<u>SENIOR DESIGN I</u>

SCAN: Smart Check-in & Analytics Network

University of Central Florida
Department of Electrical and Computer Engineering

Initial Project and Group Identification Document
Divide and Conquer, Version 2.0

GROUP 35

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2. PROJECT DESCRIPTION

2.1 Project Background and Motivation

At a large public university like UCF, data collection is not just important—it is essential. Graduation rates, enrollment statistics, and faculty-to-student ratios are carefully tracked each year and reported to institutions for accreditation and ranking. Another crucial measurement often overlooked is engagement: How many students attend major university events? How long are they staying? What are their activity patterns week-to-week throughout the academic year? The answers to these questions are crucial, as they directly influence key decisions on resource allocation, staffing, and campus planning. Without access to accurate, accessible engagement data, the university risks missing crucial insights that could impact its future.

UCF students, faculty, and staff already use their UCF ID cards—embedded with a combination of magnetic stripe and NFC technology—for many daily functions, whether it's scheduling appointments at Student Health Services, accessing restricted buildings, or checking into locations like the UCF Recreation and Wellness Center (RWC). Due to their widespread use, these cards present a prime and overlooked opportunity to streamline engagement data collection, uniquely identifying each student and capturing valuable insights in real time.

The UCF RWC is a prime case example. With an occupancy tracking system in place, the RWC could transform and adjust its daily operations. Staff could predict peak hours precisely, manage staffing levels throughout the week, and even gather detailed demographic data on the types of students utilizing the facility. By tracking this engagement data, not only is the efficiency of the RWC's operations enhanced, but the experiences of individual attendees are improved by ensuring that resources are allocated exactly when and where they're needed most.

2.2 Project Function

We propose SCAN: a Smart Check-in and Analytics Network capable of tracking such user data. Using the UCF Recreation and Wellness Center as our example, we will design a low-cost scalable network of kiosks equipped with an NFC reader and interactive display to log check-ins and check-outs of RWC attendees. Multiple kiosks can be used in synchronicity to provide more than one access point to the facility. Encoded NFC tags will emulate UCFIDs to avoid any security concerns involving the direct use of actual IDs. However, the SCAN system could be easily integrated with UCFIDs in the future.

For authentication and analytics, user data will be stored in a secure database on a server external to the kiosk, and the kiosk will query the database to ensure that the user has permission to access the area. In addition, a web application will display analytics based on the check-in data, which can be made available to staff and students to enhance the user experience.

2.3 Project Objectives and Goals

This project aims to provide a low-cost, scalable internet-of-things (IoT) alternative to existing check-in and authentication kiosks, opting for NFC-based authentication to utilize existing technology within UCF's ecosystem (the UCFID). We will use the UCF Recreation and Wellness Center as a use case within this report, as it is a prime demonstration of the technology's use and is relatable to many students. However, the technology can be adapted for various applications at UCF and beyond.

Basic Goals
- SCAN will be used to identify, authenticate, and check in users.
- SCAN will collect and track user data through a user database.
- SCAN will analyze user data and provide useful statistics.
- A web application accompanying SCAN will display the collected data.

Advanced Goals
- SCAN will provide multiple indicators of a successful check-in to users, including visual and audible indicators.
- SCAN can operate as a network of kiosks, providing synchronous check-in and analytics from multiple locations.
- SCAN's web application will be mobile-friendly.

Stretch Goals
- SCAN will be capable of being charged by solar power.
- The SCAN database will use end-to-end encryption to secure user data.

2.3.1 Hardware Objectives

The primary function of the SCAN kiosk is to verify a user's identity and either grant or deny the user access to the RWC. A Wi-Fi-capable microcontroller is used at the heart of the kiosk to process check-ins and communication with the external user database through a client-server connection.

In a typical interaction, the user will approach the kiosk, and a proximity sensor will detect his or her presence and bring the kiosk out of low-power mode. The display on the kiosk will then prompt the user to check in using their identification tag. As an added form of redundancy, the smart kiosk will also support a keypad to enter the user's ID directly. For ease of use, the user's ID will be encoded in a standard near-field communication (NFC) tag, and the kiosk's NFC reader will transmit the ID to the database for authentication. Upon successful authentication, the screen will display a message to indicate that the user's ID was accepted, in addition to LEDs and an audible indicator. Following an interaction with the user, the kiosk will remain active for a short duration to seamlessly authenticate the next user during high-traffic intervals. After this, it will return to low-power mode and remain on standby until the next user approaches.

The SCAN team wishes to make the hardware for this project as cost-effective, power-efficient, and accessible as possible. For these reasons, all of the necessary hardware for the project will be packaged inside the kiosk, which will sit on a stand at the height of a typical user. Additionally, the kiosk will have the option to be powered by either a standard wall outlet or an internal battery, enabling portability. Careful consideration for power consumption will be taken when selecting core components such as the microcontroller, kiosk display, and NFC reader. For increased accessibility, SCAN can operate as a network of multiple kiosks that can be used to process check-ins in parallel. This will require synchronization between multiple kiosk clients and a single server, which manages the user information database. Multiple kiosks enable the RWC and other organizations to eliminate queues, increase check-in throughput, and support multiple regulated entry points into the facility.

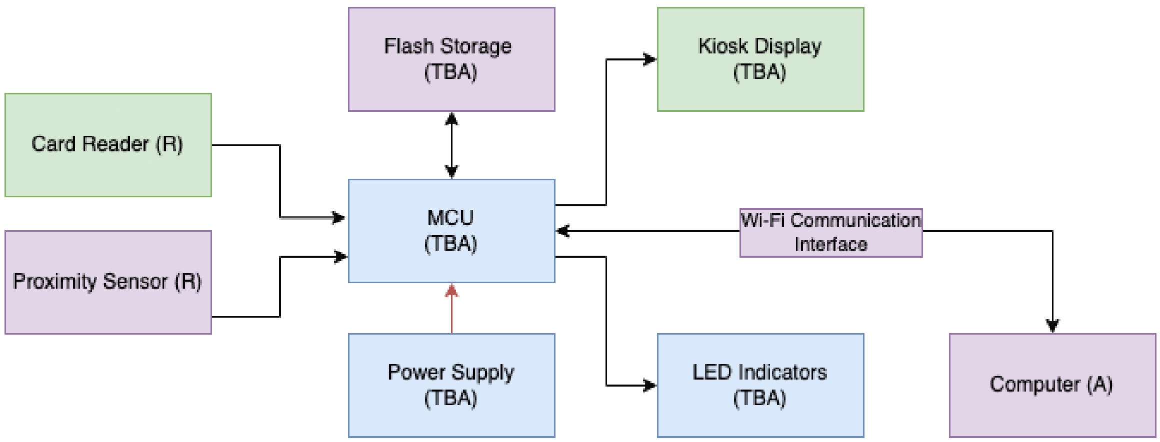


Figure 2.1 Hardware Block Diagram

Table 2.1 Hardware Block Diagram Legend

Member Assigned to Block	**Signal Type**	**Status**	
Cory Brynds	Power	To Be Acquired (TBA)	Designing (D)
Jonah Sprandel	Other: Data	Acquired (A)	Prototyping (P)
DeAndre Hendrix		Researching (R)	Completed (C)

Stretch Goal: Solar Charging

In applications outside of our RWC use case, kiosks are often used for outdoor events such as sports games and concerts, where sunlight is readily available. Access to power outlets can be limited in these situations, so extending the battery runtime is crucial. In addition to reducing power consumption, introducing solar charging capabilities will further enhance the robustness of the SCAN system, increasing its portability and ease of use in outdoor environments. Furthermore, introducing solar charging enables the SCAN system to be a more environmentally friendly solution.

2.3.2 Software Objectives

SCAN's software can be split into four main deliverables, each corresponding to separate groups of software objectives: the GUI, embedded application, web application, and database.

1. The SCAN GUI will guide users through the check-in and check-out process.
2. The SCAN system's embedded application will interface the GUI, LEDs, NFC reader, and proximity sensor to a microcontroller for processing and later transmission to a database over Wi-Fi.
3. SCAN will utilize a backend server to store centralized data between kiosks and web application instances.
4. The web application will interface with the backend server database to display occupancy analytics.

Kiosk GUI Objectives

SCAN's GUI is responsible for providing an intuitive, responsive, and efficient interface for interacting with SCAN's technologies. This interface should be responsive and user-friendly, displaying visual feedback to the user throughout each step of the NFC scanning process. It should also update in real time, showing messages such as "Access Granted," "Authentication Failed," or "Please Retry" immediately after a response has been returned from the backend server. Sprites and other graphics for the display will be stored in the microcontroller's flash memory. By providing visual feedback and a low-latency interface, our design satisfies the goal of having an easy-to-use and responsive GUI.

Embedded Kiosk Application

SCAN's embedded application's primary goal is to interface all of the hardware and software components using a central processor/microcontroller. To meet this goal, our first objective is for the embedded application to handle the NFC scanning process, ensuring each user's NFC tag is correctly identified and sent to the database for authentication and processing. This involves configuring the MCU and NFC systems individually and then properly interfacing them via embedded software. Along with interfacing with the NFC scanner, our embedded application should also be capable of interfacing with status LEDs and audio signaling devices. The status LEDs should be activated depending on triggers from the MCU, while the audio devices should play proper sound queues for different events. The MCU should also be capable of interfacing with the LCD and displaying buttons, messages, and user data throughout each step of the check-in process. The interface should be quick to ensure the system is as responsive as possible. Finally, the embedded application should be optimized for power efficiency, especially in instances where it is running solely from battery power, such as outdoor events.

Server Backend

A back-end storage database is essential for facilitating communication between SCAN's kiosk and web applications, especially when SCAN is operating as a network of kiosks. The backend database will securely store and safely manage user profiles, including a user's name, ID, and facility-centric credentials (e.g. whether they have signed a waiver). Using this information, the server application will process scanned NFC IDs transmitted from the kiosk and search for valid user information in the database to authenticate users. The database will then return a boolean decision of the user's authentication status and record their attendance in the facility for analytics purposes.

Frontend Web Application

The web application will display up-to-date user statistics, allowing owners and building managers to monitor real-time occupancy and analyze user data. The following list describes the user data that the web application will display:

- Number of attendees currently checked in
- History of past attendance for a maximum interval of time
- Histogram of peak attendance hours for a given day and hour during the week
- The average duration of an attendee's stay

Stretch Goal: Data Encryption

As a stretch goal, SCAN will support secure data transmission between the data server, kiosks, and web application instances using end-to-end encryption. It will also encrypt the user data stored within the database. The encryption scheme used to secure data will meet current standard security levels (e.g. AES 128 or 256-bit security).

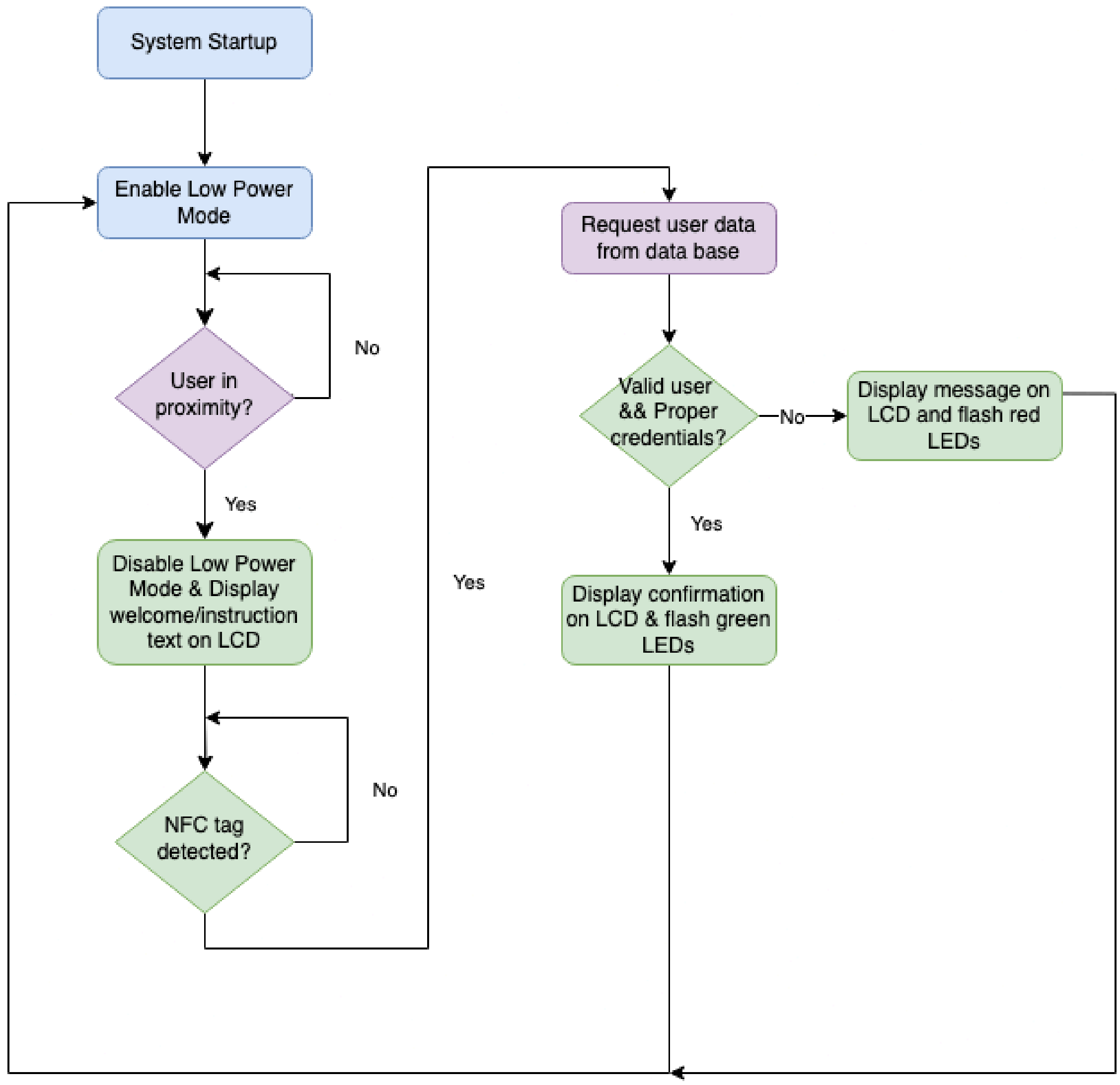


Figure 2.2 Embedded Software Flowchart

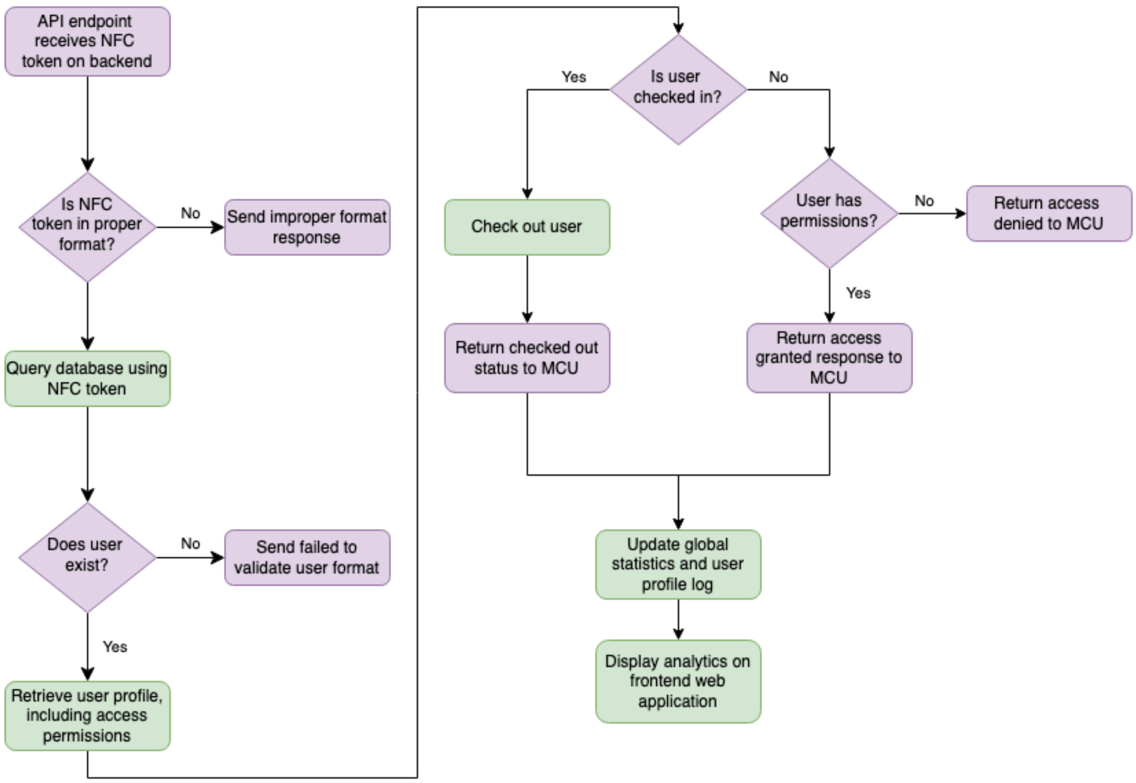


Figure 2.3 Frontend and Backend Software Flowchart

Table 2.2 Software Diagram Legend

Legend (Member Assigned to Block)
Cory Brynds
Jonah Sprandel
DeAndre Hendrix

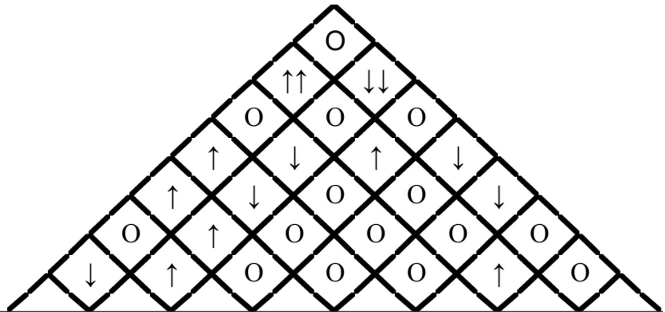
2.4 Requirement Specifications

In the previous sections, the goals, objectives, and motivations behind the SCAN project were described. To transition SCAN from a set of goals into a physical project, we now define a set of requirement specifications. These requirements will be used to assess the functionality of the project and demonstrate a successful design. This set of requirement specifications is summarized in **Table 2.3**, and the requirements highlighted in yellow will be used for the project demonstration to our peers and committee in Senior Design II.

Table 2.3 SCAN Requirement Specifications

Requirement	**Specification**
Minimum number of authentication methods	SCAN will support **at least two methods** of authentication: NFC tags and manual entry of a user ID through a keypad.
Minimum Battery Runtime	SCAN will have a minimum operating time of **2 hours** on battery power under typical operating conditions.
Minimum Charging Power	SCAN will have a minimum supported charging power of **10W**.
Time to Authenticate	SCAN will be able to authenticate the credentials of a user ID in **less than 10 seconds**.
Number of Check-in Statistics	SCAN will display **at least three forms of analytics** based on check-in data, including occupancy, peak hours throughout the week, and the average duration of a user's stay.
Minimum Proximity Sensing Range	SCAN will switch to active mode once a user is within **3 meters** of the system's range.
Maximum Enclosure Size	The maximum size of the enclosure for each SCAN system will be **1 cubic foot**.
Analytics Refresh Rate	The analysis of SCAN's collected data will be updated on the webpage every **three minutes**.

Correlation & Desirability Key	
O	no correlation
↑	weakly positive
↑↑	strongly positive
↓	weakly negative
↓↓	strongly negative
+/-	high/low desirability



Customer Requirements / Engineering Requirements		Number of Auth. Methods	Battery Runtime	Charging Power	Authentication Time	Number of Check-in Statistics	Proximity Sensing Range	Enclosure Size	Analytics Refresh Rate
		+	+	+	-	+	+	-	+
Energy Efficiency	+	↓	O	↑	↑	↓	↓	O	↓
Affordability	+	↓↓	↓	↓	↑	O	↓	↓	O
Ease of Use	+	↑↑	↑	↑↑	↓↓	↑	↑↑	↓↓	↑
Redundancy	+	↑↑	↓	O	O	O	O	O	O
Reliability	+	↑	O	O	↓	↑	↑	O	↑↑
Targets for Engineering Requirements		2 methods	2 hours	10W	10 seconds	3 forms	3 meters	1 cubic foot	3 minutes

Figure 2.4 House of Quality Diagram

10. ADMINISTRATIVE CONTENT

10.1 Project Budget and Financing

The budget for our project will come from an even split of funding provided by each of the three group members. **Table 10.1** breaks down the anticipated costs for each section of the project, including the cost for prototyping and end-product components, and it will be routinely revised throughout the project. The goal is to keep the budget for each kiosk relatively low to provide a cheaper alternative to more robust smart check-in products. For this reason, each kiosk will have a total budget of at most $100.

Table 10.1 Per-Kiosk Budget Breakdown

Subsystem	**Budget**
Kiosk peripherals	$30.00
Embedded device	$15.00
PCB, interconnects, and enclosure	$35.00
Power	$20.00
Total	$100.00

It is important to note that in the following estimated budget presented in **Table 10.2**, parts are included from multiple iterations of the prototyping and design process. The total price listed in the budget estimate includes prototyping and testing materials in addition to the final design. High-importance items such as the microcontroller and display have been allocated a larger portion of the budget than connectivity-oriented parts such as voltage regulators and jumper wires.

Table 10.2 Estimated Budget

Component	**Quantity**	**Unit Cost Estimate**	**Total Cost Estimate**
Tag Reader	2	$12.00	$24.00
Tags	30	$0.50	$15.00
Display	1	$20.00	$20.00
LEDs	1	$9.00	$9.00

Microcontroller	3	$5.00	$15.00
PCB and Testing Components	1	$20.00	$20.00
Jumpers	1	$7.00	$7.00
Breadboard	1	$5.00	$5.00
Enclosure Materials	1	$19.00	$19.00
Battery	2	$17.00	$17.00
Total			$151.00

10.3 Project Milestones

The SCAN team was initially formed over the summer to begin preparation and planning for Senior Design I. At the beginning of the fall semester, the team brainstormed and finalized a project idea, and a set of milestones and objectives was planned for the Fall and Spring semesters to ensure that the project remains on track. In addition to **Tables 10.3** and **10.4**, the team uses a Gantt chart that is automatically updated with newly created issues on the project's GitHub repository.

Table 10.3 Senior Design 1 Project Documentation Milestones

Task	**Start Date**	**End/Due Date**	**Status**
Brainstorm projects and ideas	8/18/2024	8/25/2024	Completed
Select the project and define the scope	8/30/2024	9/6/2024	Completed
Submit the initial divide-and-conquer 10-page document (Project proposal, objectives, administrative content)	8/30/2024	9/6/2024	Completed
Attend Divide and Conquer revision meeting with Dr. Wei	9/9/2024	9/11/2024	Completed
Upload revised D&C report onto the group website	9/20/2024	9/27/2024	Completed
Reach 30-page document milestone (Project objectives, initial technology research, hardware diagrams)	8/30/2024	9/30/2024	In progress

Reach 45-page document milestone (Technology research, component selection, system requirements)	8/30/2024	10/12/2024	In progress
Submit the 60-page document draft (Design constraints, ChatGPT comparison)	8/30/2024	10/25/2024	In progress
Attend the 60-page document meeting and receive feedback from reviewers	10/28/2024	10/30/2024	Not started
Upload the revised 60-page report to the project website	11/1/2024	11/8/2024	Not started
Upload draft SD1 final report and mini demo video to website	11/11/20243	11/18/2024	Not started
Submit SD1 final report on webcourses	11/19/2024	11/26/2024	Not started

Table 10.4 Senior Design 1 Project Design Milestones

Task	**Start Date**	**Expected End Date**	**Status**
Initial system design and breadboarding	10/1/2024	10/21/2024	Not started
Initial system testing and revision	10/21/2024	10/28/2024	Not started
Initial database and website design	10/21/2024	11/4/2024	Not started
First integration of prototyped hardware and software	11/4/2024	11/15/2024	Not started
PCB design and final parts ordering	10/28/2024	11/15/2024	Not started

Table 10.5 Senior Design 2 Project Milestones

Task	**Start Date**	**Expected End Date**	**Status**
Testing of PCB assembly	1/6/2025	1/13/2025	Not Started
Software/hardware integration with server application (Database and frontend)	1/13/2025	2/10/2025	Not Started
Design revisions based on testing (if necessary)	2/10/2025	2/17/2025	Not Started
Mock project demonstration and presentation	3/24/2025	3/31/2025	Not Started
Final testing and documentation	3/31/2025	4/7/2025	Not Started
Final Report Submission	TBD	TBD	Not Started
Final Presentation	TBD	TBD	Not Started

10.4 Work Distribution

The following tables present the workload distribution between the three group members. While each table lists the specific responsibilities of each member, there is communication and cooperation at each stage of the design process to ensure that each subsystem is seamlessly integrated into the SCAN system.

Table 10.6 Work Distribution

Computer Engineering	**Responsibilities**
Cory Brynds	Project Lead
	User Database Implementation
	Embedded Software for LCD and NFC
	Mechanical Design of Kiosk
Computer Engineering	**Responsibilities**
	Embedded software for proximity sensor, Wi-Fi interface, and SD card

DeAndre Hendrix	Schematic/PCB layout
	User Database Implementation
Electrical Engineering	**Responsibilities**
Jonah Sprandel	Schematic/PCB layout
	Firmware Task Management/RT Control
	Administrative Documentation
	Embedded software for low-power mode and LEDs

10.5 Declaration

We hereby declare that we have not copied directly from Large Language Models (LLMs). We have utilized LLM resources such as ChatGPT and Perplexity for drafting, outlining, comparing, summarizing, and proofreading.