

# **FSAE Electrical Systems**

# **Acceptance Testing Plan**

ECE 492 - Spring 2019

Latest Revision: April 26th, 2019

Prepared by: Hayden Dodge, Alex Kmetz, Katherine Lee

## **Abstract**

This document details the acceptance testing plan for the dynamometer system and car electronics being developed for the Lafayette Formula Electric Vehicle Design Project.

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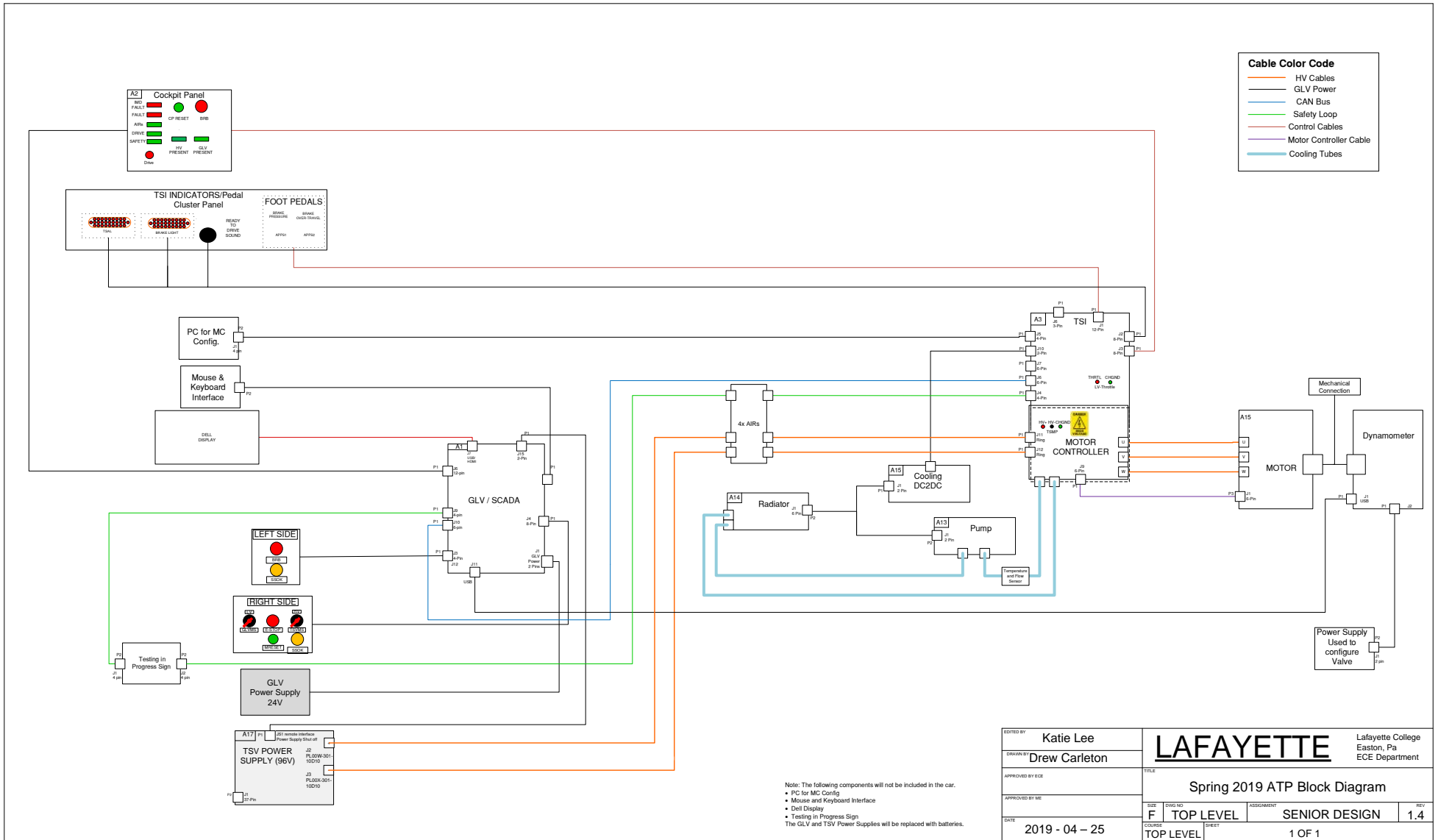
## **System Summary**

The goal of this project is to provide components for the Class of 2020 to build a car to take to the Formula Hybrid Competition. This semester, the electrical systems needed to construct a car for the FSAE Formula Electric Car competition will be delivered as an integrated system. The systems that will be integrated are the motor, motor controller, GLV, TSI, SCADA, and Cooling. A dynamometer will be utilized to simulate a load on the motor. Additionally, a battery management system prototype will be delivered.

This document explains all of the tests we plan to run on the system. In our compliance matrix, system requirements are listed along with associated system design documents, testing, analysis, and inspection needed to show that the requirement is met.

# Dynamometer Testing Block Diagram

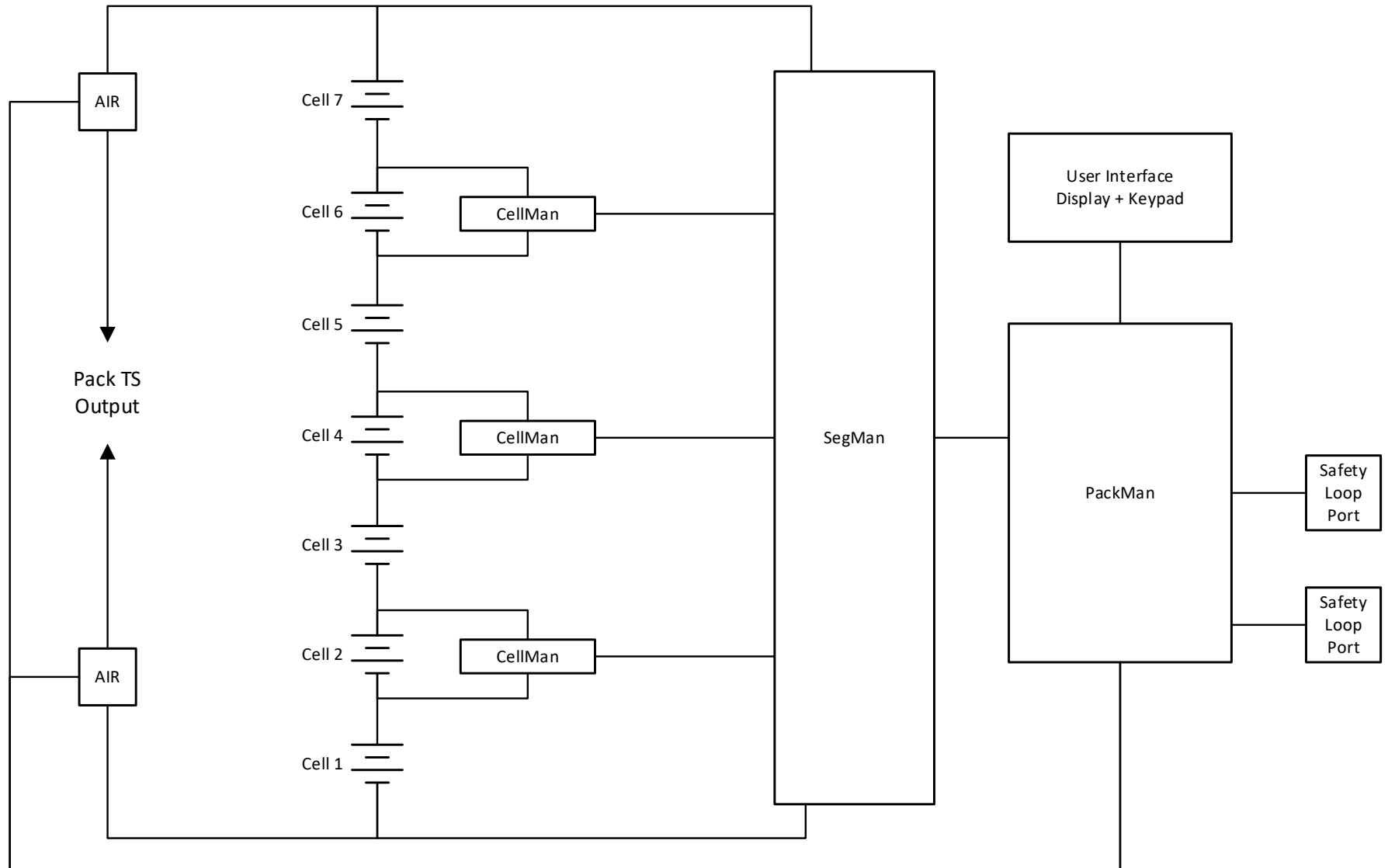
[https://sites.lafayette.edu/motorsports/files/2019/04/HighLevelBlock\\_Dyno\\_v1.4.pdf](https://sites.lafayette.edu/motorsports/files/2019/04/HighLevelBlock_Dyno_v1.4.pdf)



Note: The following components will not be included in the car.  
 • PC for MC Config  
 • Mouse and Keyboard Interface  
 • Bell Display  
 • Testing in Progress Sign  
 The GLV and TSV Power Supplies will be replaced with batteries.

EDITED BY Katie Lee	<b>LAFAYETTE</b>		Lafayette College Easton, Pa ECE Department
DRAWN BY Drew Carleton	TITLE Spring 2019 ATP Block Diagram		
APPROVED BY ECE	SIZE F	DWG NO. TOP LEVEL	ASSIGNMENT SENIOR DESIGN
APPROVED BY ME	COURSE TOP LEVEL	SHEET 1 OF 1	REV 1.4
DATE 2019 - 04 - 25			

# TSV/AMS Testing Block Diagram



18650 LiFePO4 cells will be used in place of the 60Ah LiFePO4 prismatic cells.  
Cells may be replaced with lab power supplies for ease of testing.

We will not be delivering a prototype that can facilitate cell charging, measuring charging & balancing current, measuring TS current, determining cell state of charge, active balancing, or communicate of CAN.

AMS Prototype Block Diagram	
Drawn By: Hayden Dodge	
Date: 04/26/2019	Rev: 1.0
ECE 492 – Senior Design II	

## Compliance Matrix

Design documents needed to show requirement compliance are linked to in the Acceptance Testing Report (ATR). Page numbers of design documents are provided in the ATR for ease of checking rule compliance. ATP Test Results are reported in the ATR. Analysis documentation are uploaded to the website and referenced in the ATR. Inspection reports are uploaded to the website and referenced in the ATR.

Requirements	Design Document	ATP Test Procedure	Analysis Document	Inspection Report
GPR001				10, I1
GPR005	User Manuals & Schematics			I2, I3, I4, I6, I7
GPR006	User Manuals, Maintenance Manuals, & Schematics	8		
GPR007	User Manuals & Schematics			I5, I8
GPR008	User Manuals	10		
GPR011				I10
GPR012				I10
T7.4.1	TSI Schematic	4.7		
EV2.8.3	Discharge analysis, TSI schematic	4.1		
EV2.10			A2, A3	
EV2.10.1	Drive State FSM, Pre-charge analysis, TSI schematic, shutdown diagram	1.3		
EV2.10.3	Drive State FSM, Pre-charge	1.1, 1.3		



	analysis, TSI schematic, shutdown diagram			
EV2.11.2	TSV schematics, safety loop diagram	1.8, 9.1, 9.2, 9.3		
EV3.5.2	Drive State FSM	1.2		
EV3.5.3	Drive State FSM	1.2		
EV3.5.4	Drive State FSM	1.2		
EV3.5.5	Drive State FSM	1.2		
EV3.5.9	Safety loop diagram	1.4		
EV7.1	Safety loop diagram, shutdown diagram		A1	
EV7.1.1	Safety loop diagram	1.4, 2.1		
EV7.3.1	Safety loop diagram, shutdown diagram	1.5, 2.1		
EV7.4.1	Safety loop diagram	2.1, 2.4		
EV7.4.3	Safety loop diagram, GLV current draw analysis	2.6		
EV7.5.4	Safety loop diagram	2.1		
EV7.6.3	Safety loop diagram	2.1, 2.3		
EV7.6.5	Safety loop,	1.6		

	shutdown diagram			
EV7.7.1	Safety loop diagram, shutdown diagram	3.1		
EV7.7.2	Drive State FSM	1.1, 1.2		
EV7.8.2	Drive State FSM	1.1, 4.2, 4.3, 4.4		
EV7.9.6	Safety loop, shutdown diagram, TSI schematic	1.7		
EV7.9.7	Safety loop, shutdown diagram, TSI schematic	1.7		
EV9.1.3	TSI Schematic	4.6		
EV9.1.8	TSI schematic	4.5		
EV9.2.1	Drive State FSM	1.1, 1.2		
EV9.2.2	Drive State FSM	1.2		
EV9.3.3	Drive State FSM, Safety loop diagram, shutdown diagram	1.1, 1.4, 1.5, 1.8, 2.2, 9.3		
EV9.3.4	Drive State FSM, Pre-charge analysis, TSI schematic, safety loop, shutdown diagram	1.3, 1.6, 1.7, 2.2		
EV9.4.1	Safety loop, shutdown diagram, TSI schematic	1.7		

EV9.4.2	Safety loop, shutdown diagram, TSI schematic	1.7		
EV9.6	Safety loop diagram	9.3		
EV10.1.2	Safety loop, shutdown diagram, TSI schematic	1.7		
EV10.4	Safety loop diagram	1.8, 9.3		

## Waived Requirements

Requirement	Reason
GPR003	EMI / EMC waived
GPR004	Analysis waived
GPR005	Enclosure Sealing Process Waived, NEC ANSI/NFPA 70 Analysis Waived, not connecting to the Lafayette Power Grid, not using lasers or RF
GPR006	Analysis waived, will still perform 24 hour test
GPR007	Software Maintainability Plan waived, Cell Phone software will not be used
EV2.1.2	Will not be using pouch type cells
EV2.4.10	Accumulator Containers will not be completely sealed
EV2.5.5	Will not be using a monocoque
EV2.6.3	Will not be using nPmS connections
EV2.6.4	Will not be using nSmP
EV2.6.5	Will not be reducing fuse ratings
EV2.6.6	Will not be reducing fuse ratings
EV2.10.2	Will not be using a timed circuit for the pre-charge

EV2.10.6	Will not be using an always-on discharge circuit
EV2.12	Will not be using Virtual Accumulators
EV3.1.8	Will not be using interlocks
EV3.1.10	Will not be meeting rain test requirements
EV3.2.6	Will not be using conduit
EV3.2.7	Will not be using conduit
EV3.2.8	Will not be using outboard wheel motors or TS cabling outside the roll hoop
EV3.5.2	Will not be producing a foot pedal
EV3.5.3	Will not be producing a foot pedal
EV4.1.5	Will not be using a battery, will be using Shore Power
EV4.1.6	Will not be using a wet-cell battery
EV5.2.1	Will not be using conduit
EV7.3.3	Will not be using GLV charging system such as alternators or DC/DC converters
EV7.9.6	Will not be using latching circuitry for the IMD
EV9.1.2	Will be using an amber TSAL
EV10.5	Will not be conducting rain test
EV11	Will not be using pouch type cells
EV12.3.2	Will not be using and hand cart with a brake
EV12.3.3	Will not be using a hand cart with a brake

# 1. System State Integration

## 1.1 Non-Drive State Throttle Demo

- 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: EV7.7.2, EV 7.8.2, EV9.2.1, EV9.3.3, EV2.10.3
- Observation: Safety loop closes but motor does not spin
- Materials: N/A
- Pass Criteria:
  - a. Pre-charge relay closed (SCADA reported TSI state is Drive\_Setup)
  - b. SSOK Lights are illuminated
  - c. TSAL is illuminated
  - d. Motor does not spin when the throttle is increased

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 1.2 Drive State Throttle Demo

- Summary: Follow the start up procedure and put the system into drive mode. Slowly increase the throttle to observe if the motor spins. Interrupt the torque command signal by causing the throttle to be implausible and ensure the motor stops spinning. Verify that the Ready To Drive Sound is loud enough at the distance described by the competition rules.
- Requirements Met: EV3.5.2, EV3.5.3, EV3.5.4, EV3.5.5, EV7.7.2, EV9.2.1, EV9.2.2
- Measurement: Ready to Drive Sound loudness at a distance of 2 meters
- Materials: Stopwatch, Sound Meter, Meter Stick or Tape Measure
- Pass Criteria:
  - a. Ready To Drive Sound occurs when drive button is pressed and lasts for 1-3 seconds
  - b. Motor does not rotate before throttle is applied
  - c. Motor rotates when throttle is applied
  - d. When the throttle pots are returned to their original position the motor stops spinning
  - e. When throttle is applied and the torque command signal is interrupted, the motor slows down within 1 second

- f. SCADA indicates Throttle Implausibility after interrupting torque command signal.
- g. Ready To Drive Sound is at least 80 dB at 2 meters away from the sound source

## Results:

- 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: \_\_\_\_\_

### 1.3 Pre-charge System Integration

- Summary: Verify that pre-charge circuitry will reach at least 90% of TSV before the Pre-charge 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 pre-charge relay closing event on the oscilloscope.

Reset the system and follow the start up procedure until the Cockpit Reset. Press the Cockpit reset 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: EV2.10.3, EV2.10.1, 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:
  - a. Precharge is not allowed to reach completion when Cockpit BRB is opened during Precharge process
  - b. Precharge is allowed to reach completion when Cockpit BRB is not opened during Precharge process

- c. The Pre\_Charge\_Ready signal intersects with the  $V_{R33}$  signal above 90% TSV
- d. 24 V present at Precharge Relay after 90% TSV charged

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 1.4 Brake Over Travel Switch During Drive State Demo

- Summary: Follow the start up procedure and put the system in drive mode. Apply throttle. Once throttle has been applied, open the Brake Overtravel Switch to ensure that the motor stops spinning. Verify by hand that the motor is free spinning.
- Requirements Met: EV3.5.9, EV7.1.1, EV9.3.3
- Measurement: N/A
- Materials: Stopwatch
- Pass Criteria:
  - a. SSOK lights are not illuminated after Brake Overtravel Switch is opened.
  - b. AIRs are open after the Brake Overtravel Switch is pressed
  - c. Motor stops spinning within 60 seconds.
  - d. Motor is free spinning.

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 1.5 GLVMS During Drive State Demo

- Summary: Follow the start up procedure and put the system in drive mode. Once throttle has been applied, open the GLVMS to ensure that the motor stops spinning.
- Requirements Met: EV7.3.1, EV9.3.3
- Measurement: N/A

- Materials: Stopwatch
- Pass Criteria:
  - a. SSOK lights are not illuminated after GLVMS is opened.
  - b. AIRs are open after the GLVMS is opened
  - c. Motor stops spinning within 60 seconds.

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 1.6 TSMS During Drive State Demo

- Summary: Follow the start up procedure and put the system in drive mode. Once throttle has been applied, open the TSMS to ensure the motor stops spinning.
- Requirements Met: EV7.6.5, EV 9.3.4
- Measurement: N/A
- Materials: Stopwatch
- Pass Criteria:
  - a. SSOKs remain illuminated after TSMS is opened
  - b. AIRs are open after the TSMS is opened
  - c. Motor stops spinning within 60 seconds

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 1.7 IMD Fault Demo

- Summary: Follow the start up procedure and put the system in drive mode. Set the TS power supply to 100V. Use two 51k Ohm resistors in parallel to short the HV+ TSMP to ground to induce an IMD fault. Remove the fault and wait one minute. Follow the start up procedure to re-energize the system. Use the same resistor configuration to short the HV- TSMP to ground to induce an IMD fault.
- Requirements Met: EV7.9.6, EV7.9.7, EV9.3.4, EV9.4.1, EV9.4.2, EV10.1.2
- Measurement: N/A
- Materials: Stopwatch, resistor



- Pass Criteria:
  - a. High voltage shuts off within 30 seconds of inducing the IMD fault on the HV+ TSMP
  - b. IMD Fault Light illuminates when a fault is induced on the HV+ TSMP
  - c. After the resistor is removed from the HV+ TSMP, the system does not re-energize without user input
  - d. High voltage shuts off within 30 seconds of inducing the IMD fault on the HV- TSMP
  - e. IMD Fault Light illuminates when a fault is induced on the HV- TSMP
  - f. After the resistor is removed from the HV- TSMP, the system does not re-energize without user input
  - g. While the IMD Fault light is on the SSOKs are off

## Results:

- 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: \_\_\_\_\_

**1.8 AMS Fault Simulation**

- Summary: Follow the start up procedure and put the system in drive mode. Remove the safety loop jumper to simulate an AMS fault.
- Requirements Met: EV2.11.2, EV9.3.3, EV9.6, EV10.4
- Measurement: N/A
- Materials: N/A
- Pass Criteria:
  - a. AMS Fault light illuminates less than 60 seconds after the jumper is removed
  - b. SSOK lights turn off when the jumper is removed
  - c. AIRs open when the jumper is removed

## Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2. Safety Loop

### 2.1 Grounded Low Voltage Master Switch (GLVMS)

- Summary: Verify GLV only turns on when the side BRBs and GLVMS are closed.
- Requirements Met: EV7.1.1, EV7.3.1, EV7.4.1, EV7.5.4, EV7.6.3
- Observation: GLV current and voltage from GLV multimeter display
- Materials: N/A
- Pass Criteria:
  - a. The system only turns on the Left and Right BRBs are closed and the GLVMS is closed.

Observations:

GLVMS	R. BRB	L. BRB	SCADA Screen On	GLV Light	GLV Multimeter On	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				

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2.2 Master Reset Button and SSOKs

- Summary: Pressing the Master Reset Button while GLVMS is on and while Fault light is off will illuminate the SSOK Lights. Pressing the Master Reset button while the GLVMS is off and / or while the fault light is on will not illuminate the SSOK lights. Cause IMD fault by shorting any single TSMP to Ground.
- Requirements Met: EV9.3.3, EV9.3.4
- Observation: SSOK Lights are illuminated when the correct start up procedure is followed. The SSOK Lights will not illuminate if the the GLVMS is off or the Fault light is on.
- Materials: N/A
- Pass Criteria:
  - a. SSOK Lights light up when MReset is pressed
  - b. SSOK Lights remain on when MReset is released
  - c. SSOK Lights do not light up if the GLVMS is off but the Fault light is off
  - d. SSOK Lights do not light up if the IMD Fault light is on and the GLVMS is on
  - e. SSOK Lights do not light up if the Brake Overtravel button is pushed and the GLVMS is on
  - f. SSOK Lights do not light up if the SCADA Relay is open and the GLVMS is on

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL
- e. PASS / FAIL
- f. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2.3 Cockpit Big Red Button (BRB) and Cockpit Reset

- Summary: Closing the Cockpit Big Red Button allows the system to follow the behavior described in the Safety Loop table. Verify AIRs light is on by following the Startup Procedure.

- Requirements Met: EV7.6.3
- Observation: AIRs light status
- Materials: Oscilloscope or Voltmeter
- Pass Criteria:
  - a. AIRs light turns on when following Startup Procedure when after Cockpit Reset is pressed
  - b. AIRs light turn off when Cockpit BRB is pressed
  - c. AIRs light turns on when Cockpit BRB is opened and Cockpit Reset is pressed
  - d. AIRs light remains off when Cockpit BRB is pressed and the Cockpit Reset is pressed

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### **2.4 Tractive System Master Switch (TSMS)**

- Summary: Follow start-up procedure through turning the TSMS on and pressing the Cockpit Reset Button to close the AIRs. Turn off TSMS to turn off high voltage. Check that AIRs light is on. Turn TSMS back on.
- Requirements Met: EV7.4.1
- Observation: AIRs light illuminates on cockpit panel
- Pass Criteria:
  - a. AIRs light illuminated after TSMS is turned on and Cockpit Reset is pressed
  - b. AIRs light turns off after TSMS is turned off

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2.5 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. Will be tested at a minimum of 2 different thresholds set in configuration file.
- Requirements Met: N/A
- Observation: The SSOKs turn off when an out of range sensor value is detected
- Materials: Oscilloscope, Voltmeter, thermometer
- Pass Criteria:
  - a. Observe the SSOKs turn off when throttle voltage exceeds programmed threshold specified in configuration file
  - b. Observe the SSOKs turn off when the GLV temperature sensor exceeds threshold specified in configuration file
  - c. Observe the SSOKs turn off when the Motor RPM exceeds programmed threshold specified in configuration file

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2.6 AIRs Operation

- Summary: Verify that the GLV has the ability to close all 4 of the AIRs in the Safety Loop under full load of Safety Loop components, motor controller, and cooling system. Using a modified safety loop cable, connect 4 AIRs in series with safety loop. Power the GLV to the point before turning on the TSMS and pressing Cockpit Reset button. Check that cooling system is on and running. Monitor AIRs light on Cockpit Panel.
- Requirements Met: N/A
- Observation: AIRs light on Cockpit Panel
- Materials: EV7.4.3
- Pass Criteria:
  - a. AIRs light is off before pressing Cockpit Reset and turning on TSMS
  - b. AIRs light illuminates after turning on TSMS and pressing Cockpit Reset

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 2.7 GLV System Voltage and Current Measurements

- Summary: Close AIRs, energize the motor controller, and run cooling system. Measure and record maximum, minimum, and average GLV voltage and current during each stage of the startup procedure. Compare GLV system meter measurements with voltmeter measurements. Record current and voltages on oscilloscope during transitions between stages of Safety Loop startup.
- Requirements Met: N/A
- Measurement: GLV System Current, GLV System Voltage
- Materials: Oscilloscope, Voltmeter
- Pass Criteria:
  - a. Maximum current measurement does not exceed 10 A.

Observations (Attach documents of data and all plots):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 3. Startup Procedure

### 3.1 Startup Procedure

- Summary: Following the procedure described in the Startup Procedure Maintenance Manual takes the system from fully de-energized to Drive Mode
- Requirements Met: EV7.7.1
- Observation: Startup Procedure was followed and no Faults occur. Ends in Drive state
- Materials: N/A
- Pass Criteria:
  - a. GLV light turns on after side panel BRBs are closed and GLVMS is turned on
  - b. SSOKs turn on after MReset button is pressed
  - c. Safe light turns on after MReset Reset button is pressed

- d. AIRs light and TSAL turn on after Cockpit BRB is closed and TSVMS is turned on
- e. Drive light stays off if drive button is pressed and brake is not pressed
- f. Pressing the drive button and the brake at the same time before turning the TSVMS on does nothing
- g. Safe light will not illuminate if Cockpit reset button is pressed while GLVMS is off
- h. TSAL and AIRs lights remain off after Cockpit BRB is closed if the GLVMS is still off
- i. TSAL and AIRs lights remain off after Cockpit BRB is closed if the side panel BRBs are closed
- j. TSAL and AIRs lights remain off after Cockpit BRB is closed if the MReset button has not been pressed

Observations:

- 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: \_\_\_\_\_

## 4. TSI

### 4.1 Discharge

- Summary: TSV must drop below 30 V in under 5 seconds after Safety Loop is broken or AIRs are opened.
- Requirements Met: EV2.8.3
- Measurement: Plot the voltage across the discharge resistors versus time.
- Materials: Oscilloscope, Isolated Differential Probe
- Pass Criteria:
  - a. The signal across the discharge resistors is below 30 V within 5 seconds.

Observations (Attach a document / Pictures of graphs):

Results: PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 4.2 Drive - Over Current Transitions

- 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 the testing above for the new threshold.
- Requirements Met: EV7.8.2
- Observation: Lower the overcurrent limit in the TSI firmware to below the normal system operating current. SCADA displays the current state as Drive followed by Over Current.
- Materials: N/A
- Pass Criteria:\*
  - a. The motor stops spinning when in the over-current state
  - b. The Drive Light in the cockpit flashes while in the over-current state.
  - c. The drive state field on the SCADA display shows that the system is in the over current state.
  - d. 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.
  - e. The TSI overcurrent setting is not set by re-compiling and uploading firmware to the TSI microprocessor.



Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL
- e. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

\*Note: TSI Current Sensor to be verified in order for this test to be valid.

#### 4.3 Return to Drive Setup or Idle State Transitions

- Summary: Breaking the Safety Loop in any state returns to Idle state
- Requirements Met: EV7.8.2
- Observation: SCADA displays the current state as Idle after breaking the Safety Loop. The drive light turns off in any state that is not the Drive State.
- Materials: N/A
- Pass Criteria:
  - a. The drive state field on the SCADA display shows that the system is in the Idle State when the safety loop is broken.
  - b. The drive light turns off when the safety loop is broken

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 4.4 Drive to Drive Setup State Transition

- 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: EV7.8.2

- Observation: SCADA displays the current state as Drive Setup after breaking the Safety Loop
- Materials: N/A
- Pass Criteria:
  - a. The drive light turns off when in Drive Setup state
  - b. SCADA displays the current state as Drive Setup after the throttle is implausible
  - c. SCADA displays the current state as Drive Setup after turning off the motor controller
  - d. SCADA displays the current state as Drive Setup after pressing the drive button

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 4.5 High Voltage Indicator Lights

- Summary: Follow the start up procedure until high voltage is present. The high voltage power supply should be set to 100 V. Tractive System Active Light (TSAL) and High Voltage present lights (HVPL) in the cockpit illuminate when high voltage is present in the system. Reduce the TS voltage supplied by the power supply. Record the voltage when the TSAL and HVPL turn off. Increase the TS voltage supplied by the power supply. Record the voltage when the TSAL and HVPL turn on.
- Requirements Met: EV9.1.8
- Measurement: TS voltage when TSAL and HVPL turn off
- Materials: N/A
- Pass Criteria:
  - a. TSAL turns off when the power supply is less than 40 V.
  - b. HVPL turns off when the power supply is less than 40 V.
  - c. The difference between the voltages when the TSAL and HVPL turn off is less than 2V.
  - d. TSAL is on when the power supply is greater than 60 V.
  - e. HVPL is on when the power supply is greater than 60 V.
  - f. The difference between the voltages when the TSAL and HVPL turn on is less than 2V.

Measurements:

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

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL
- e. PASS / FAIL
- f. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

**4.6 Tractive System Active Light**

- Summary: Follow the start up procedure such that there is high voltage present in the system. The Tractive System Active Light (TSAL) flashes whenever there is high voltage present in the system outside of the power supply.
- Requirements Met: EV9.1.3
- Observation: TSAL flashes between 2 Hz and 5 Hz
- Materials: N/A
- Pass Criteria:
  - a. When high voltage is turned on, TSAL is flashing
  - b. When high voltage is turned off, the TSAL turns off

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 4.7 Brakes

- Summary: When the GLV is on (GLV light is on), pressing the Brake button sends a signal and is recognized by the TSI board
- Requirements Met: T7.4.1
- Measurement: SCADA displays that the brake is being pressed and the brake light illuminates
- Materials: N/A
- Pass Criteria:
  - a. The brake light is illuminated when the brake button is being pressed.
  - b. The brake light is not illuminated when the brake button is not being pressed.
  - c. SCADA display indicates that the brake is being pressed when the brake button is being pressed.
  - d. SCADA display indicates that the brake is not being pressed when the brake button is not being pressed.

Results:

Brake Button State	Brake Light	SCADA Brake Status
Pressed (1)	OFF (0) / ON (1)	
Released (0)	OFF (0) / ON (1)	

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 5. Motor Characterization

### 5.1 SCADA Motor Data Acquisition

- Summary: SCADA is able to produce CSV of Motor RPM, Motor Torque, TS Current, TS Voltage relevant to motor characterization
- Requirements Met: N/A
- Observations: Motor RPM, Motor Torque, TS Current, TS Voltage
- Materials: N/A
- Pass Criteria:

- a. SCADA produces a CSV only containing Motor RPM, Motor Torque, TS Current, and TS Voltage data

Observations (Attach a document / Pictures of graphs):

Results: PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 6. Motor Temperature & Cooling

### 6.1 Uncooled Motor Controller and Cooled Motor Controller

- Summary: Disable the cooling system by unplugging J8 from the TSI board. Allow motor controller to operate such that it heats up. Measure temperature over 30 minute time period or until 60°C (safety limit). Repeat with cooling system active for motor controller.
- Requirements Met: N/A
- Measurement: Plots of motor controller temperature versus time with and without cooling.
- Materials: Timer or Stopwatch
- Pass Criteria:
  - a. Plot of motor controller temperature vs time for cooled and uncooled conditions
  - b. Plot of cooled motor controller temperature always less than or equal to uncooled motor controller temperature

Observations (Attach a document / Pictures of graphs):

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 6.2 Motor and Cooling Stress Test

- Summary: Run motor and measure time needed for motor controller temperature to reach 60°C or until 1 hour has elapsed. Throttle must be at least 50%.
- Requirements Met: N/A
- Measurement: Time, Motor Controller Temperature

- Materials: Timer or Stopwatch
- Pass Criteria:
  - a. Cooled Motor Controller temperature does not reach 60°C in 30 minutes.
  - b. No cooling leaks are observed during or immediately after the 1 hour stress test.

Observations (Attach a document / Pictures of graphs):

Results:

- a. PASS / FAIL
- b. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 7. System Sensor Calibration Verification

All sensors need to go through primary calibration according to procedure in the system user manuals. Primary calibration records are posted on the website. Information on the expected uncertainty of error is posted on the website under testing: sensor analysis of uncertainty.

### 7.1 Motor Temperature

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

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 7.2 Motor Controller Temperature

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

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 7.3 Motor Velocity at Motor Output Shaft

- Summary: Verify the functionality of the Motor Controller velocity sensor and Huff Box RPM sensor. Sample data at a minimum of 20 operating points between 0 RPM and 4000 RPM. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: Motor RPM
- Materials: Handheld tachometer
- Pass Criteria:
  - a. Motor Controller - The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.
  - b. Huff Box - 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: \_\_\_\_\_

#### 7.4 Huff Box Motor Output Shaft Torque

- Summary: Verify the functionality of the Huff Box Dynamometer Torque sensor. Apply static load to perform measurement using known weights. The motor has a maximum continuous torque output of 80 N-m and torque is transferred to the dynamometer pump through a 0.4 gear ratio. The dyno must be able to measure 200 N-m (~150 ft-lbs) for torque. Sample data at a minimum of 15 operating points with a static load between 0 and 150 ft-lbs. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: Torque
- Materials: Known weights
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

#### 7.5 Motor Controller Motor Torque

- Summary: Verify the functionality of the Motor Controller Torque sensor. Apply dynamic torque load with the motor spinning the dynamometer pump. Compare to Huff Box torque reading on SCADA. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: Torque
- Materials: Known weights
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):



Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 7.6 Tractive System Voltage and Motor Controller Voltage Sensors on TSI

- Summary: Verify the functionality of the Tractive System Voltage and Motor Controller Voltage sensors. Place system in Drive Setup state before sampling. Sample data at a minimum of 10 operating points between 0 and 100 V. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: Tractive System Voltage and Motor Controller Voltage sensors on TSI
- Materials: Oscilloscope or Voltmeter, Isolated Differential Probes
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 7.7 Tractive System Current Sensor in TSI

- Summary: Verify the functionality of the Tractive System Current sensor in TSI enclosure. Use the TS power supply to apply a current limit such that current is known through system. Induce current by applying short between High Voltage TSMPs. Record the current reported by the SCADA. Sample data at a minimum of 20 operating points between 0 and 300 A. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: Tractive System Current sensor in TSI board
- Materials: Power Supply, Disabled IMD
- Pass Criteria:

- a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 7.8 Grounded Low Voltage Sensor

- Summary: Verify the functionality of the external multimeter sensor and SCADA reporting. Sample data at a minimum of 10 operating points between 22 and 25 V. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: GLV
- 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: \_\_\_\_\_

### 7.9 Grounded Low Voltage Current Sensor

- Summary: Verify the functionality of the external multimeter sensor and SCADA reporting. Create a special safety loop jumper that has a variable load rated for 24V. Measure GLV current at a minimum of 10 operating points. Perform statistical analysis

according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.

- Requirements Met: N/A
- Measurement: GLV Current
- 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: \_\_\_\_\_

### 7.10 Grounded Low Voltage Temperature Sensor

- Summary: Verify the functionality of the GLV temperature sensor. Produce heat using heat source and compare with Fluke thermometer. Sample data at a minimum of 10 operating points between 0 and 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: GLV Temperature
- Materials: Heat source, Fluke Thermometer
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 7.11 TSI Temperature Sensor

- Summary: Verify the functionality of the TSI temperature sensor. Produce heat using heat source and compare with Fluke thermometer. Sample data at a minimum of 10 operating points between 0 and 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met: N/A
- Measurement: TSI Temperature
- Materials: Heat source, Fluke Thermometer
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

### 7.12 Cooling Temperature Sensors

- Summary: Verify the functionality of the Cooling temperature sensor. Add / replace water with warmer water in order to modify temperature. Compare with Fluke thermometer. Sample data at a minimum of 10 operating points between ambient temperature and 60°C. Perform statistical analysis according to the Calibration Verification Procedure procedure in Appendix A - Statistical Methods.
- Requirements Met:N/A
- Measurement: Cooling Temperature
- Materials: Fluke Thermometer
- Pass Criteria:
  - a. The expected sensor uncertainty is within the confidence interval constructed from observed sensor uncertainty.

Statistical Analysis (Attach Document):

Results:

- a. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_



## 8. Reliability Demo

### 8.1 24 Hour Demonstration

- Summary: Verify the system is able to be in an operational state for a continuous 24 hour period without raising a fault or requiring intervention. Run ATP tests in the above sections during this time period that will not require the system to be significantly altered. Must run motor at least once for 3 minutes above 1000 RPM during this time. At the end of the 24 hour period, the motor must spin above 1000 RPM for at least 1 minute.
- Requirements Met: GPR006, GPR007
- Measurement: 24 hour time period without fault, error, or system failure requiring human intervention.
- Materials: Timer or Stopwatch
- Pass Criteria:
  - a. A timer or stopwatch reaches 24 hours of system active time without powering the system down as a result of a fault, error, or system failure. (Powering the system down as required by an ATP test is acceptable and should be noted in the observation/notes section.)
  - b. Motor runs above 1000 RPM for 3 minutes.
  - c. Motor runs above 1000 RPM for 1 minute after 24 hours of the system being on.

Observations:

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 9. TSV/AMS Prototype

### TSV Prototype Requirements (included above):

- EV2.1 - Design Document
- EV2.11.2 - Test 9.1, Test 9.2
- EV2.11.4 - Design Document, Test 9.1, Test 9.2, Test 9.3
- EV2.11.5 - Design Document - High Level Block Diagram
- EV2.11.6 - Design Document
- EV2.11.7 - Design Document
- EV2.11.8 - Design Document
- EV2.11.9 - Design Document, Test 9.3.4

All other rules are outside the scope of the TSV/AMS prototype and will not be tested explicitly in this document. (Other rules may be checked through the rules walkthrough.)

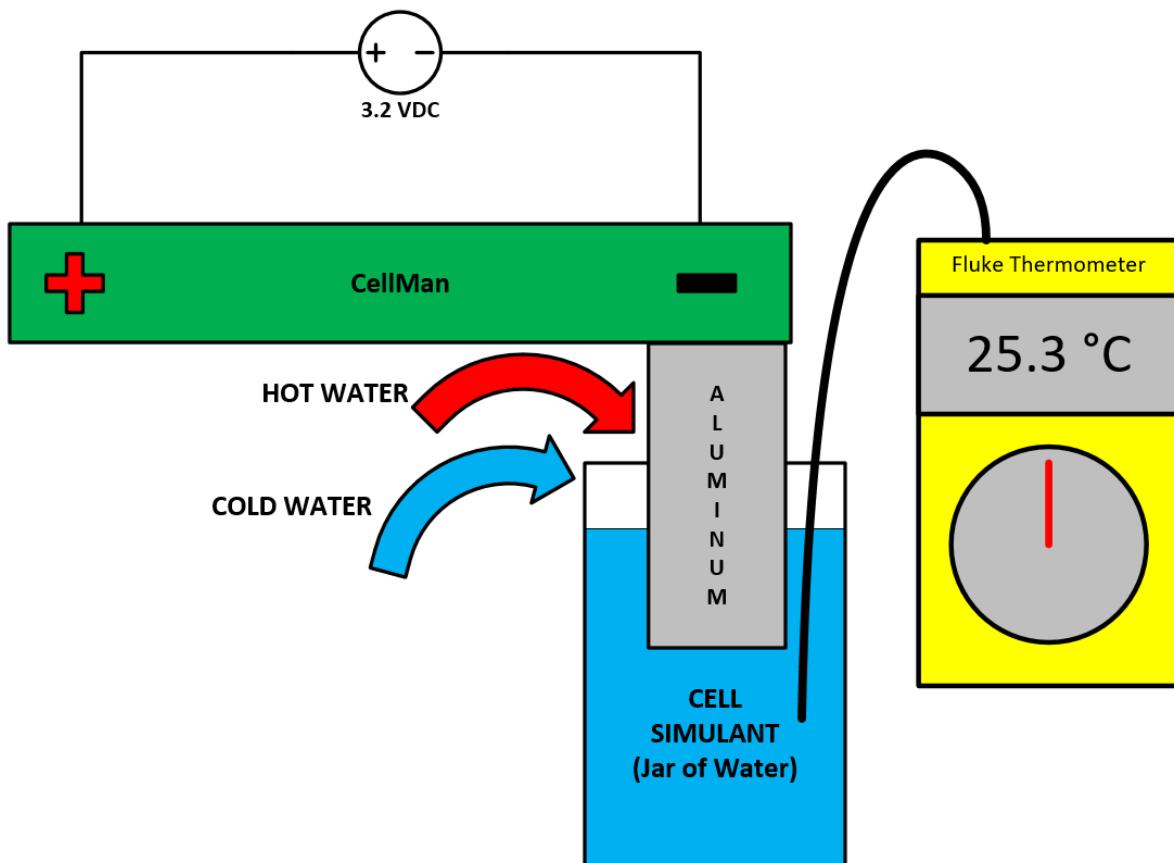


Figure 2 - TSV Prototype CellMan Configuration for Temperature Measurement Testing

### 9.1 Cell Voltages

- Summary: Measure 3 CellMan voltages on SCADA with the AMS for at least 20 different operating points between 2.0 V and 4.0 V.

- Requirements Met: EV2.11.2
- Measurement: CellMan voltage
- Materials: 3 DC Bench Power Supplies, voltmeter
- 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 Cell Temperature

- Summary: Measure 3 CellMan temperatures on SCADA with the AMS with cell temperatures at ambient room temperature and near 40 °C and 60 °C. Use at least 10 different operating points. Set up each CellMan according to Figure 2.
- Requirements Met: EV2.11.2
- Measurement: CellMan temperature
- Materials: Fluke temperature, hot and cold water, 3 water containers, 3 aluminum bars
- 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: \_\_\_\_\_

### 9.3 AMS Faults

- Summary: If a sensor reading is out of the range specified by PackMan, the AMS relay will close and short the safety loop in (SLOOPIN) and safety loop out (SLOOPIN) signals on the PackMan board in less than 60 seconds.
- Requirements Met: EV2.11.2, EV9.3.3, EV9.6, EV10.4
- Measurement: The AMS relay closes, timing before relay switches
- Materials: Oscilloscope, Voltmeter, time measurement device
- Pass Criteria:
  - a. Observe the AMS relay opens when the measured cell voltage is above the threshold set by PackMan.



- b. Observe the AMS relay opens when the measured cell voltage is below the threshold set by PackMan.
- c. Observe the AMS relay opens when the measured cell temperature is above the threshold set by PackMan
- d. Observe the AMS relay open when the watchdog is timed-out.

Results:

- a. PASS / FAIL
- b. PASS / FAIL
- c. PASS / FAIL
- d. PASS / FAIL

Test Observed By: \_\_\_\_\_ Date: \_\_\_\_\_

## 10. Project Deliverables

### D000: PDR

Completed in the Fall Semester.

### D001: CDR

Waived. Team will instead complete two (2) weekly design reviews on individual components with detailed minutes recorded.

### D002: User Manuals

Part	SCADA	GLV	TSI	TSV	Motor / Motor Controller / Dyno	Cooling	Interconnect
Annotated Drawing of Physical System							
Annotated Screenshots of all UI							
Annotated Drawings of any Physical Control Panels, Indicator Buttons, Power Switches, and other controls							
Simplified Block Diagram							
“Getting Started”							
“FAQ”							
Detailed Explanations of All Functions and Control							
User Level Troubleshooting, Calibration, and Maintenance							

### D003: Final Report and Maintenance Manual

#### Final Report

Check	Completed
Maintenance Manual	
Static Copy of the Website	
Flash Drive Delivered in a Professional Quality Case	
Delivered to Advisors and Department Head on a Flash Drive	

**Maintenance Manual**

Part	SCADA	GLV	TSI	TSV	Motor / Motor Controller / Dyno	Cooling	Interconnect
Maintenance / Calibration							
Schematics / Layouts							
Connector Pinouts							
Cable Signal Assignment							
Interface Semantics							
Block Diagrams							
State Diagrams							
Source Code Trees							
Additional Low Level Information							

**D004: Acceptance Test Plan**

The ATP shall describe the inspections, analyses, and demonstrations that will be used to demonstrate the final project is compliant with the Statement of Work and FH Rules.

**D005: Acceptance Test Report**

The ATR shall document the results of the tests laid out by the ATP.

**D007: Project Website**

The project website shall be updated on a weekly basis with purchasing reports, project status letters, individual progress reports, source code, block diagrams, schematics, and layouts.

**D008: Final Presentation and Delivery**

Check	Completed
Project Posters Displayed	
Project Video Present	
Project Demonstrated	

**D010: Project Posters**

Part	SCADA	GLV	TSI	TSV	Motor / Motor Controller / Dyno	Cooling	Interconnect
Subsystem Summary							
47x35 inches							
High Resolution Text and Images							
Website URL Link							
Website QR Code							

**D013: Purchasing Report**

Check	Completed
Table for all Purchase Orders	
Purchasing Summary Organized by Week	
Purchasing Summary Organized by Team	

Website Budget Information: <https://sites.lafayette.edu/motorsports/finance/>

**D014: Project Management and Status Letters**

Check	Completed
Project Status Letters Delivered	
ATP Delivered	
Individual Progress Reports Delivered	
Work Breakdown Structure Delivered	

**D015: Motor Characterization Curves**

Check	Completed
Motor Characterization Curves Delivered	

**D016: Rules Walkthrough**

Check	Completed
Informal Competition Rules Walkthrough with Course Instructor(s)	

## Analysis Provided in Required Documentation

Supporting analysis will be provided in the system or subsystem documentation required by D001.

Analysis Number	Requirements Met	Subject of Analysis	Acceptance Signature
A1	EV7.1	Safety Loop Rules Compliance <ul style="list-style-type: none"> <li>• Ensure that the design of the Safety Loop will be in compliance with the competition rules.</li> <li>• Compare Safety Loop schematic to Figure 37 in Formula Hybrid competition rules</li> <li>• A written step-by-step procedure for operating the Safety Loop and operating the AIRs</li> </ul>	
A2	EV2.10	Precharge Circuitry <ul style="list-style-type: none"> <li>• Provide circuit analysis and calculations showing that precharge capacitors will reach at least 90% of TSV in before connecting power to Motor Controller.</li> </ul>	
A3	EV2.10	Discharge Circuitry <ul style="list-style-type: none"> <li>• Provide circuit analysis and calculations showing that discharge circuitry allows the high voltage to be discharged to below 30 V in under 5 seconds.</li> </ul>	

## Additional Inspection & Analysis Documents

All inspections will be delivered with or contained within the ATR. Some inspection forms will have additional analysis sections. Below are descriptions of the inspection documentation necessary for requirement compliance.

### I1. Documentation

- Summary: This inspection sheet will be used to demonstrate that all documentation is delivered and provides the information required by GPR001.
- Requirements Met: GPR001

### I2. Cable and Wire Inspection

- Summary: This inspection sheet will be used to demonstrate that all cabling complies with GPR005 and is rules compliant. It will contain a list of all cables and wires used in

the system that shows UL listing, a picture indicating wire temperature, gauge rating, correct crimps, and strain relief.

- Requirements Met: GPR005
- I3. Controls and Indicators Inspection
- Summary: This inspection sheet will be used to demonstrate that all of the controls and indicators present on the system, such as stickers or lights, are correctly labeled.
  - Requirements Met: GPR005
- I4. Fuse Analysis and Inspection
- Summary: This analysis will be used to demonstrate that all fuses are correctly rated and that UL listed fuse holders are utilized.
  - Requirements Met: GPR005
- I5. Software & HDL Inspection
- Summary: This inspection will be used to demonstrate that all software, firmware, and HDL is in compliance with the software maintainability plan.
  - Requirements Met: GPR007
- I6. Thermal Analysis
- Summary: This analysis will be used to demonstrate all components that dissipate any significant amount of power comply with GPR005
  - Requirements Met: GPR005
- I7. Safety Plan
- Summary: This document will be used to provide a standard for team safety methodology by which safety is monitored during system operation and testing.
  - Requirements Met: GPR005
- I8. Maintainability Plan
- Summary: This document will include Team and System Level Maintainability Expectations for all hardware produced.
  - Requirements Met: GPR007
- I9. Car Integration
- Summary: Ensure systems have been designed such that they will be rules compliant for car integration
  - Requirements Met: N/A
- I10. End of Project Inspection
- Summary: Ensure that GPR012 is complied with.
  - Requirements Met: GPR012
- I11. Sensor Accuracy and Calibration
- Summary: A statistical analysis will be performed on the sensor data collected section 7 to ensure that the sensors utilized by the system meet the 90% confidence interval specified by D004.
  - Requirements Met: D004

## Appendix A - Statistical Methods

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