Acceptance Test Plan

ECE 492 - Spring 2016

Table of Contents

Abstract

This document describes the test plan of the 2016 Lafayette Electric Vehicle Team. The plan is first presented in an overview and is detailed later on.

Acceptance Test Plan Overview

How the table is organized

The following table is an overview of the tests that are run as well as the documents to be submitted. A more detailed version is found further below. The item description is a brief summary of what the item is and to the right is what requirements the item demonstrates. The next column provides a summary of what completing the item entails. The final column is what kind of Item it is. A test is an item that involves a demonstration meeting the requirements. An analysis is an item that involves looking at relevant acquired data, processing it, and then writing conclusions. An inspection involves a detailed check and sign off to ensure correctness. A report involves a little of both analysis and report items in one document.

Full System Requirement and Deliverables

Item #	Item Description	Demonstrates Requirements	Successful Test Summary	Type of Verification
Items Requiring Demos				
1	VSCADA talks to PAC-MAN, reading/setting values and displaying calibrated output data using automated script functionality on the VSCADA. The system is also able to run 24 hours straight	GPR006 R001b R002a, R002c, R002d, R002e, R002g, R002k, R002l, R002f, R002h, R002i, R002m, R002n R003c, R003d, R003f, R003g	Integrated system functions as expected and we receive similar results to that of individual QA tests. VSCADA values match values read on pack display, navigated to through on pack controls. The throttle is set to the values we have planned at the proper time and in the proper sequence Throttle responds to VSCADA control matching those of QAR002f1	Test

	without failure.		Data viewed in the logs and graphs is representative of what is observed and backed up by QAR002m QA tests While the safety loop is closed the GLV systems is powered on. System is able to operate 24 hours straight without failure and with no human intervention	
2	Safety loop demonstration	R002b, R002o, R002m R003b, R003c, R003d, R003e	The GLV light turns on when power is supplied through the master switches, the safety loop light must remain off once GLV power is first enabled and only turn on once all faults are cleared and the reset button is pressed, and the safety loop light turns off on a system fault. Additionally, the VSCADA system is able to monitor and log the status of the safety loop.	Test
3	Analysis report exists with summaries and discussion of data for static and dynamic characterization, efficiency and cooling. Analysis report describes the physics model, featuring a diagram of a Simulink model and discussion of results.	R005a, R005b, R005c, R006a, R006b, R006c	Report prepared and submitted including all data collected for characterization, graphs of measurands vs time, and descriptions of the constraints and efficiency determinations for the system. Report also includes an equation for the system's physics model, including a discussion of all assumptions made for parameters of the fully integrated car. Diagram of model is present and plots are displayed and correlated with the expected results of the physics model. Results of the modeling are included with estimates of efficiency,	Report

			gear ratios, throttle operation, energy requirements, and torque.	
4	Final Project Presentation	GPR011, GPR012, D008	Each of the requirements is presented to be met with proper citation and reasoning as to why Required Documents are presented and fulfill their individual requirements	Analysis
5	Fully charge and discharge an accumulator on 30A port and Discharge an accumulator though AIRs while connected to a safety loop.	R001a, R001c, R001d, R001e, R001f R002j	PAC reads fully charged when it is fully charged and reads empty when empty. PAC charges fully from multiple starting states of charge. PAC discharges without issue with varying load. PAC opens SL while charging. The PAC discharges successfully without component failure, software lock ups, or unexpected human intervention.	Test
6	Motor spun with dynamometer close to FDD to demonstrate working capability of the system for specific RPM and torque measurements and show that the system has been correctly modeled.	R006a, R006b	Motor in dynamometer setup is successfully spun using old VSCADA software for controlling throttle and load. Data collected using VSCADA software agrees with results of mathematical / Simulink model within specified standard uncertainty specified in Calibration & Accuracy document D011.	Test

Items Requiring Deliverables				
7	Interface Control Document	R004b	Submitted document provides detailed documentation of every cable in the system, including length, pinout, wire colors, gauges, connector specification, assembly instructions and discussion of the signals transmitted including source, destination, and purpose.	Inspection
8	Project Management and Status Letters	D014	Weekly individual status letters are received and approved by professors Weekly Group status letter is received, presented, and then approved by professors	Report
9	User Manual Assurance	GRP007 D002	A novice is able to figure out a common issue and resolve it. An expert is able to figure out an uncommon issue and resolve it using documentation A full system user manual is approved	Analysis
10	Document Integrity and Safety	R000/EV GPR001	Analysis of formula EV rules and processes.	Inspection
11	Safety Plan and Adherence	GPR005	Documentation proving our commitment to safety in the lab space.	Report

12	Maintainability Report	D012	An analysis is explaining why our software and hardware are effective moving forward	Report
13	PDR Report, Presentation, and ITCP	D000	Preliminary Design Review is submitted and approved by the team and Professors	Report
14	CDR Presentation	D001	CDR is presented and approved along with an approved ATP	Report
15	Project Poster	D010	Poster is presented and approved	Report
16	Final Report and Maintenance Manual	D003	Complete report and manual are accepted by team and professors and passes self-imposed requirements that are put forward for GPR001	Report
17	Acceptance Test Plan	D004	Complete report is accepted by team and professors and passes self-imposed requirements that are put forward for GPR001	Report
18	Acceptance Test Report	D005	Complete report is accepted by team and professors and passes self-imposed requirements that are put forward for GPR001	Report
19	QA Results Report	D006	All individual QA tests are individually reviewed by the team and compiled into an overall report	Report
20	Project Web Site	D007	A professional and organized website containing all other deliverables is	Report

			present.	
21	Calibration and Accuracy Analysis	D011	Complete report is accepted by team and professors and passes self-imposed requirements that are put forward for GPR001	Report
22	Purchasing Report	D013	All purchases are tracked, recorded and presented in an appealing fashion	Report

Acceptance Test Plan Details

Item 1 - General Operations and Reliability Test

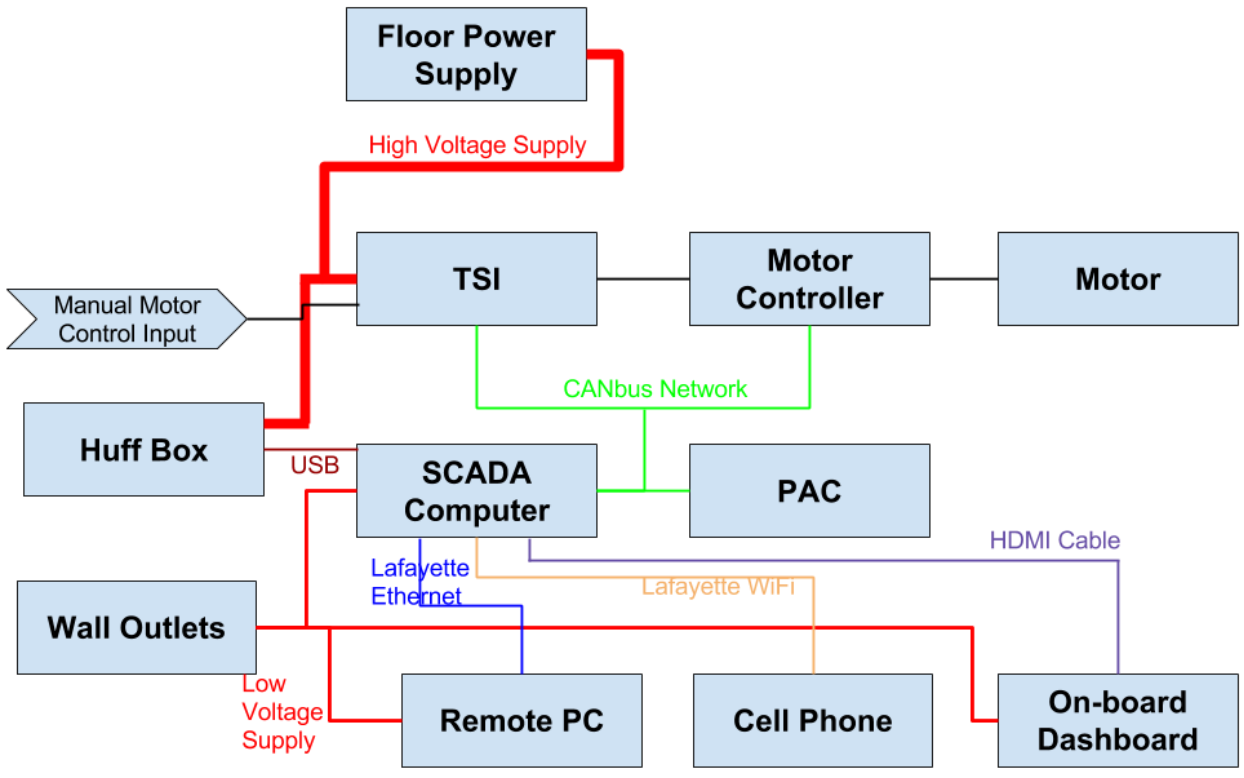
Item Overview

SCADA talks to PAC-MAN, reading/setting values and displaying calibrated output data using automated script functionality on the VSCADA.

This also is a test designed to meet requirement GPR006. The test involves a 24 hour reliability demo that is done on the system. The system should run without failure or human intervention for 24 straight hours.

scadad software used in this item will match the deployment build.

Configuration Diagrams



Detailed Procedure

Maintenance mode is tested first. It involves controlling the motor, which is powered off of a power source, via remote PC or cell phone and draws power from the battery packs. Live data is displayed on the Cell Phone, the remote PC, and the Dashboard. SCADA demonstrates the ability to be run by an automated script in Maintenance mode.

Drive mode is next and the same visual outputs as maintenance mode are displayed. The main difference is that the SCADA computer is unable to set the motor Controller in this mode, instead the drive controller is controlled by some manual input.

Lastly, drive demo mode does not drive the motor at all but still displays all values from the previous tests.

The 24 hour system test is done by running the motor off of the power supply. Both are controlled by SCADA. SCADA logs any non-obvious failures into its database to verify a successful test

How and why requirements are met

GPR006: Reliability

- The 24 hour test is monitored and run via SCADA while being fed off of the power supply.
    - Pass/Fail: 0 faults are recorded or accur

R001b: Data Acquisition

- VSCADA successfully retrieves values for all parameters from PacMan and these values are calibrated.
    - cell voltage
    - pack voltage
    - cell temperatures
    - pack internal temperatures
    - pack current
    - State of Charge estimates
    - charge algorithm state
- Values can be seen on various displays connected to the system
- Measurand verification is included in R002m verification
- Pass/Fail: Displayed values when compared with expected values, fall within acceptable ranges calculated by D011
    - Expected values are retrieved from an external measuring device.

R002a: Car dash Display

- Refer to R002m for verifying that displayed values are correct
- Pass/Fail: Able to read the status of the system from the car dashboard screen
    - Car dash information is current, estimated vehicle speed, and state of charge

R002c: VCI

- The throttle is controlled by SCADA system
    - The throttle is set and displayed using SCADA system. Information is proven accurate by referring to several QA tests from R005 and R006 concerning calibration.
    - Pass/Fail: The results should be consistent within tolerance computed in D011 when compared to the results of the motor monitoring team

R002d: Cell Phone Interface

- Pass/Fail: Cell phone is able to access the same page that a PC can access and is capable of all features a PC has

R002e: Remote PC Interface

- Pass/Fail: A computer screen can display stats and allows for control of the system as outlined by SOW.
    - Refers to requirement R002m for what is displayed and how we know that it is calibrated
    - The controls available are defined per operating mode available in the statement of work

R002g: Maintenance Mode

- Pass/Fail: In order for the motor to be controlled by SCADA, it needs to be in maintenance mode
- Pass/Fail: Capable of disabling safety checks
- Pass/Fail: Safety considerations are taken to prevent this mode from accidental access

R002k: Shutdown Mode

- Pass/Fail: Demonstrate that the shutdown scada computer draws zero current
- Pass/Fail: Device is capable of turning back on in operable state and without corruption
- Pass/Fail: SOC of the PAC that is connected to the loop does not decrease any faster when the pac is attached to a shutdown system as opposed to not being plugged into anything

R002l: Monitoring and Data Acquisition

- Pass/Fail: Data Logs and monitors are displayed using PC interface
    - For what is displayed see R002m
    - Pass/Fail: Logging is still completed in drive mode even though you may not be looking at the maintenance screen

- Pass/Fail: All normal data can be displayed on all connected displays at once no matter the mode
- Pass/Fail: All normal data can be displayed while the pac is being charged

R002f: Throttle Control Interface

- Throttle is shown to be adjustable via SCADA
    - We know from looking at it that it turns on
    - Pass/Fail: Our values for RPM and torque should match or very closely resemble those we expect. The expected values will be done by the modeling team and will be analyzed in D011 Calibration and Accuracy Analysis.

R002h: Drive Mode

- Pass/Fail: SCADA is switched to drive mode at which point the motor controller does not respond to the throttle control interface.
- Pass/Fail: Motor is controlled by the manual motor control input
    - Pass/Fail: Our values for RPM and torque should match or very closely resemble those we expect. The expected values will be done by the modeling team and will be analyzed in D011 Calibration and Accuracy Analysis.
- Pass/Fail: Safety functions cannot be disabled in this mode
- Pass/Fail: Drive mode does not function without a detecting a complete system first

R002i: Drive Demo Mode

- Pass/Fail: Drive Demo mode does function without a detecting a complete system first
- Pass/Fail: Minus the above requirement, the mode functions identically to drive mode

R002m: Modular Data Acquisition System

- Data collected is visible through various means display screens outlined above. Each data item has associated QA tests to ensure accuracy and correctness. The following data items are available
    - Overall voltage, current, and power delivered to the load
        - From TSI
    - Individual cell voltages, aggregate pack voltage, and total TSV
        - From PACMAN
    - Tractive system DC current and motor phase currents
        - From TSI
    - Sensor outputs required to diagnose failure in the pack fuse and AIRs
        - TSI detects lack of voltage despite pac present
        - This indicates that possibly a fuse is blown and will point a crew in the right direction
    - Rate of charge or discharge of accumulator and cells
        - Keeps track of SOC percentage and displays the rate of change
    - Temperatures of all subsystems and cells
    - Vehicle Speed and Distance traveled

        - These are calculated items based on expected vehicle weight and torque.
    - Data available from Dyno stand
        - torque
        - oil temp
        - RPM
        - coolant flow rate
- Pass/Fail: Acceptable thresholds are outlined in document D011 Calibration and Accuracy Analysis. The test passes when calculated and actual values fall within the threshold. This pass/fail is evaluated for each bulleted measurand on the list

R002n: Closed Loop VSCADA control

- Most of the demonstration is run using a premade automated script to put the motor through its paces.
    - Pass/Fail: Scada is run seen to be control values on a timeline without user intervention

R003c: Vehicle user interface

- Pass/Fail: The dashboard display from R002a is operational and R002a has passed

R003d: Tractive System Interface

- TSI monitors the TSV and GLV to ensure that they remain isolated from one another
- Pass/Fail: TSI is capable of driving the motor controller
- Pass/Fail: TSI is capable of delivering the variables and statistics in R002m that are stated to come from TSI. R002m is also passed.
- TSI is implemented using a separate embedded system independent of the SCADA computer

R003f: Throttle

- A manual throttle that controls the motor when SCADA is set to drive mode

R003g: GLV CAN bus

- CAN bus operates on GLV to allow SCADA to communicate with system sensors
- Pass/Fail: When manual throttle is applied the motor spins faster, reaching max speed when the manual throttle is all the way pushed.
- Pass/Fail: The motor does not spin at all when the manual throttle is applied

QA Tests and Test Memos

QAR001b - Data Acquisition

1. Calibration Accuracy and Analysis (D011)
2. Test I2C messages
3. Test all CAN messages with Lab Terminal, in test stand, in all states
4. Test all CAN messages with VSCADA board, in test stand, in all states

5. Test all CAN messages with Lab Terminal, in Accumulator with LiFePO4 cells, in all states
6. Test all CAN messages with VSCADA board, in Accumulator with LiFePO4 cells, in all states

QAR002m - Measurand Collection

1. Collect data from measurands and compare the results to external instruments to verify proper calibration.
2. When possible reference R005 and R006 requirements to avoid redundancy

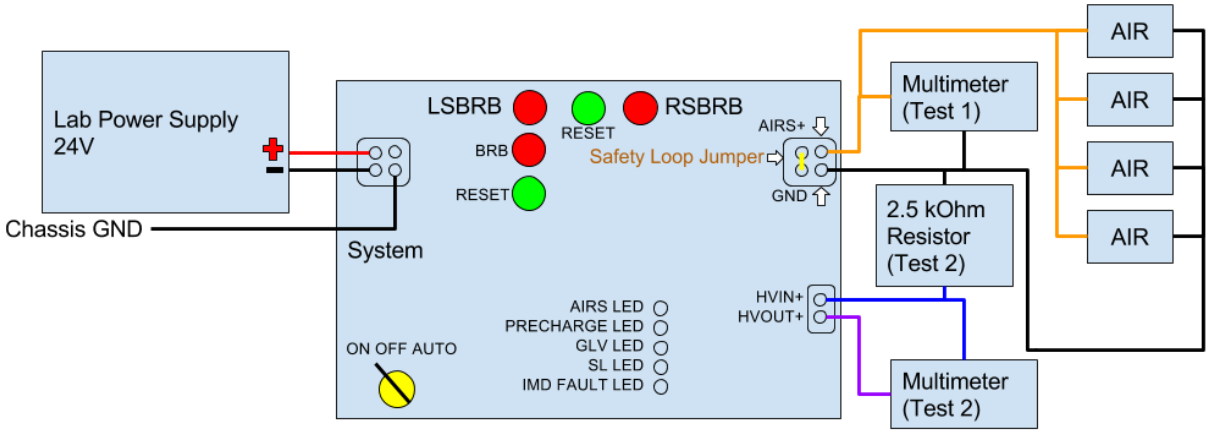
Item 2 - Safety Loop Test

Item Overview

The test configuration shows that the AIRs can be opened and closed with the presence of the 24V safety loop voltage. This safety loop voltage is monitored and can be controlled by scada and the external E-stop buttons.

scadad software used in this item will match the deployment build.

Configuration Diagram



This test requires the VCI/Safety/Power Box, the Cockpit controls and one battery pack and a minimum of five relays(including AIRs inside the battery pack). This test could also be performed with five relays independently of the battery packs. The GLV battery is a power supply.

Detailed Procedure A

- If the safety loop components are in their closed state the GLV voltage is to be present
- Press the green reset button on the SCADA/GLV Power/Safety Box
- Press the green reset button on the cockpit panel which should then close all five relays
- The GLV LED, SL LED and the AIRs LED should all be lit
- Press the the BRB on the cockpit panel to open the AIRs (five relays); the SL LED and AIRs LED are off if it is correct
- Put the cockpit BRB into the closed position then press the cockpit reset to restore power to the AIRS
- Press either the LSBRB or the RSBRB to open the airs
- The system can then be reset by repeating steps 1-3

Detailed Procedure B

- Set the switch to its ON position (+24V)
- Check continuity across the precharge relay to ensure that it has closed
- Set the switch to its OFF position (GND)
- Check continuity again, but to ensure that it remains open
- Set the switch to its AUTO position (JGB ctrl)
- Set the TSILV to send a signal that closes the precharge relay when the motor controller is giving out +24V
- Check continuity to confirm that it closes the precharge relay when the TSILV activates
- Set the switch back to its ON position
- Apply a resistance of 250 ohms/volt between the GLV ground and the TSV+
- Confirm that the IMD opens the safety loop within 30 seconds
- Verify that the SCADA has logged the incidents of the safety loop tripping

How and why requirements are met

R002b: Safety Loop Integration

- VSCADA is capable of monitoring safety loop status
    - Pass/Fail: UI correctly displays when the loop is triggered
    - Pass/Fail: When safety loop is triggered a log of the triggering is created by SCADA

R002m: Modular Data Acquisition System

- Pass/Fail: Safety loop status is displayed on the dashboard and is correct throughout all tests

R002o: Event Logging
- Pass/Fail: Logs occurrences of safety loop trips and when they happened

R003b: GLV Safety Loop
- Various fault situations are able to successfully cut power to the majority of the safety loop
    - Pass/Fail: BRBs can trigger the safety loop
    - Pass/Fail: TSI can trigger the safety loop
    - Pass/Fail: SCADA can trigger the safety loop
    - Pass/Fail: A triggered safety loop can not be cleared until appropiate resets are done
        - A cockpit loop trigger can be reset with just the cockpit reset button
        - Outer safety loop must be reset by pressing both the cockpit and system reset buttons

R003c: Vehicle User Interface Panels
- The interface includes the GLVMS, TSVMS, BRBLS, BRBRS, and reset button.
    - Pass/Fail: These are proved to properly operate in the context of the safety loop
- Pass/Fail: All switches and buttons are integrated into the interface and labeled such that they can be identified at a glance.
- Vehicle interfaces are designed such that they are capable of being housed and tested within a 19” rack cabinet, in addition to the car setup.
    - Pass/Fail: Interface is seen mounted to the 19” rack cabinet

R003d: Tractive System Interface
- TSI monitors the TSV and GLV to ensure that they remain isolated from one another
    - Pass/Fail: When shorted together the IMD relay goes off triggering the safety loop
- TSI is capable of disabling the safety loop and motor controller under system faults or driver input
    - Pass/Fail: R003b TSI section has passed

R003e: VCI Hardware
- Support all needs of SCADA to make sure all parts that exist on the car are supplied power via GLV.
    - SCADA is powered on and fully functional
    - Pass/Fail: All other tests in this item pass
- User interface hardware such as dashboard is demonstrated.

QA Tests and Test Memos

QAR002b - Safety Loop Integration

1. Ensure that when safety loop is triggered and only when its triggered the UI displays it as such

QAR002o - Event Logging

1. Show logs of events such as safety loop trigger with expected times of recording

QAR003b - GLV Safety

1. Test for safety loop operation under system faults

QAR003c - Vehicle User Interface Panels

1. Test that buttons and interfaces operate as expected

QAR003d - Tractive System Interface

1. Test that the TSI interacts properly with the safety loop and trips it as needed
2. Monitor that TSV remains isolated from the GLV and ground
3. Test that the Motor/Motor Controller can be engaged and disengaged from driver input

Item 3 - Motor Characterization and Dynamic Modeling Reporting Analysis

Item Overview

Analysis report exists with summaries and discussion of data for static and dynamic characterization, as well as efficiency and cooling. Static data is represented in plots covering the full range of torque and RPM estimated for the fully integrated car. The estimates for this range are backed up by discussion that anticipates characteristics of operation for the car. Analysis report also describes the physics model, featuring a diagram of a Simulink model and discussion of results.

Configuration Diagrams

N/A

Detailed Procedure

Plots are included in a presented analysis report which shows static data across the estimated full range of torque and RPM for the fully integrated car. Supporting information is provided which reinforces these ranges. Plots are also present which are representative of the dynamic characteristics of the motor+controller system. Dynamic parameters are listed and any calculations are shown. A brief analysis of collected cooling data and calculations for efficiency is shown in the report. A list of assumptions has been prepared about the expected parameters of the fully integrated car. These assumptions include mass, frictional losses, compliance, and gear ratios. The data included in these assumptions is included in a physics model, which is fully described and rationalized with motor + controller data for support. The diagram of a Simulink model which implements this model is shown, and plots of the simulation results verify proper implementation. A results and conclusions section is included which provides analysis of energy requirements, and estimates of maximum torque, speed, and accumulator current. This section also addresses vehicle efficiency losses, and best possible gear ratios. Optimum throttle operation for max efficiency, acceleration, and handling are listed.

How and why requirements are met

R005a: Static Characteristics

- Static data was collected with constraints and torque/RPM ranges determined
    - Torque
    - Power supply voltage
    - Power supply current
    - Motor RPM
- Analysis report exists which presents the static performance curves of the vehicle with constraints of the dynamometer and motor discussed.
    - Torque vs. RPM graph included
    - Ranges determined based on operating region for motor + dynamometer tests
    - Pass/Fail: Portion included as part of full analysis report is accepted by professors

R005b: Dynamic Characteristics

- Dynamic data is provided alongside a report analyzing the data and conclusions are discussed regarding the function of the vehicle in dynamic conditions.
    - RPM vs. time
    - Torque vs. time
    - PS current vs. time
    - Figures taken from oscilloscopes included as supporting data
    - Pass/Fail: portion included as part of full analysis report is accepted by professors

R005c: Efficiency and Cooling

- A report analyzing efficiency and cooling from static characterization is provided in the analysis report mentioned in R005a.
    - Temperature vs. time
    - Torque vs RPM graphs for cold and hot starting temperatures
    - Efficiency calculations based on input and output power (taken from static data)
    - Pass/Fail: portion included as part of full analysis report is accepted by professors

R006a: Physics Model

- Physics models are included which are based on assumptions made for mass, frictional losses, compliance, and gear ratios
    - Models fully integrated car's speed as a function of throttle using parameters listed above
    - Pass/Fail: portion included as part of full analysis report is accepted by professors
        - Explanations of parameters and how they were chosen
        - Math shown and supported for model

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R006b: Simulation

- A simulink model exists using the physics models and the parameters measured in R005.
    - Pass/Fail: portion included as part of full analysis report is accepted by professors
        - Includes graphs of Simulink model simulations of speed vs throttle

R006c: Results and Conclusions

- An analysis exists, similar that written for the requirements in R005, discussing new results and conclusions drawn from a more realistic vehicular model.
- The results and conclusions address efficiency, cooling, recommended gear-ratio, expected throttle limits, and optimal throttle operation.
- Pass/Fail: portion included as part of full analysis report is accepted by professors

QA Tests and Test Memos

QAR005a - Static Characteristics

1. All specified data measured across full range of operation for torque and RPM
2. Data calibration/accuracy falls within specified tolerances

QAR005b - Dynamic Characteristics

1. All desired model parameters estimated
2. Accuracy analysis determines that parameters are calibrated correctly within proper tolerances

QAR005c - Efficiency and Cooling

1. Motor + controller efficiency and cooling requirements have been successfully measured
2. Tests comparing expected cooling system behavior to measured values are successfully completed

QAR006a - Physics Model

- Physics model output provides reasonable prediction of fully integrated system performance

QAR006b - Simulation

- Simulation is able to provide outputs expected by the generated physics model
- Working demonstration to professors successfully completed

QAR006c - Results and Conclusions

1. All data and calculations included in results and conclusions documentation falls within required tolerances, and model provided generates expected outputs for fully integrated system

Item 4 - Final Project Presentation

Item Overview

A final presentation of our work as a team including many details concerning non-testable requirements.

Configuration Diagrams

This is an oral and visual presentation references notes and displaying figures in a powerpoint format.

Detailed Procedure

Create a powerpoint that touches on each of the requirements that are demonstrated. Each requirement demonstrates completion by meeting the requirements in the fashions laid out below:

How and why requirements are met

GPR011: Project Video and Final Demonstration

- A 5-minute video is produced and shown briefly introducing and summarizing the project and achievements of this year.
- A live demonstration is coordinated and performed for the viewing pleasures of the ECE faculty, showing the successful progress made this semester.
- Pass/Fail: Video is approved by faculty

GPR012: Final Disposal of Projects

- Procedure for disposal is outlined in the powerpoint presented on FDD
    - Provisions are laid out the final delivered project (split into what is to be demoed and other extra pieces), as well as any documentation, trash, wires, and other materials
    - Labels are applied to all non-obvious components being stored in the lab
- Pass/Fail: Checklist which covers final disposal of all materials and is created and checked off as each material is addressed
    - Ensures that all materials are taken care of and safely and maintainably stored for future access
    - Completed checklist is signed by instructors to indicate acceptance of project disposal

Final Disposal Checklist:

Disposal Requirement		**Completed**
General Cleanliness		
Tools and Equipment Returned		
Dyno setup still working		
Battery Packs integrated and stored or components are labeled and stored		
Spare wires collected, labeled, and stored or thrown out		
Loose papers recycled or compiled, labeled, and stored		
Spare boards and components labeled and stored		
Final Professor Signoff	**Date:**	

D008: Final Presentation and Delivery

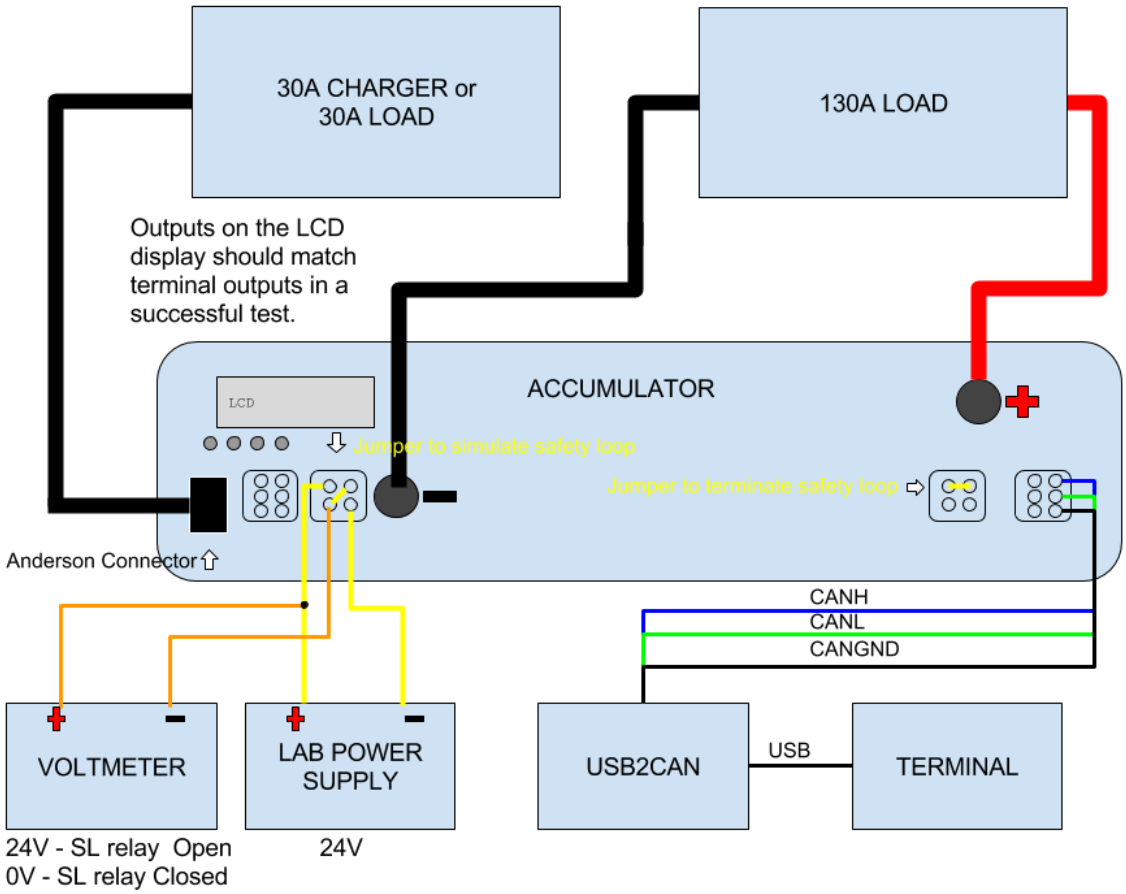
- ATP is the guidelines for a completed and tested project
    - ATR will show what tests have been completed
- Final presentation is completed per GPR011
- Project cleanup is completed per GPR012

Item 5 - Charging and Discharging Accumulator

Item Overview

Fully charge and discharge an accumulator through the 30A port. Also, discharge an accumulator though AIRs while connected to a safety loop. If available, and properly tested, use the GLV safety loop. If unavailable, use jumpers on the safety loop connector and 24 V DC power supply to stand in place of the GLV safety loop. Vary the load during the test.

Configuration Diagrams



Detailed Procedure

During all charge and discharge steps, data collected via CAN on a computer terminal are plotted versus time. This includes overall pack current and voltage, and individual cell temperatures and voltages.

- All system menus are navigated to while pack is near 0%, and values noted.
- A charger set to 20 A is connected to the accumulator with SOC near 0%
- Charging commences automatically.
- All system menus are navigated to while pack is charging, and values noted.
- Charging ends automatically at 100% SOC.
- All system menus are navigated to while pack charged, and values noted.
- The charger is disconnected.
- The charger is reconnected to ensure charging does not continue.
- All system menus are navigated to, and values noted.
- A load is connected to the 30 A port and the accumulator is discharged to about 50% to set up the second charge test.
- All system menus are navigated to while discharging, and values noted.
- A charger is connected to the accumulator with SOC near 50%
- Charging commences automatically.
- Charging ends automatically at 100% SOC.
- A load is connected to the 30 A port and the accumulator completely discharged.
- The charger is reconnected and the accumulator is charged to prepare for discharge through the AIRs.
- Verify that SOC is near 100% on LCD screen and disconnect the charger. Check that the system is properly connected to all components, and a suitable load is attached to the accumulator.
- Close the safety loop and put the system in demo mode.
- Apply load to draw 20 A for 30 sec.
- Apply load to draw 75 A for 30 sec.
- Apply load to draw 130 A (this is a maximum for the load) for 30 sec.
- Set load to 75 A and allow SOC to fall to 10%.
- Apply load to draw 20 A for 30 sec.
- Apply load to draw 75 A for 30 sec.
- Apply load to draw 130 A for 30 sec.
- Set load to 75 A and allow SOC to fall to 0%.
- Verify that the safety loop has opened to prevent damage to cells.

How and why requirements are met

R001a: Charging Algorithm

- Pass/Fail: The pack charges successfully, and stops charging near 100% SOC on LCD screen.
- Pass/Fail: The accumulator does not require human intervention (plug and forget) to complete a charge cycle.
- Pass/Fail: An accumulator Thevenin resistance and voltage are calculated from the results of a load test with the pack fully charged and is consistent with the design values.

R001c: Displays and Indicators

- Pass/Fail: The state of the accumulator (idle, charging, charge complete), and all pertinent data, are displayed.
    - SOC, overall pack voltage, pack current, cell voltage and temperature, and pack state, cell balancing state, safety loop state, charging history, discharge history, and calibration factors.
    - For specifics refer to QAR001c
- Pass/Fail: A ‘pack-alive’ light is illuminated when the AIRs are closed

R001d: Pack Controls

- Pass/Fail: The controls allow navigation to all menus.
    - Pass/Fail: A top level menu with SOC, overall voltage, and highest temperature reading
        - Cycle up and down buttons select each cell and drill down button.
    - Pass/Fail: A menu for each cell available by drilling down from top level that contains voltage, temp, and calibration factors
        - Drill down to select calibration factor.
    - Pass/Fail: Accept button returns to next highest menu level

R001e: Low Current Output

- The output is used to supply power to a load
    - Pass/Fail: This is satisfied if the accumulator can power the load without component or software failure in all SOC and from near 100% to near 0%.

R001f: Complete Accumulator

- Pass/Fail: All requirements related to completing an accumulator are tested with this test.

R002j: Plug and Forget Charging

- Pass/Fail: The pack charges successfully, and stops charging near 100% SOC on LCD screen.
- Pass/Fail: The accumulator does not require human intervention (plug and forget) to complete a charge cycle.

QA Tests and Test Memos

These tests are completed in preparation for ATP test 8. Documentation of their completion are attached.

QAR001a - Charge Algorithm

1. Mathematical analysis of battery charging/discharging state of charge. The method includes a cell model and coulomb counting.
2. Testing on accumulator test stand.
    a. charging starts appropriately, normal operation

b. charging stops appropriately, normal operation
c. charging stops appropriately, all failure modes

3. Charging a discharged TSV accumulator with LiFePO4 cells

QAR001c - Displays and Indicators

1. Test all desired displays in test stand, in all states.
2. Test all desired displays in Accumulator with LiFePO4 cells, in all states.

QAR001d - Pack Controls

1. Test navigation to each desired data, or set value, in all states.
2. Set a range of values via controls, in all states.
3. Reset PacMAN in all states.
4. Reset each AMS in all states.

QAR001e - Low Current Output

1. Apply load to draw 20 A.
2. Test Charging functionality.

QAR001f - Delivery of one complete accumulator

1. Annotated photographs of wiring harness.
2. Documentation (Maintenance, User's Manual, BOM, etc.)
3. Demonstration of System States, and availability of TSV power

Item 6 - Motor+Controller Dynamometer Demonstration Test

Item Overview

Motor spins via dynamometer close to FDD in order to demonstrate working capability of the system for specific RPM and torque measurements and shows that the system has been correctly modeled.

Configuration Diagrams

N/A

Detailed Procedure

Using old VSCADA software, motor is spun to reach specified RPM values. All measurements (torque, current, speed, etc) are compared to calculations using physics and Simulink model outputs for given input conditions of load and throttle. Calibration and Accuracy document D011 provides an expected accuracy range to show that test results reflect that the model is correct.

How and why requirements are met

R006a: Physics Model

- Pass/Fail: Physics models exist based on assumptions made for mass, frictional losses, compliance, and gear ratios. Test is run to verify that system has been acceptably modeled.

R006b: Simulation

- Pass/Fail: A simulink model is produced using the physics models and the parameters measured in R005. Test is run to verify that system has been acceptably simulated.

QA Tests and Test Memos

QAR006a - Physics Model

- Physics model output provides reasonable prediction of fully integrated system performance

QAR006b - Simulation

- Simulation is able to provide outputs expected by the generated physics model
- Working demonstration to professors successfully completed

Item 7 - Interface Control Document

Item Overview

Documentation discussing the cabling and signals present in the system. TSV and GLV verify that this document is adequate. MCM and SCADA perform sanity checks on the document. The final document is approved by the professors.

Configuration Diagrams

N/A

Detailed Procedure

- Include information regarding length, pinout, wire colors, gauges, connector specification, and assembly instructions
- Discuss signals transmitted, including source, destination, and purpose

How and why requirements are met

R004a: Cabling

- Cables utilized are documented such that they can be identified, disconnected and reconnected to indicated systems, and replaced if necessary.
    - The team signs off on this
    - Pass/Fail: Profesor signs off on this

R004b: Interface Control Document

- Pass/Fail: Provides documentation of every cable utilized in the system as well as signals that pass through them.

Item 8 - Project Management and Status Letters

Item Overview

Status letters are submitted to the faculty by 4pm every Friday.

Configuration Diagrams

N/A

Detailed Procedure

The letters are submitted via email and also posted on the website and comply with requirements in SOW.

How and why requirements are met

D014: Project Management and Status Letters

- Pass/Fail: The letters are made available on the website prior to their 4 pm deadline weekly and are approved by professors.

Item 9 - User Manual Assurance

Item Overview

This is a two part test designed to meet requirement GPR007. The first part of the test requires a novice to troubleshoot a perceived common problem. The second part of the test requires an expert user to troubleshoot an uncommon problem via documentation.

Configuration Diagrams

N/A

Detailed Procedure

The common problem is a blown fuse in a battery pack. Select a novice user and, without any more guidance than the documentation, have the novice diagnose and repair the problem.

The uncommon problem is an incorrectly configured CANbus network on SCADA. Select an expert user and without any more guidance than the documentation, have the expert diagnose and repair the problem.

The full system user manual undergoes checking outlined in GPR001 and meets all its requirements from the SOW.

How and why requirements are met

GPR007: Maintainability

- Pass/Fail: An untrained person troubleshoots a common problem. Tests is conducted referencing the generated Manuals.
- Pass/Fail: An expert troubleshoots an uncommon problem. Tests is conducted referencing the generated Manuals.

D002: User's Manual

- Pass/Fail: Documents are generated for the system and are made available on the project website. These documents go through the process outlined in , Documentation and Safety.
- Pass/Fail: Successful troubleshooting indicates that the documentation works in practice (GPR007)

Item 10 - Documentation Integrity

Item Overview

This item ensures quality in documentation as well as adherence to documentation guidelines and official racing guidelines. The same process also ensures that designs and tests adhere to safety guidelines and best practices. This item applies for all documents delivered after CDR.

Configuration Diagrams

N/A

Detailed Procedure

- Submit an analysis report confirming adherence to the formula EV rules
- All documents and code have a location for the name of the creator, and the name of a reviewer that was not directly involved in the creation of the document.
- Documents are reviewed by person not directly involved in their creation. Attach a signature sheet to ATR to document a reviewers approval.
    - The following documents will be reviewed under this item
        - D002: User's Manual
        - D003: Final Report & Maintenance Manual
        - D006: QA Results Report
        - D007: Project Website
        - D010: Project Poster
        - D011: Calibration & Accuracy Analysis
        - D013: Purchasing Report
    - The sheet is comprised of a table similar to the following:

Document File Name	Creator	Reviewer

- Document reviewer writes down any revisions that are suggested and submits them to the professor to show that it was reviewed in earnest.

How and why requirements are met

R000/EV

- The document is in accordance with Formula EV rules.
- Pass/Fail: A reviewer reviews and signs that the content of the document with is consistent with Formula EV rules.

GPR001: Documentation

- The creator creates the document in accordance with GPR001 in the SOW.
- The reviewer reviews the content of the document with respect to GPR001.
- Pass/Fail: The reviewer submits his written critique for each document.
- Pass/Fail: The reviewer signs off on for each final document.

Item 11 - Safety Plan and Adherence

Item Overview

This item contains the safety plan, proof that it was adhered to, and an analysis that

states how the parts and designs that were chosen fall within safety guidelines.

Configuration Diagrams

N/A

Detailed Procedure

A safety plan is generated for any subsystem operating with potential differences greater than 30V. It includes:

- Analysis confirming any parts operating with greater than 30V are appropriately chosen.
  - Specifically for TSI and TSV
- A process for properly closing the subsystem prior to operation.
- A list of precautions that are followed to ensure the safety of participants.
- ECE Director of laboratories, or an alternate designated by him, reviews and accepts all electrical safety plans before any such assembly is closed or tested. The Director or alternate must sign a label that is placed on the assembly. The label includes the following:

Approved Assembly:_____
File Name of Safety Plan: _____
Approval Signature:_____ Date:_____
Approval Expires(Date, if Applicable): _____

How and why requirements are met

GPR005: Safety and Good Practice

- Pass/Fail: The creator creates the document in accordance with GPR005 in the SOW.
- Pass/Fail: The reviewer reviews the content of the document with respect to GPR005.
- Pass/Fail: Safety Plan was accepted by the team and the ECE Director of Laboratories

Item 12 - Maintainability Document

Item Overview

The maintainability document contains reasoning as to why the software and hardware is easily extendable and manageable for future use.

Configuration Diagrams

N/A

Detailed Procedure

The analyses are done in accordance with requirement D012 in the SOW and are submitted for instructor approval.

How and why requirements are met

D012: Maintainability Plan

- Pass/Fail: The presented plan for maintainability is approved by a professor.
- Pass/Fail: A professor agrees that the plan demonstrates that at the end of the year there is a project that is easily configurable and extendable for years to come.

Item 13 - PDR Report & Presentation

Item Overview

These items comprise the Preliminary Design Report. They include a Report document a presentation file, minutes from the presentation, and ITCPs.

Configuration Diagrams

N/A

Detailed Procedure

The generated documents are available on the project website.

How and why requirements are met

D000: PDR Materials

- Pass/Fail: All materials are accepted following PDR, and posted to the project website.

Item 14 - CDR Presentation

Item Overview

These items comprise the Critical Design Review. They include a Report document a presentation file, an ATP document, safety plans, and minutes from the presentation.

Configuration Diagrams

N/A

Detailed Procedure

The generated documents are available on the project website 24 hrs prior to CDR.

How and why requirements are met

D001: CDR Materials

- Pass/Fail: The materials are posted to the project website 24 hrs prior to CDR and eventually achieve professor aproval.

Item 15 - Project Poster

Item Overview

A project poster is made to SOW specifications and goes through GPR001 specification.

Configuration Diagrams

N/A

Detailed Procedure

Documents are generated for each subsystem and are made available on the project website prior to FDD.

How and why requirements are met

D010: Project Poster

- Pass/Fail: Poster is attractive and interesting
- Pass/Fail: Provides an appropriate and correct summary of project
- Pass/Fail: Large, full color, and on display in the hallway

Item 16 - Final Report and Maintenance Manual

Item Overview

The Final Report is a professional document that summarizes high level functionality and points to other documents with greater detail. The Maintenance Manual indexes all low level documents.

Configuration Diagrams

N/A

Detailed Procedure

These documents go through the process outlined in Item 10, Documentation and Safety to ensure they comply with the SOW, and are made available on the project website prior to FDD.

How and why requirements are met

D003: Final Report and Maintenance Manual

- Pass/Fail: Three thumb drives containing these documents are delivered to faculty at FDD
- Pass/Fail: The documents are available on the website prior to FDD.
- Pass/Fail: Document passes GPR001 review process
- Pass/Fail: Faculty approves of document.

Item 17 - Acceptance Test Plan

Item Overview

This document outlines all items that are checked to determine that the project is successfully completed.

Configuration Diagrams

N/A

Detailed Procedure

The document is prepared by the team and edited continuously until it gets approved by professors. It is made available on the project website prior to CDR.

How and why requirements are met

D004: Acceptance Test Plan

- Pass/Fail: ATP is verified by the team and then approved by professors prior to CDR. It is made available on the project website prior to CDR.

Item 18 - Acceptance Test Report

Item Overview

The acceptance test report is a deliverable record of what was delivered and accomplished on the Acceptance Test Report

Configuration Diagrams

N/A

Detailed Procedure

A completed report has signatures and paperwork that references the ATP and provides proof that ATP items were verified.

How and why requirements are met

D005:Acceptance Test Report

- Pass/Fail: ATR includes signatures and references for all tests the team believes were successful
- ATR is submitted at the final delivery date

Item 19 - QA Results Report

Item Overview

QA Results Reports are generated following any QA test. The comply with requirements detailed in the SOW.

Configuration Diagrams

N/A

Detailed Procedure

These documents go through the process outlined in Item 10, Documentation and Safety to ensure they comply with the SOW, and are made available on the project website prior to any related ATP test.

How and why requirements are met

D006: QA Results Report

- The document is available prior to related ATP tests.
- Pass/Fail: Document contains all QA tests completed for ATP
- Pass/Fail: Document passes GPR001 review process
- Pass/Fail: Faculty approves of document.

Item 20 - Project Web Site

Item Overview

A project website archives all documents and software generated during the project. Website goes through the same QA outlined by GPR001.

Configuration Diagrams

N/A

Detailed Procedure

All materials are stored on the website, or are linked to from the website if cloud storage services are used. Website is reviewed by a peer.

How and why requirements are met

D007: Project Website

- The website is currently available. All materials are present, or linked, prior to FDD.
- Website is orderly and neat.
- Pass/Fail: Document passes GPR001 review process
- Pass/Fail: Faculty approves of document.

Item 21 - Calibration and Accuracy Analysis

Item Overview

An analysis document is generated to satisfy the requirements in the SOW. This document is used to judge the successfulness of the measurands. The document is submitted continously until it recieves professor aproval.

Configuration Diagrams

N/A

Detailed Procedure

This document goes through the process outlined in Item 10, Documentation and Safety to ensure it complies with the SOW, and it is made available on the project website 2 weeks prior to FDD. A draft is available with the CDR materials on the project website.

The following measurands will be covered by D011:

- Throttle Percentage
- Motor RPM
- Torque
- Overall voltage, current, and power delivered to the load
- Individual cell voltages, aggregate pack voltage, and total TSV
- Tractive system DC current and motor phase currents
- Rate of charge or discharge of accumulator and cells as a percentage of total SOC
- Temperatures of all subsystems and cells
- Coolant flow rate

How and why requirements are met

D011: Calibration and Accuracy Analysis

- The document is made available 2 weeks prior to FDD.
- Pass/Fail: Document passes GPR001 review process
- Pass/Fail: Faculty approves of document.

Item 22 - Purchasing Report

Item Overview

A Purchasing Report with the details laid out in the SOW is generated.

Configuration Diagrams

N/A

Detailed Procedure

The document goes through the process outlined in Item 10, Documentation and Safety to ensure that it complies with the SOW, and it is made available on the project website prior to FDD.

How and why requirements are met

D013: Purchasing Report

- A purchasing report is made available on the project website prior to FDD.
- Pass/Fail: Document passes GPR001 review process
- Pass/Fail: Faculty approves of document.

Requirements Matrix

About

This lays out all the requirements, who is responsible, and where they are met. There is also a column to initial when a requirement is completed.

Matrix

Requirement	Description	Team Member Responsible	Item Numbers	Grade
Deliverables				
D000	PDR	Jae	13	
D001	CDR	Geoff	14	
D002	User Manual	Brandon	9	
D003	Final Report/Maintenance Manual	Armen	16	
D004	ATP	Nick	17	
D005	ATR	Tim	18	
D006	QA Results Report	Brendon	19	
D007	Website	Brandon	20	
D008	Complete System, Final Presentation Demo/Delivery	Joe	4	
D009	Conference Paper, Presentation, and Paper	N/A - waived	N/A	
D010	Poster	Armen	15	
D011	Calibration and Accuracy	Dan	21	
D012	Maintainability Plan	Brendon	12	
D013	Purchasing Report	Joe	22	

D014	Individual Progress Report, Project Status Letters, and Status Presentation	Dan	8	
General Project Requirements				
GPR001	Documentation	Jae	10	
GPR003	EMI/EMC	N/A - waived	N/A	
GPR004	Hazmats	N/A - waived	N/A	
GPR005	Safety and Good Practice	Nick	11	
GPR006	Reliability	Tim	1	
GPR007	Maintainability	Brendon	9	
GPR008	Manufacturability	N/A - waived	N/A	
GPR011	Project Video and Final Documentation	Armen	4	
GPR012	Final Disposal of Projects	Dan	4	
R000: General Rules and Requirements				
R000/EV	General Rules and Requirements	Jae	10	
R001: TSV Battery Pack Accumulator				
R001a	Charge Algorithm	Geoff	5	
R001b	Data Acquisition	Geoff	1	
R001c	Displays and Indicators	Jae	5	
R001d	Pack Controls	Jae	5	
R001e	Low Current Output	Geoff	5	
R001f	One Complete Accumulator	Geoff	5	
R002j	Plug and Forget Charging	Geoff	5	
R002: VSCADA				
R002a	Car Dash Display	Brendon	1	
R002b	Safety System	Brendon	2	
R002c	VCI	Brendon	1	
R002d	Cell Phone Interface	Brendon	1	
R002e	Remote PC Interface	Nick	1	
R002f	Throttle Control Interface	Nick	1	
R002g	Maintenance Mode	Brendon	1	
R002h	Drive Mode	Tim	1	
R002i	Drive Demo Mode	Brendon	1	
R002k	Shutdown Mode	Nick	1	
R002l	Monitoring and Data Acquisition	Nick	1	
R002m	Modular Data Acquisition System	Nick	1, 2	

R002n	Closed Loop VSCADA Control	Nick	1	
R002o	Event/Error Logging	Brendon	2	
R003: Grounded Low Voltage System				
R003a	GLV Power	N/A - waived	N/A	
R003b	GLV Safety Loop	Tim	2	
R003c	Vehicle User Interface	Tim	1, 2	
R003d	TSI	Brandon	1, 2	
R003e	VCI Hardware	Joe	2	
R003f	Throttle	Bryan	1	
R003g	GLV CAN Bus	Brandon	1	
R004: System Cabling and Interfaces				
R004a	Cabling	Joe	7	
R004b	Interface Control Document	Tim	7	
R005: Motor+Controller Test and Characterization				
R005a	Static Characteristics	Armen	3	
R005b	Dynamic Characters	Dan	3	
R005c	Efficiency and Cooling	Armen	3	
R006: Dynamical Model				
R006a	Physical Model	Dan	6	
R006b	Simulation	Armen	6	
R006c	Results and Conclusion	Dan	6	