Tri-Mark Corporation UWB Digital Key

Design Document

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Executive Summary

Development Standards & Practices Used

- IEEE 802.15.4 HRP UWB Standard
  - This standard works to promote and standardize the Digital Key technology. It also gives recommended practices when working with UWB.
- IEEE 802.15.1: Bluetooth and BLE
  - This standard is a low-data-rate, low-power wireless networking standard aimed at replacing cables between lightweight devices.
- Apple App Store Guidelines
  - https://developer.apple.com/app-store/review/guidelines/
- AES128 Encryption Standard
  - This standard gives open-source functions that provide secure encryption of digital data.

Summary of Requirements

- Mobile app should be able to unlock/lock a vehicle
- Remote start a vehicle
- When a user touches the capacitive sensing door handle, the vehicles module shall check if the a digital key is nearby within range to unlock the vehicle
- Add digital key to wallet
- Vehicle should unlock when a digital key is found within 10ft
- Application should use encryption for login credentials
- User interface of the application should be easy to navigate

Applicable Courses from Iowa State University Curriculum

- COM S 309: Software Development Practices
- COM S 319: Construction of User Interfaces
- CprE 288: Embedded Systems
- CprE 281: Digital Logic

New Skills/Knowledge acquired that was not taught in courses

- Soldering
- Bluetooth/UWB knowledge
- Swift
- Nearby Interactions API
- PIC32 Microcontrollers
- RTOS

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Definitions

UWB - Ultra Wideband is a wireless communication protocol for precise location tracking.

BLE - Bluetooth low energy is used to form the initial connection to the vehicle.

UART - Universal Asynchronous Receiver-Transmitter is the device used to transmit data between circuit boards.

Figures

Tables

Team

1.1 Team Members

Kaili Lawson

David Bone

Lakin Jenkins

Shayla Lunn

Hanan Zahid

Erica Hollander

1.2 Required Skill Sets for Your Project

- App Development
- Database Management
- Swift Development
- Technical Communication
- App Security
- Soldering
- UART Knowledge
- PIC32 Microcontrollers
- C Development

1.3 Skill Sets covered by the Team

- App Development: Erica Hollander, Lakin Jenkins, Hanan Zahid
- Database Management: Erica Hollander, Lakin Jenkins, Hanan Zahid
- Swift Development: Erica Hollander, Lakin Jenkins, Hanan Zahid
- Technical Communication: Erica Hollander, Lakin Jenkins, Hanan Zahid, Shayla Lunn, Kaili Lawson, David Bone
- App Security: Erica Hollander, Lakin Jenkins, Hanan Zahid
- Soldering: Shayla Lunn, Kaili Lawson
- UART Knowledge: Shayla Lunn, Kaili Lawson, David Bone
- PIC32 Microcontrollers: Shayla Lunn, Kaili Lawson, David Bone
- C Development: Shayla Lunn, Kaili Lawson, David Bone

1.4 Project Management Style Adopted by the team

- Agile Development

1.5 Initial Project Management Roles

- Kaili: Client Interaction
- Shayla: Embedded Systems Design
- David: Hardware and Software Communication
- Hanan: Security
- Lakin: App Design and Interface
- Erica: Team Organization and Scrum Master

2 Introduction

2.1 Problem Statement

Many RV and industrial vehicle owners encounter a constant issue of keeping track of key fobs and ensuring the safety of the vehicles. In today's day and age, everything has become virtual. Even our wallets are now accessible through our phones. The next step in digitizing our world and ensuring better security is to add our key fobs onto our phones. With Ultra-Wideband technology that is now widely available and integrated into most smartphones, we are able to accomplish this next step. By having a digital key via our phones, we add an extra level of security, as most smartphone users have password or biometric safety features enabled. In order to develop such a system, we need to determine some solutions to a few problems. First, how might we use an application for a vehicle owner so that they can unlock their vehicle without a physical key? How might we use a UWB module for the engineers so that we can have a secure system that has precise distance measurements to the vehicle? Finally, how might we determine the accurate location of a phone for a user so that we can only unlock a vehicle when we are within a certain distance? Once we figure out these solutions, we will be able to unlock this new generation by using keyless entry.

2.2 Intended Users and Uses

Our intended users are RV/Industrial Vehicle owners who want to be able to unlock their vehicles from a mobile phone. This benefits these users because it allows for them to be able to ditch the key fob and enable them to unlock their vehicle using biometric protected or password protected devices. This project will lead to the future of automation throughout an RV/Industrial Vehicle. Other users include OEM system engineers needing to integrate this system into a vehicle, or TriMark's technical managers / test engineers.

RV Owners

1. Key Characteristics
    a. Family people
    b. Owners of multiple vehicles
    c. Organized
2. Needs related to the project
    a. To have centralized location to hold all keys
    b. Multiple people needing access to the vehicle (families)
    c. To provide a more secure system
3. Use/benefit from the product
    a. All keys stored in one location
    b. Multiple people can have access to one key through mobile devices
    c. UWB is more secure than wifi/bluetooth

Industrial Vehicle Owners

1. Key Characteristics
    a. Mostly private groups and/or multiple users
    b. Potential owner is a corporation leasing vehicles out to contractors
2. Needs related to the project
    a. Give access to lessees
    b. Keep track of/organize multiple keys
3. Use/benefit from the product
    a. No need to keep track of a physical fob
    b. Multiple people can have access to one key through mobile devices
    c. The ability to quickly grant keys to lessees.

Vehicle Manufacturers

1. Key Characteristics
    a. Manufacturers can have lots of different equipment/machinery
    b. Financially literate
    c. Efficient
    d. Business oriented
2. Needs related to the project
    a. To easily add to each vehicle
    b. To encompass many different types of vehicles with different locking schemes
    c. To include desires of their customers
3. Use/benefit from the product
    a. More interest from their consumers
    b. Fewer keys/fobs to produce

2.3 Requirements & Constraints

Functional Requirements:

- The application shall be able to unlock the vehicle.
- The application shall be able to remote start the vehicle.
- When the unlock/lock button is pressed and the Digital Key is in range of the vehicle, the vehicle shall unlock/lock.
- When a user's credentials are validated, the Digital Key shall be added to their in app wallet.
- When a user is the admin of the Digital Key, they shall be able to grant access to additional users.
- When a user touches the capacitive sensing mechatronic handle, the vehicle's module shall check whether the Digital Key corresponding to the vehicle is in range and unlock the door.

Nonfunctional Requirements:

- Look & Feel
    - The app should contain the TriMark Corporation logo and incorporate the style and feel of the company itself.
- Usability
    - The app should be well organized and have a good user interface.
- Performance
    - After pressing the unlock/lock the vehicle should respond within a reasonable amount of time.
- Operational

        - The vehicle should unlock by using the application when the device is within 10 feet away from the vehicle.
        - The vehicle should unlock when a user touches the capacitive sensing mechatronic handle and the phone is in range.
        - The vehicle should remote start by using the application when the device is within 1 foot from the vehicle.
        - The application should be able to hold up to 10 keys at once per user.
        - Each key shall only be accessible by 25 people at one time.
    - Maintainability
        - If the system becomes unavailable for any reason it should be under maintenance within 2 hours.
    - Security
        - The application shall require valid credentials to gain access to each key.
        - The application shall use standard encryption for login credentials.
        - Only the owner shall be able to grant access to a user via the app.
    - Legal
        - Each user shall conform to the terms and conditions of this application.

2.4 Engineering Standards

IEEE 802.15.4 HRP UWB Standard

- This standard works to promote and standardize the Digital Key technology. It also gives recommended practices when working with UWB.

IEEE 802.15.1: Bluetooth and BLE

- This standard is a low-data-rate, low-power wireless networking standard aimed at replacing cables between lightweight devices.

Apple App Store Guidelines

- https://developer.apple.com/app-store/review/guidelines/

3 Project Plan

3.1 Project Management/Tracking Procedures

We are using the agile project management style. This works for our project, as this way, our application and the physical embedded locking suite can be worked on independently and consistently, without having to completely create an application prior to starting the embedded work. This will help mitigate issues with connecting the embedded side and application side. We will use Yodiz to track user stories throughout the project.

3.2 Task Decomposition

- Research UWB standards
    - Car connectivity consortium.
    - FiRa consortium.
- Definition of Done document - GitLab standards
- App requirements document
- Develop UART/message standards for our application.

    - Explore TriMark's existing UART code
- Create a UWB API that communicates between the PIC32 and UWB module.
    - Step through TriMark code in order to understand flow
    - Incrementally add in our updates
- Modify Mobile Knowledge UWB code to communicate with our mobile application.
    - Watch the UWB Kit Mobile Knowledge online training videos
    - Develop secure 2 way communication.
- Create a prototype smartphone app that communicates with the UWB module and demonstrates some of the basic features of the system.
    - Create mockup
    - Get feedback from TriMark
    - Update mockup
- Learn more about bluetooth interactions and Nearby Interactions
- In app, use nearby interactions send a bluetooth signal to unlock a vehicle
- Develop out the app based on requirements

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

- Documentation
    - Easy-to-read documentation allowing TriMark engineers to take over development of this project once we are done. This will outline the communication protocols in detail, allowing for simple recreation.
- Hardware to Hardware Communication
    - Hardware will communicate using the UART protocol, and we will be able to see the messages being transmitted from the TriMark module to the Mobile Knowledge UWB Module.
- Hardware to Software Communication
    - Application and UWB module will be able to securely communicate back-and-forth. The range of this communication should be approximately 150 meters.
- User Interface
    - Develop out the app based on requirements
    - Create an intuitive and stylistic application
    - Approval from TriMark on design and implementation

3.4 Project Timeline/Schedule

- A realistic, well-planned schedule is an essential component of every well-planned project
- Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity
- A detailed schedule is needed as a part of the plan:
    - Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar (including both 491 and 492 semesters). The Gantt chart shall be referenced and summarized in the text.
    - Annotate the Gantt chart with when each project deliverable will be delivered
- Project schedule/Gantt chart can be adapted to Agile or Waterfall development model. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.

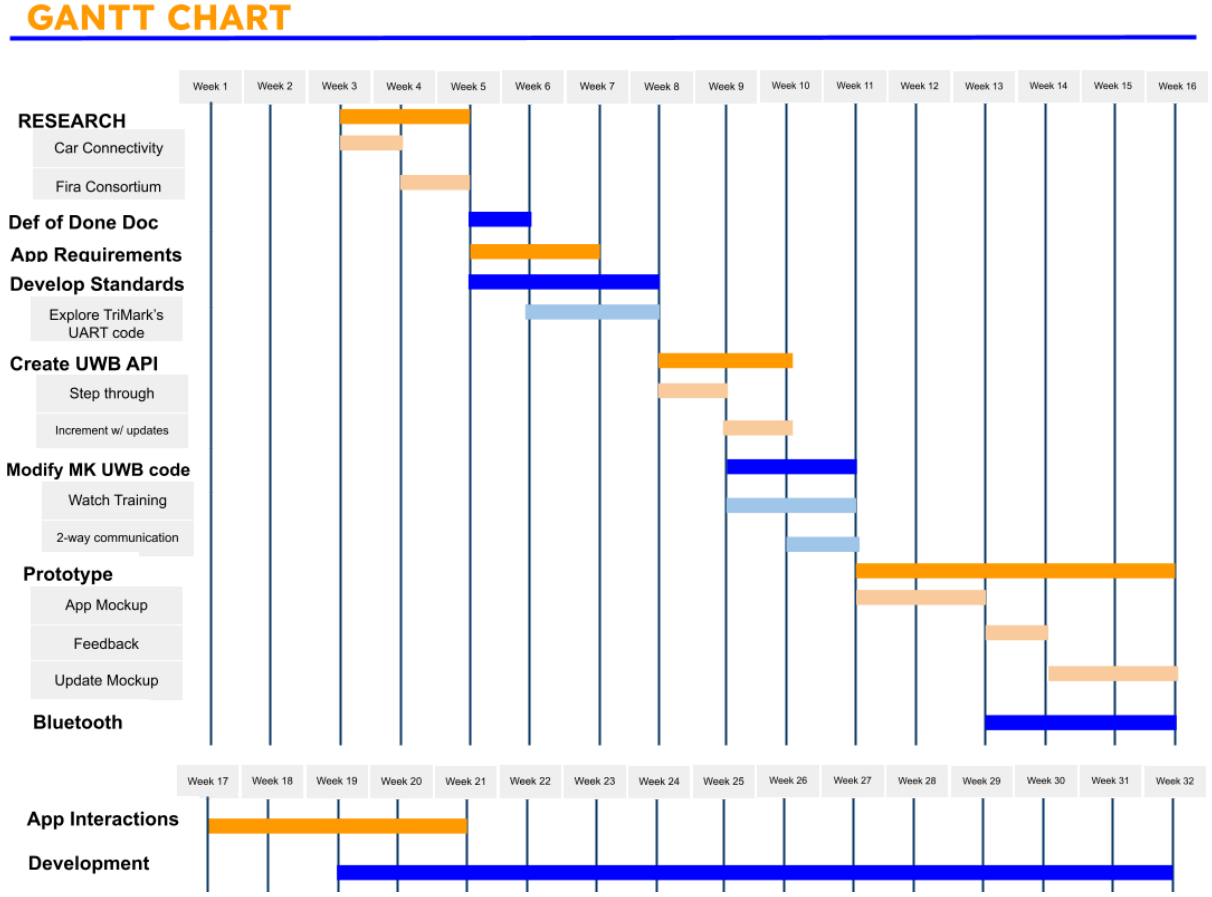

Figure 1: Gantt chart to outline proposed schedule

3.5 Risks And Risk Management/Mitigation

- Creating a prototype smartphone app to communicate with UWB Module
    - Risk of not achieving performance target for interacting with the UWB Module and getting precise location within 10cm
    - Risk Score: 7/10
- The risk of doing app development before Trimark has decided on their requirements
    - This risks our development team losing time in features that the company may not want. This is one potential issue with Agile where we can potentially start this development before our customer knows what they want
    - Risk Score: 4/10
- Creating a UWB API that communicates between the PIC32 and UWB module.
    - Risk of not UWB API not being able to communicate with PIC32 microcontroller
    - Can be mitigated by incrementally adding and testing code
    - Risk Score: 7/10

3.6 Personnel Effort Requirements

Task	Person-hours
• Research UWB standards	3

○ Car connectivity consortium. ○ FiRa consortium.	
• Definition of Done document - GitLab standards	1
• App requirements document	1
• Develop UART/message standards for our application. ○ Explore TriMark's existing UART code	8
• Create a UWB API that communicates between the PIC32 and UWB module. ○ Step through TriMark code in order to understand flow ○ Incrementally add in our updates	55
• Modify Mobile Knowledge UWB code to communicate with our mobile application. ○ Watch the UWB Kit Mobile Knowledge online training videos ○ Develop secure 2 way communication.	55
• Create a prototype smartphone app that communicates with the UWB module and demonstrates some of the basic features of the system. ○ Create mockup ○ Get feedback from TriMark ○ Update mockup ○ develop application based on requirements	55
• Learn more about bluetooth interactions and Nearby Interactions	3
• In app, use nearby interactions send a bluetooth signal to unlock a vehicle	30

Table 1: Personal Effort Requirements

3.7 Other Resource Requirements

- TriMark I/O circuit board
- Hardware Debuggers
- MK UWB Kit
- Power Supply

4 Design

4.1 Design Context

4.1.1 Broader Context

Area	Description	Examples

Public health, safety, and welfare	The implemented solution will have increased safety for the user.	Users can access their vehicles using a secure low power radio protocol (UWB) without a key fob and the worry of getting their vehicles stolen.
Global, cultural, and social	The groups this project affects are workplaces with commercial vehicles. It also affects people who own Rv's.	Companies can manage their fleet of vehicles digitally in a workplace environment. Family members can share one digital key with others without the need of keeping track of keys.
Environmental	Environmentally, this reduces the amount of toxic waste created by the process of manufacturing key fobs.	Decreasing the amount of metals being mined and plastic used in manufacturing.
Economic	It is cost effective for manufacturers. The effect it has on users is creating a more convenient way to access their vehicles.	Eliminating manufacturing of key fobs. Users will also save money by not having to replace keyfobs if lost.

Table 2: Broader Context

4.1.2 Prior Work/Solutions

UWB is a relatively new technology, but many companies are rushing to get this technology working. Only a few companies actually have this digital key technology on the market, a few being Audi and BMW. Samsung created an application, much like the application that we will be creating, that allows users to pair, honk the horn, or remotely start the car, all from your smartphone. These features are only available in select cars and countries, therefore our project will be cutting-edge, especially for the industrial vehicle market.

Our target solution differs from the existing market, as these solutions have only been made for cars. TriMark is in the industrial vehicle and RV market, which will offer a few of the same functionalities as well as additional features. Some similarities between our application and that of a normal car include passive keyless entry (unlocking the vehicle when within a certain distance), remote start, and digital key storing and sharing. In addition to this, companies offering UWB technology, such as BMW as described by David Barnwell, along with our application, will reference the Car Connectivity Consortium, which is the leading producer and researcher of digital key solutions. Our application may differ in that some RV's have compartments underneath that our application would also be able to lock and unlock.

In our market segment, there is no competition yet. Because this is a relatively new technology to cars, industrial vehicles and RV's are slightly behind the curve. Our target solution has many pros, a few listed below:

- no need for a key fob

- faster entry to vehicle
- everything can be stored on phone - no need to carry around set of keys
- can lock/unlock from phone

While there are many pros, this product also has a few cons, many stemming from the fact that this is such cutting edge technology. A few of these cons are listed below:

- maintenance and upkeep of application
- addition of UWB modules on existing TriMark modules costs time and money

4.1.3 Technical Complexity

1. UWB (Ultra Wide Band)
    a. UWB is a technically complex component required for the project. It is a wireless communication protocol used for precision tracking. The nearby interactions API is used for communicating with the UWB module. This is technically complex because it is relatively new technology accessible with smartphones.
2. TriMark boards
    a. The Trimark boards are a technically complex component of our project. We need to understand and modify the TriMark code base. We will have to create a UART interface and communication protocol. We need to establish communication between the TriMark and mobile knowledge boards.
3. Swift App Development
    a. Developing a swift app is something that this project requires, and this is technically complex because it is in a language that Iowa State students have not had exposure to. There is a lot of learning that our students working on this component of the project have to learn. In addition, that group is striving to create a secure app that fits the specifications of the Apple App store, which is pretty intensive. We need to learn how to write swift tests and tests for the UI.
4. Nearby Interactions
    a. Another component of the app development that is technically complex is Nearby Interactions. This is a Swift API that acquires the position of UWB devices. Our team gets to learn about Apple UI chips and how orientation affects connection to the UWB devices.
5. Software for the UWB module to provide secure two-way UWB communication to/from the TriMark mobile app.
    a. UWB is a very cutting edge technology. There are very few solutions on the market. Our product will focus on integrating UWB with commercial vehicles which is not yet on the market.
6. A mobile application for iPhone to demonstrate basic capabilities of the system.

a. We will develop a fully new application for our company whom does not yet have one on the market.

4.2 Design Exploration

4.2.1 Design Decisions

1. Our application development will first focus on iOS development using the swift coding language and nearby interactions API. We chose this as our focus for application development because all of the developers on the team have an iPhone available for testing, and the nearby interactions API is the most well fleshed out API using UWB available to us. In addition, iPhone support was the main thing that our clients asked for. The nice thing about the iPhone is the U1 chips within the iPhone works very well in connecting with UWB devices.
2. Our embedded development will run on a combination of two boards, one from TriMark Corporation, and a daughterboard that includes UWB functionality from Mobile Knowledge. We chose this architecture as it removes the complexity of designing a new board with UWB functionality from scratch, allowing the developers to solely focus on the embedded software on the boards.
3. Our iOS development will start with simple capabilities that assist more with testing the functionality of UWB<>UI interaction. Originally, we had a fully fleshed out mockup with features that allow admin key users to distribute key permissions to general key users and the ability to know the lock status of the vehicle. After we proposed this with our client, they liked out ideas, but wanted first a simple application. One that uses nearby interactions, connects through bluetooth displays how far away we are from the device, and unlocks the device when we approach the vehicle.
4. Our application design will have to have a color-scheme. This is important to our application because colors are what relates a product to a company, what allows for an application to be accessible for all users, and even can direct a user's attention. It is important for this application to compliment TriMarks company especially since this application may be used for demo purposes to other companies.

4.2.2 Ideation

One design decision we had to go through was what our entire app color coordination was going to look like. We used a lotus blossom technique to do so where we brainstormed all possible color options and narrowed down from there. A few options we considered were completely black and white for the “clean” look, just orange, just blue, orange and blue, making the app more friendly to those we are selling to by using “nature” colors like greens and browns, or even going completely off book and choosing bright colors to stand out.

4.2.3 Decision-Making and Trade-Off

In order to come to a final decision on what colors to use when designing our application we were able to use a weighted decision matrix. In this we chose a few important criteria to consider when choosing a color-scheme and weighted it based on importance to the project.

Criteria	Weight	“clean”	orange	Blue	orange&blue	natural	bright!
pleasing	3	5	4	5	4	5	4
client	3	2	3	3	5	4	1
accessible	2	5	5	5	5	2	0
contrast	1	5	5	5	5	2	5
notifiable	1	0	2	1	5	2	5
		36	38	42	47	33	25

Table 3: Decision-Making and Trade-Off

We decided to go with the colors tri-mark had chosen for their own logo: orange and blue. In this way, the application would correlate well with the company’s branding. They are contrasting colors and are pleasing to the eye and not many companies have this color choice so therefore could become a reputable color to the company (“color association”).

4.3 Proposed Design

4.3.1 Overview

At a high level, we will have three major parts to implement in our project. First, we have a circuit board given to us by our client, TriMark, which runs their firmware. We will add in logic for our application that will allow the TriMark board to communicate with the UWB module to know when to lock and unlock the vehicles. The next part is the UWB module, which is produced and given to us by a company called Mobile Knowledge. This module is loaded with initial code and libraries to help with our application, but we will be updating these according to our client’s needs. This module will communicate with both the TriMark board, through UART, as well as the Mobile Application, through bluetooth and UWB. The mobile application will have a user interface that allows the user to lock/unlock the vehicle manually as well as remote start the vehicle.

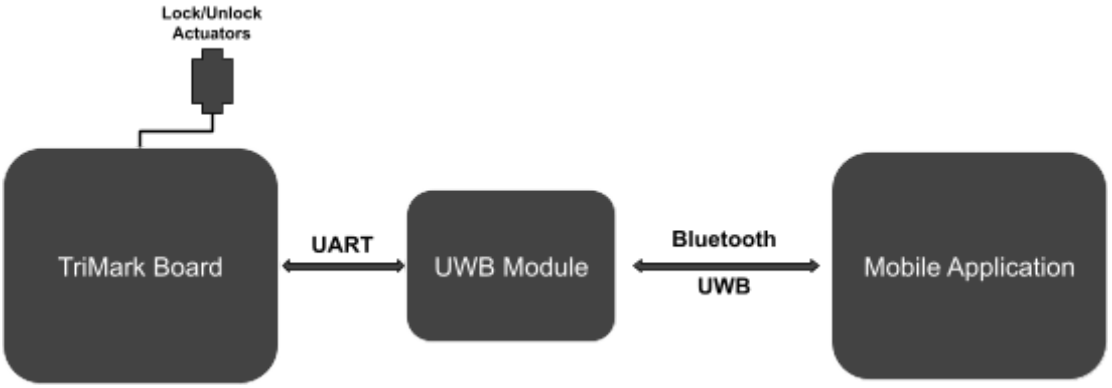

Figure 2: High level design

4.3.2 Detailed Design and Visual(s)

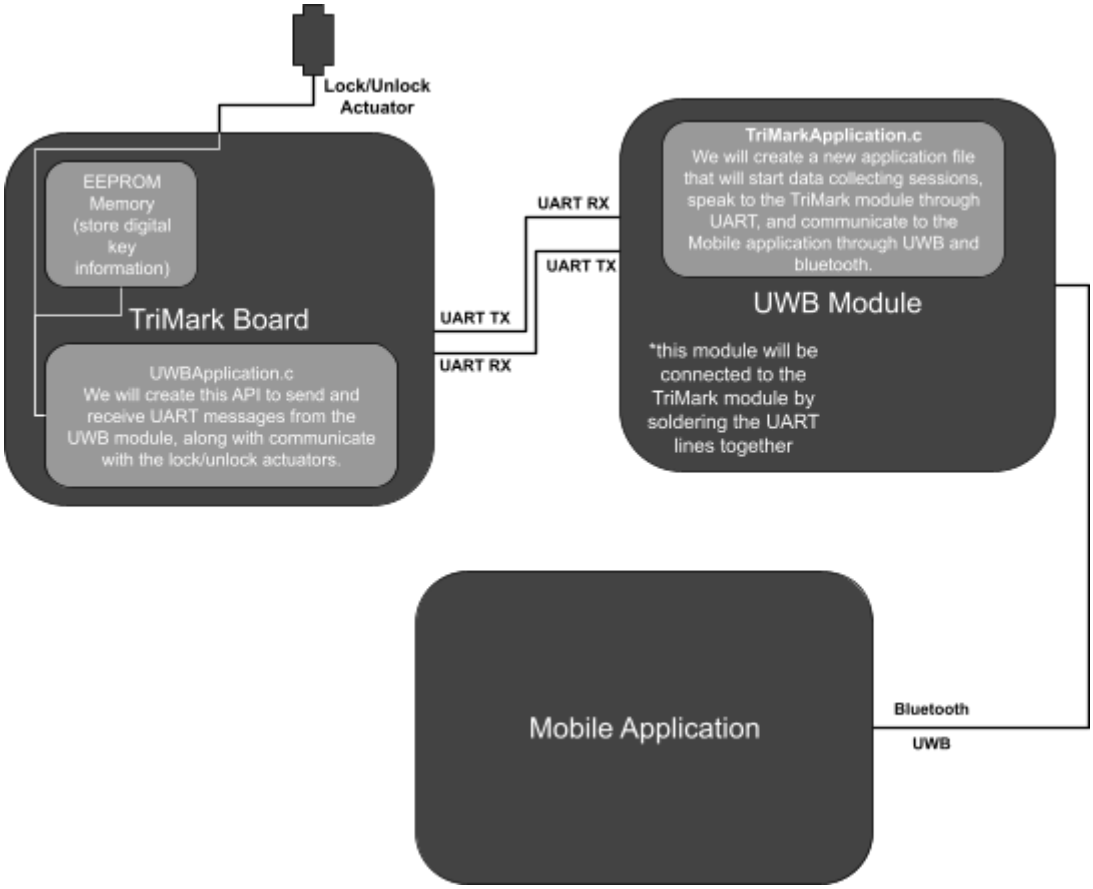

Figure 3: Detailed Design

4.3.2.1 UART Message Standard

Our UART messages will all be packaged and sent according to the standard outlined below. Each message will have a specific type, length, and value, that will allow our handlers to be able to quickly and easily parse messages.

Figure 4: UART Message Standard

4.3.2.2 TriMark Firmware

In order to get our application integrated with the existing TriMark codebase, we need to add our own API. This API will have UART transmit and receive functionalities. When a UART message is received on the RX line specified for our application, it will enter a handler for this event. This handler will process the message, deciding whether to lock/unlock a door, add a user, or remote start the vehicle. This API will also communicate with the EEPROM memory in order to save information about digital keys. When a new

digital key is added, information will need to be stored in EEPROM in order to validate each user when a phone is detected.

4.3.2.3 UWB Module

The UWB module comes with libraries and SDK's that help with the creation of new applications. Using some existing libraries, we will be creating our own API that can communicate with the TriMark board as well as the mobile application. This API will begin a UWB detection session, which will begin searching for phones nearby. If a mobile phone with UWB capabilities is detected, the UWB module will communicate with the TriMark board and validate that the digital key associated with the phone corresponds to one stored in EEPROM memory of the TriMark module. If this validation is successful, then the UWB module will allow the mobile application to lock/unlock the vehicle. If this device gets within the range of automatic unlocking, the UWB application will send a UART message to the TriMark module, signifying an unlock action. If the device leaves the unlocking range, then the UWB module will send a UART message, signifying a lock action.

If the user clicks the automatic start button, the UWB module will check whether the device is in automatic start range. If within range, the module will send an automatic start UART message to the TriMark module. A success message will be sent back to the UWB module, which will communicate back to the mobile device, displaying the success.

4.3.2.4 Mobile Application

The mobile application will use both BLE connection and the Nearby Interactions API to create a connection with the UWB module.

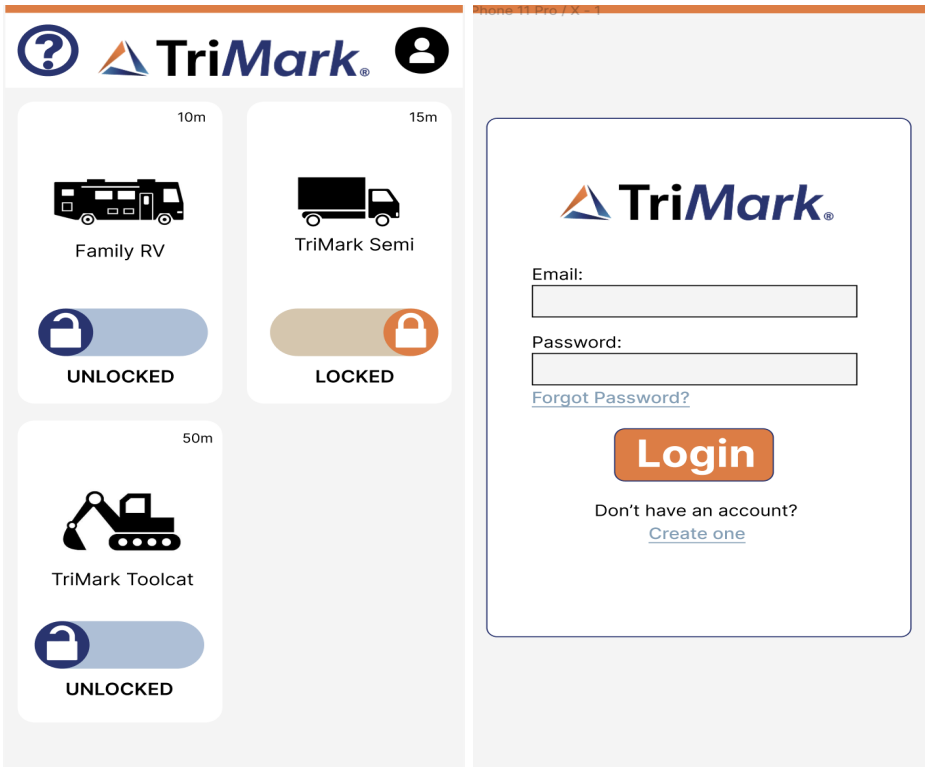

Figure 5: Mobile Application Design

4.3.3 Functionality

When a user has the TriMark digital key installed and associated with their vehicle, a user should be able to approach a vehicle and, once within a specified distance, unlock the vehicle without taking a key or phone out of their pocket. They can also use the mobile app to unlock or lock the vehicle, and see the distance from the vehicle (when in UWB range).

4.3.4 Areas of Concern and Development

The current design satisfies all current known requirements set by our clients. One area of concern that we have identified is the cyber security risk. None of us are cybersecurity experts, and this is a major risk for this type of application. We have questions about how to mitigate these risks and what steps to take in order to keep user information safe. We are going to have these conversations with our clients, as they may already have some cybersecurity protocols in place.

4.4 Technology Considerations

We are utilizing UWB technology for our project. It is a wireless communication protocol for precise location tracking. It is a radio signal with an instantaneous bandwidth of over 500 MHz. You are able to send and receive data over short distances at a very high speed and pinpoint location down to a few centimeters. This is more accurate than other technologies such as Bluetooth which can only pinpoint location within meters. There is also increased security compared to bluetooth. UWB has a high frequency so there is limited probability of any signal interference which is often the case with Bluetooth and Wifi. UWB is a relatively new technology so there are not as many examples to reference.

One mobile technology consideration made was starting with developing this for Apple products (i.e. iPhone 11 and above and Apple Watches). The motivation to start with Apple products was the U1 chips and the established Apple API, Nearby Interactions. The strengths of Nearby Interactions is it uses a Low Energy Bluetooth (BLE) connection to create a session and then is able to communicate via UWB. Android was also considered for us to start this project with. Due to the lack of documentation, example project, and physical devices for testing, it made sense for our project to start with Apple and keep it modular so in the future the app could support both.

4.5 Design Analysis

4.5.1 Embedded Side

This project has a steep learning curve, so a lot of our time so far has been spent familiarizing ourselves with the various codebases and hardware elements necessary. We began work and testing on the Mobile Knowledge board, creating a base application that detects the UWB tag within 200cm. This initial test worked, and we were able to see the UART message being created by stepping through with the debugger. It is looking like our proposed design will work, with only minor issues so far.

4.5.2 Mobile Application

In our mobile application design we had to create a wireframe of what we wanted the application to look like. Our original design had a lot more functionality than what we have finalized here. We showed the initial design to TriMark and they wanted it much simpler where we simply have the unlock/lock capabilities and the login page. This should be quite a bit easier to implement in the application itself however, we will still include functionality that is not accessible to the user. This includes the lock and unlock within a certain parameter without actually opening up the application. This does create a concern

for how the app shall run in the background and we are focusing on getting this accomplished first which is why they wanted a simpler application overall.

5 Testing

5.1 Unit Testing

5.1.1 Embedded

On the embedded side, we have two main parts to test both separately and together- the TriMark module and the Mobile Knowledge module. On both sides, we will need to do unit testing to make sure that our UART transmit and receive functionality works. We can test this by simulating a UART receive through PuTTY to test our interrupt handler, as well as reading the PuTTY logs to test our transmit functionality. Along with these units, we will need to test the module that connects and communicates with the mobile application. In order to do this, we can set up unit tests that simulate a connection between the iPhone and the board. These unit tests will then extensively test each possible case, such as if the phone is within unlock range, if the phone leaves lock range, and if a manual lock/unlock is initiated by the phone.

5.1.2 App Development

For the app development side, we will be using Swift tests to test the individual functions that are called throughout the app. Swift has a testing library and we will use that to work towards 100% code coverage. In addition to having passing unit tests, we will also strive for a response app. We will do a lot of testing with response time of functions to make sure when we layer function calls, we still have a quick application. Our main goal there is to prevent

5.2 Interface Testing

5.2.1 App Development

There are multiple ways of testing the interface of the mobile application. We will be making sure all functions implemented in the application are working. This includes testing a button press and making sure the right function is being called. Functionality of the buttons may include, unlocking/locking a vehicle. Login accounts will also be tested to make sure a digital key is attached with the correct user account.

5.3 Integration Testing

Integration testing will involve testing the end to end communication between the various components of our application, using a top-down integration testing methodology. First we must test the integration of the front end of our mobile application to the back end that services the application with data. For this, we can use tools included in the programming language of the application. Then we must test the UWB and BlueTooth connection between the mobile app and the Mobile Knowledge board, using a manual testing method. Once connection is ensured, we then can test the connection between the Mobile knowledge board and the Trimark Board. We can test this using embedded C testing frameworks. Using integration testing on these many connections through our application will allow us to fully test our end to end services from initiating on the application to actuating the vehicles locks using the TriMark board.

5.4 System Testing

We will ensure the entire system is functioning properly by implementing end-to-end testing. We will establish different protocols such as having the key lock or unlock within a certain distance. We will test to

ensure that if you are outside of the automatic unlock distance but still in UWB range you will be able to lock and unlock the vehicle via the application.

5.5 Regression Testing

We plan to employ both our unit testing and integration testing while implementing new features of the project by automatically running tests in our GitLab CI/CD pipeline. This will ensure that as we implement new features, no code that breaks previously deployed and tested modules will be merged in with main.

5.6 Acceptance Testing

In our acceptance testing we plan to implement multiple procedures to guarantee that all or our requirements will be met. One way we plan on executing this is by using end-user testing. In our end-user testing we will focus on the functions of our application most used by the user such as the lock/unlock mechanism by walking up, the distance from capability in the application, and the manual lock/unlock functionality from inside the lock/unlock radius. We will first do this via alpha testing when we are at the final steps in our testing. First our team will make a list of actions our application should successfully execute and all of us will go through and mark in a shared excel sheet. If something is not working correctly, then we shall redo the process once that issue is fixed. Then once we have tested it to the best of our ability we will have one or two of our clients go through the same testing process so they can give us feedback.

5.7 Security Testing (if applicable)

We plan to implement security testing by implementing several methods to make sure our security is not breached. We will attempt to gain access to an unauthorized key. We can also use tools to verify the encryption of various parts of our application, such as the BlueTooth connection, UWB connection, and username and password authentication. As far as the embedded technology, we will test the devices against physically flashing a new program to obtain the digital key signatures, owners or vehicles, or other sensitive information.

5.8 Results

We have just begun working on the implementation, so we haven't done too much testing yet. On the embedded side, we are incrementally developing the UART transmit and receive functionality, which we are testing as we go. We have connected the sample application to the Mobile Knowledge board, which we have done initial tests on. As more development is done, we will implement more of these testing frameworks.

6 Implementation

- Documentation
    - We have already begun a master document that will outline details on our implementation. It contains information about our UART standards, set-up of both of the circuit boards, and download information for the mobile application. As we develop more standards, we will continue to add to this document in order for TriMark engineers to better understand our implementation.
- Hardware to Hardware Communication
    - We have been developing UART transmit and receive abilities on both the TriMark and Mobile Knowledge boards. These boards are currently able to communicate with a serial

port reader(PuTTY), and in the future, we will solder UART Tx/Rx lines together, successfully transmitting between the modules.

- Hardware to Software Communication
    - We have established communication between the sample application and the Mobile Knowledge code through UWB and Bluetooth connection. In the coming semester, we will update the messages being sent to-and-from these devices to conform to our application's requirements.
- User Interface
    - We have created an initial mock-up for the design of our application, as well as began diving deeper into the sample application. In the coming semester, we will adapt this sample application to conform to our design, as well as our application's user requirements.

7 Professional Responsibility

7.1 Areas of Responsibility

Area of responsibility	Definition	NSPE Canon	IEEE Code of Ethics
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.	I think the IEEE Code of Ethics has a lot of pieces that fit into Work Competence. I think most of the Ethics that the IEEE code brings up could be under work competence, since it talks a lot about how to treat and interact with peers, in respecting their feedback. Some of the Ethics that I thought resonated most with work Competence are listed as below: to avoid unlawful conduct in professional activities, and to reject bribery in all its forms; to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations; These are different from the NSPE because they are more detailed in how to be qualified and detailed deceptive acts more, but this group is pretty similar.

Financial responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	I feel like the IEEE Code of Ethics really only hits on not taking bribes, and doesn't really discuss being trustees for the clients. to avoid unlawful conduct in professional activities, and to reject bribery in all its forms I think a lot of the IEEE Codes that involve learning and educating people about technologies would lend itself to having well informed workers, who can therefore make better financial decisions. This is different than the NSPE because it takes financial responsibility as being a good faithful agent and trustee to clients, where
Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.	I think the IEEE Code of Ethics has a lot of pieces that fit into Communication Honesty and specifically the NSPE canons. I think most of the Ethics that the IEEE code brings up could be under communication honesty, since it talks a lot about how to treat and interact with peers, in respecting their feedback. Some of the Ethics that I thought resonated most are listed as below: to avoid unlawful conduct in professional activities, and to reject bribery in all its forms; to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist; to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment; to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems;
Health, Safety, and Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.	I think the IEEE Code of Ethics has a piece that fits into Health, Safety, and Well-Being. This IEEE Code specifically calls out health, safety, and well-being: to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment The NSPE and IEEE Ethics are very similar for this, but the IEEE mentions sustainability.

Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.	I think the IEEE Code of Ethics has a piece that fits into Property Ownership. This IEEE Code specifically calls out the continuation of educating the community about new technology and systems: to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems; This is different than the NSPE canon and I think the IEEE one I selected shows a better understanding and rule for property ownership based off the definition.
Sustainability	Protect environmen t and natural resources locally and globally.		I think the IEEE Code of Ethics has a piece that fits into Sustainability. This IEEE Code specifically calls out sustainability: to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment NSPE doesn't mention sustainability and that is one of the shortcomings of that code of ethics. IEEE does a good job of not only mentioning the importance of sustaining the environment, but also making designs that lend themselves to a sustainable development.
Social Responsibility	Produce products and services that benefit society and communitie s.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	I think the IEEE Code of Ethics has two pieces that fit into social responsibility. This IEEE Code specifically calls out health, safety, and well-being: to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems; to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment; The NSPE canon and the IEEE ethics for social responsibility are very different. I really like the NSPE canon here because it talks about keeping to the law and maintaining a good reputation. The IEEE codes take a couple codes to encapsulate this idea.

Table 4: Areas of Responsibility

7.2 Project Specific Professional Responsibility Areas

Area of responsibility	Level of Importance	Current Level of Performance
Work Competence	High - I think our company that we work for in this project would prioritize work competence. They want us to produce the best product for them and their customers.	Med - Work competence is something that our team is working to improve on. The main part of work competence that we are missing is timeliness. We are busy college students, most of whom work part time jobs as software developers.
Financial responsibility	Medium - I feel like some companies have room for the definition of this workplace competency to not be perfect. Many companies want to spend the least amount of money to maximize their profits, but also I think a lot of companies acknowledge that sometimes something needs to be tried out to see if it would work/be secure/etc. As for the NSPE Cannon for this competence. I think that is a high priority. Information, especially financial, should be highly confidential and the employees working with such information should treat it as such.	Med - I feel like our group is doing a good job in recognizing the financial contributions our company (client) is making to this project, so we are doing our best to take that dedication into us working with the equipment. We are definitely trying our best to make sure we don't break anything that we would financially have to replace.
Communication Honesty	High - This is a super important workplace competency, and in my opinion one of the most important ones. It is important to be communicating accurately and honestly with ourselves, our clients, the employers, and co-workers. If we are not honest there can be many issues.	High - I think our team is doing a great job at communicating honestly. We are doing a lot of things that we have never done before. For example, I had an idea to re-architect our application, but I was honest in communicating that I'm not sure how to set it up, or if it is possible since the api we are working with requires specifically a macOS and talks to the U1 chip within the phone. This changes how we will continue working with our app dev team. We will continue working with the sample app, to make sure that works and I will also concurrently be working on this spike to make it better.
Health, Safety, and Well-Being	High - This is definitely a high priority for our project, specifically with safety. Since this project is working with locks to people's personal vehicles, we want only authorized users to be able to get into their vehicles.	Med - Right now we are working on a lot of proof of concept ideas, working to make sure this is possible and safety and authentication we still have to discuss more with our clients about, since they will be hosting the database and have their own security guidelines to follow.

Property Ownership	High - We are working with a company and have signed NDAs because we are using a lot of their code on our embedded side.	Low - Since this is a senior design project, we are in a way required to share more about this project than our company would probably like. We use Google Drive, when we should use TriMark's Teams to host our documents.
Sustainability	Low - our project doesn't really tamper with the world around us. We will need a database to store user and key information, but we are updating technology that has already been created. We need to continue to be conscious of needing less equipment, so we can manufacture less, but other than that there is not much of an environmental issue with our project.	Low - This project doesn't have many environmental issues, so this has been in our back burner. Something we are trying to continue to consider is how to make our project maintainable, so resources in the future can be saved because our project is able to be worked off of.
Social Responsibility	High - This project would be helpful and beneficial to those who use it. It is not the most needed product, but a helpful one that can help the environment by not having to manufacture as many key fobs down the line. This project also is law abiding.	High - We are doing our best to produce this project because we know the cool impact in can have on our consumers.We are also working writing the best code and working to review security because we know how important it is to have this project be successful.

Table 5: Project Specific Professional Responsibility Areas

7.3 Most Applicable Professional Responsibility Area

One area of professional responsibility that is important to our project and our team has demonstrated a high level of proficiency in the context of our project is Work Competence. This responsibility includes putting the adequate amount of time into the project and putting forth high quality work. This is a project that when put in production, could be a source of potential malicious attacks since this involves allowing clients to use their phone to unlock their vehicles. The ways our team is working toward work competence is working closely with our company to put forth the best code. We have outlined our acceptance criteria, which involves high code coverage and thorough testing.

8 Closing Material

8.1 Discussion

Our project is still in the early stages of development, so many of the requirements have not been met yet. We believe that we are on the right track to being able to meet the baseline requirements, as well as the possibility of adding additional functionality. Throughout next semester, we will continue to develop the minimum viable product, testing this thoroughly. Once this is finished, we will move on to stretch goals!

8.2 Conclusion

The main goal of this semester was to gather requirements, plan, conduct research on necessary new skills that we may need, and outline how we will complete this project. We have been focused on understanding the scope of this project on both the embedded systems side as well as the application development side, along with creating documents that explain our understanding. In addition to this, we have begun development of the actual product. We have worked on diving deeper into our initial codebases and outlining what needs to be done in each module in order to continue development.

Our plan of action for next semester is to ramp up on our time spent developing and testing, as we have now finished the planning and requirements gathering stages. In order to accomplish this, we will continue working in teams based on skill set - embedded and application development. We will have a constant line of communication between the teams, frequently testing at the system level to make for a seamless integration.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

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8.4 Appendices

Cleveland, Nikki. "If You Have These 10 Personality Traits, You're Meant to Be a Full-Time Rver." *DoItYourselfRV*, 21 July 2018, https://www.doityourselfrv.com/personality-traits/.

Mearian, Lucas. "Ultra Wideband (UWB) Explained (and Why It's in the Iphone 11)." *Computerworld*, Computerworld, 31 Dec. 2019, https://www.computerworld.com/article/3490037/ultra-wideband-explained-and-why-its-in-the-iphone-11.html#:~:text=With%20precise%20ranging%2C%20UWB%20has,secure%20area%20within%20a%20building.

8.4.1 Team Contract

Team Members:

1) Kaili Lawson
2) Shayla Lunn
3) Erica Hollander
4) David Bone
5) Hanan Zahid
6) Lakin Jenkins

8.4.2 Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings:
    - Wednesdays 5-7 (face-to-face or hybrid if necessary) With the company will be dependant on the company's schedule choice
2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):
    - group message via text
3. Decision-making policy (e.g., consensus, majority vote):
    - Majority vote with evidence to support your claims.
4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):
    - Erica has elected to take notes for the majority but everyone will take their own notes that they feel like they may need for future reference and if for any reason she has to be absent for a meeting then we will elect someone who is present to take over the note taking We also will be making tickets/story cards on GitLab to keep track of important tasks that we have to accomplish. We will also be using Google Drive to hold any shared documents, such as the Design Document

8.4.3 Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:
    a. We expect our group to do their best to commit to the full length of the meetings and try to be as punctual as possible especially when we meet with the company as to create a formal atmosphere
2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:
    a. Fulfill all team assignments on time with equal participation between all team members
3. Expected level of communication with other team members:
    a. listen to what everyone has to say respectfully. Ask questions where clarification is needed and answer as concisely as possible and understand that there are no stupid questions.
4. Expected level of commitment to team decisions and tasks:
    a. We expect every member of the team to respect and commit to any and all decisions we make as a team through our majority vote. We also expect everyone to commit to all work they have been assigned, and if an issue arises, that team member should communicate it to the rest of the group.

8.4.4 Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):
    a. Kaili: Client Interaction
    b. Shayla: Embedded Systems Design
    c. David: Hardware and Software Communication
    d. Hanan: Security
    e. Lakin: App Design and Interface
    f. Erica: Team Organization and Scrum Master
2. Strategies for supporting and guiding the work of all team members:

    a. We plan on using story cards on GitLab to help everyone on our team know what they are to do and when deadlines are coming up. It also helps to give extra steps on what to work on next once a card is completed
3. Strategies for recognizing the contributions of all team members:
    a. Drop shout-outs in the group chat if you recognize that someone is doing exceptionally well and a recap during our weekly meetings to share what we have accomplished

8.4.5 Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.
    a. Kaili: Experience with embedded systems programming, organizational skills, app development in Unity.
    b. Shayla: I have experience with full stack development and embedded programming.
    c. David: Experience in full stack development, with large scale architecture design and with runtime engineering.
    d. Hanan: Experience with backend app development.
    e. Lakin: Experience with app development and graphic design on the front end of applications. I have quite a bit of experience with cross platform development tools such as unity.
    f. Erica: I have a lot of UI experience with Web Applications in React. In addition, I am very comfortable with backend development and API work. I am a full stack developer and have experience with infrastructure as code.
2. Strategies for encouraging and supporting contributions and ideas from all team members:
    a. Give everyone ample time to think and an opportunity to talk during team brainstorming sessions
    b. Provide availability to pair on problems people are having issues with
    c. Every two to three weeks have a check-in or a retrospective meeting on our sprints
3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)
    a. Avoid placing blame on anyone if something goes wrong, attack the problem not the person.
    b. Allow for a “free space” during our weekly meetings to allow for any team member to bring up any issue that they may have with the team or the team environment.

8.4.6 Goal-Setting, Planning, and Execution

1. Team goals for this semester:
    a. Spend time creating a well-planned out design document
    b. Understand the requirements
    c. Create a mock-up for the application
    d. Begin work on the embedded aspect
2. Strategies for planning and assigning individual and team work:
    a. Using story cards on GitLab
    b. Have everyone keep track of what they have to accomplish for the week
    c. Upload all meeting notes after the meeting to our shared google drive in case they forget/lose their own notes and tasks
3. Strategies for keeping on task:

a. Agenda our meetings
b. Time box our meetings and try and be respectful of the time our teammates

8.4.7 Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?
    a. Bring it up in one of our weekly meetings and try and address the problem in person
2. What will your team do if the infractions continue?
    a. If the problem is not resolved, we will bring it up to our TA for further action.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) Kaili Lawson	DATE 11/30/2022
2) Shayla Lunn	DATE 11/30/2022
3) David Bone	DATE 11/30/2022
4) Erica Hollander	DATE 11/30/2022
5) Hanan Zahid	DATE 11/30/2022
6) Lakin Jenkins	DATE 11/30/2022