Site Asset Tracking System

Final Design Report

Volume 1: Final Design Summary Report

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Executive Summary

At Moss Construction Management, technology is becoming a priority as part of the industrialization of construction. Job sites, in particular, are highly active environments, with a variety of people and equipment entering and leaving the site throughout the workday. A Site Asset Tracking System actively tracks these people and equipment throughout the day, as it can be crucial in the event of an emergency, as well as used as a tool to track productivity and project management.

The intent of this project is to enable project management professionals on the construction site to actively track the employees and equipment and their location on the jobsite. This improves the safety for the individuals and can measure the productivity of the employees. The proposed design features a hardware infrastructure, server side API library and a 3D software client. Data will be collected through the hardware infrastructure using bluetooth technology and existing wifi receiver beacons. Raw data collected from the hardware infrastructure will be transmitted securely to a server where they will be stored and processed for client ready visualization. Lastly, data will be visualized on a read-only 3D software client, where site specific information will be visualized live in a 3D virtual environment.

The Site Asset Tracking System, SATS, is developed to improve the safety of the construction worker, ensure that all assets are involved in the site are accounted for, and potentially run an efficiency study on each subteam that is on-site. As such, the main focus is not to generate revenue, but is aimed towards cost savings. Cost savings will be based on increasing efficiency by addressing the efficiency of their subcontractors as well as their own team, and potentially cutting down on build time. In addition, the initial development and production costs will eventually be overshadowed by the costs of upkeep and improvement on the system. The initial development and production costs will go into housing, data transmission, integration into existing software, and electrical board design.

As of date, the Tagtical Tracers development team has successfully implemented the read-only 3D software client, selected hardware components for hardware infrastructure, as well as delivered an initial housing design for tag and receiver beacons. Moving forward, the focus of team will revolve around the following goals: 1) Develop and build a manufacturable prototype for hardware infrastructure, 2) Build a configuration system to map on-site data with 3D virtual ones, 3) Produce iterative housing design on tags and receivers, and finally 4) Test the entire Site Asset Tracking system for integrity and validity of of data visualization.

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1.0 Introduction

Moss and Associates is a privately held construction firm headquartered in Fort Lauderdale, with three additional offices in Florida, as well as offices in Hawaii, California, Texas, and the US Virgin Islands. With a vested interest in safety compliance on construction sites, the Site Asset Tracking System aims to track employees, subcontractor individuals, and assets.

The Site Asset Tracking System's goal is to enable project management professionals to actively track the quantity of employees and equipment on a jobsite in a 3-dimensional map along. This system provides data to actively improve safety on construction sites as well as collect data to analyze productivity of their subcontractors and employees.

The development of this system will enable the project management professionals on a construction site to actively track the quantity of employees and equipment and their location on a jobsite. This is important to Moss as the search for improved safety and productivity measures seeks to leverage technology. The Site Asset Tracking System is capable of integrating into every construction project's workflow, while providing an advanced emergency preparedness component to how Moss operates. Moss is a family and improving the safety of every employee is better for everyone involved. Measuring and improving productivity is also a way to minimize exposure and better manage risk.

The system architecture of the Site Asset Tracking System is developed centered around the construction industry however, this system is designed with enough modularity to serve other industries to improve and track internal human resources and asset management.

Below you will find a high level overview of the entire Site Asset Tracking System design and the landing page for the final user-end software product. Detailed technical design and final prototype can be found on other sections of the final design report.

Figure 1.1: Site Asset Tracking System Landing Page

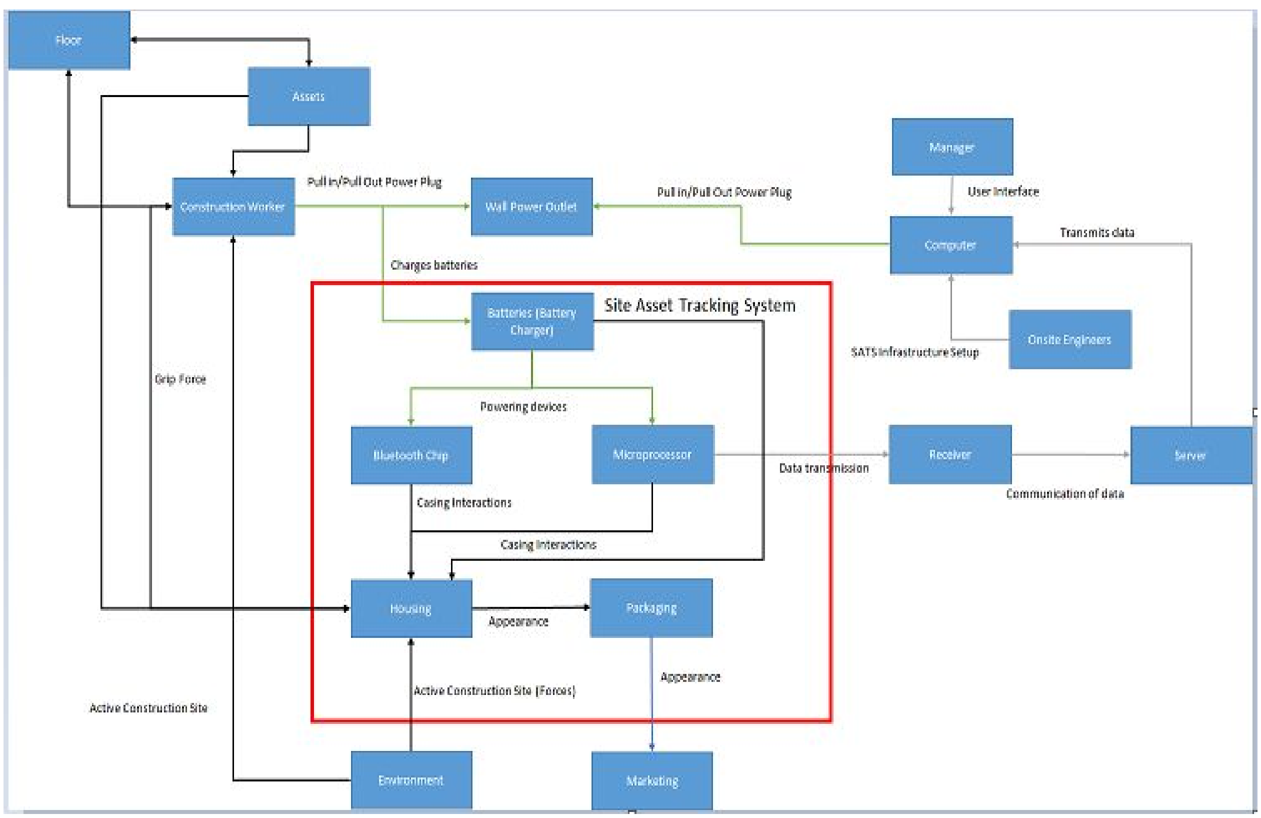

Figure 1.2: Site Asset Tracking System High Level Functioning Diagram Overview

2.0 Results Summary

This section describes results of the final Site Asset Tracking System and how they were obtained. This section includes photos, renderings and screenshots of the prototype system and its sub-systems.

2.1 Mechanical Component Results

This housing is to be made with ABS PC plastic and will follow the NEMA4 standard as well as the corresponding IP66 standard. These standards guarantee that it can withstand both indoor and outdoor conditions, as well as falling dirt, dust, snow, rain, and sleet. There is an o-ring groove within the bottom faces of both the tag and the receiver to keep out water from leaking into the electrical components of the system. There will be three 6-32 screws that hold together the plastic components, with Dodge Standard Expansion Inserts.

The ideal tag will have an exterior length and width of 1.25”. The interior has an o-ring groove that allows for an o-ring with an ID nominal size 1” with a 1/16” thickness. This allows for a common coin cell to be placed within the circumference of the o-ring, as well as a custom PCB board.

The tag for this final design review will be larger, and will not be water resistant, with an exterior length of 3.2” and width of 2.2” as well as an exterior height of 0.65”. This tag allows for only the PCB and common coin cell to be placed within a cavity in the tag. There are two 2-56 screws and inserts that hold the plastic components together.

Figure 2.1.1
Top view of the tag

Figure 2.1.2
Isometric view of the tag

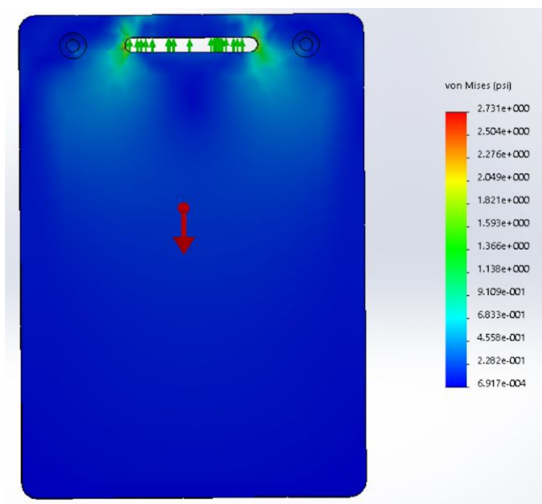

Figure 2.1.3
Tag's static test, shows the stresses on the larger size tag that houses the PCB design that will be presented

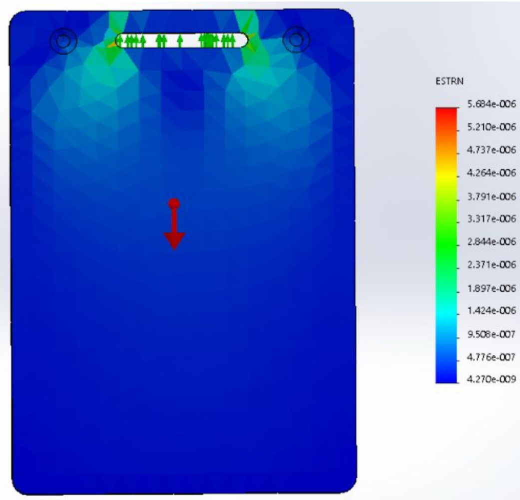

Figure 2.1.4
Tag's static test, shows the strain that is on the larger size tag that houses the PCB design that will be presented

The receiver is mounted within the room, with a 3/16 screw and corresponding Dodge Standard Expansion Insert. The screw will vary with the decision of the sponsor company on where to mount the receiver in the room. The plastic components will also be fastened together with 6-32 screws. The exterior length of the rectangular portion to be 3.5" and height of 0.25", with a circular section having a 3.5" diameter and 2.25" height. The interior has a 3" nominal ID o-ring, with its corresponding groove. The receiver's PCB and battery will be placed within the inner diameter of the ring.

Figure 2.1.5
Top view of the receiver

Figure 2.1.6
Isometric view of the receiver

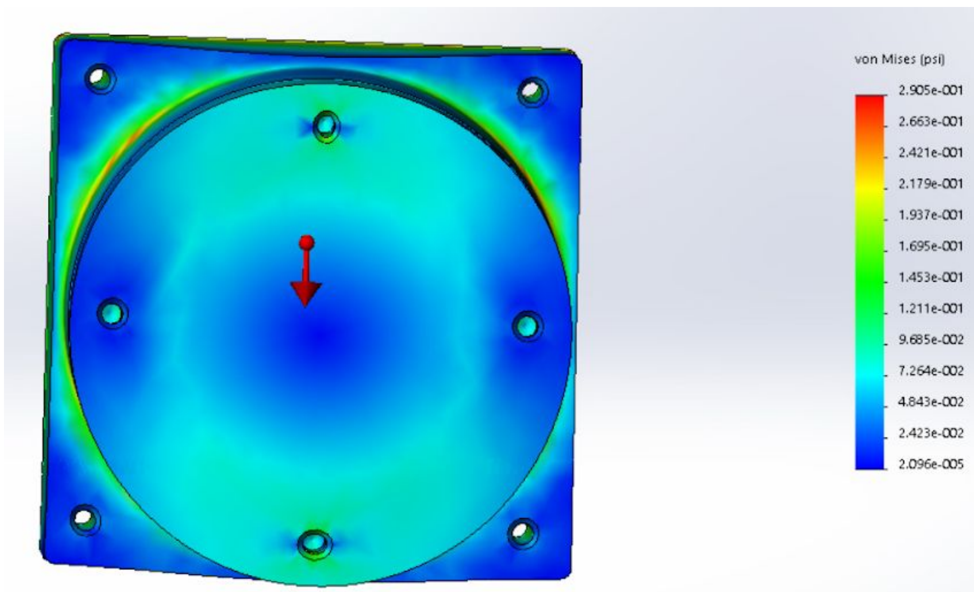

Figure 2.1.7
Receiver's static test, shows the stress that is on the larger size receiver that houses the PCB design that will be presented. Its maximum stress is 0.29 psi, and is located only at the very edges of the circular component.

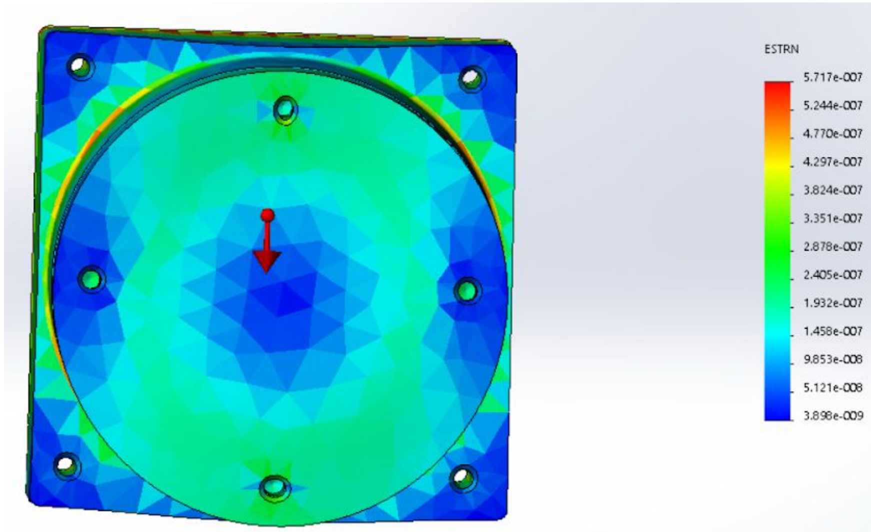

Figure 2.1.8
Receiver's static test, shows that the strain that is on the larger size receiver that houses the PCB design that will be presented. There is negligible strain

Revit models were generated with the help of the IPPD program, and exported out to Unity to provide a 3D map of a potential site.

Figure 2.1.9
Rinker Hall 3D Model

2.2 Hardware Component Results

In this section we will go in depth of all the hardware components the tag and the receiver contain. Each of the components that were picked for both designs fulfilled a specific reason. Recommendations to new hardware in order to improve the design are also listed here.

Components

- HC-05 Bluetooth Module
- ESP8266 Wifi Module
- TPS 60210 TI Voltage Regulator
- Resistors
- Capacitors

TAG

For the tag, HC-05 bluetooth module was selected for the prototype even though there are better alternatives on the market due to the cost constraint. TPS 60210 voltage regulator made by Texas Instruments that can keep the output voltage at 3.3 V from a wide range of input voltage from 1.6 V to 3.6 V is used in combination with 3.3V coin cell battery to supply power to HC-05 module.

Once the tag is powered, it will broadcast the signal which can be picked up by receivers nearby. RSSI (Received Signal Strength Indicator) values are used to determine proximity of the tags to a particular receiver which enables us to determine the approximate locations of the tags.

Performance Measures		
Specifications	Final Design	Recommendation
Range	18-23 fts (without interference)	N/A
Size	2”x1.65”x0.5”	Use CC2650 Bluetooth Module
Power	15 Minutes	Use 3.3 V lithium battery instead of coin cells
Cost	Less than $5 per tag	N/A

Figure 2.2: Performance Measures (Tag)

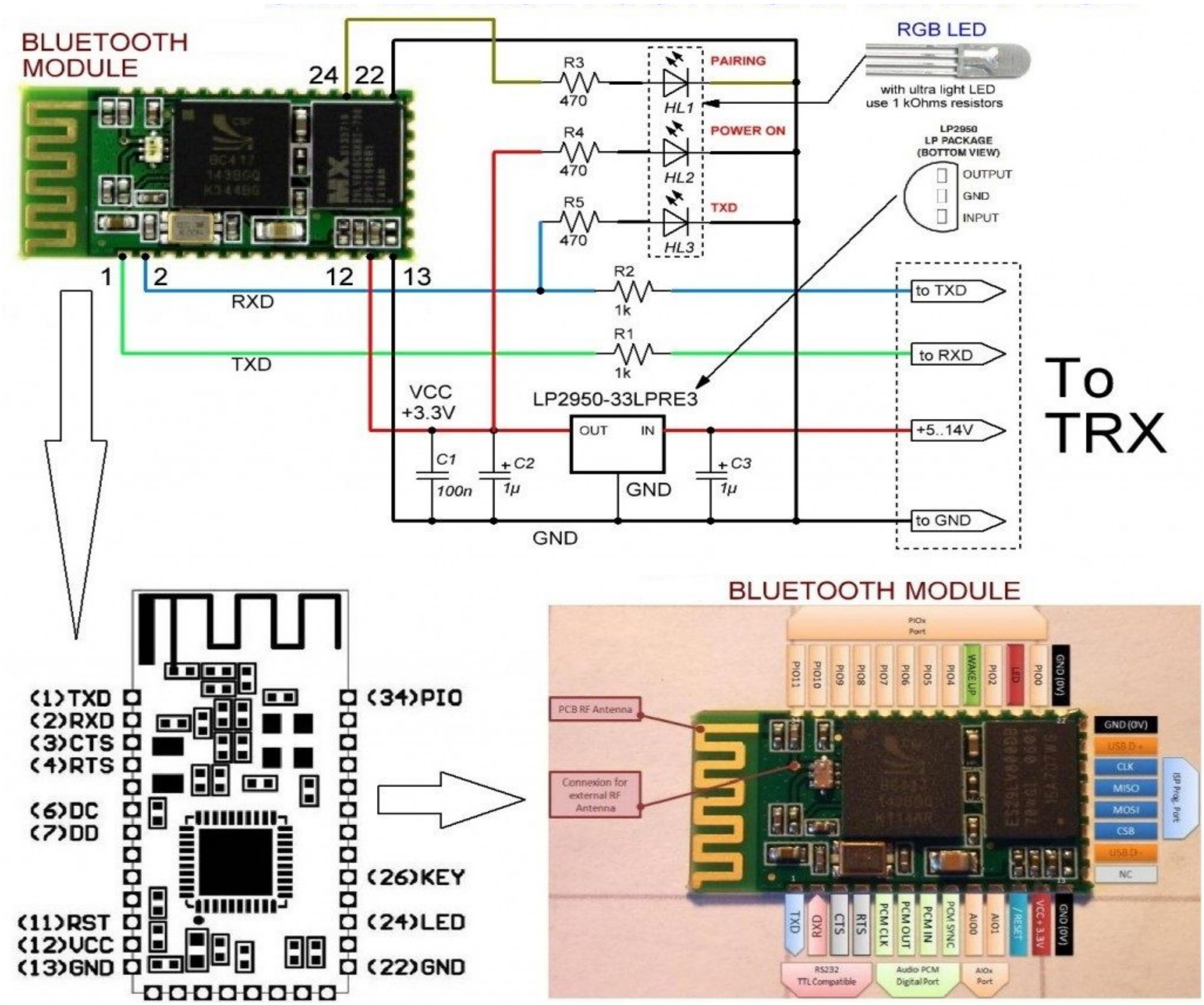

Figure 2.2.1: Final PCB Design (Tag)

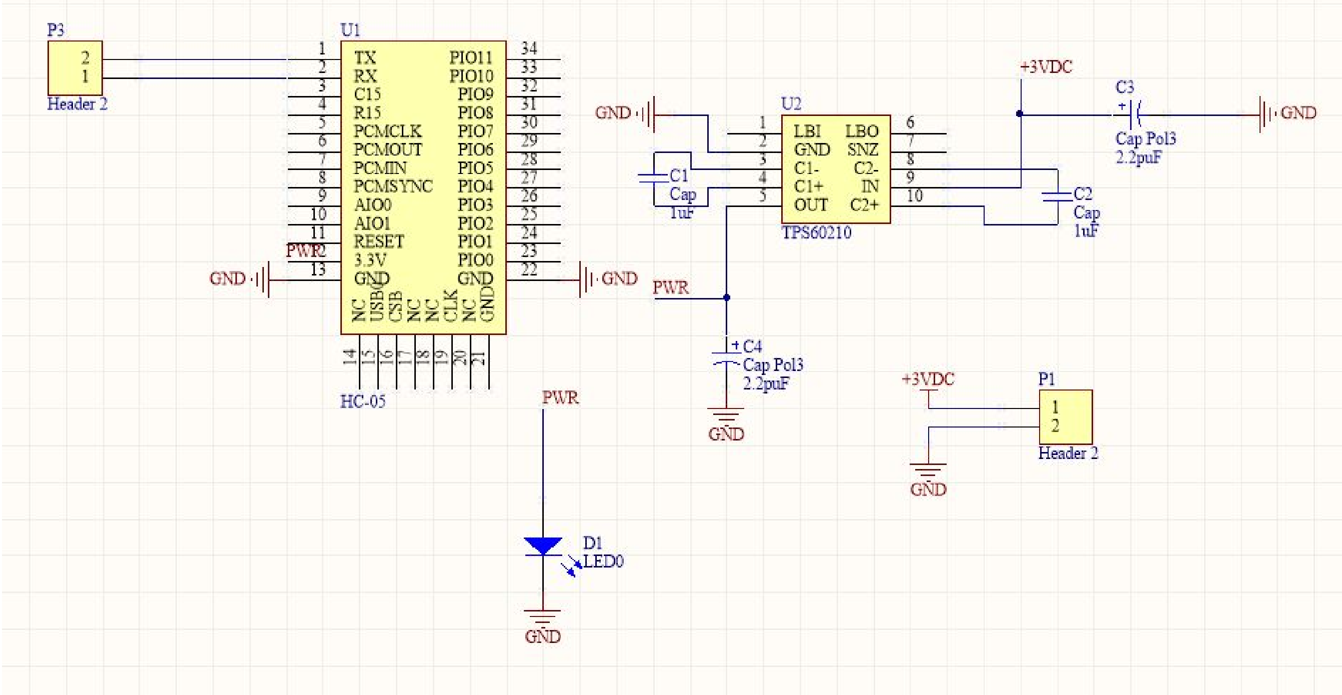

Figure 2.2.2: Schematic PCB Design (Tag)

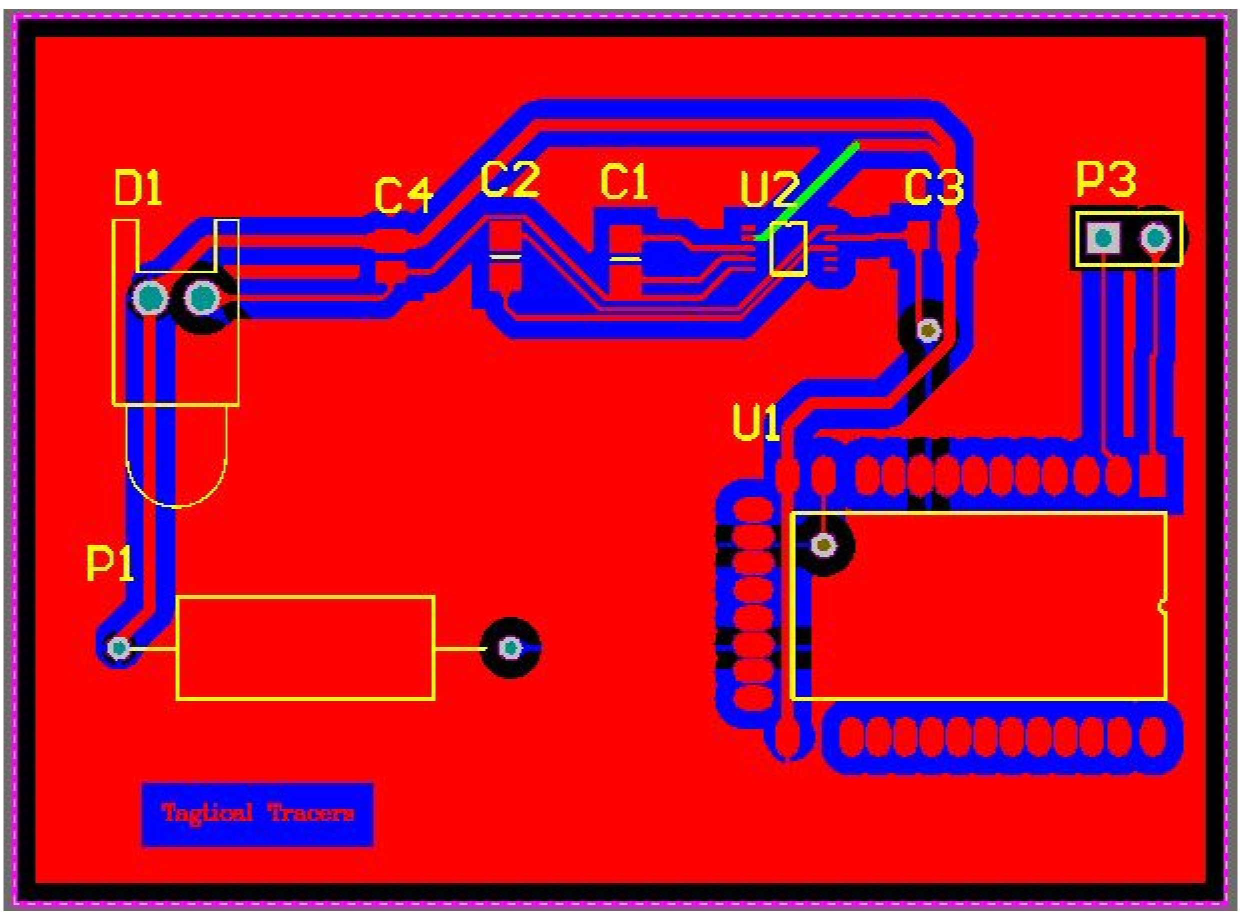

Figure 2.2.3: PCB Design (Tag)

RECEIVER

The receiver design consists of HC-05 bluetooth and ESP-8266 microprocessor with wifi capabilities on board. The function of HC-05 here is different as it is used to scan the area for the available bluetooth devices. The data is transferred to ESP-8266 using UART (Universal Asynchronous Receiver/Transmitter) which then transfer the data to the backend server using the on-board wifi capability. A 5 V voltage regulator in combination with a 9V battery can power the board for about a day, but as the final implementation of the receiver will be connected to a constant power supply battery life is not an issue.

Performance Measures		
Specifications	Final Design	Recommendation
Range	25-30 fts (without interference)	New technologies can increase this (ie: Bluetooth 5.0, new zigbee)
Size	2.25”x1.6”x2.5”	Size is not an issue if the unit is mounted in a wall.
Power	5V regulated from a 9V battery	Power from a wall, regulated to be used with the chips.
Cost	Less than $8 per receiver	ESP32 or CC2650 + CC3100

Figure 2.2.4: Performance Measures (Receiver)

Final design of the receiver pcb is displayed next:

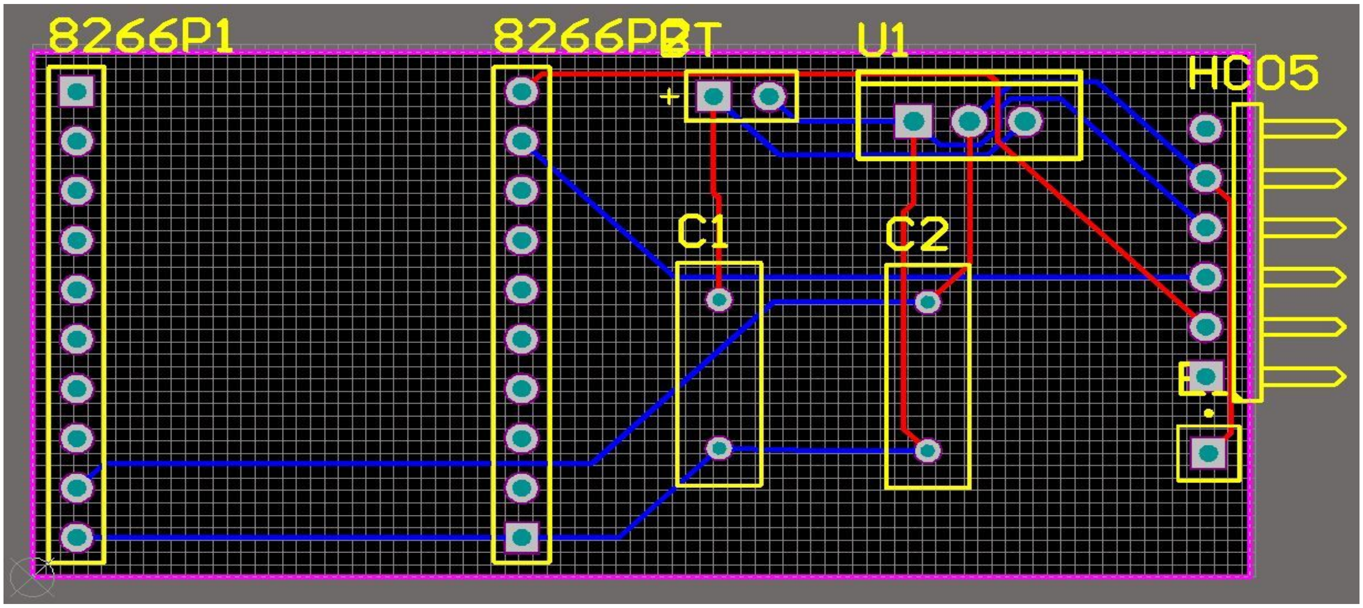

Figure 2.2.5: PCB Design (Receiver)

2.3 Software Component Results

This section will go into the software design, from the server side which receives the data from the 8266 all the way to the UI the end user sees.

2.3.1 Server Design

MQTT (MQ Telemetry Transport) is a publish-subscribe protocol with an extremely low data overhead (two bytes). It has built-in support for offline messaging and multiple qualities of service levels. Moreover, it can run on both standard TCP/TLS and over WebSocket (HTTP/HTTPS). It also offers a simple key/value store in the form of retain messages. All these features make it a good protocol to implement IoT systems.

We will be using be transferring our sensor data (tag id, transceiver id, rssi) over MQTT and WiFi to our MQTT broker. There the data will be readily available for any service that would like to subscribe to that data (Redis, Mongodb, Web Applications). The usage of both a cluster of MQTT brokers and load balancer will scale out the server architecture as well as handle more traffic. The main benefit of such a setup is that if one of the broker servers is not available, the still available brokers can handle the traffic. In other words, if one of the two or more nodes stop working the load balancer will reroute all incoming traffic to the working cluster node and there would be no interruptions on the client side.

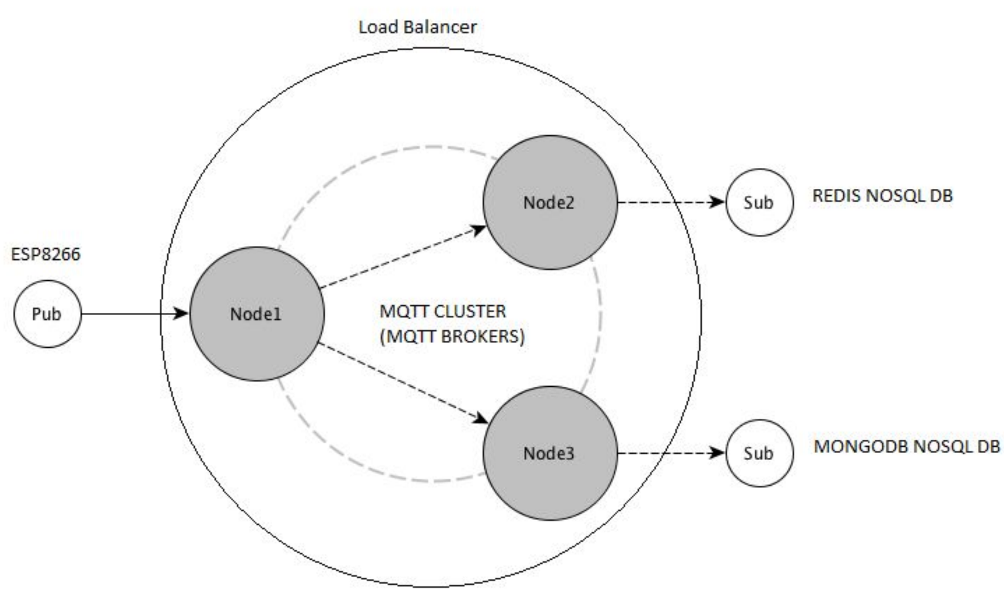

Figure 2.3.0: MQTT Server Architecture

We will be using both Redis and Mongodb NoSQL databases. Both these services can utilize the publish-subscribe model as well, thus scaling out even further and allowing us to extend functionality to more services. The reason we're using both of these databases with identical schemas is because they have different purposes. Redis utilizes a variety of specialized data structures for datastore in memory. This allows the update of real-time information that requires lots of querying to be done with sheer speed. Mongodb on the other hand allows for more schem-able data as well as more persistent datastore on a hard disk.

2.3.2 Database schema

Below you will find our Database Schema and a high level overview of how our data is being stored. For this prototype, the Tagtical Tracers utilized the limited free hosting of MongoDB from mLab. From above, raw data collected from the hardware infrastructure will be represented as a **Receiver** object where it stores a list of **TrackableObjects** that can include **Object of Interest** and **Person of Interest.** Each individual **TrackableObject** will be identified with an UniqueID. These UniqueIDs will later be queried so that the front-end client will show readable data such as User names, occupations and etc. The implemented a user management system distinguishes any particular user as regular users or admin users. Regular users only have access to their personal profiles and update any relevant information about themselves. On the other hand, Admin users, will be able to view all active users across the entire platform and update any individual's information as needed. Please refer to **section 2.3.3** for system screenshots and examples.

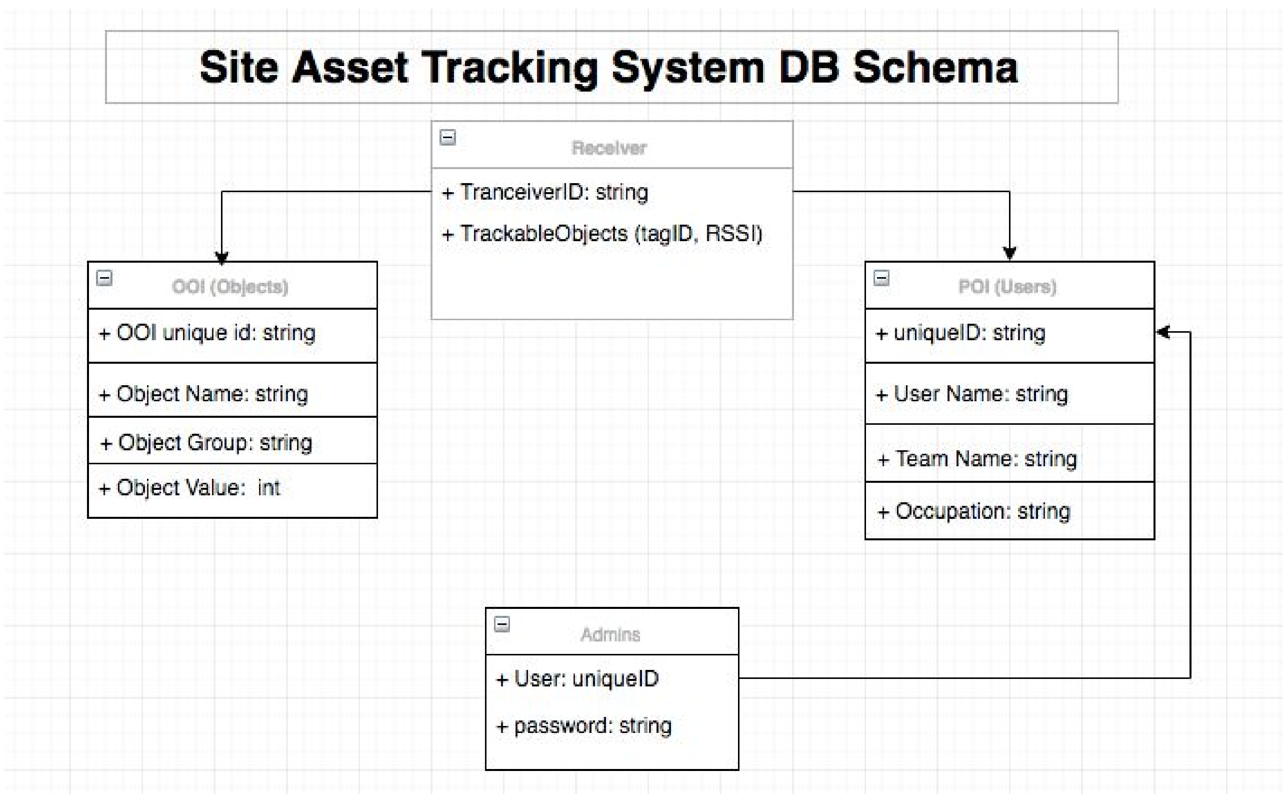

Figure 2.3.1: Site Asset Tracking System MongoDB Schema

2.3.3 Front-End System Design and render

Figure 2.3.3.1: Site Asset Tracking System 3D Render - Unity

Figure 2.3.3.2: Site Asset Tracking System 2D GUI - Unity

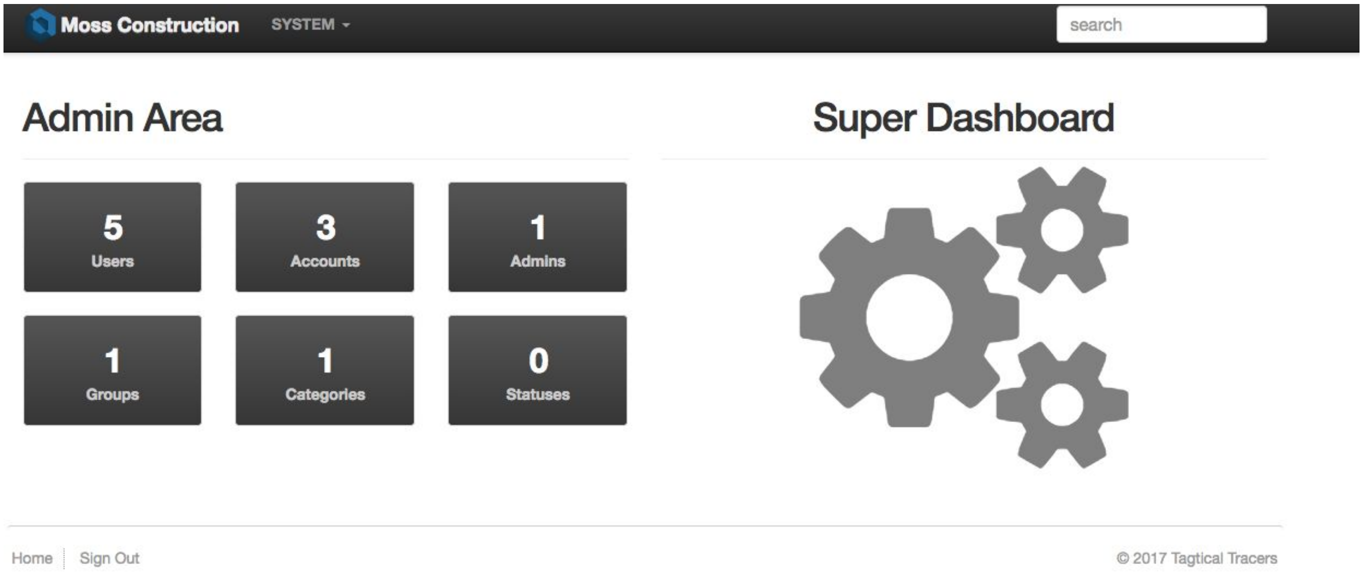

Figure 2.3.3.1: Site Asset Tracking System Config System - Admin Dashboard

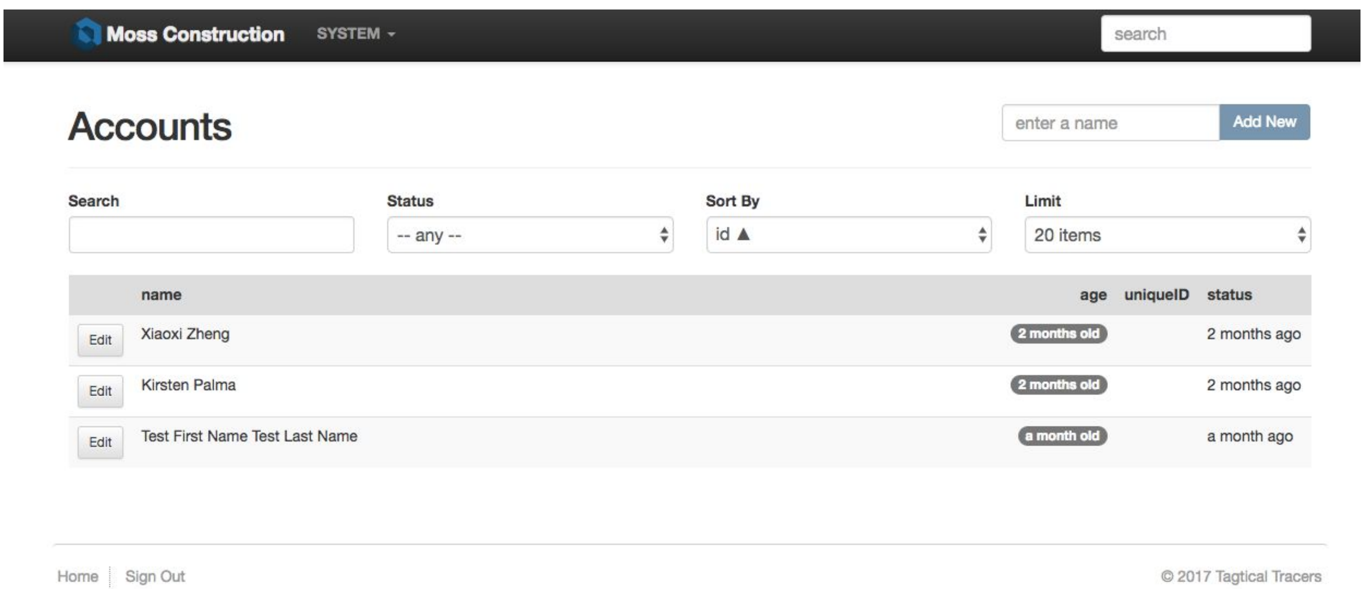

Figure 2.3.3.2: Site Asset Tracking System Config System - Admin Features

3.0 Conclusion and recommendations

This section contains technical conclusion and recommendations for next steps in developing the Site Asset Tracking System.

3.1 Customer Needs and Product Features

Below you will find a highlight of implemented customer needs outlined from the System Level Design Report. The chart ranks each individual features in order of importance.

Figure 3.1: Customer Needs Table

Feature Title	Feature Details
Accuracy of the overall system	● Ability to create and update logs of people on real time (every one minute or less) and assets every 10 minutes ● Accuracy within a range of approximately 10 feet ● Designing the overall physical hardware infrastructure to have the ability to cover the entire range of the construction site.
High modularity high configurability of overall system design	● High portability of system Tags ● Hardware interfacing with a Wi-Fi+Bluetooth module ● Cross platform front-end user interface and mobile platform ● Interface with a backend Web Server or cloud based service
Cost effectiveness	● Provide hardware and component suggestions that can be scaled in a reasonable manner.
Intuitive User Interaction and User experience	● Visualize log data in 3-Dimension ● Provide a configuration t system to provide the means to map hardware raw data to meaningful user and object details.

3.2 Open Tasks and Known issues

A lof of the earlier of the project documentation showed that we were trying to use the ESP32. This chip was ideal for the receiver since it combined wifi and bluetooth into one chip. After waiting for a more sophisticated software development kit, it never arrived so we had to use a wifi module combined with a bluetooth module. Changing into the ESP32 or new technologies for the future is advised.

Also the tag does not utilize the most energy efficient bluetooth modules that are available. The Tagtical Tracers team were going to utilize the TI cc2650 bluetooth module for the tag, but the chip needs to be soldered utilizing machines which made it outside of the budget restriction that we have. This chip not only is it more energy efficient than the HC05, but it has a microcontroller inside, has more range for transmission and reception and is smaller. For developing the tag this chip would be the best for mass producing this product.

3.3 Next Step Recommendations

Further development can be made in many areas of the project. In this section we will go into areas the project can be improved upon, all the way from the hardware end to the UI end.

3.3.1 Hardware Selection

With the new technology being released or recently released, such as bluetooth 5.0 and the new Xbee, to implement a mass scale production of this product utilization of these technologies will give Moss many more features that the technologies used in our product does not offer. Such as bigger range, the capabilities of mesh networks and other useful features or applications that the new technologies can offer. As mentioned before if the company wants to utilize the current technologies, using the TI CC2650 for the tag is a highly recommended move as it will give greater range and less power consumption.

3.3.2 Investment

After selecting the proper hardware an investment for creating design that can be sleek, durable, and cheap must be made for the tag and receiver. This document will touch a little on the possibilities of how such a device will look and be, but the actual design, with the new technologies, must be pursued by Moss in order to mass produce this product.

3.3.3 Further work

Utilizing our design another IPPD team can take what we have and further develop the software and the hardware in several ways. We tried utilizing the ESP32 as a receiver since it has bluetooth and wifi in one chip, but since the chip was released very recently the software development kit was very rudimentary, so we could not utilize it and had to use a combination of two modules. A new team can develop new hardware utilizing new technologies as mentioned before. A new route the company can als take is that they can utilize only the receivers and use phones as tags, which will save the company in the tag creation part of the product, but will require app development in order to use the phones as tags.

Current location tracking algorithm compares the RSSI values of a tag versus all of the receivers nearby, then placing the location of the tag in the vicinity of that receiver. The accuracy of such an algorithm is around 10 feet, depending on the frequency of the receiver placement. Utilizing new technologies can create a more accurate localization of the tags, if the hardware and backend is already developed a whole IPPD team can focus on developing a highly efficient localization algorithm.

Appendix

Process Assessment

This section highlights the the proposed project roadmap and the actual project road map followed for the duration of the development of Site Asset Tracking System. The Tagitical Tracers team followed the proposed project roadmap with about 80% consistency.

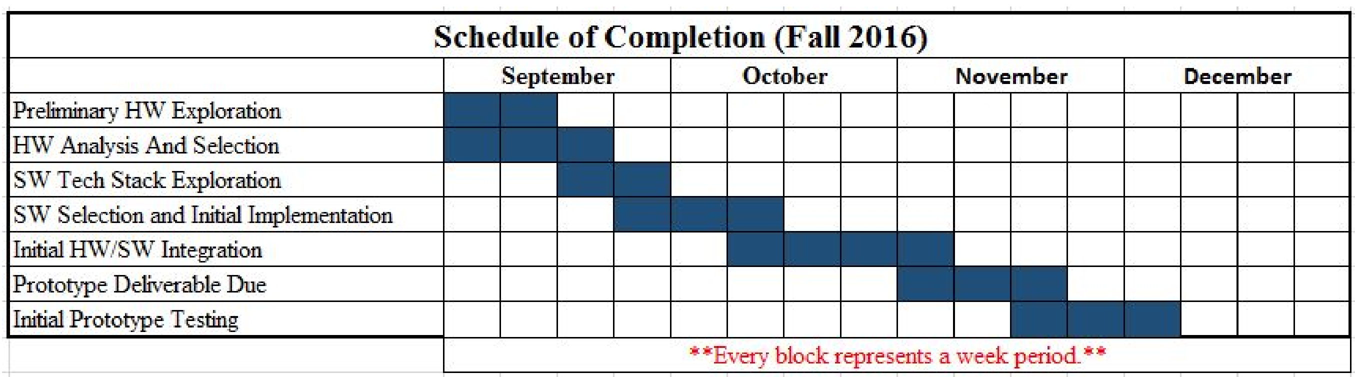

Figure A.1 Proposed Project Schedule (Fall 2016)

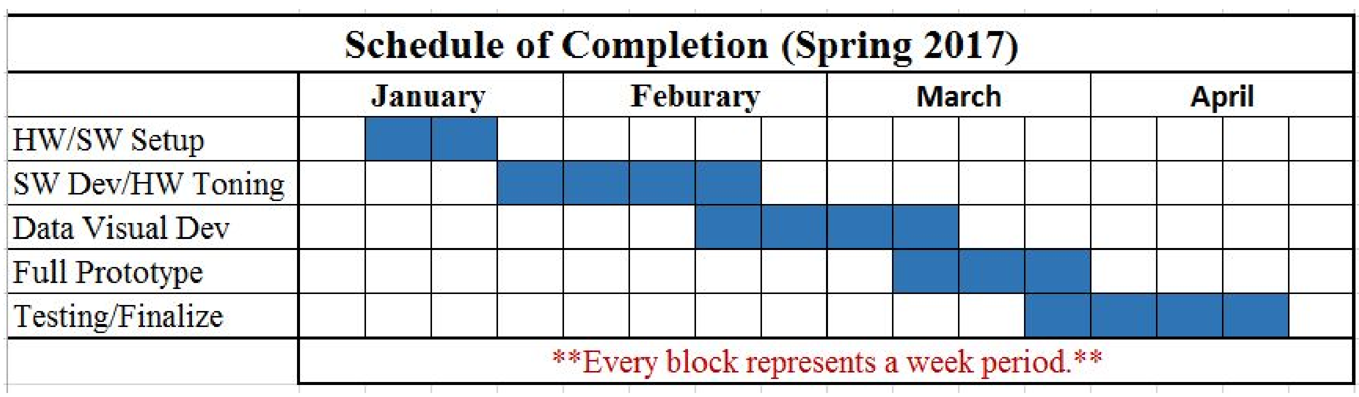

Figure A.2 Proposed Project Schedule (Spring 2017)

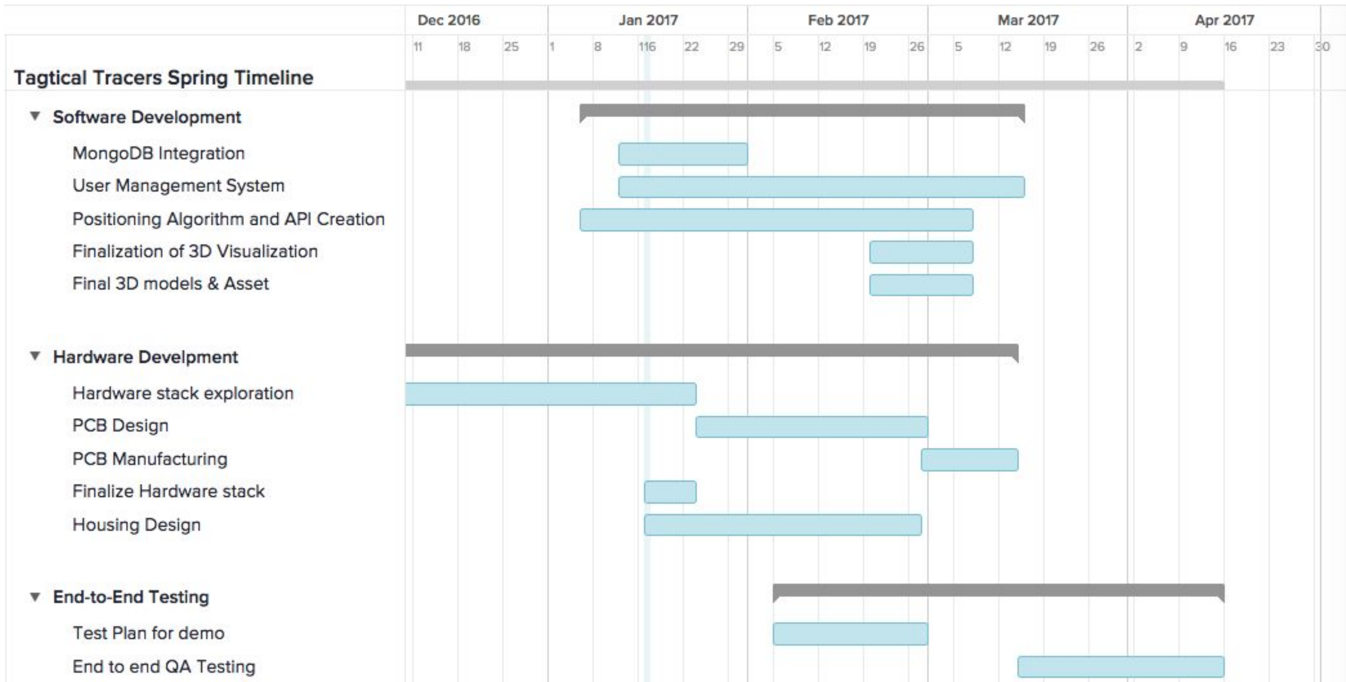

Figure A.2 Actual Project Gantt Chart