

**Software Requirements Specification**

**for**

**Baja SAE Drivetrain Optimization**

**Version 2.0 approved**

**Prepared by Krystal Bernal, Edit Vosganians, Roi Chico,**

**Bowen Waugh, and Huang Xu**

**Cal State LA Baja SAE**

**3/22/2020**

# Table of Contents

<b>Table of Contents</b>	<b>2</b>
<b>Revision History</b>	<b>4</b>
<b>1. Introduction.</b>	<b>5</b>
1.1 Purpose	5
1.2 Intended Audience	5
1.3 Product Scope	5
1.4 Definitions, Acronyms, and Abbreviations	5
1.5 References	5
<b>2. Overall Description</b>	<b>6</b>
2.1 Product Perspective	6
2.1.1 - Level 0 Data Flow Diagram	6
2.1.2 - Level 1 Data Flow Diagram	6
2.2 Product Functions	7
2.3 User Classes and Characteristics	8
2.4 Operating Environment	8
2.5 User Documentation	8
2.6 Assumptions and Dependencies	8
<b>3. External Interface Requirements</b>	<b>10</b>
3.1 User Interfaces	10
3.2 Hardware Interfaces	10
3.3 Software Interfaces	10

3.4 Communications Interfaces	11
<b>4. Requirements Specification</b>	<b>12</b>
4.1 Functional Requirements	12
4.2 Design Constraints	13
<b>5. Other Nonfunctional Requirements</b>	<b>15</b>
5.1 Performance Requirements	15
<b>Appendix A: Glossary</b>	<b>16</b>
<b>Appendix B: References</b>	<b>17</b>

# Revision History

<b>Name</b>	<b>Date</b>	<b>Reason for Changes</b>	<b>Version</b>
<b>Initial Submission</b>	<b>11/28/19</b>	<b>First Draft</b>	<b>v 1.0</b>
<b>Final Submission</b>	<b>3/22/20</b>	<b>Final Draft</b>	<b>v 2.0</b>

# **1. Introduction.**

## **1.1 Purpose**

This document encompasses all software requirements for the Drivetrain Optimization system. It will outline all major modules as well as their functions. At the end of this document, the reader should have an understanding of the system architecture and functionality.

## **1.2 Intended Audience**

This document is intended for use by the Cal State LA Baja SAE team members and faculty advisors as they use the Drivetrain Optimization data acquisition system. More specifically, the Electrical and Drivetrain subsections of the team may use this document to understand and further develop an analysis methodology for optimizing the vehicle and presenting results to competition judges.

## **1.3 Product Scope**

The purpose of this product is to aid the Cal State LA Baja SAE student-run competition team in optimizing the drivetrain for the vehicle that is going to be used for the 2020 Baja SAE competition, as well as any future vehicle that uses a Continuously Variable Transmission (CVT). Sensors will be placed in strategic areas to measure various aspects of vehicle performance, and our software will interpret the readings. The interpretations will be analyzed for different configurations of the mechanical tuning of the transmission components using various data analysis techniques. The developed software will determine if performance has been improved, which mechanical configurations are ideal for different course environments, and provide insight for how previously uninvestigated components work.

## **1.4 Definitions, Acronyms, and Abbreviations**

See Appendix A.

## **1.5 References**

See Appendix B.

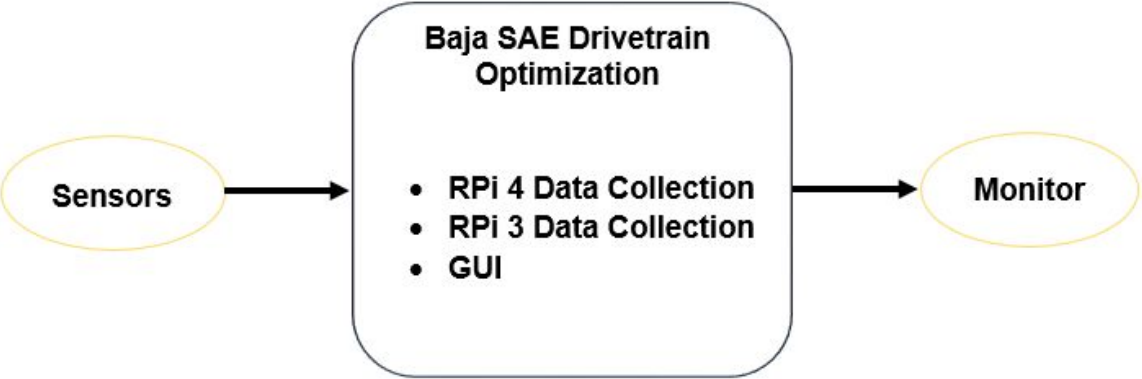
# 2. Overall Description

This section provides a description of the system architecture and components.

## 2.1 Product Perspective

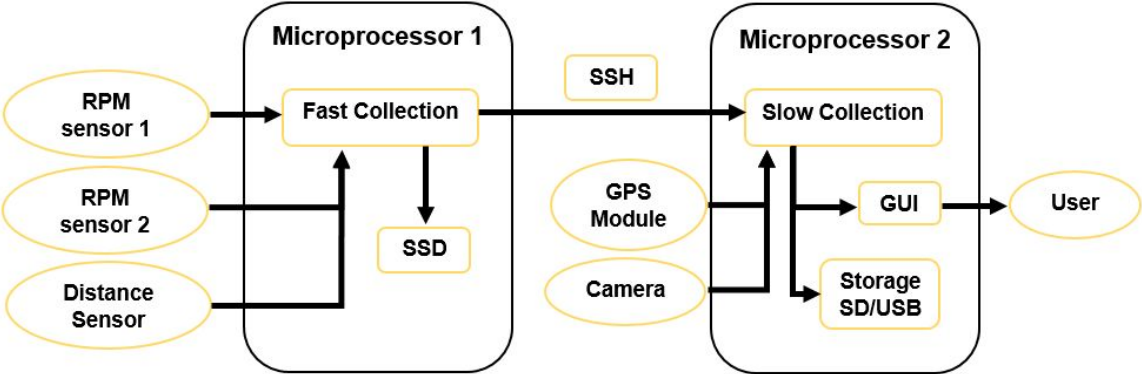
### 2.1.1 - Level 0 Data Flow Diagram

The software is designed in a way to accept input from designated sensors. The microprocessors process, transfer and analyze the data and display the appropriate information on the monitor.



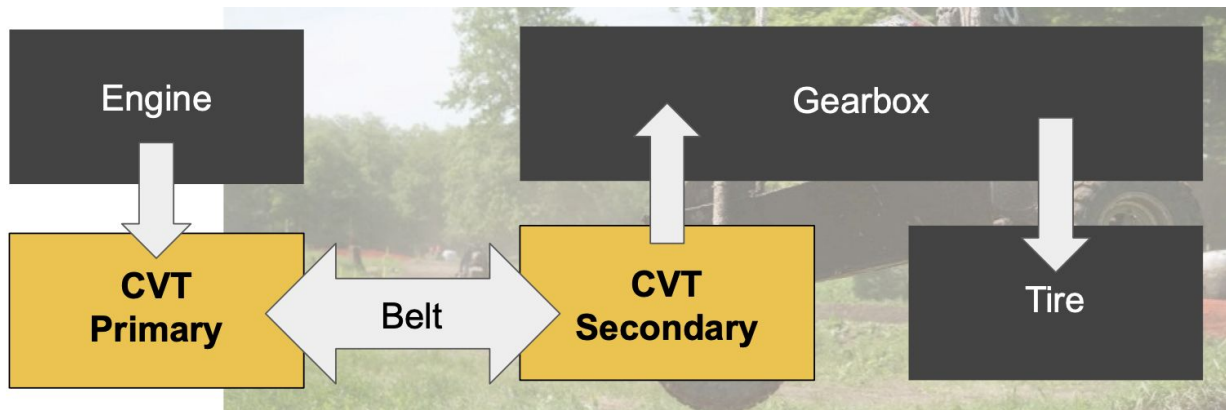
### 2.1.2 - Level 1 Data Flow Diagram

The software is implemented on a structure made of two microprocessor units. The microprocessor one is taking in the data input from two RPM sensors and a distance sensor as part of the “fast data collection” system. The second microprocessor takes in input from the GPS sensor and camera as part of the “slow data collection” system. In addition, microprocessor two collects all the data to process and display in order to not compromise the collection speed of the first one.



## 2.2 Product Functions

The main function of the Drivetrain Optimization system is to provide feedback about the Cal State LA Baja SAE vehicle drivetrain configuration. The drivetrain for the Baja vehicle includes the engine, Continuously Variable Transmission (CVT), and the Gearbox. The part of the drivetrain our project focuses on is the CVT. The CVT consists of a Primary and Secondary, both of which are rotating mechanical parts connected by a belt. Inside of the Primary are weights and springs that can be changed to be heavier or stiffer, respectively. Inside of the Secondary is a return spring that can also be substituted for one with a different stiffness.



*Figure 1: Components of Cal State LA Baja SAE drivetrain*

The configuration of the weights and springs inside the Primary and Secondary affects the ratio of their rotational speeds throughout a course. Exploring how these ratios change from one configuration to another allows the mechanical engineers to determine whether the power output by the engine is efficiently reaching the tires after passing through the rest of the system. The configuration of the Secondary return spring affects how quickly the CVT engages, affecting vehicle performance as well. There are five potentially unique tunes we need to find that correspond to the best performance for each dynamic competition event: Hill Climb, Tractor Pull, Acceleration, Maneuverability, and Endurance.

The Drivetrain Optimization system will record the rotational speed of the CVT Primary and Secondary, the change in position over time of the Secondary, the course environment, and the vehicle position and speed during test time. At analysis time, we will calculate the CVT ratio and compare it to the course, vehicle position, and vehicle speed to determine which tune performed the best and predict which type of tunes are the best for the defined competition events.

## 2.3 User Classes and Characteristics

The product is designed to be used by the Cal State LA Baja SAE competition team. A member of the drivetrain subsection of the team should have general prerequisite knowledge about how

a CVT works and how to mechanically tune it. A member of the electrical subsection of the team should have general prerequisite knowledge about the purpose of data acquisition as it applies to the competition. They should also have general knowledge about wiring and interfacing sensors with the Raspberry Pi operating system. In order for a member of the electrical team to continue the development of the Drivetrain Optimization system, they should have a strong understanding of how to interpret the data collected by the system.

## 2.4 Operating Environment

- Data collection will be done on a Raspberry Pi 3 and a Raspberry Pi 4 microprocessor, whose operating systems are both Raspbian, a Linux-based system.
- We will use libraries developed for use with the Python 3.7 language version and the Raspberry Pi's native General Purpose Input and Output (GPIO) pins.
- We will use external software for data analysis that may be used on a Windows 10 or Mac OS operating system. The specific data analysis software is listed in Section 2.6.

## 2.5 User Documentation

Will be provided in a different document.

## 2.6 Assumptions and Dependencies

- Computer Peripherals
  - Bluetooth Keyboard
  - Mouse
  - Monitor
  - USB
- Python IDE Software
  - Python IDLE
- Gmplot library API
  - Library necessary to plot coordinates in google map.
- ImageAI library
  - Library necessary for object detection in still images.
  - Dependent on the following software:
    - TensorFlow
    - OpenCV
    - Keras
- ADC library Adafruit\_MCP3008 Adafruit\_GPIO.SPI
  - Library necessary to convert analog to digital.
- ADC library VI6180x



- Library necessary for the distance sensor.
- MATLAB
  - Software necessary to process and filter the gathered data.

## 3. External Interface Requirements

This section will describe how the Drivetrain Optimization system will interact with external interfaces.

### 3.1 User Interfaces

The Baja SAE DriveTrain Optimization system will be displayed on the touch-screen Elecrow LCD Display, which measures 5” and has a resolution of 800 x 480. The display presents information relevant to the state of the drivetrain. This information shall include a visual of the measured RPMs, distance gathered from the VL6180X Distance Sensor, and GPS location.

### 3.2 Hardware Interfaces

Component	Purpose
Raspberry Pi 3 Version B+	Slow data collection system.
Raspberry Pi 4	Fast data collection system.
55140 Series Hall Effect Sensors	Measure CVT Primary and Secondary RPMs.
VL6180X Distance Sensor	Track the position of CVT Secondary.
VK162 GPS Module	Collect Baja Vehicle Location.
PiCamera V1	Photograph environment at set intervals.
Adafruit MCP3008	Convert analog to digital.

### 3.3 Software Interfaces

- Fast Data Collection
  - System will collect data and produce an RPM and average changes of distance.
  - System will filter out outliers or errors, making sure corrupt data will not be collected.
  - System will restart whenever an error occurs.
  - System will send appropriate processed data to GUI.
  - System will send all data collected to RPi3 to be saved in a central location.
- Slow Data Collection
  - System will store GLL data from the GPS module.

- System will record images every three seconds of the course environment.
- System will send appropriate processed data to GUI.
- System will save all data into a central location.
- GUI
  - System will have a way to input date, time, and CVT configuration
  - System will display the CVT Secondary return rate.
  - System will display the CVT Primary and Secondary ratio RPM.
  - System will display some live sensor data being collected.
- Data Analysis Module
  - System will determine the best weight and spring to use for each respective course type.
  - System will determine the best clocking and stiffness to use in the secondary for each respective course type.
  - System will track the path taken during the course runs.
  - System will determine the speed of the vehicle at different points throughout the course.
  - System will classify each recorded image, such as an uphill slope, turns, and rocks.

## **3.4 Communications Interfaces**

A Secure Shell Connection shall be used for communication between the Raspberry Pi 3 and Raspberry Pi 4.

# 4. Requirements Specification

## 4.1 Functional Requirements

<b>Module 4.0 - Fast Data Collection (RPi4)</b>	
	Requirement Description
<b>4.0-1</b>	The system shall interpret the data collected from the Hall Effect Sensors to produce RPMs of the Primary and Secondary.
<b>4.0-2</b>	The system shall record the position of the Secondary.
<b>4.0-3</b>	The system shall record all sensor data collected with a timestamp.
<b>4.0-4</b>	The system shall send appropriate processed data to the GUI.
<b>4.0-5</b>	The system shall save data to non-volatile memory.

<b>Module 4.1 - Slow Data Collection (RPi3)</b>	
	Requirement Description
<b>4.1-1</b>	The system shall store GLL data from the GPS Module.
<b>4.1-2</b>	The system shall record an image of the course environment every 3 seconds.
<b>4.1-3</b>	The system shall send appropriate processed data to the GUI.
<b>4.1-4</b>	The system shall save data to non-volatile memory.

<b>Module 4.2 - Graphical User Interface (GUI)</b>	
	Requirement Description
<b>4.2-1</b>	The system shall provide a way to input the test date, time, CVT Primary and Secondary weight and spring configurations, and course type.
<b>4.2-2</b>	The system shall display the CVT Secondary return rate.

<b>4.2-3</b>	The system shall display the ratio of RPMs of the CVT Primary and Secondary.
<b>4.2-3</b>	The system may be required to show more live sensor data as required by the Cal State LA Baja SAE team.

<b>Module 4.3 - Data Analysis</b>	
	Requirement Description
<b>4.3-1</b>	The system shall determine which weight and spring configuration primary was the best for the respective course type.
<b>4.3-2</b>	The system shall determine which clocking and stiffness was best for secondary for each course type.
<b>4.3-3</b>	The system shall determine the path the vehicle traveled throughout the course.
<b>4.3-4</b>	The system shall determine the speed of the vehicle at different points throughout the course.
<b>4.3-5</b>	The system shall classify each recorded image - ex. uphill, turn left, turn right, hit a rock.

## 4.2 Design Constraints

<b>Hardware Limitation</b>	
Component	Limitation
VL6180X Distance Sensor Range	5mm - 100mm
55140 Series Hall Effect Sensor Range	10mm - 20 mm
VK162 GPS Module	Needs clear sky, no walls, needs to be below 40 mph and no dead-zone.
Pi Camera V1	1024 x 768 image resolution for object recognition to work.

<b>Sensor Constraints</b>	
Sensor Name	Constraint
55140 Series Hall Effect Sensor	The system has no constraints to our knowledge.
VL6180X Distance Sensor Range	The system shall gather data in units of inches.

<b>RPI3 Constraints</b>
Requirement Description
The operating system and local memory is limited to the size of the micro SD card (currently 64GB).
The distance between the RPi4 and RPi3 connected by a ~6 ft Ethernet Cable.

<b>Graphical User Interface Constraints</b>
Requirement Description
The system shall receive data from RPi4 and RPi3.
The system shall use a screen of 5" 800 x 480 to display information.

# 5. Other Nonfunctional Requirements

## 5.1 Performance Requirements

- The Baja SAE Drivetrain Optimization System must be easy to use for non-technical Cal State LA Baja SAE team members.
- The GUI must display sensor data as requested by the Cal State LA Baja SAE team.
- The Fast Data Collection Module must be able to reliably collect RPM values with an upper bound of 4500 RPM.
- No module shall interfere with the reliability of the collection speed of the Fast Data Collection Module.
- The system should perform reliable data collection in remote testing locations.
- Data collection and storage should not exceed memory available by hardware.
- The RPi3 system shall take images of a required size of less than 200 kB.
- The system shall collect GPS data every second and save it to a .csv file.
- The system shall have a margin of error less than 2% for rotational speeds up to 4500 RPM.
- The system shall have a margin of error less than 2% for distances recorded.
- The sensor should be able to record distances of up to 1.5 inches

# Appendix A: Glossary

## Abbreviations and Acronyms

- GPIO - General Purpose Input and Output
- RPi 3 - Raspberry Pi 3
- RPi 4 - Raspberry Pi 4
- OS - Operating System
- GUI - Graphical User Interface
- ADC - Analog to Digital Converter
- DFD - Data Flow Diagram
- NMEA - National Marine Electronics Association
- GLL - Geographic Latitude and Longitude
- SSH - Secure Shell Protocol

## Definitions

- CVT - Continuously Variable Transmission. A type of clutch that has a Primary and Secondary component, which are connected by a belt
- Primary - A rotating body connected to the engine by the engine output shaft. It drives the Secondary member by transferring power through a belt. The primary may be tuned by changing the internal weights and springs
- Secondary - A rotating body connected to the Gearbox by the Gearbox input shaft. It is driven by the Primary through a belt. The Secondary may be tuned by clocking and changing the stiffness of its return spring
- Gearbox - A mechanical device whose internals consists of gears that create a speed reduction from the input rotational speed to the output rotational speed. The input rotational speed comes from the Secondary and the output rotational speed goes to the vehicle wheel.



# Appendix B: References

## Documents

### NMEA Reference Manual

SiRF Technology, Inc., January 2005. Revision 1.3.

### Collegiate Design Series Baja SAE® Rules 2020

Baja SAE, September 8, 2019. Revision A.

## Setup Guides

- **Distance Sensor Setup Guide:**  
<https://learn.adafruit.com/adafruit-vl6180x-time-of-flight-micro-lidar-distance-sensor-breakout/python-circuitpython>
- **Analogue Sensors On The Raspberry Pi Using An MCP3008:**  
<https://www.raspberrypi-spy.co.uk/2013/10/analogue-sensors-on-the-raspberry-pi-using-an-mcp3008/>