Car Management Enclosure (CarMan), fitted with a sensory contol and data acquisition system (SCADA), the Grounded Low Voltage BOB (GLV) and the Tractive System Interface BOB (TSI) inside. GLV is powered by the GLV battery and not the HuffBox. The low voltage system will power all cockpit devices located on the Dyno rack, which includes all LEDs and the Driver Display. This system will have a fully integrated safety loop controlled by the GLV BOB and a State Diagram that operates according to rule EV7.8, which is controlled by the TSI BOB. Overall this system will be capable of operating the Dynamometer and spinning an EMRAX 208 Motor controlled by a emdrive 500, both of which are watercooled in a fully closed loop.

The only “electrical systems” present on the intended car not present in this system will be manual accelerator pedals and throttle.

Materials Needed to Test System

- ❏ Dynamometer
- ❏ Motor Mount
- ❏ Torque USB Interface
- ❏ Power Supply Valve Load Control
- ❏ Finger Probe Test Stick
- ❏ IMD Test - Resistor Gadget
- ❏ AMS test Connector (power supply)
- ❏ Handheld Tachometer
- ❏ Sound Level Meter
- ❏ Voltmeter
- ❏ Ohmmeter
- ❏ Temperature Probe / Thermometer
- ❏ Water

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	1.14,1.15,1.16, 1.22		
T7.4 (Brake Light)	TSI Manual	1.4, 1.5		
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-2	-		
EV2.1.1 & EV2.1.3 (Permitted Cells)	ESF-2	-		

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	1.2, 1.3, 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)		1.2, 1.3		
EV2.10.4, 2.10.6, 2.10.7 (Discharge)	TSI Manual	2.7		
EV2.10.5	TSI Schematic			

EV2.11.1 (If TS on- AMS on)		1.1, 1.6, 1.7, 1.8	Pack Testing Manual	
EV2.11.2 (AMS volts & temps)		2.1,2.3, 1.8, 1.11, 1.12		
EV2.11.3 (TS disabled)		1.8, 1.9,1.10, 1.12, 1.13, 1.14		
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	-		
EV3.5.6 (Accelerator Limit Shutoff)	TSI Schematic	-		
EV3.5.7-EV3.5.8 (MC inputs isolation)		-		Cable, Wiring and Connector Inspection Document
EV3.5.9 (Motor Free Spinning)		1.10, 1.17		
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 Documen
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, 1.16		
EV7.1.4 (Rated for max current)	TSI Manual, Safety Loop Diagram	-		
EV7.1.5 (AMS, IMD, O-T Fault)		1.6, 1.7, 1.8, 1.9		
EV7.1.6 (No Feeding Power Back)	TSI Schematic, GLV Schematic			
EV7.2 (Master Switches) **EV7.3.4** (GLV Switch Identifier)	Safety Loop Diagram	1.16		Indicator Inspection Document

EV7.3.1 (GLVMS)		1.1, 1.16		
EV7.3.2 (GLVMS current)	Safety Loop Diagram	-		
EV7.3.3 (GLV charging isolation)	GLV Schematic	-		
EV7.4.1 (TSMS)		1.11		
EV7.4.3 (TSMS AIRs)	Safety Loop Diagram	1.11		
EV7.5 (SMSB)	Safety Loop Diagram	1.1		
EV7.6 (CSB)		1.1, 1.3, 1.11		
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	1.2, 1.15		
EV9.1.3 (TSAL Flashes)		1.15		
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)		1.6, 1.7, 1.8, 1.9, 1.10, 1.16, 3.1		Safety Loop Document
EV9.3.4 (SSOK CSB, TSMS)		1.3, 1.11		
EV9.4 (IMD status light)		1.9		
EV9.5 (Accumulator voltage light)		2.6, 2.7, 2.8		
EV9.6 (AMS CP indicator light)		1.6, 1.7, 1.8		

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)		1.6, 1.7, 1.8		
EV 13 (ESF)	ESF-2	-		

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.

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:

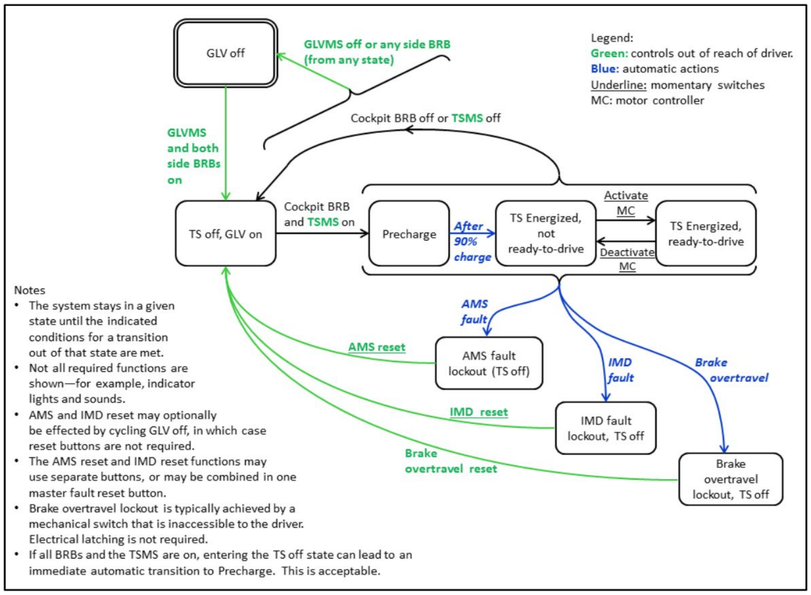


Figure 2 - FSAE Given System Shutdown Circuit

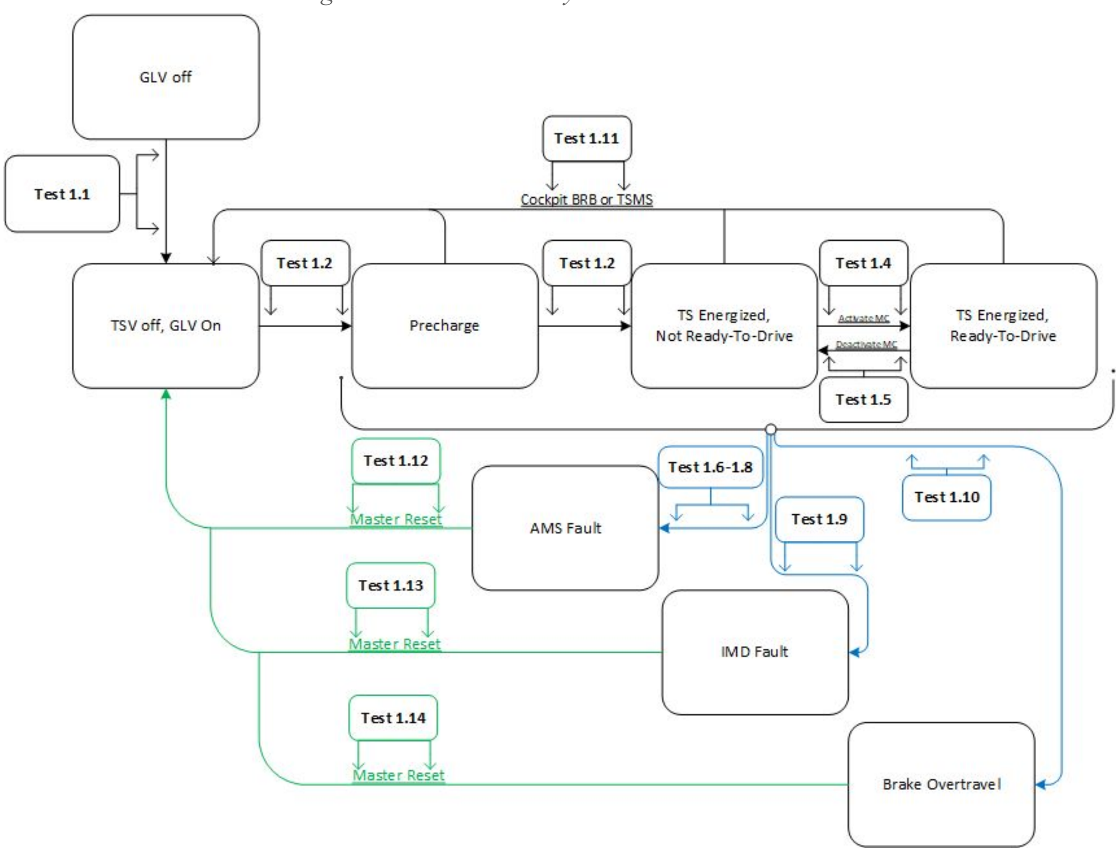


Figure 3 - Lafayette Motorsports Test Diagram

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 light only activates when all are closed.
    - If GLV system is active increasing throttle does nothing
    - TSI is in Idle State
    - Cooling System is not on
    - SCADA screen is on
    - AIRs are open
    - CarMan voltmeter reads above 20V
    -
- 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 Pre-Charge

- Summary: Starting with GLV system on, put the system into pre-charge. When in GLV on, close the safety loop with the IMD/AMS Master Reset. Close the Tractive System Master Switch, and press the cockpit reset to close the AIRS.
- Requirements: EV2.8.4, EV2.10.1-2.10.3, EV 9.3, EV 7.8
- 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, cockpit high voltage light turns on.
    - During precharge increasing throttle does not move motor
- 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

Test Observed By:____ **Date:**____________________

1.3 Precharge to TS Energized Not Ready-To-Drive

- 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, EV 7.8

- <u>Measurement:</u> 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
  - During TS Energized NRTD increasing throttle does not spin motor
- <u>Results</u>

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

Test Observed By:____ Date:____________________

1.4 TS Energized Not Ready-To-Drive to Drive Mode

- <u>Summary:</u> Follow the start up procedure to TS Energized Not Ready-To-Drive. Press the brake and the drive button at the same time. System should enter drive mode.
- <u>Requirements Met:</u> T7.4, EV9.2, EV 7.8
- <u>Materials:</u>
- <u>Pass Criteria:</u>
  - Brake light turns on when the brake button is pressed
  - System enters drive mode when both buttons are pressed
  - Cockpit Drive light turns on
  - SCADA reports the car enters drive mode
  - Throttle is capable of moving motor
- <u>Results:</u>

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

1.5 Drive Mode to TS Energized Not Ready-To-Drive Mode

- Summary: Follow the start up procedure to Drive Mode. Press the Brake and the drive button at the same time. System should leave drive mode.
- Requirements Met: T7.4, EV 7.8
- Materials:
- Pass Criteria:
  - Brake light turns on when the brake button is pressed
  - System leaves drive mode when both buttons are pressed
  - Cockpit Drive light turns off
  - SCADA reports the car enters ts energized on not ready-to-drive state
  - Throttle is not capable of moving the motor.
- Results:

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

Test Observed By:____ **Date:**____________________

1.6 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, EV 7.8, 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:**____________________

1.7 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, EV 7.8, 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:**___________________

1.8 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, EV 7.8, 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:**___________________

1.9 AMS Fault Simulation - During Precharge

- Summary: Follow the start up procedure, put the car in precharge-state, observe the voltage rise on an oscilloscope, cause an AMS fault in any way before the precharge relay closes. Verify the AMS fault light turns on and press cockpit reset.
- Requirements Met: EV2.11.1, EV2.11.2, EV2.11.3, EV7.1.1, EV7.1.5, EV 7.8, 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:**__________________

1.10 AMS Fault Simulation - During TS Energized Not Ready-To-Drive

- Summary: Follow the start up procedure, put the car in precharge-state, observe the voltage rise on an oscilloscope, hear the precharge relay close when the system reaches 90% TS voltage. Cause an AMS fault in any way. Verify the AMS fault light turns on and press the cockpit reset.
- Requirements Met: EV2.11.1, EV2.11.2, EV2.11.3, EV7.1.1, EV7.1.5, EV 7.8, 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:**__________________

1.11 IMD Fault Drive State Test

- Summary: Put the System into Drive State. 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, EV 7.8, 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
J. PASS / FAIL

Test Observed By:____ **Date:**____________________

1.12 IMD Fault Precharge State Test

- Summary: Follow the start up procedure, put the car in precharge-state, observe the voltage rise on an oscilloscope, cause an IMD fault similar to 1.11 before the precharge relay closes. Verify the AMS fault light turns on and press cockpit reset.
- Requirements Met: EV2.11.3, EV7.1.1, EV7.1.5, EV 7.8, 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
J. PASS / FAIL

Test Observed By:______________________________ **Date:**____________

1.13 IMD Fault TS Energized NRTD State Test

- Summary: Follow the start up procedure, put the car in precharge-state, observe the voltage rise on an oscilloscope, hear the precharge relay close when the system reaches 90% TS voltage. Cause an IMD fault the same way as 1.11. Verify the IMD fault light turns on and press the cockpit reset.
- Requirements Met: EV2.11.3, EV7.1.1, EV7.1.5, EV 7.8, 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
J. PASS / FAIL

Test Observed By:____ Date:____________________

1.14 Drive State Brake Over-Travel Switch

- Summary: Follow the start up procedure into drive state, 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, EV 7.8, 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:____________________

1.15 Pre-Charge Brake Over-Travel Switch

- Summary: Follow the start up procedure into precharge, observe the voltage rise on an oscilloscope, flip the brake over-travel switch before the precharge relay closes. 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, EV 7.8, EV9.3.3
- Materials: N/A
- Pass Criteria:
  - SSOK's are not illuminated
  - AIRs are open after switch is flipped

- TS stays inactive after flipping Brake OT back
- Results:

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

Test Observed By:____ Date:____________________

1.16 TS-Energized, NRTD, Brake Over-Travel Switch

- Summary: Follow the start up procedure into precharge, observe the voltage rise on an oscilloscope, hear the precharge relay close when it reaches 90% TS voltage. Flip the break overtravel 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, EV 7.8, EV9.3.3
- Materials: N/A
- Pass Criteria:
    - SSOK's are not illuminated
    - AIRs are open after switch is flipped
    - TS stays inactive after flipping Brake OT back
- Results:

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

Test Observed By:____ Date:____________________

1.17 TSMS/Cockpit BRB During Drive State

- Summary: Follow the start up procedure to Drive State, move the motor using the throttle, and turn the TSMS. Similarly when in drive state, press the cockpit BRB.
- Requirements Met: EV7.1.1, EV7.4.1, EV7.4.3, EV 7.6.5, EV 7.8, 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:____________________

1.18 TSMS/Cockpit BRB During Precharge State

- Summary: Follow the start up procedure to Precharge state observe the voltage rise on an oscilloscope before the precharge relay closes, turn the TSMS. Similarly when in precharge state again, press the cockpit BRB.
- Requirements Met: EV7.1.1, EV7.4.1, EV7.4.3, EV 7.6.5, EV 7.8, EV9.3.4
- Materials: N/A
- Pass Criteria:
  - SSOK's remain illuminated
  - AIRs are open after switch is flipped and AIRs light turns off
- Results:

A. PASS / FAIL
B. PASS / FAIL

Test Observed By:____ Date:____________________

1.19 TSMS/Cockpit BRB During TS Energized NRTD State

- Summary: Follow the start up procedure to Precharge state observe the voltage rise on an oscilloscope and after the precharge relay closes, turn the TSMS. Similarly when in TS Energized NRTD state again, press the cockpit BRB.
- Requirements Met: EV7.1.1, EV7.4.1, EV7.4.3, EV 7.6.5, EV 7.8, EV9.3.4
- Materials: N/A
- Pass Criteria:
  A. SSOK's remain illuminated
  B. AIRs are open after switch is flipped and AIRs light turns off
- Results:

A. PASS / FAIL
B. PASS / FAIL

Test Observed By:____ Date:____________________

1.20 Master Reset after AMS Fault

- Summary: Press the cockpit reset and verify the system cannot be reset from the cockpit. Verify system enters GLV on state when master reset button is pressed after an AMS fault.
- Requirements Met: EV2.11.3, EV 7.8
- Materials: N/A
- Pass Criteria:
  - TSV system remains off.
  - GLV system only activates after master reset is pressed.
  - AMS Active Light is no longer on.
- Results:

A. PASS / FAIL

B. PASS / FAIL
C. PASS / FAIL

Test Observed By:____ **Date:**____________________

1.21 Master Reset after IMD Fault

- Summary: Press the cockpit reset and verify the system cannot be reset from the cockpit. Verify system enters GLV on state when master reset button is pressed after an IMD fault.
- Requirements Met: EV2.11.3, EV 7.8
- Materials: N/A
- Pass Criteria:
  - TSV system remains off.
  - GLV system only activates after master reset is pressed.
  - IMD Fault Light is no longer on.
- Results:

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

Test Observed By:____ **Date:**____________________

1.22 Master Reset after Brake Overtravel

- Summary: Press the cockpit reset and verify the system cannot be reset from the cockpit. Verify system enters GLV on state when master reset button is pressed after brake overtravel.
- Requirements Met: T7.3, EV2.11.3, EV 7.8
- Materials: N/A
- Pass Criteria:
  - TSV system remains off.
  - GLV system only activates after master reset is pressed.
- Results:

A. PASS / FAIL
B. PASS / FAIL

Test Observed By:____ **Date:**____________________

1.17 Drive State Throttle

- Summary: Follow the start up procedure and enter drive mode. 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, EV 7.8, EV9.3

- <u>Observations:</u>
- <u>Materials:</u> Meter Stick or Tape Measure, Sound Meter, Stopwatch
- <u>Pass Criteria:</u>
    - SCADA reports state
    - SSOK's illuminated
    - TSAL illuminated
    - Motor spins when throttle is increased
    - Motor stops when throttle goes to original position
    - Motor gradually stops spinning when Throttle Implausible
    - Ready to drive sound is at least 80dB from 2M
- <u>Results:</u>

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:**____________________

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

- <u>Results:</u>

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

- <u>Summary:</u> 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.
- <u>Requirements Met:</u> EV7.8.1, EV7.8.2
- <u>Materials;</u>
- <u>Pass Criteria:</u>
  - ○ 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:**___________________

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 5 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:___________________

7.6 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:**____________________

7.7 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

Test Observed By:____ **Date:**____________________

Motor Characterization

8.1 Motor Characterization csv

- 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

System Sensor Verification

9.1 Cooling Temperature Sensors

- Summary: Verify the Cooling temperature sensors are displaying the proper value by replacing normal water with warmer water. Compare using a fluke thermometer. Sample the data at 10 points from ambient to 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Fluke Temperature Sensor, Water heater, Water
- Pass Criteria:
    A. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- Results:
    A. PASS / FAIL

Test Observed By:____ **Date:**____________________

9.2 GLV Voltage Sensor

- Summary: Verify the functionality of the external multimeter sensor and SCADA reporting. Sample data at a minimum of 10 operating points between 20 and 25 V. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Variable DC power supply (~24V and needs to be able to supply 8A), Special cable allowing GLV to be powered from variable DC power supply
- Pass Criteria:
    A. GLV multimeter - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
    B. SCADA - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty. Statistical Analysis (Attach Document):
- Results:
    A. PASS / FAIL
    B. PASS / FAIL

Test Observed By:____ **Date:**____________________

9.3 GLV Current Sensor

- Summary: Verify the functionality of the external multimeter sensor and SCADA reporting. Using a variable load rated for 24V, measure at 10 operating points. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Variable DC power supply (~24V and needs to be able to supply 8A), Special cable allowing GLV to be powered from variable DC power supply
- Pass Criteria:
    A. GLV multimeter - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
    B. SCADA - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty. Statistical Analysis (Attach Document):
- Results:

A. PASS / FAIL
B. PASS / FAIL

Test Observed By:____ **Date:**____________________

9.4 TSI Voltage Sensor

- Summary: Verify the Tractive System Interface voltage sensor and the Motor Controller Voltage sensor when in Drive State or TSI energized NRTD. Sample data at a minimum of 10 operating points between 0 and 100V. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Oscilloscope, Differential Probes
- Pass Criteria:
    A. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- Results:
    A. PASS / FAIL

Test Observed By:____ **Date:**____________________

9.5 TSI Current Sensor

- Summary: Verify the Tractive System Interface current sensor when in Drive State or TSI energized NRTD. Using the TS load vary the current limit so the current in the system is known and short the HV measuring points. Vary it at a minimum of 20 operating points between 0 and 250A. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A

- Materials: Disabled IMD, TS Power Supply
- Pass Criteria:
  A. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- Results:
  A. PASS / FAIL

Test Observed By:____ Date:____________________

9.6 Motor Temperature

- Summary: Using a temperature sensor, verify the functionality of the motor temperature sensor. Sample data at a minimum of 10 operating points between ambient room temp and 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Temperature Probe
- Pass Criteria:
  A. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- Results:
  A. PASS / FAIL

Test Observed By:____ Date:____________________

9.7 Motor Controller Temperature

- Summary: Using a temperature sensor, verify the functionality of the motor controller temperature sensor. Sample data at a minimum of 10 operating points between ambient room temp and 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Materials: Temperature Probe
- Pass Criteria:
  A. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- Results:
  A. PASS / FAIL

Test Observed By:____ Date:____________________

9.6 Motor Velocity

- <u>Summary:</u> Using a handheld tachometer, verify the functionality of the motor controller's velocity sensor . Sample data at a minimum of 20 operating points between 0 and 3500 RPM. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- <u>Requirements Met:</u> N/A
- <u>Materials:</u> Handheld tachometer
- <u>Pass Criteria:</u>
    A. Motor Controller - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
- <u>Results:</u>
    A. PASS / FAIL

Test Observed By:____ **Date:**____________________

Appendix A- Statistical Method

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

<u>Calibration Verification Procedure:</u> 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 $\{x_1, x_2, \ldots, x_n\}$, the RMS is

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)}.$$

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 is 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 (Delivered)

D001: CDR (Doesn't Exist)

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

Group Photo

Errata

E003: Electrical ATP

E004: Electrical ATR

M000: WBS

M001: Gantt Chart

M002: Budget