Final Design Report

Metaverse Maintenance

University of Cincinnati Senior Design Project

Cory Gish and Ryan Logsdon

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Team Members

The team members consist of:

- Ryan Logsdon | logsdori@mail.uc.edu – 4th year computer science major with a focus in virtual reality.
- Cory Gish | gishcd@mail.uc.edu – 5th year electrical engineering major

The project advisor for this project is:

- David Mackenzie | dmackenzie@ite.com – VP of Product Development at ITE

Project Description

Project Abstract

This project is a data collection and analysis tool for consumer and commercial automotive vehicles. Users for this device include mechanics, fleet managers, data analysts, and conventional drivers. The system will allow users to view, analyze, and improve vehicle performance through a multi-platform analysis tool including in-vehicle display, web application, and a virtual reality environment.

Inadequacy of Current Solutions

The current solution to this project can be seen through the Progressive Snapshot. This device reads on-board diagnostic data (OBDII data) from your vehicle and reports your driving habits to the insurance company. The inadequacy of this solution is that users can never see the data being collected through the Snapshot device. Moreover, other solutions include handheld OBD diagnostic tools. These devices take a single reading of the diagnostic data and display it on the connected device. This solution does not provide real-time vehicle diagnostics while driving, or the ability to track this data over time.

Technical Background Applicable to the Problem

Both team members worked at ITE, a product development company in Cincinnati, Ohio. During their time at ITE, both team members were exposed to cloud based IOT tracking through Losant. This tool allows a set of assets to track, collect, monitor, and send live data from anywhere in the world. Losant offers the ability for this data to be modified and displayed through a variety of out-of-the-box dashboard development tools. Furthermore, Ryan's experience in virtual reality and software development provides a firm foundation in the capabilities of modern equipment to provide users with the best possible viewing experience. Cory's background in electrical engineering will allow him to contribute towards the optimization of hardware throughout the system, as well as provide understanding into how the asset can safely monitor the vehicles diagnostic data.

Approach

Due to the complexity and multitude of functionality that is required of the system discussed above, the team has broken the system into three major categories. The first category is the automotive-device interface. This area of focus will include designing hardware components to gather real-time automotive data points to be analyzed throughout the system. A Raspberry Pi 3 Model B will collect data through a Bluetooth OBD diagnostic board. This data will be displayed through a human machine interface (HMI) that provides an operator with a dashboard of real-time attribute values.

The second major category is internet of things (IOT) capability. For this system to provide an immersive cross-platform experience, it is necessary that automotive data can be accessed through a variety of interfaces. Well-designed IOT connectivity will limit the latency of data retrieval and provide a real-time experience across any platform. To incorporate these requirements within the system, the team will use a Blues Wireless Cellular Notecard to send live diagnostic data from the Raspberry Pi to Losant. From here, data will be collected and displayed on a real-time and historical dashboard.

The last category of focus for this project is user interfaces. The project team would like to implement a virtual reality (VR) experience to provide users with three-dimensional data visualization of automotive attributes. However, since VR could become a barrier to entry for an average user, the team will also provide a browser-based application to allow the system to be viewed on any network capable device. This application will provide users with the ability to create an account, register a vehicle, and display the vehicles real-time and historical device data. For the VR environment, Noda.io, a mind-mapping tool, will be used to integrate the dashboards into a 3-D environment. This environment will include a model of a user's vehicle and appropriate sensors to represent the attribute data being collected from the vehicle.

Test Plan and Results

To verify the functionality of the Metaverse Maintenance diagnostic system, this testing procedure will first test the functionality of all individual software and hardware components. Simulated data will be utilized to understand the connectivity of various components and the latency between the vehicle and final data analysis points. Next, the system, as a whole, will be tested using multiple automotive vehicles to analyze its functionality, accuracy, and reliability. Moreover, both normal and abnormal testing conditions will be utilized to ensure the system is performing in extraordinary operating conditions.

Test Case Descriptions

NC1.1 **Notecard Connectivity**
NC1.2 This test will ensure the IOT connection between the Blues.io notecard and the

	IOT cloud platform.
NC1.3	The raspberry pi with connected Blues.io cellular notecard will be powered on. A data simulation program will be run to require the cellular notecard to pass values to Losant. The device log will be assessed to ensure communication is established between the device and Losant.
NC1.4	Inputs: Simulated data from the raspberry pi.
NC1.5	Outputs: The device log inside Losant will update with the simulated data from the raspberry pi.
NC1.6	Normal
NC1.7	Blackbox
NC1.8	Functional
NC1.9	Unit Test

OB1.1	**On Board Display Connectivity**
OB1.2	This test will ensure the interface inside the automobile is connected to the raspberry pi and displaying the appropriate dashboard.
OB1.3	The raspberry pi with connected Blues.io cellular notecard will be powered on. A data simulation program will be run, displaying the in-car dashboard.
OB1.4	Inputs: Simulated data from the raspberry pi.
OB1.5	Outputs: The dashboard will display the updating simulation data
OB1.6	Normal
OB1.7	Blackbox
OB1.8	Functional
OB1.9	Unit Test

NI1.1	**Noda Interface 1**
NI1.2	This test will ensure the interface connection between Noda and Losant is working correctly.
NI1.3	Inside of Noda, a vehicle import will be initialized. Losant will process this request and return the vehicle node point map of the selected vehicle. The corresponding map of a vehicle will be displayed for a user. Multiple requests should be attempted for multiple vehicle types to ensure the interface is working.
NI1.4	Inputs: Import model request inside of Noda
NI1.5	Outputs: Vehicle map is displayed for the user.
NI1.6	Normal
NI1.7	Blackbox
NI1.8	Functional
NI1.9	Unit Test

NI2.1 **Noda Interface 2**
NI2.2 This test will ensure the communication between Noda and Losant is working properly.
NI2.3 Data will be simulated for a device inside of Losant. With the vehicle map loaded inside of Noda, corresponding sensor values should change, matching the values from the simulator.
NI2.4 Inputs: Import model request inside of Noda, Losant data simulation
NI2.5 Outputs: Vehicle map is displayed with sensor values and colors changing.
NI2.6 Normal
NI2.7 Blackbox
NI2.8 Functional
NI2.9 Unit Test

NI3.1 **Noda Interface 3**
NI3.2 This test will ensure the communication between Noda and Losant is working properly.
NI3.3 Data will be simulated for a device inside of Losant. With the vehicle map loaded inside of Noda, corresponding sensor values should change, matching the values from the simulator. The simulator will be turned off. Values within Noda should stop changing.
NI3.4 Inputs: Import model request inside of Noda, Losant data simulation
NI3.5 Outputs: Vehicle map is displayed with sensor values and colors changing, then not changing.
NI3.6 Abnormal
NI3.7 Blackbox
NI3.8 Functional
NI3.9 Unit Test

NI4.1 **Noda Interface 4**
NI4.2 This test will ensure the communication between Noda and Losant is working properly.
NI4.3 Inside of Noda, a vehicle import will be initialized. Losant will process this request and return the vehicle node point map of the selected vehicle. The corresponding map of a vehicle will be displayed for a user. A clear model request should be executed. The node map should disappear.
NI4.4 Inputs: Import model request inside of Noda, clear model request inside of Noda.
NI4.5 Outputs: Vehicle map is displayed and then removed.
NI4.6 Normal
NI4.7 Blackbox
NI4.8 Functional

NI4.9 Unit Test

WA1.1 **Web Application 1**
WA1.2 This test will ensure the communication between the web interface and Losant is working properly.
WA1.3 Data will be simulated inside of Losant for all vehicle sensor attributes. Within the web application interface, the real time and historical overview displays should update properly.
WA1.4 Inputs: Losant data simulation.
WA1.5 Outputs: Updating dashboards
WA1.6 Normal
WA1.7 Blackbox
WA1.8 Functional
WA1.9 Unit Test

WA2.1 **Web Application 2**
WA2.2 This test will ensure that the request device ID functionality is working for the web application and that administrators are notified via email.
WA2.3 A request device ID transaction will be triggered through the web application. An email notification should be received by an administrator.
WA2.4 Inputs: Request device ID trigger
WA2.5 Outputs: Email notification
WA2.6 Normal
WA2.7 Blackbox
WA2.8 Functional
WA2.9 Unit Test

WA3.1 **Web Application 3**
WA3.2 This test will ensure the communication between the web interface and Losant is working properly for adding a vehicle.
WA3.3 An add vehicle transaction will be initiated in the web application. All appropriate information will be filled out and submitted. A new entry should appear in Losant corresponding to this vehicle.
WA3.4 Inputs: Add vehicle transaction
WA3.5 Outputs: Updated Losant data table
WA3.6 Normal
WA3.7 Blackbox
WA3.8 Functional
WA3.9 Unit Test

WA4.1 **Web Application 4**

WA4.2 This test will ensure the communication between the web interface and Losant is working properly for removing a vehicle.

WA4.3 A remove vehicle transaction will be initiated in the web application. The corresponding entry should be removed from the Losant data table.

WA4.4 Inputs: Remove vehicle transaction

WA4.5 Outputs: Vehicle removed from data table

WA4.6 Normal

WA4.7 Blackbox

WA4.8 Functional

WA4.9 Unit Test

WA5.1 **Web Application 5**

WA5.2 This test will ensure the communication between the web interface and Losant is working properly for adding a user.

WA5.3 An add user transaction will be initiated in the web application. All appropriate information will be filled out and submitted. A new entry should appear in Losant corresponding to this user.

WA5.4 Inputs: Add user transaction

WA5.5 Outputs: Updated Losant data table

WA5.6 Normal

WA5.7 Blackbox

WA5.8 Functional

WA5.9 Unit Test

WA6.1 **Web Application 6**

WA6.2 This test will ensure the communication between the web interface and Losant is working properly for logging a user into the application.

WA6.3 A user will enter their log-in information into the web application and click "Login". They will be accepted into the system.

WA6.4 Inputs: User login information

WA6.5 Outputs: Access to the system

WA6.6 Normal

WA6.7 Blackbox

WA6.8 Functional

WA6.9 Unit Test

WA7.1 **Web Application 7**

WA7.2 This test will ensure the communication between the web interface and Losant is working properly for logging a user out of the application.

WA7.3 A user will enter their log-in information into the web application and click "Login". They will be accepted into the system. They will then log out of the system and not be able to access the system.

WA7.4 Inputs: User login information, log out transaction

WA7.5 Outputs: Access to the system is no longer granted

WA7.6 Normal

WA7.7 Blackbox

WA7.8 Functional

WA7.9 Unit Test

WA8.1 **Web Application 8**

WA8.2 This test will ensure the communication between the web interface and Losant is working properly for keeping a user from logging into the application.

WA8.3 A user will enter their log-in information incorrectly into the web application and click "Login". They will not be accepted into the system.Various variations of a username and password should be tried to ensure security.

WA8.4 Inputs: Incorrect user login information

WA8.5 Outputs: Access to the system is not granted

WA8.6 Abnormal

WA8.7 Blackbox

WA8.8 Functional

WA8.9 Unit Test

VT1.1 **Vehicle Test 1**

VT1.2 This test will ensure the proper power requirements are met by a vehicle to power the system.

VT1.3 The device will be plugged into the vehicle's USB charging port. The in-car display should power on.

VT1.4 Inputs: Power cord plugged into the USB port.

VT1.5 Outputs: Powered display

VT1.6 Normal

VT1.7 Blackbox

VT1.8 Functional

VT1.9 Unit Test

VT2.1 **Vehicle Test 2**

VT2.2 This test will ensure the vehicle is communicating with the device.

VT2.3 The bluetooth OBD II connector should be connected to the car. With the device powered on, vehicle data should be displayed on the dashboard.

VT2.4 Inputs: OBD II connection
VT2.5 Outputs: Vehicle data displayed on dashboard
VT2.6 Normal
VT2.7 Blackbox
VT2.8 Functional
VT2.9 Unit Test

VT3.1 **Vehicle Test 3**
VT3.2 This test will ensure the vehicle is communicating with the device.
VT3.3 The bluetooth OBD II connector should be disconnected from the car. With the device powered on, vehicle data should not be displayed on the dashboard.
VT3.4 Inputs: Powered device with no OBD II connection
VT3.5 Outputs: Vehicle data is not displayed on dashboard
VT3.6 Abnormal
VT3.7 Blackbox
VT3.8 Functional
VT3.9 Unit Test

VT4.1 **Vehicle Test 4**
VT4.2 This test will ensure the vehicle is communicating with the device accurately.
VT4.3 The bluetooth OBD II connector should be connected to the car. With the device powered on, vehicle data should be displayed on the dashboard. Speed, RPM, and runtime should be monitored by the vehicle's odometer, and clock. These values should be compared for accuracy.
VT4.4 Inputs: Vehicle data
VT4.5 Outputs: Vehicle data displayed on dashboard
VT4.6 Normal
VT4.7 Blackbox
VT4.8 Functional
VT4.9 Unit Test

VT5.1 **Vehicle Test 5**
VT5.2 This system functions properly for a vehicle.
VT5.3 The bluetooth OBD II connector should be connected to the car. With the device powered on, vehicle data should be displayed on the dashboard. The car should be operated normally by a user. Vehicle data should be compared with the Losant dashboards, web application, and Noda interface, to ensure proper function.
VT5.4 Inputs: Vehicle operation with device connected
VT5.5 Outputs: Data measurements across multiple displays.
VT5.6 Normal

VT5.7	Whitebox
VT5.8	Performance
VT5.9	Integration Test

OA1.1	**OBD II Adapter 1**
OA1.2	This test ensures all LEDs on the OBD II adapter are operational.
OA1.3	The OBD II connector should be connected to the car. With the device powered on and vehicle data properly displayed on the dashboard, the LEDs on the OBD II connector should have a red LED always on, a green LED to indicate data sent from the device to the vehicle, a yellow LED to indicate data sent from the vehicle to the device, another green LED to indicate data sent from the device to the raspberry pi, and another yellow LED to indicate data sent from the raspberry pi to the device.
OA1.4	Inputs: OBD II connection
OA1.5	Outputs: LEDs
OA1.6	Normal
OA1.7	Blackbox
OA1.8	Functional
OA1.9	Unit Test

OA2.1	**OBD II Adapter 2**
OA2.2	This test ensures correct communication between the vehicle and OBD II adapter.
OA2.3	The OBD II connector should be connected to the car. With the device powered on, the OBD II connector should also be connected to a computer instead of the raspberry pi. Manually send commands through the OBD II port to the vehicle and observe its output. Ensure vehicle output is intended based on command. Ensure red power LED stays on, green LED for communication sent from device to vehicle flashes when commands are sent to the vehicle, and the yellow LED for communication sent from the vehicle to device flashes when commands are sent to the device.
OA2.4	Inputs: OBD II connection, laptop
OA2.5	Outputs: LEDs, laptop
OA2.6	Abnormal
OA2.7	Whitebox
OA2.8	Performance
OA2.9	Integration Test

OA3.1	**OBD II Adapter 3**
OA3.2	This test ensures correct communication between the OBD II adapter and the raspberry pi.

OA3.3	The OBD II connector should be connected to the car so it can be powered on. With the device powered on, the OBD II connector should also be connected to the raspberry pi and a laptop. Manually send commands from the raspberry pi to the adapter, and manually send commands from the adapter to the raspberry pi. Ensure the commands are correct and receive correct responses. Ensure red power LED stays on, green LED for communication sent from device to raspberry pi flashes when commands are sent to the raspberry pi, and the yellow LED for communication sent from the raspberry pi to device flashes when commands are sent to the device.
OA3.4	Inputs: Raspberry pi, laptop
OA3.5	Outputs: LEDs, laptop
OA3.6	Abnormal
OA3.7	Whitebox
OA3.8	Performance
OA3.9	Integration Test

Test Case Matrix

Test Case ID	Normal/ Abnormal	Blackbox/ Whitebox	Functional/ Performance	Unit/ Integration
NC1	Normal	Blackbox	Functional	Unit
OB1	Normal	Blackbox	Functional	Unit
NI1	Normal	Blackbox	Functional	Unit
NI2	Normal	Blackbox	Functional	Unit
NI3	Abnormal	Blackbox	Functional	Unit
NI4	Normal	Blackbox	Functional	Unit
WA1	Normal	Blackbox	Functional	Unit
WA2	Normal	Blackbox	Functional	Unit
WA3	Normal	Blackbox	Functional	Unit
WA4	Normal	Blackbox	Functional	Unit
WA5	Normal	Blackbox	Functional	Unit
WA6	Normal	Blackbox	Functional	Unit

WA7	Normal	Blackbox	Functional	Unit
WA8	Abnormal	Blackbox	Functional	Unit
VT1	Normal	Blackbox	Functional	Unit
VT2	Normal	Blackbox	Functional	Unit
VT3	Abnormal	Blackbox	Functional	Unit
VT4	Normal	Blackbox	Functional	Unit
VT5	Normal	Whitebox	Performance	Integration
OA1	Normal	Blackbox	Functional	Unit
OA2	Abnormal	Whitebox	Performance	Integration
OA3	Abnormal	Whitebox	Performance	Integration

User Manual

The following link provides access to a complete user manual for this project:
Metaverse Maintenance User Manual

Overview

The Metaverse Maintenance system consists of a physical car diagnostic device and associated web analytics tools. The device reads and displays sensor data from the vehicle via an in-car display. Web diagnostic tools, including real-time and historical dashboards, allow users to track vehicle performance remotely. An optional virtual reality data visualization tool is also provided for users possessing a VR headset.

1. Getting Started

2. Vehicle Installation

Frequently Asked Questions

- Do I need a VR headset?

No. No VR headset is required to use Metaverse Maintenance. The web application can be accessed from any browser on a connected device.

- What VR headsets work with Metaverse Maintenance?

Many! Any VR headset that is compatible with Noda will work for Metaverse Maintenance.

- Do I need to purchase a Noda Core or Noda Plus?

Yes. Due to API restrictions, the core version of Noda is required to import vehicle data into Noda. This consists of a separate one-time $30 purchase, and a $5 monthly subscription for Noda Plus.

- Do I need to do anything for the OBDII device and in-car display to work properly?

The only thing that needs to be done is for both devices to be plugged in fully. The OBDII device is operational with the red LED indicator turned on. The in-car monitor is operational with DC power supplied to its power input.

- The monitor is not displaying current data properly. What should I do?

If the monitor is not displaying data properly, there could be a communication issue between the car and the OBDII port or between the OBDII port and the monitor. There are LEDs on the OBDII port indicating communication. If the LEDs are not lighting up, this would indicate a communication error. Try disconnecting both devices and reconnecting them to reestablish communication. If that does not work, the OBDII device or monitor could be defective.

Spring Final Presentation

The presentation slides and video (links provided below) document the general overview of the project and a demonstration:

- Powerpoint Slides – Project Presentation Slides
- Presentation Video – Project Presentation Video

Final Expo Poster

Below is an image and link to the final poster that was presented at the CEAS Expo on April 6th, 2023:

Poster Link: Final Expo Poster

Self-Assessment Essays

Initial Self-Assessments

The following self assessments document the initial project views of both team members.

Cory Gish

Within this initial phase of our project, I have been focused on part sourcing, programming within the microcontroller, and PCB design. The first item is important to get crucial parts for the board, such as the microcontroller for the OBD connector and the screen dashboard. Several different dashboards were considered, such as a display with touchscreen and better resolution, but it was decided to go for a cheaper alternative due to budget constraints. The microcontroller goes out of stock frequently, so sourcing this was important to ensure the OBD connector can be created. An additional part that was important to source was the Bluetooth module that goes in the OBD connector, as this was hard to source in the past.

The next item I worked on was initial programming within the microcontroller. I used a breakout board for the SAMD21, where I got used to the registers and capabilities of the device. I used this to program initial LED control for the status LEDs and to get familiar with UART, which would be used to communicate with the vehicle. I also began working with the Bluetooth module to establish a connection between itself and the microcontroller.

Over the next semester, I will continue to program within the microcontroller now that I am used to its capabilities and registers. I will also continue to work on PCB design, which I have little progress on currently as the microcontroller is not fully programmed yet. This PCB design will progress along with getting better control over the Bluetooth module and its transmission of data received from the car to the Bluetooth module, then to the display.

At our current progress, I feel confident that we will finish our project on time and that it will be successful, as we already have many parts of the project working. The main issue I see for the work I have ahead of me is the transmission of data between the car, OBD connector, and display, but that is where the majority of my attention will be in the upcoming months for this project. Now that the software development, IOT capabilities, and important parts have been sourced, I believe we are on track to finish on track with our deadline.

Ryan Logsdon

Throughout the first 3 months of this project, I have been focused on the software development and IOT capabilities of the system. The first item I designed was the source code for hosting the Metaverse Maintenance website. W3 Spaces was utilized to host this website. I used JavaScript, CSS, and HTML programming languages to design a user interface that interacts with the cloud based IOT platform, Losant. Moreover, I used an API to interact with Noda.io. This API allowed vehicle node point data to be brought into a virtual reality environment. Thus, the data visualization of live vehicle data can be done via the web application or in a virtual environment.

The other major aspect of the project I have contributed to was in the design and development of the Raspberry Pi data collection system. Using the OBD python library and an OBD to USB connection cable, the Raspberry Pi can communicate with the diagnostic sensors of any modern vehicle. I utilized a blues wireless cellular notecard to create a network connection for transferring to the Losant data system. Moreover, an active GPS antenna was installed to create an asset tracking system for the project.

Over the next semester, I will focus on continuing to develop the virtual environment to create an immersive user experience. This will primarily consist of designing and developing interactive user dashboards to display live and historical vehicle data. I will also research the OBD sensors used for diagnostic readings to understand what maintenance can be provided when a given metric is out of specification. With this data in mind, I believe the system can be modified to offer maintenance information such as when and how to replace a malfunctioning sensor, or to notify a user of when a vehicle needs service.

Overall, I am very satisfied with the current state of the project and believe that we can complete the system on-time. I believe the most difficult portion of the remaining project timeline will be designing the OBD to Bluetooth connection. This component will require a significant amount of time to design the circuit board and fully test the connection with the rest of the system. I am confident that Cory and I will be able to fully develop this component, however, there may be changes and simplifications required to complete it within the project timeline.

Final Self-Assessments

The following self assessments document the final project views of both team members.

Cory Gish

For this project, my main objective was to produce the hardware and software for the OBD II adapter device for the OBD II port within a vehicle. In order to complete this, I utilized a Bluetooth RN-42 module, SNT1110 chip for multiprotocol OBD to UART interpreter, and a SAMD21 microcontroller. The main protocol focus for the STN1110 chip was CAN bus (ISO 15765) as it is mandatory in US cars since 2008 and is used today in the majority of cars. However, this chip also gives support for ISO 14230-4, ISO 9141-2, SAE J1850 VPW, and SAE J1850 PWM. Within this OBD II adapter device, the microcontroller relays information from the STN1110 chip to the Bluetooth chip through UART. Once the data has been sent over to Bluetooth, it can then send it over to the Raspberry Pi.

For Metaverse Maintenance, I got to learn about different technologies and apply concepts learned throughout college. As I always want to try to find new ways of improving a project, being able to fully focus on the hardware and software for the OBD reader was greatly beneficial for implementing a successful OBD reader device. Due to the variety of challenges our project was tasked with, my teammate, Ryan, was able to develop the system for creating data visualization and a VR environment for additional visualization of vehicle data. Being able to work on a team with a diverse set of skills allows us to focus on our strengths and gave us experience on working with a multidisciplinary team.

Our group has been able to fully complete the tasks we set earlier in the project. We researched, designed, prototyped, and implemented our system for communication between a vehicle and our data visualization tool, Losant. Our project sponsor, Prodigy, and their partner, Blues Wireless, were valuable throughout our project as they provided us with the tools and resources necessary for our project to succeed.

Without the committed contributions of both Ryan and myself, this project would not have been possible. I believe our multidisciplinary skills and frequent communication led to our success in this project. Being able to frequently meet and discuss updates on both sides of the project was efficient as we were able to work both of our parts of the project together in this method. Additionally, any issues brought up could be discussed here and we were able to split tasks appropriately between ourselves so we could complete this project on time. Overall, I believe that Ryan and I were able to create a well-engineered product that met our expectations

Ryan Logsdon

Throughout the course of this project, I felt that I was able to contribute to almost every functional aspect of our final design. Although my initial focus was to build out the software and IoT capabilities of the system, I was able to dive into the more complex hardware infrastructure associated with our device. My main focus for this project was developing a multi-platform web application that was capable of hosting data visualization tools to analyze the diagnostic data of the vehicle. In order to complete this task, I utilized W3 spaces to host the website. From here, I used JavaScript, CSS, and HTML programming languages to design a user interface that interacts with Losant, a cloud based IoT platform. Through webhooks, I was able to create a seamless environment in which real-time data could be collected through Losant and passed into the web application. Lastly, I designed and implemented a 3D virtual environment in Noda.io that allows users to visualize diagnostic data across numerous vehicles.

Being able to immerse myself in the full design, creation, and implementation of Metaverse Maintenance has taught me a variety of skills and competencies. As a associate software engineer at Prodigy, I am tasked with being on the leading edge of innovation across multiple industries. However, Metaverse Maintenance showed that the ability to work fluently on a multidisciplinary team far outweighs the ability to be a successful individual contributor. I believe one of the core competencies I developed throughout this project was the ability to manage a software development lifecycle from inception to completion. Moreover, the ability to work alongside Cory created plentiful learning opportunities based around both the computer science and electrical engineering fields. The greatest barriers we faced during this project were implementing previously unknown technologies, such as the Blues Notecard and Bluetooth OBD module. The ability to overcome these obstacles resulted in our greatest successes, namely, the opportunity to present Metaverse Maintenance for over 100,000 people at CES 2023, the world's largest consumer electronics show.

Our group was able to accomplish every goal we outlined at the beginning of this project's lifecycle. We ideated, designed, created, and implemented a fully functional car diagnostic tool and associated multi-platform analysis tool. Although the technical accomplishments of our team were rewarding, a greater accomplishment came through the recognition from our project sponsor Prodigy and their partner Blue Wireless. Both of these organizations showed full support of our project goals and provided the resources necessary to see out its completion. Moreover, the ability to present our project at CES 2023 opened up numerous networking opportunities for both Prodigy and our individual team members.

Metaverse Maintenance would not have been able to be completed without the dedicated team efforts of both Cory and myself. The primary aspect of teamwork that lead to this success, in my opinion, was communication. Both Cory and I were able to set aside weekly times to meet and discuss where the project was at, what needed to be completed, and how we were going to complete each task. This clear channel of communication allowed any obstacles to be addressed by both team members in a timely manner. Moreover, clear communication allowed both team members to have an equal contribution of efforts toward the project. If one member felt overwhelmed with their respective tasks, the other was able to assist in whatever capacity they could. Overall, I believe Cory and Myself were able to create a well-designed product that we are proud to have created and engineered.

Summary of Hours

The following section documents the individual contributions of each team member over the course of the project:

Cory Gish

Week:	Task	Hours
8/21	Began researching microcontrollers, Bluetooth modules, and displays.	10
8/28	Created Losant backend logic to control user authentication, page navigation, and signing out.	30
9/4	Created the frontend of the Losant page for authorized users to access data to all permitted vehicles. Allows viewing of all vehicle data simultaneously.	25
9/11	Researched and identified different diagnostic port types and how they interact with vehicles.	12
9/18	Began laying out components in KiCAD and making connections.	10
9/25	Purchased the microcontroller. Began testing on the selected microcontroller, getting LED functionality operational.	30
10/2	Continued testing the microcontroller. Worked on getting UART operational.	20

10/9	Began laying out different port types in KiCAD and programming for it in the microcontroller.	11
10/16	Added to the Fall Slide Show Presentation. Documented two major project constraints, expected accomplishments, hardware, and the expected demo.	10
10/23	Purchased the display. Continued research into Bluetooth modules for their use with the microcontroller.	15
10/30	Purchased the Bluetooth module. Began testing with logic for the Bluetooth module.	17
11/6	Updated documentation and continued debugging	10
11/13	Continued to test communication between microcontroller and car	6
11/20	Finished the schematic for the current version of the board. Began making the layout.	12
11/27	Continued making the layout and finding parts for the 3D model.	8
12/4	Continued making the layout and debugging messaging structures for car communication in C++.	10
Fall Total	- -	238
12/11	Finished getting 3D models for layout and continued working on layout	5
12/18	Began to rework schematic	6
12/25	- - - - -	0
1/1	- - - - -	0
1/8	Researched more into OBD communication protocol ICs and found the STN1110	8
1/15	Ordered kit with STN1110 for OBD communication	4
1/22	Tested with successful communication between the car and microcontroller using the STN1110	6

1/29	Reworked schematic with STN1110	4
2/5	Continued Bluetooth testing with RN-42	3
2/12	Tested with successful communication between RN-42 and phone	4
2/19	Adjusted Bluetooth design in the schematic	7
2/26	Tested with successful communication between car and phone through microcontroller, STN1110, and Bluetooth	6
3/5	Reworked the schematic from parts getting out of stock	4
3/12	Finalized the schematic and worked on 2nd layout version	9
3/19	Finalized layout and ordered parts for final OBD board	8
3/26	Prepared presentation materials for CEAS Expo and soldered the final OBD board	12
4/2	Presented final project at CEAS Expo	12
4/9	Created a draft of final assessments and design report	10
4/16	Completed final assessments and design report	5
Spring Total	- -	113
Grand Total	Fall Hours: 236 Spring Hours: 113 Total Hours: 349	349

Ryan Logsdon

Throughout the fall and spring semester, Ryan was able to work part-time with Prodigy, the product development company that sponsored this project. Through this experience, Ryan was able to dedicate consistent effort each week on improving the design and functionality of the final product. Moreover, Ryan was able to present a prototype of this design at CES 2023, the world's largest consumer electronics trade show. The following table documents his hours:

Week:	Task	Hours
8/21	Purchased and configured Raspberry Pi. Purchased OBDII cable. Installed OBDII python libraries on PI.	12

8/28	Tested OBD II Readings on 4 Vehicle Types. Investigated Losant IOT Software. Investigated Noda Software. Investigated W3 Spaces Web Development Tools	20
9/4	Created a Losant environment. Created User datatables, dashboards, workflows, and webhooks.	30
9/11	Created a website for hosting dashboards in VR. Connected webhooks with Losant	20
9/18	Developed vehicle node point maps for Noda. Used Noda API to connect with Losant Dashboards. Test OBD port readings with Losant MQTT	30
9/25	Purchased Blues Wireless Cellular Modem. Configured modem for PI.	15
10/2	Modified python scripts in PI to live-stream OBD data via Notecard	20
10/9	Tested prototype PI with PC Losant Dashboard. Modified python scripts	10
10/16	Created Fall Slide Show Presentation. Documented current state of hardware, software, IOT.	10
10/23	Enabled email notifications for new user login and ID requests. Improved website functionalities and appearances	14
10/30	Purchased GPS Active Antenna. Testing and Debugging of GPS Accuracy. Developed in-vehicle GUI.	16
11/6	Updated documentation including fall design report	10
11/13	Updated and organized fall design review with project advisor	2
11/20	Tested HDMI GUI interface connection	10
11/27	Update Noda vehicle node point maps	10
12/4	Tested user-login verification features with Losant data tables	12
Fall Total	- -	241
12/11	Created Casing Model	5
12/18	Printed Casing Model	5

12/25	- - - - -	0
1/1	- - - - -	0
1/8	Presented Prototype of project at CES 2023	40
1/15	Updated GPS tracking system with notecard	3
1/22	Enabled remote firmware updates with notecard	4
1/29	Tested full functionality of prototype using OBD to USB adapter	3
2/5	Updated Casing model for larger connection sizes	4
2/12	Tested improved mobile dashboard using Losant user experiences	5
2/19	Created custom 3D visualization components using D3	3
2/26	Updated python script on raspberry pi to read any incoming OBD readings regardless of connection type	8
3/5	Tested updated Notecard and raspberry pi settings using Losant simulator	5
3/12	Recorded demo videos for CEAS Expo	5
3/19	Printed updated casing, installed casing on in-car display	3
3/26	Prepared presentation materials for CEAS Expo	12
4/2	Presented final project at CEAS Expo	12
4/9	Drafted final assessments and final design report	10
4/16	Completed final assessments and design report, submitted all materials	5
Spring Total	- -	127
Grand Total	Fall Hours: 241 Spring Hours: 127 Total Hours: 368	368

Summary of Expenses

The following Table outlines the budget for the project:

Item	Description	Link	Price	Quantity	Total
1	Solder Paste Stencil	JLCPCB	$ 7.00	1	$ 7.00
2	Printed Circuit Board	JLCPCB	$ 9.50	1	$ 9.50
3	Shipping and tax	JLCPCB	$ 42.56	1	$ 42.56
4	Bluetooth SMD Module - RN-42	Sparkfun	$ 18.95	1	$ 18.95
5	SparkFun FTDI Basic Breakout	Sparkfun	$ 16.50	1	$ 16.50
6	OBD-II to DB9 Cable	Sparkfun	$ 10.95	1	$ 10.95
7	SparkFun OBD-II UART	Sparkfun	$ 56.95	1	$ 56.95
8	Break Away Headers - Straight	Sparkfun	$ 1.75	1	$ 1.75
9	Shipping and tax	Sparkfun	$ 7.25	1	$ 7.25
10	CAP CER 560PF 50V C0G/NP0 0603	Digikey	$ 0.10	5	$ 0.50
11	CAP CER 27PF 50V C0G/NP0 0603	Digikey	$ 0.05	10	$ 0.46

12	CAP CER 0.1UF 50V X7R 0603	Digikey	$ 0.02	10	$ 0.19
13	CAP CER 1UF 16V X5R 0603	Digikey	$ 0.03	15	$ 0.50
14	CAP CER 10UF 6.3V X5R 0603	Digikey	$ 0.11	6	$ 0.66
15	CAP CER 2.2UF 10V X7R 0603	Digikey	$ 0.10	5	$ 0.50
16	DIODE GEN PURP 75V 200MA SOT23	Digikey	$ 0.10	5	$ 0.50
17	LED ORANGE CLEAR SMD	Digikey	$ 0.24	5	$ 1.20
18	LED RED CLEAR SMD	Digikey	$ 0.26	5	$ 1.30
19	DIODE SCHOTTKY 40V 1A DO214AC	Digikey	$ 0.59	2	$ 1.18
20	LED YELLOW CLEAR SMD	Digikey	$ 0.28	4	$ 1.12
21	FERRITE BEAD 10 OHM 0603 1LN	Digikey	$ 0.06	10	$ 0.58
22	IC	Digikey	$ 1.44	2	$

	TRANSCEIVER HALF 1/1 8SOIC				2.88
23	IC COMPARATOR 4 DIFF 14TSSOP	Digikey	$ 0.42	2	$ 0.84
24	CONN HEADER VERT 10POS 2.54MM	Digikey	$ 0.28	2	$ 0.56
25	N-CHANNEL ENHANCEMENT MODE MOSFE	Digikey	$ 0.17	4	$ 0.68
26	MOSFET P-CH 60V 185MA SOT23-3	Digikey	$ 0.49	2	$ 0.98
27	RES 1K OHM 1% 1/8W 0603	Digikey	$ 0.06	30	$ 1.83
28	RES SMD 510 OHM 5% 1/2W 0805	Digikey	$ 0.11	10	$ 1.10
29	RES SMD 100 OHM 0.5% 1/16W 0603	Digikey	$ 0.14	8	$ 1.12
30	RES 10K OHM 1% 1/8W 0603	Digikey	$ 0.06	20	$ 1.22
31	RES 4.7K OHM 1%	Digikey	$ 0.02	10	$ 0.19

	1/10W 0603				
32	RES 866 OHM 1% 1/10W 0603	Digikey	$ 0.10	5	$ 0.50
33	RES 374 OHM 1% 1/10W 0603	Digikey	$ 0.02	10	$ 0.19
34	RES 240 OHM 1% 1/10W 0603	Digikey	$ 0.02	10	$ 0.19
35	RES 62K OHM 1% 1/10W 0603	Digikey	$ 0.02	10	$ 0.19
36	RES 1.2K OHM 1% 1/10W 0603	Digikey	$ 0.02	10	$ 0.19
37	RES 220 OHM 1% 1/10W 0603	Digikey	$ 0.01	10	$ 0.12
38	RES 1.5K OHM 1% 1/10W 0603	Digikey	$ 0.01	10	$ 0.13
39	IC REG LIN POS ADJ 1.5A D2PAK-3	Digikey	$ 0.98	2	$ 1.96
40	IC REG LINEAR 3.3V 300MA SOT23-5	Digikey	$ 0.43	3	$ 1.29
41	DIODE ARRAY GP 100V 215MA SOT23	Digikey	$ 0.18	8	$ 1.44
42	IC REG	Digikey	$ 0.76	2	$

	LINEAR 5V 150MA SOT23-5				1.52
43	CRYSTAL 16.0000MHZ 18PF SMD	Digikey	$ 1.02	2	$ 2.04
44	TRANS NPN 40V 0.6A SOT23-3	Digikey	$ 0.30	6	$ 1.80
45	Shipping and tax	Digikey	$ 9.74	1	$ 9.74
46	Display Monitor	Amazon	$ 42.99	1	$ 42.99
Total					$ 255.79

Appendix

Justification of Hours

This section seeks to provide a clear view of the amount of time and effort both team members invested in this project. The following outlines the semester breakdown for each team member:

Cory:

Throughout the fall and spring semester, Cory worked on project research, design, prototyping, and implementation for the OBD reader board. The final board was able to be developed due to the access Prodigy, our sponsor company for the project, gave us to their lab. The following table documents his hours:

Semester	Primary Task Focus	Hours Worked
Fall	- Research OBD protocols - Order parts for testing - Begin schematic and layout	236
Spring	- Finish schematic and layout	113

	- Solder final board and test - Documentation	
Total:	- -	349

Ryan:

Throughout the fall and spring semester, Ryan was able to work part-time with Prodigy, the product development company that sponsored this project. Through this experience, Ryan was able to dedicate consistent effort each week on improving the design and functionality of the final product. Moreover, Ryan was able to present a prototype of this design at CES 2023, the world's largest consumer electronics trade show. The following table documents his hours:

Semester	Primary Task Focus	Hours Worked
Fall	- Creation of Losant account - Noda web page creation - Raspberry Pi programming	247
Spring	- Complete software testing and debugging - Documentation - Expo presentation design and set-up	127
Total:	- -	368

A complete list of tasks and hours worked can be found using this link: Weekly Updates