FAMU-FSU College of Engineering

Department of Electrical and Computer Engineering

SAE Baja Car Data Acquisition System

Needs Analysis and Requirements Specifications

SAE Baja Car Data Acquisition System

Team E#5

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Date	Revision No.	Author	Comments
9/14/14	1	Christopher Riker	Initial document creation
9/17/14	2	Christopher Riker	Added information from sponsor meeting, and drafted preliminary requirements
9/17/14	3	Hebe Perez	Completed preliminary requirements
9/18/14	4	Christopher Riker & Dewey Williams	Revised requirement analysis and performed preliminary research
9/18/14	5	Hebe Perez	Drafted preliminary test plan

1 Executive Summary

This report is an overview of the planned SAE Baja Car Team Data Acquisition System. It covers the required specs, an analysis of all end project requirements, as well as implementation ideas for the eventual design. In the analysis, the needs and wants of the customer are weighed against technical possibilities and financial feasibility. This document will serve as a set of guidelines and reference materials for the team and advisors to refer back to as the project progresses.

2 Overview of Design Team

Project Manager
Christopher Riker
Technical Area: General Programming

The Project Manager (PM) will control the overall structure of the team and its completion of the project. This includes, but is not limited to, maintaining communication with all team members, actively monitoring and encouraging project progress, and ensuring that deadlines are met. In effect, the PM will maintain constant contact with all team members about their progress and concerns with the particular tasks they have been assigned to ensure that the project is completed and delivered within the allotted time frame (**before** the Baja competition on April 7th-April 12th) on budget, and within scope.

Data Coordinator
Tyler Dudley
Technical Area: Power Electronics

The Data Coordinator (DC) will essentially handle all data associated with the project. This includes, but is not limited to, keeping meeting minutes, maintaining and organized report archive (complete with hard copies of each deliverable report), and collecting and organizing testing data from the DAQ prototype. The DC will ensure that a structured system is in place in which team members can quickly and easily find data that is needed from any particular deliverable/testing date. Optimally, this data will be stored on a physical drive of some sort (thumb drive or portable hard drive) as well as on the team's Google drive.

Financial Manager
Dewey Williams
Technical Area: Hardware and Interfacing

The Financial Manager (FM) will be entrusted with the general financial needs of the project. This includes, but is not limited to, keeping an inventory of all project parts, maintaining a project budget, requesting parts/funds from the ECE department, and writing and delivering sponsorship requests. This will ensure furthermore that the project is completed within a reasonable budget to be set in stone at a later date. The FM will ensure that any design decisions made by the team are financially feasible before they are set in stone.

DAQ Leader
Hebe Perez
Technical Area: Embedded Systems, Networks

The DAQ Leader (DAQL) is in charge of the overall integration of the DAQ into the Baja car itself. As the brains behind the DAQ idea, the DAQL act as a sort of ambassador, maintaining regular contact with the SAE Baja team in order to ensure the DAQ can be as useful to the Baja team as possible and stay within the limitations of the Baja car with regard to competition regulations. In addition, the DAQL will assist the FM with sponsorship requests. The DAQL will also ensure that, if possible, the proper arrangements are made such that the DAQ team can attend the Baja competition (location and date TBD).

3 Needs Assessment

3.1 Problem Statement

The acquisition of data can be a very important part of efficiently optimizing designs of many kinds, especially those involving mechanical systems such as automobiles, provided that the data collected is used in an appropriate manner. The design team aims to design and implement a Data Acquisition System (or DAQ) that will collect important data and will ultimately make the FAMU-FSU Baja team's vehicle more successful in this year's competition.

The DAQ will inform the Baja team of the proper changes and procedures needed to improve the vehicle mid-race, allowing them to focus less on problem identification and more on problem solving. The DAQ will tell the driver and the pit crew when a fuel change is needed, when a tire change is needed, when a suspension adjustment is needed, and any other information the team may find helpful, all remotely and in real time.

3.1.1 Background/Context

The SAE International Baja Series is an endurance race in which teams from all over the world compete to finish the most laps on a treacherous off-road course in a 4-hour period. Every team is provided with a 10 HP Briggs & Stratton engine on which to base the Baja car, which places every team on a level playing field and places the focus of the competition on design reliability and the creativity and feasibility of the accessory subsystems.

The FAMU-FSU Baja Team finished 75th at the Rochester, NY Baja Series competition in 2013, and in 2014 moved up nearly 30 places to 46th place in Illinois. The DAQ will be designed to assist the team as much as possible to improve even further in the 2015 competition.

3.1.2 Statement of Needs

The SAE Baja team hopes to obtain a data acquisition system for their vehicle that will allow them to more efficiently and effectively make changes to the vehicle during and before a race. The team wishes to collect data such as the amount of fuel in the vehicle, the speed of the vehicle, the acceleration of the vehicle, the tire pressure, the vibration in the vehicle, and the suspension travel. The goal is to have this information streamed to the pit so that they can make decisions about the vehicle during the race.

Currently, the Baja team pit crew makes a calculated guess as to when the vehicle needs to be refueled. This was a major factor in the placement of the team in previous years, as the vehicle was being pulled off the track and refueled unnecessarily. The DAQ will give them an accurate reading of the fuel level, meaning more of the allotted time will be spent on the track instead of in the pits. The crew will also receive information about the remaining tire pressure, notifying them when a tire change is needed. Information about the suspension and ride of the vehicle will be sent and collected as well, allowing the team to adjust the stiffness as needed to fit course conditions. The driver and pit will have mirrored displays and warning lights notifying them of the status of the system and important information about the vehicle.

The DAQ will also help the Baja team prepare for the race. The DAQ will provide the team with information about acceleration and speed, allowing them to make and verify adjustments to the vehicle using accurate measurements. Data about vibrations in the vehicle will also be collected, assisting the team in improving the comfort of the driver. This data may also aid the driver in learning both the limits of the vehicle and how to race in the most efficient way possible. To this end, much of the collected data will be stored on removable media so that the team can review it and make mechanical and behavioral changes as they see fit.

3.1.3 Supporting Information

3.1.3.1 Marketing Requirements

Customer Needs

1. Measurements of
    a. Speed
    b. Fuel
    c. Acceleration
    d. Vibration
    e. Tire pressure
    f. Suspension travel
2. Mirrored indicator lights for low fuel and tire pressure

Customer Wants

1. Speedometer and fuel gauge
2. Driver-to-Pit communication

3.1.3.2 Prioritization Analysis

	Aesthetics	Cost	High Performance	Ease of Use	Modularity	Geom. Mean	Norm. Mean
Aesthetics	1	1/7	1/9	1/9	1/7	**0.296**	**0.044**
Cost	7	1	1	3	1/5	**1.332**	**0.200**
High Performance	9	1	1	3	3	**2.408**	**0.361**
Ease of Use	9	1/3	1/3	1	1	**1.000**	**0.150**
Modularity	7	5	1/3	1	1	**1.635**	**0.245**

Using the pairwise comparison matrix above, the team determined that the most important factor of this product is high performance, with modularity in second place. The team feels that this project will be important to the SAE Baja team this season and into the future, and the team wants the system to be both future proof and easily expandable by members of the Baja team. The least

important aspect is aesthetics, since the equipment will be used outdoors and is not expected to look nice. The team feels that an effort to make it aesthetically pleasing will be detrimental to both cost and modularity.

3.1.3.3 Ranking of Needs

Needs	Create secondary power source for DAQ
	Sense & display speed & fuel level to driver
	Record sensor data to removable media
	Sense tire pressure and report to driver
	Wirelessly mirror warnings/data to pit
	Measure vehicle acceleration
	Measure vibration to improve ergonomics
Wants	Voice communication to pit
	Measure suspension travel in real time
	Install tachometer
	Camera

3.1.4 Statement of Objective

The goal of this project is to design a system that collects useful data about the FAMU-FSU SAE Baja vehicle to assist the team in making improvements to the vehicle and the way it is driven. The system should be user-friendly, easily repairable (modular), high performance, and relatively low-cost.

3.1.4.1 Preliminary Solution Concepts

Speed measurement
Hall Effect sensor with a magnet mounted on a wheel.

Fuel measurement
Float, tentative, depending on whether or not the fuel tank can be modified.

Acceleration
Accelerometers mounted somewhere on the vehicle, optimally close to the center of mass.

Tire pressure monitoring
Similar approach to production automobiles. Pressure sensor in the valve stem which sends a signal wirelessly to another sensor, one for each wheel.

Communication
Radio module, potentially one for voice communication and one for data transmission depending on the throughput of the chosen module.

3.1.5 Preliminary Research on Technologies & Systems

Our research on automotive computer systems shows that CANs (Controller Area Networks) are widely used in the automotive industry for connecting the many computer systems and subsystems within a vehicle, without the need for a central hub or "host". In our circumstance, the team believe a fully spec'd CAN system would drive up costs and increase development time, so the team decided to investigate the use of I^2C, SPI, and other widely used interfaces for interconnecting our systems. The team believes the use of these interfaces instead of a custom designed or more complex interface will better fit our system and will allow us to create a product which can be more easily understood and modified by future Baja and DAQ teams.

The team has also located a model of inexpensive wireless transmitters and receivers which will transmit serial or parallel data over 20 miles line-of-sight with plenty of bandwidth. However, it may require some additional research and testing to determine its effective range on the course.

4 Requirements Specification

4.1 List of Engineering Requirements

4.1.1 Functional Requirements

REQF-001 - The system must accurately measure and report the speed of the vehicle.

REQF-002 - The system must accurately measure and report the fuel level of the vehicle.

REQF-003 - The system must accurately measure and report the linear acceleration of the vehicle.

REQF-004 - The system must measure and report the intensity (frequency and amplitude) of vibrations in the vehicle.

REQF-005 - The system must accurately measure and report the tire pressure of the vehicle.

REQF-006 - The system must accurately measure and report the suspension travel.

REQF-007 - The system must alert both the driver of the vehicle and the pit crew if the fuel or tire pressure is below a certain threshold.

REQF-008 - The driver must be able to communicate with the pit crew wirelessly with reasonable sound quality.

REQF-009 - The system must display the speed and fuel level to the driver in an easy-to-read display.

REQF-010 - The data collected by the DAQ must be stored in an SD card for later use.

4.1.2 Non-Functional Requirements

REQN-001 - The system must be designed and implemented within an initial budget of $600, with the possibility of obtaining more funds through sponsorships.

REQN-002 - The system must be completed before the Auburn, AL Baja competition on April 9th, 2014.

REQN-003 - The system must include its own power source - the Baja vehicle's battery may not be used.

REQN-004 - The system must be easy to use for both the driver and the pit crew.

REQN-005 - The system must be easily repaired (i.e. modular) so that the entire system need not be taken apart in the event of part failure.

REQN-006 - The system must maintain a high level of performance.

4.1.3 Constraints

CONS-001 - The system must be completed within an initial budget of $600.

CONS-002 - The system must be completed before the Baja competition on April 9th, 2014.

CONS-003 - The system must be designed to withstand external temps of 100 degrees Celsius.

CONS-004 - The vehicle's engine cannot be modified in any way.

CONS-005 - The data transmission range must be at least 3 miles urban.

CONS-006 - The system cannot add significant weight to the vehicle.

4.1.4 Operating Environment

OE-001 - The vehicle will be operated in an outdoor environment. The system should be durable and resistant to outdoor particles such as dust and dirt.

OE-002 - The system will be subject to high temperatures and UV radiation from the sun, as well as ambient engine heat.

OE-003 - The system will be subject to large amounts of shock and vibration.

OE-004 - The communication system may be subject to RF interference.

OE-005 - The system may be subject to rain and other weather conditions.

4.1.5 Environmental and Health & Safety Requirements

EHS-001 - Special care will be taken in choosing the system's power source. It must be recyclable with minimal environmental impact, and it must last for a large number of recharge cycles.

EHS-002 - To ensure the safety of the Baja driver and other drivers on the track, the system must not interfere with or undermine any essential systems of the Baja.

EHS-003 - The system must be attached to the vehicle securely to prevent creating a hazard for other drivers.

EHS-003 - As the Baja may be subjected to rain or other water sources, it is important that the DAQ be resistant to water, and that systems are in place so that the Baja is safe to operate and repair when wet.

4.1.6 Usability Requirements

REQU-001 - The system must be easy to use by both the driver and the pit crew to allow them to focus on the competition.

REQU-002 - The system must not require a significant amount of setup work to run.

4.1.7 Reliability

REQR-001 - The system must remain functional for the entirety of the race, which lasts 4 hours.

REQR-002 - The components of the system must be easy to replace or repair in the event of failure.

REQR-003 - The system must remain securely mounted to the vehicle at all times during the competition.

5 Preliminary Test Plan

5.1 Requirements Test Plan

REQT-001 - *Speed Measurement*

A magnet will be attached to a rotating disk. The rotating disk will be set to a slow setting and the rotations will be hand counted. At the same time, the Hall Effect sensor will count the number of rotations. The rotations will be compared for accuracy.

REQT-002 - *Acceleration Measurement*

Accelerometers can be easily calibrated using the “tumble test” which uses the known acceleration of gravity to provide reference points between which sensor output is typically accurate within a few percent. The accelerometer will be removable so that this calibration can be performed.

REQT-003 - *Display*

Visual Testing. The data collected directly from the individual sensors will be used to verify that the information displayed is correct.

REQT-004 - *Fuel Sensor*

A predetermined amount of fuel will be poured into the tank and use this known amount to calibrate the sensor.

REQT-005 - *Tire Pressure Sensor*

The output of the digital sensor will be compared with a standard tire pressure gauge.

REQT-006 - *Driver to Pit Notification Lights*

The notification lights will be tested before they are mounted into the vehicle and again after their installation. The testing will be performed by

manually triggering a notification event and verifying that the notification light at a simulated pit crew station is lit to determine whether the signal transmission was a success.

REQT-007 - *SD Card Storage*

Data files will be written in a predictable format so that file corruption and errors will be apparent when viewed on a computer.

Optional Features

REQT-008 - *Driver to Pit Crew Voice Communication*

Listening tests will be performed while the vehicle is stationary and while in motion to verify that the communications will not fail during use.

REQT-009 - *Suspension Travel Measurement*

Suspension travel will be tested by manually finding the travel distance of the shocks when putting a predetermined amount of weight on the vehicle. This value will be used as constant. Using the same weight the value given by the sensor will be checked against the constant.

5.2 Constraints Test Plan

CONST-001 - The financial manager will keep an up-to-date ledger of expenses and remaining funds so that the project does not go over budget. This information will be made available to the DAQ team as well as the faculty advisors.

CONST-002 - Any parts which may be placed near the engine will be chosen so that the external heat does not exceed the device's safe operating range.

CONST-003 - Communication systems will be tested at distances exceeding 3 miles in an urban environment to verify complete and reliable data transmission.

CONST-004 - The system will be weighed regularly to ensure unnecessary weight is not added to the vehicle.

6 Preliminary Project Budget

The initial project budget is $600 (USD). The team will reach out to outside entities in search of sponsorships if the project requires additional funding. However, it is not expected that this will be the case.

7 Conclusion

By April 9th, there will be a data acquisition system consisting of sensors that collect data from various parts of an off road vehicle and keep an archive of the data in the form of log files. In addition to providing the Baja team members the data that will help in the design of a better vehicle, having a self-built data acquisition system will qualify the team for more points in the design portion of the competition and may move the team up in the rankings. This project will serve as a starting point that may lead to more intricate electronic systems in future competitions.