LFEV-Y4-2016

Lafayette Formula Electric Vehicle
Year 4

ECE 492 - Spring 2016

LAFAYETTE
ELECTRICAL & COMPUTER ENGINEERING

Mission Statement

Our design philosophy -

Aim low, and develop elements that work well, are well documented, and provide the core functionality.

We aim to have a demo of a motor being spun by TSV via TSI and VSCADA.

Successive years will benefit from a maintainable system.

Team Breakdown

Team Leadership: Geoff Nudge and Tim Andrews

VSCADA

- Brendon and Domenick

TSV

- Geoff, Joe, and Jae

GLV/Cabling

- Tim, Bryan, and Brandon

Motor Characterization and Dynamic Modeling

- Dan and Armen

General Requirements Breakdown

Requirement	Description	Team Member
Deliverables		
D000	PDR	Jae
D001	CDR	Geoff
D002	User Manual	Bryan
D003	Final Report/Maintainability Problem	Bryan
D004	ATP	Nick
D005	ATR	Tim
D006	QA Results Report	Brendon
D007	Website	Brandon
D008	Complete System, Final Presentation Demo/Delivery	Joe
D009	Conference Paper, Presentation, and Paper	N/A waived
D010	Poster	Armen
D011	Calibration and Accuracy	Dan
D012	Maintainability Plan	Brendon
D013	Purchasing Report	Joe
D014	Individual Progress Report, Project Status Letters, and Status Presentation	Dan

General Requirements Breakdown

General Project Requirements		
GPR001	Documentation	Jae
GPR003	EMI/EMC	N/A - waived
GPR004	Hazmats	Bryan
GPR005	Safety and Good Practice	Nick
GPR006	Reliability	Tim
GPR007	Maintainability	Brendon
GPR008	Manufacturability	Brandon
GPR011	Project Video and Final Documentation	Armen
GPR012	Final Disposal of Projects	Dan
R000: General Rules and Requirements		
R000/EV	General Rules and Requirements	Jae
R001: TSV Battery Pack Accumulator		
R001a	Charge Algorithm	Geoff
R001b	Data Acquisition	Geoff
R001c	Displays and Indicators	Joe
R001d	Pack Controls	Jae
R001e	Low Current Output	Jae
R001f	1 Complete Accumulator	Joe

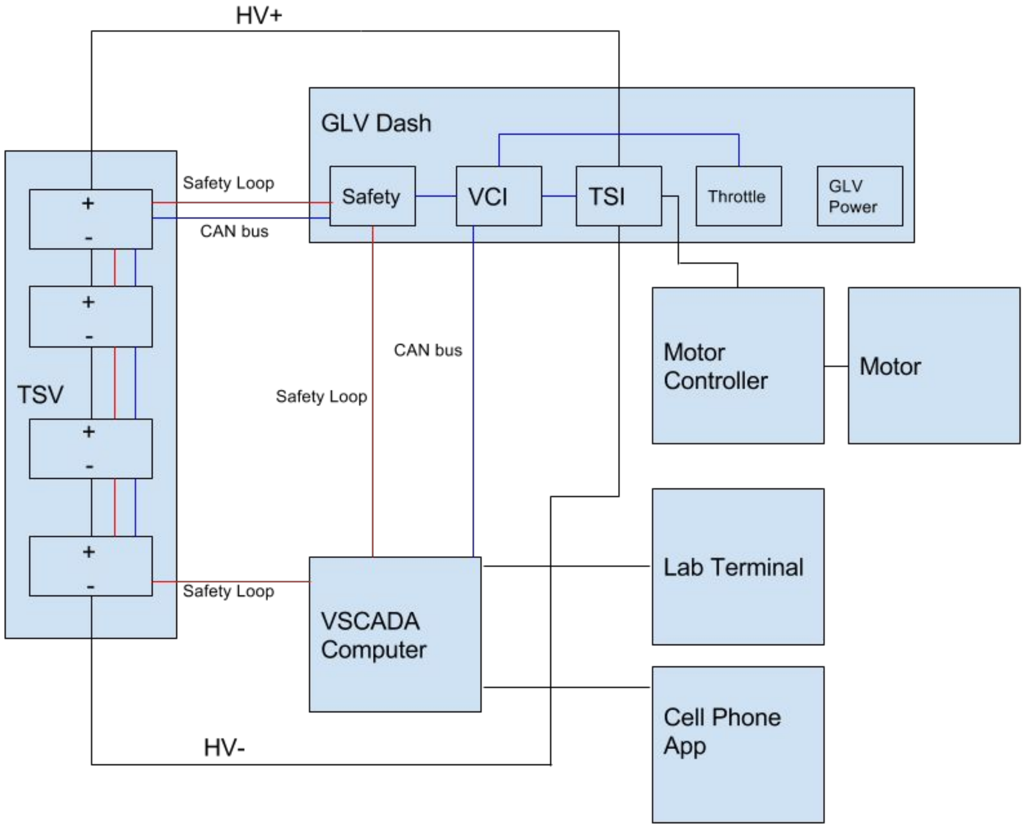
General Requirements Breakdown

R002: VSCADA		
R002a	Car Dash Display	Brendon
R002b	Safety System	Brendon
R002c	VCI	Brendon
R002d	Cell Phone Interface	Brendon
R002e	Remote PC Interface	Nick
R002f	Throttle Control Interface	Nick
R002g	Maintenance Mode	Brendon
R002h	Drive Mode	Tim
R002i	Drive Demo Mode	Brendon
R002j	Plug and Forget Charging	Geoff
R002k	Shutdown Mode	Nick
R002l	Monitoring and Data Acquisition	Nick
R002m	Modular Data Acquisition System	Nick
R002n	Closed Loop VSCADA Control	Nick
R002o	Event/Error Logging	Brendon
R002p	Capability Additional Features	Brendon
R002q	Robust API	Nick

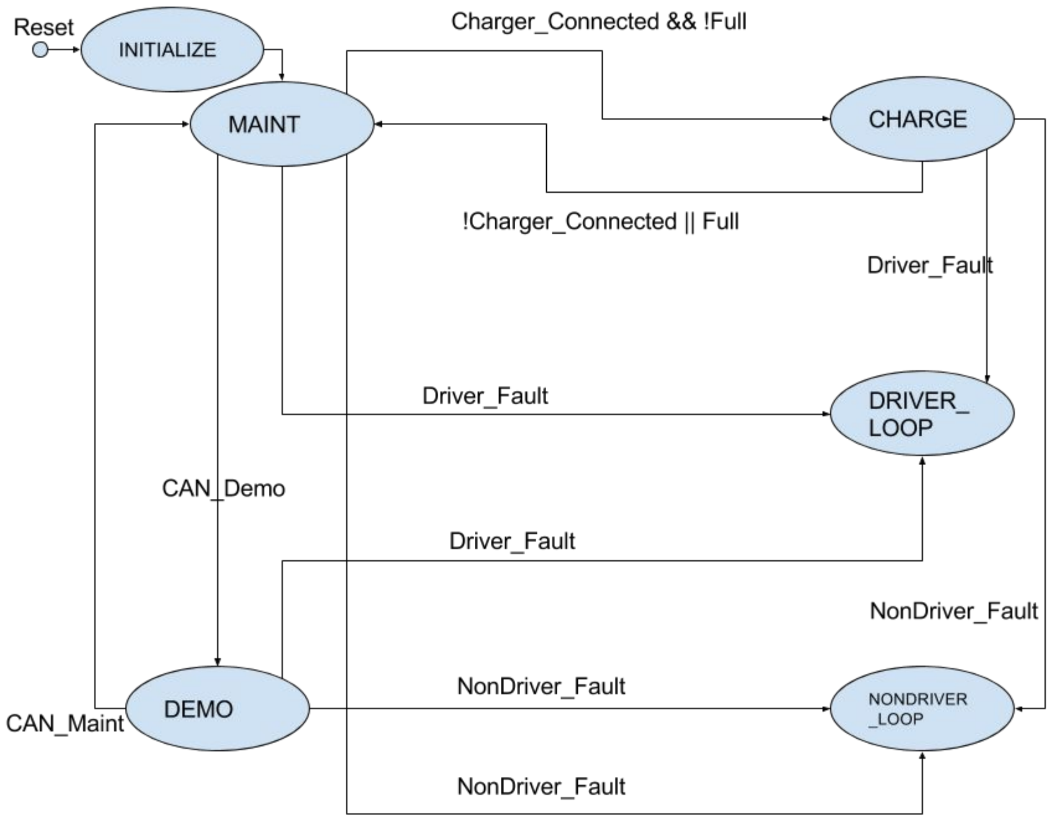
General Requirements Breakdown

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

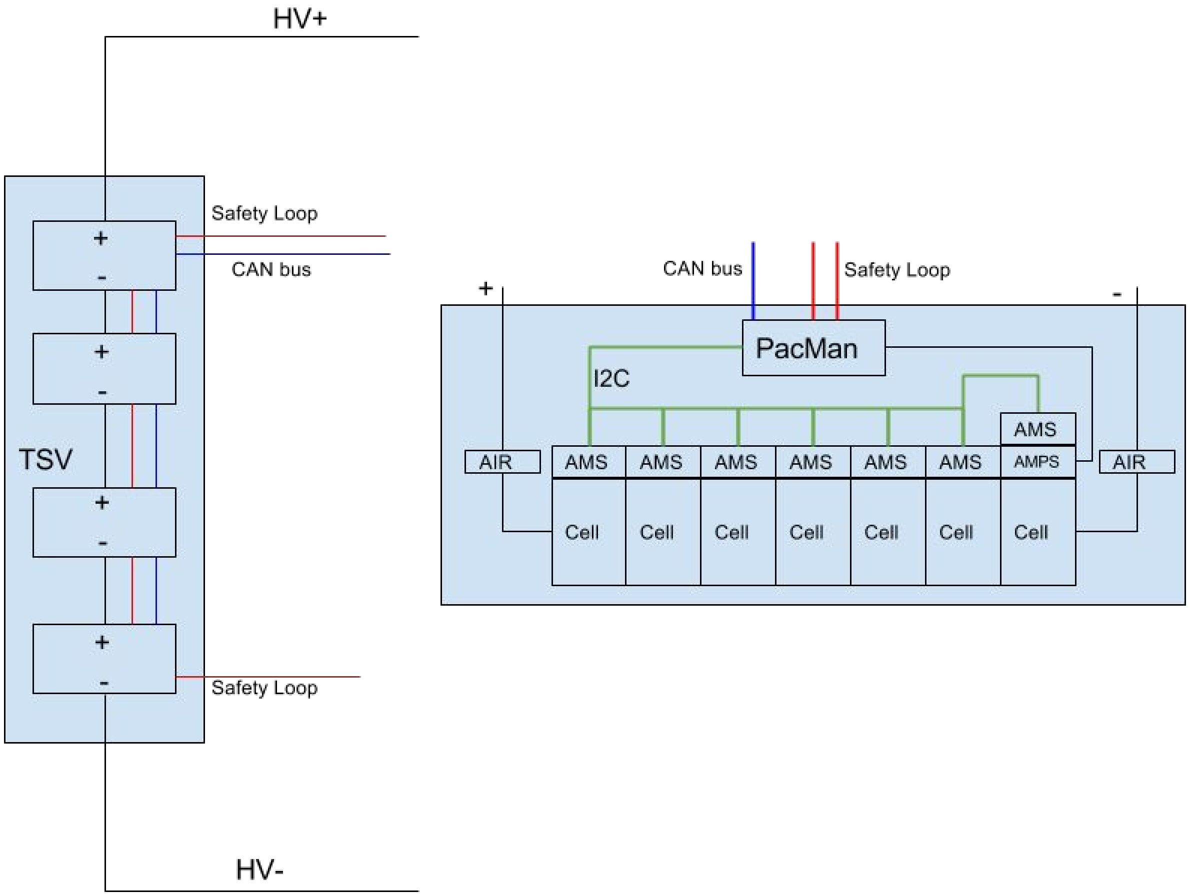
Overall Design



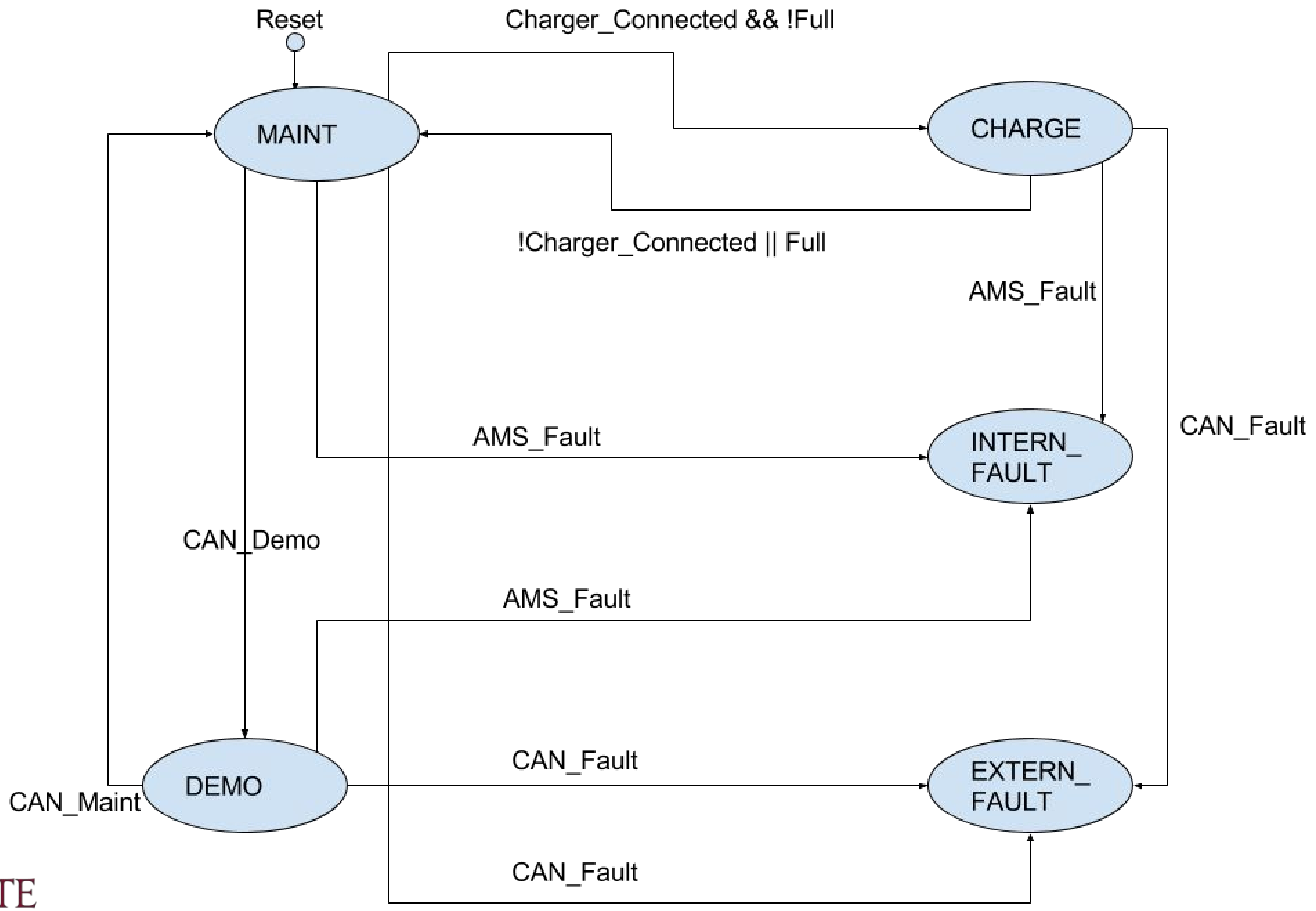
Overall Design



TSV


HV+
Safety Loop
CAN bus
TSV
+
-
Safety Loop
HV-
CAN bus
Safety Loop
PacMan
I2C
AIR
AMS
AMPS
Cell

TSV



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TSV

Current State -

AMS/Accumulator Mechanical Nearly Complete

PacMan is burnt out

Very little software exists

TSV

Requirements we propose to complete -

R001a - Charge Algorithm - a minimum of “charge until full,” aim for cell balancing

R001b - Data Acquisition - temp, voltage, current, SOC, pack state -> VSCADA

R001c - Displays and Indicators - LCD screen, navigable menus

TSV

Requirements we propose to complete -

R001d - Pack Controls - to navigate menus

R001e - Low Current Output - available at charger input

R001f - Completed Pack

We propose to complete hardware, software, and wiring/installation into packs to allow for use of the pack with GLV and VSCADA systems in a live demo.

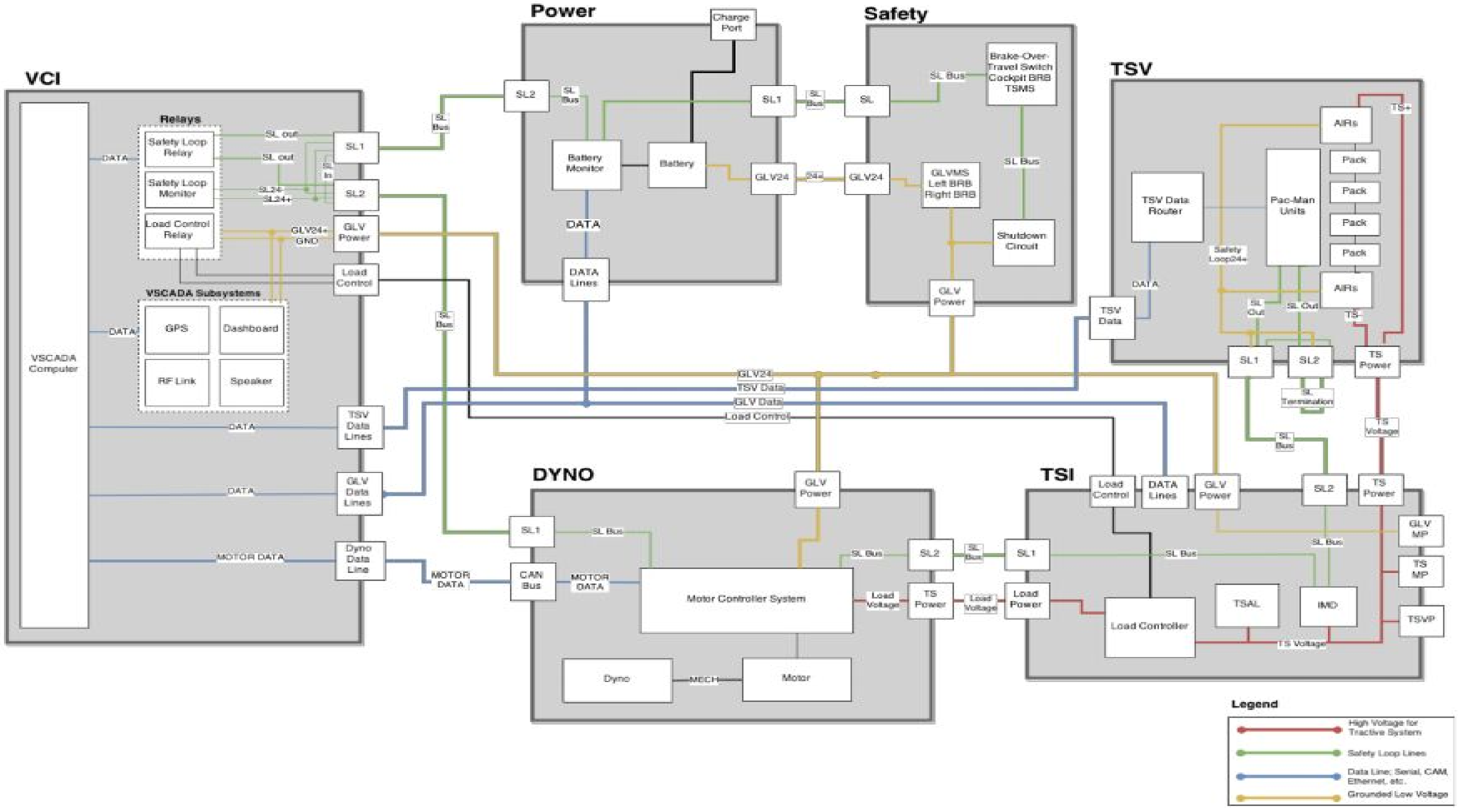
Work Breakdown Structure (Schedule) TSV

Task Name	Person Responsible	Task Due
Schematic for Display/Controls	Jae	Week 3
State Diagram + Tool Chain	Geoff	Week 3
Order Parts, mech Drawing for Panel	Jae	Week 4
PCBs and Parts Ordered	Joe	Week 4
Demonstrate Code for CAN and I2C packets	Geoff	Week 4
Build Panel	Jae	Week 5
1 Built Board	Joe	Week 5
Wiring Diagram for Pack Internals	Jae	Week 6
Confirm/Disprove Operation of Board by QA	Joe	Week 6
Choose and order wiring parts	Jae	Week 7
Demo of system on Test Stand	Geoff	Week 7
Build Pack	All	Week 8
Charge Algorithm Chosen	Geoff	Week 10
Charge Algorithm Demoed	Geoff	Week 11
Charge Pack Successfully	All	Week 12
Spin Motor Successfully	All	Week 13
Complete ATP and QA Checklist	All	Week 14
FDD Demo Prepped	All	Week 15

GLV/Cabling

...Building, with the Car in Sight

Where we are now…



Requirement Omissions

- R003a -GLV Power
  - We made the decision to omit the GLV Power requirement. We felt that GLV power system requirements in the scope of the 2016 team could be met with lab power supplies. With this decision we also believe that incorporation of the GLV system-wide power can be met with almost no modification to the work will meet the requirements for Spring of 2016. Considerations for this will be made in our design decisions and there also be an effort to reduce the variety of voltages used throughout GLV so interfacing with GLV will be easier in the future. But we consider this to be a general GLV requirement and outside of the GLV Power requirement.
- R003f -Throttle
  - We made this decision because we felt that the throttle controller in the VSCADA would meet the throttle requirement for the scope of the 2016 project. We also believe that the implementation of analog/digital throttle control system would be something that the 2017 class could manage if we meet modular connection requirements and implementation of CAN throughout the car.

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GLV Safety Loop

- Safety Loop System
  - Based off the 2015 model, which implements a two tiered safety loop system
  - Essentially isolates the driver from controlling the entire loop
  - An internal safety loop that contains the controls that the driver should be allowed to reset and an external safety loop that contains controls that the driver has no control over
  - A new specification that was added after the 2013 design

Vehicle User Interface Panels

- Vehicle User Interface Panels (VUI)
  - Heavily VSCADA-dependant or safety loop-dependant
  - Use the existing buttons, switches, and LCD display to generate this system
  - Intention is to make the buttons and interfacing systems for the car highly modular so they car be moved directly from the rack to the car.

Tractive System Interface

- TSI
  - Main purpose is to control high voltage line between the Accumulator Isolation Relays (AIRS) of the TSV and the motor controller
  - Must accomplish this task while keeping the TSV system galvanically isolated from the rest of the vehicle
  - When GLV power is present in the load controller, an LED will light up indicating that the load controller is on
  - TSI system is controlled directly from the VSCADA system
  - Load controller will also connect VSCADA to a voltage sensor that constantly measures the voltage of the high voltage line
  - Load controller is also an integral part of the safety loop because of the high voltage lines
  - The Isolation Monitoring Device constantly monitors the TSI system for an isolation failure
  - When a failure is detected, the AIRs are automatically opened, shutting down the high voltage power from the rest of the system
  - TSI is meant to house or interface with the safety procedures in TSV

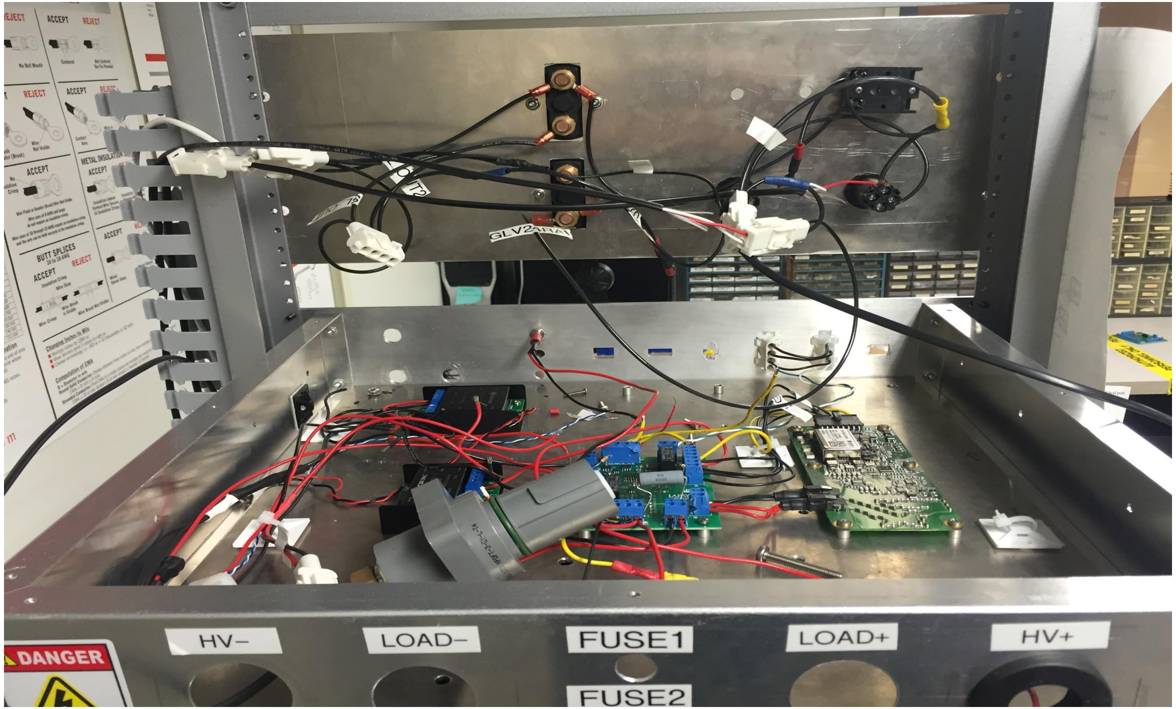
Vehicle Computer Interface Hardware

- VCI
  - Works with VSCADA to collect and implement data from sensors
  - The breakdown between VSCADA and GLV (VCI specifically) will be determined by the switch from analog to digital data
  - VCI in conjunction with TSV will be responsible for sensor systems on the car this will directly interface with VSCADA
  - VSCADA team can monitor car sensors and faults
  - Intention is to put the bulk of the work for this into VSCADA so we can focus purely on hardware

GLV CAN Bus

- CAN Bus
  - The majority of the CAN bus system relies on the GLV
  - The CAN into the Curtis relies on TSV
  - There is a CAN bus isolator that separates the GLV and TSV-reliant sections

Cabling



Sub-Requirements

R003b: GLV Safety Loop - Tim

- Develop and fabricate a new or revised safety loop system - Brandon
- Test the operation of the safety loop system - Bryan
- Analyze cabling requirements for the safety loop - Tim
- Generate a safety loop analysis document - Tim
- Interface safety loop with car and VSCADA - Brandon

R003c: Vehicle User Interface - Bryan

- Assess needed controls, indicators, switches, displays, and Big Red Buttons - Tim
- Design the layout of the interfaces - Bryan

Sub-Requirements

R003d: TSI - Brandon

- Tie TSI to GLV safety loop and VSCADA - Tim
- Ensure that TSI meets Curtis motor controller requirements - Bryan
- Observe interfacing of TSI with SCADA and CAN bus - Brandon

R003e: VCI Hardware - Bryan

- Ensure required components for display are present - Bryan
- Ensure required interface components are present - Tim

R003g: GLV CAN Bus - Brandon

- Ensure that GLV and TSV segments of CAN bus are properly connected - Bryan

Work Breakdown Structure (Schedule) GLV

Task Name	Person Responsible	Task Due
Confirm/ Disprove JGB Operation	Tim, Brandon	Week 3
Spec Drive Computer CPU and CAN shield	Tim	Week 4
List of GLV/Cabling Require Purchases	Brandon	Week 5
Order Necessary Parts and Cables	Tim	Week 5
Schematic for Interface	Bryan	Week 5
Build Safety Loop	Tim, Brandon	Week 6
TSI Design/Construction	All	Week 7
Demo Safety Loop	All	Week 10
Test Safety Loop Interface with Car/VSCADA	All	Week 11
Integrate and Test TSI	Tim, Brandon	Week 12
Safety Loop Documentation	Bryan	Week 12
Demo Proper CAN Bus Operation	Tim, Bryan	Week 13
Final Cabling Test	Brandon	Week 13
Complete ATP and QA Checklist	All	Week 14
Cabling Interface/Interconnection Document	Bryan	Week 14
FDD Demo Prepped	All	Week 15

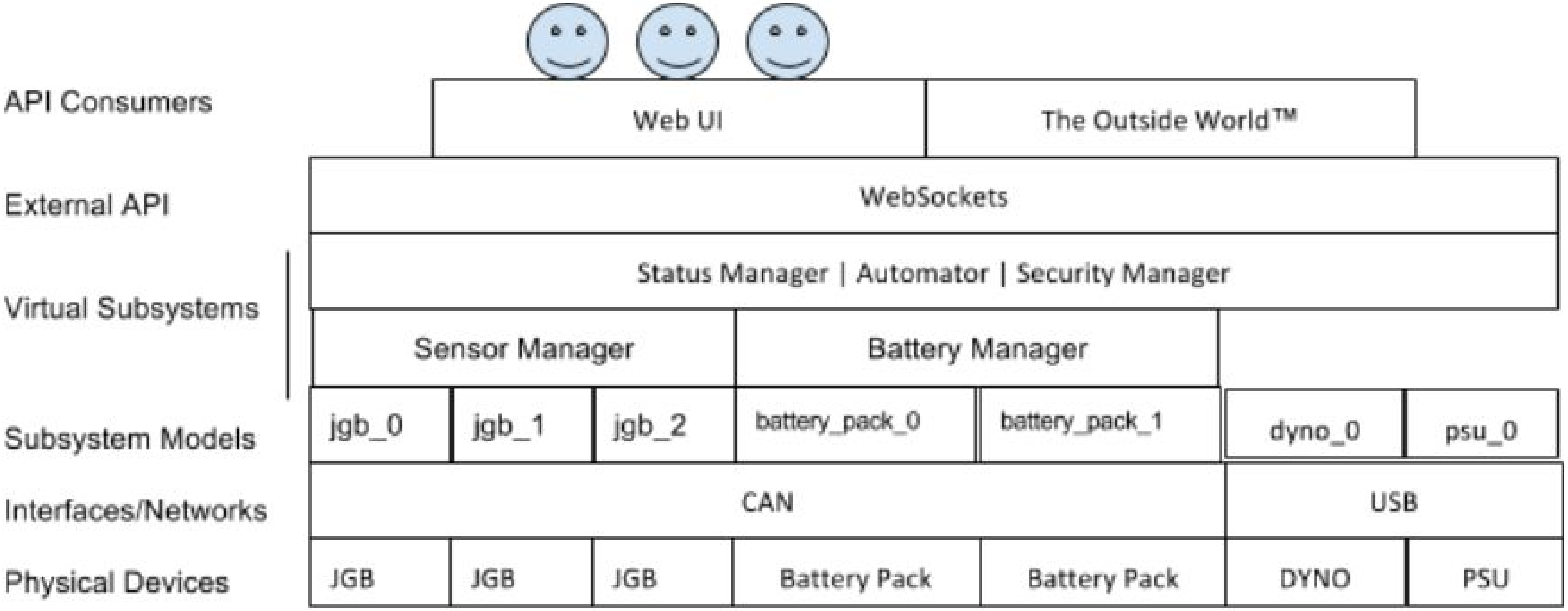
VSCADA

New Approach

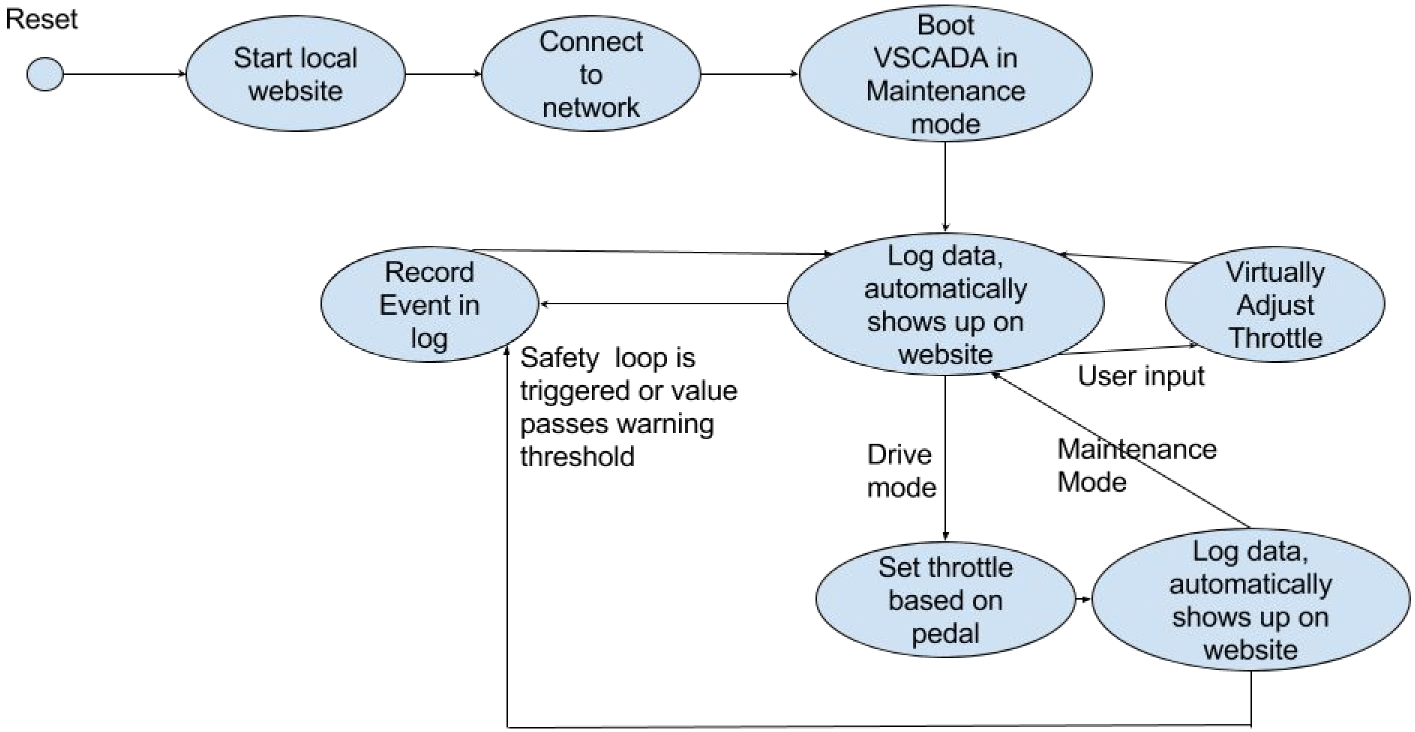
- Web App that will read data from python program and act as universal UI system
- Existing code is not maintainable and undocumented
- Python code will be reorganized with an API mindset

Core Mindset: Above all code needs to be easily maintained and expanded upon by future teams

Example Software Structure



Proposed State Diagram



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VSCADA Milestones

1. Dev environment operational start-2/10 Brendon
2. Sketch of UI start-2/12 Nick
3. Read in Virtual CANbus 2/10-2/17 Brendon
4. Graph spoofed CANbus 2/12-2/29 Nick
5. Add write functionality to web interface. 2/29-3/17 Brendon
6. Add logging to subsystem models. 2/12-2/29 Nick
7. Basic Read Only User Interface for Maintenance 2/12-3/15 Brendon
8. Dashboard UI 2/27-3/15 Brendon
9. Implement CANBus abstraction on the Dev Machines. Read in real traffic. 2/17-3/9 Nick
10. Basic setup of onboard computer 3/17-3/31 Brendon
11. Onboard computer interfaces with onboard touch-screen dashboard 3/17-4/4 Nick
12. Move Software from dev machines to actual on board computer 3/28-4/4 Nick
13. Implement subsystem models which use can. 3/15-4/20 Brendon
14. Implement local subsystem models. 3/15-4/20 Brendon
15. Integration with other groups to build final product 4/20 - end Brendon
16. Tutorial and documentation for future groups 4/20 - end Nick

Propoesed Unchanged Requirements

- R002a - DashBoard UI will be provided on provided screen
- R002c - Display and control UI will be developed
- R002e - All UI will be “remote” so it will be delivered
- R002f - Throttle will be controllable
- R002g - Primary mode will be maintenance mode
- R002j - Plug and Forget Charging
- R002n - You will be able to set values over a time and then run it as a script

Proposed Requirement Eliminations

- R002b - Safety system (controls, indicators, and interfaces)
- R002h - Drive mode not needed yet
- R002i - Drive demo mode not needed yet
- R002j - Plug and forget will be mostly handled by the PAC-MAN
- R002k - Long-term shutdown is not needed yet, just cut the power
- R002o - Should be able to be added in the future but will not be delivering functionality

Proposed Requirement Modifications

- R002d - Change the requirement from a cell phone app to just a single page javascript application
- R002l - Data will be sent to remote server to be logged
- R002m - No calibration and will only display the following
  - Individual Cell Voltages…
  - Temperatures of all major systems
  - Data available from dyno huff...

Proposed Requirement Additions

- R002p - Software should be designed in a way to facilitate adding components or modes. Doing so should be linear to the complexity of the addition
- R002q - Methods for creating additions should be intuitive and documented

Final Requirements

- See completed PDR for final draft

Work Breakdown Structure (Schedule) VSCADA

Task Name	Person Responsible	Task Due
Dev environment operational	Brendon	Week 3
Sketch of the UI	Nick	Week 3
Read in Virtual CANbus	Brendon	Week 4
Graph Spoofed CANbus	Nick	Week 6
Add Logging to Subsystem Models	Nick	Week 6
Implement CANBus abstraction on the Dev Machines. Read in real traffic.	Nick	Week 7
Basic read-only user interface for maintenance	Brendon	Week 8
Add Write Functionality to web interface	Brendon	Week 8
Basic setup of onboard computer	Brendon	Week 10
Onboard computer interfaces with onboard touch-screen dashboard	Nick	Week 11
Move Software from dev machines to actual on board computer	Nick	Week 11
Implement subsystem models that use CAN	Brendon	Week 13
Implement Local subsystem models	Brendon	Week 13
Integration with other groups for final integration	Brendon	Week 13
Tutorial and documentation for future groups	Nick	Week 13

Motor Characterization/ Dynamic Modeling

...Working towards a more predictable future

Motor + Controller Test and Characterization

R005a - Static Characteristics :

- Familiarize with Labview
- Setup development environment and get drivers to work with curtis controller
- Anticipate limits of operation for torque and RPM of formula car
- Prepare list of desired static data characteristics
- Work with Curtis controller to understand programmable parameters
- Collect operating data using current VSCADA system
- Prepare performance curves based on collected data
- Prepare Accuracy Analysis for Static Data

Motor + Controller Test and Characterization

R005b - Dynamic Characteristics :

- Assess limits of operation for torque and RPM of formula car
- Prepare list of desired dynamic data characteristics
- Use acquired static data to create estimates for dynamic model parameters
- Prepare Accuracy Analysis for Dynamic Data

R005c - Efficiency and Cooling :

- Analyze efficiency data from static data collection
- Prepare and measure efficiency and cooling requirements in static scenarios
- Determine measurands for finding cooling system performance
- Run test and analyze cooling system performance

Dynamic Modeling

R006a - Physics Model

- Prepare list of required parameters (mass, gear ratios, etc.)
- Coordinate with MechE team to find estimates for desired parameters
- Develop physics model based on analytical estimates and empirical data

R006b - Simulation

- Explore previously generated Simulink model for understanding
- Build Simulink model for simulating motor + controller setup
- Run multiple simulations using empirical and predicted data
- Demonstrate working simulation to professors

Dynamic Modeling

R006c - Results and Conclusions

- Determine energy requirements for competition and optimal values for gear ratios and throttle
- Prepare rough draft of results and conclusions documentation
- Review rough draft with Professor Yu
- Finalize results and conclusions documentation

Work Breakdown Structure (Schedule) Motor

Task Name	Person Responsible	Task Due
Paper Discussion with Professor Yu	Dan	Week 3
List of Measurands for Analysis	Armen	Week 3
Modeling Technique Chosen	Dan	Week 4
Range of of measurement/expected values chosen	Armen	Week 4
Data Acquisition	All	Week 5
Data Analysis For Static Cases Completed	Dan	Week 6
Dynamic Model Parameters Chosen	Armen	Week 6
Data Analysis For Dynamic Cases Completed	Dan	Week 8
List of Measurands for Cooling System Performance	Armen	Week 8
Analysis for Cooling System Performance	Dan	Week 9
Car Parameter Estimates from discussion with MechEs	Armen	Week 10
Physics Model Completed for fully integrated car	Dan	Week 12
Simulink Model Set Up	Armen	Week 12
Simulations Run Using Completed Simulink Model	Armen	Week 13
Energy Requirements for Competition and Optimal Gear Ratio/Throttle Outlined	Armen	Week 13
Results and Conclusion Documentation	Dan	Week 14
Final Demo of Characterization + Model	All	Week 15

Acceptance Test Strategy

R001

- R001a Charge Algorithm
  - Mathematical analysis of battery charging. Model shall include voltage and temperature, and include coulomb counting.
  - Testing on accumulator test stand.
    - charging starts appropriately, normal operation
    - charging stops appropriately, normal operation
    - charging stops appropriately, all failure modes
  - Charging a discharged TSV accumulator with LiFePO4 cells
- R001b Data Acquisition
  - Calibration Accuracy and Analysis (D011)
  - Test I2C messages
  - Test all CAN messages with Lab Terminal, in test stand, in all states
  - Test all CAN messages with VSCADA board, in test stand, in all states
  - Test all CAN messages with Lab Terminal, in Accumulator with LiFePO4 cells, in all states
  - Test all CAN messages with VSCADA board, in Accumulator with LiFePO4 cells, in all states
- R001c Displays and Indicators
  - Test all desired displays in test stand, in all states
  - Test all desired displays in Accumulator with LiFePO4 cells, in all states
- R001d Pack Controls
  - Test navigation to each desired data, or set value, in all states
  - Set a range of values via controls, in all states
  - Reset PackMAN in all states
  - Reset each AMS in all states
- R001d Pack Controls
  - Test navigation to each desired data, or set value, in all states
  - Set a range of values via controls, in all states
  - Reset PackMAN in all states
  - Reset each AMS in all states
- R001e Low Current Output
  - Apply load to draw 29 A
  - Apply load to draw 31 A
  - Test Charging functionality

Acceptance Test Strategy

- R001f Delivery of 1 complete accumulator
  - Annotated photographs of wiring harness
  - Documentation (Maintenance, User's Manual, BOM, etc.)
  - Demonstration of System States, and availability of TSV power

R002

- R002a R002c R002d R002e General UI
  - Demonstrate dashboard UI functionality over wide range of time and values
  - Simulate CAN BUS
  - Receive actual CAN BUS from a working system
- R002f Throttle Control
  - Use Scripting to demo
- R002g Maintenance mode
  - Ability to view and control system aspects
- R002l Data Logging
  - View and transfer data
- R002m Data display
  - Display all promised statistics compare to what we have in the old setup
- R002n Data Scripting
  - Demonstrate values automatically being set
- R002p R002q Modularity and documentation
  - Present professors the completed design for approval

R003

- R003b GLV Safety
  - Test for safety loop operation under system faults
- R003c Vehicle User Interface Panels
  - Test that buttons and interfaces operate as expected
- R003d Tractive System Interface
  - Test that the TSI interacts properly with the safety loop and trips it as needed
  - Monitor that TSV remains isolated from the GLV and ground
- R003e Vehicle Computer Interface Hardware
  - Observe various items displayed on the interface
  - Ensure interface hardware connects and acts properly

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Acceptance Test Strategy

R004

- R004a Cabling
  - Test continuity and resistance of cables and connections at various points
- R004b Interface Control Document
  - Present a completed document for review and approval

R005

- R005a Static Characteristics
  - All specified data measured across full range of operation for torque and RPM
  - Data calibration/accuracy falls within specified tolerances
- R005b Dynamic Characteristics
  - All desired model parameters estimated
  - Accuracy analysis determines that parameters are calibrated correctly within proper tolerances
- R005c Efficiency and Cooling
  - Motor + controller efficiency and cooling requirements have been successfully measured
  - Tests comparing expected cooling system behavior to measured values are successfully completed

R006

- R006a Physics Model
  - Physics model output provides reasonable prediction of fully integrated system performance
- R006b Simulation
  - Simulation is able to provide outputs expected by the generated physics model
  - Working demonstration to professors successfully completed
- R006c Results and Conclusions
  - All data and calculations included in results and conclusions documentation falls within required tolerances, and model provided generates expected outputs for fully integrated system

Calibration and Accuracy Analysis

TSV

- TSV Battery Pack Current
- TSV Battery Pack Voltage
- TSV Battery Pack Individual Cell Voltage
- TSV Battery Pack Individual Cell Temperature
- TSV Battery Pack 30A input/output Voltage
- TSV Battery Pack 30A input/output Current

VSCADA

- Individual Battery Voltages
- Combined Battery Voltages
- Temperature of anything hooked up to CANBus
- Motor Torque
- Motor RPM
- Motor Load
- Motor Power

GLV/Cabling

- AIRS voltage
- Ready to Drive sound length
- TSEL blinking frequency
- Pre-charge relay open/close time
- Main relay open/close time
- Discharge and pre-charge circuit voltages
- GLV Operating Voltage
- Conductive material spacing
- Cable tension tolerances

Maintainability

Hardware Design:

- Modular and discrete hardware to be designed for the rack with fully integrated car mounting in mind
- Individual hardware blocks and modules will individually meet Formula Hybrid requirements (e.g. color-coded wiring, force tolerance, water-resistance)
- Individual maintenance manuals to be developed for hardware modules in order to reduce MTTR time
- Order many more parts than required to facilitate repairs for our team and future teams

Software Design:

- Classes will be written such that config will only need to be edited in order to extend functionality by adding new classes
- Configuration will be maintained by a YML file which can be easily modified by a text editor
- Python, JavaScript, mySQL, and an Apache web server will be used: well-supported for the foreseeable future
- API will be well-documented to benefit future teams

Cost Analysis (Budget)

Item	Quantity	Unit Price	Total
TSV			
		Group Subtotal	$850
VSCADA			
		Group Subtotal	$400
GLV			
		Group Subtotal	$900
Cabling			
		Group Subtotal	$300
Motor Characterization and Dynamic Modeling			
		Group Subtotal	$250
Shipping and Handling/Tax/General			
		Group Subtotal	$300
		Project Grand Total	$3000