CMSC 25-316

Financial Receipt Capture and Analysis System

Preliminary Design Report

Prepared for

Mehul Garnara

Capital One

By

Will Southerland , Josh Tarongoy , Lindsey Marandina , Joshua Whitchurch

Under the supervision of

Thang Dinh

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Executive Summary

Project Overview

This project aims to develop an application that streamlines the process of capturing and managing hard copy credit card transaction receipts through capture, storage, and analysis of physical receipts. The system will allow users to:
- Search receipts by date, vendor, category, and other criteria.
- Analyze spending across different periods and categories.
- Identify spending trends to gain valuable insights.
- Utilize a categorization system to enhance financial tracking and analysis.

Project Goals/Objectives

To minimize costs and maximize scalability, the project will utilize open-source software. Key design objectives are:
- Receipt capture and storage by digitizing and storing physical receipts.
- Categorization by automatically and/or manually classifying receipts based on common spending categories.
- Search functionality that allows users to locate specific receipts efficiently.
- Spending analysis through comparing and analyzing spending over time and across spending categories.
- Trend Identification through identifying spending patterns to inform financial decisions.

Design Specifications

The system will meet the following specifications:

- Image processing: Accepting and processing receipts in various formats (e.g., JPG, PNG).
- OCR accuracy: Ensuring accurate extraction of text from receipts using OCR technology.
- Key information extraction: Identifying critical data points from receipts (e.g., date, vendor, amount).
- Categorization: Providing both automatic and/or manual categorization options.
- Search capabilities: Enabling efficient searching based on multiple criteria.
- Analysis tools: Offering tools for analyzing spending trends and patterns.
- Open-source integration: Incorporating at least one open-source project.

Current Progress and Future Plans

       The team has begun the construction of both the front end and back end for the receipt analysis software. Research was done into differing OCR softwares, and it was decided to use Tesseract, an open source OCR tool. A name entity recognition (NER) model was used to classify important entities from a test set, but a low success rate has led the team to look more into Tesseract's machine learning algorithms as well as Textract, an OCR service provided by AWS. On the front end, the team has made progress on a number of analysis tools for the consumer, using fake data as a representation of what the front end would look like. Further work is being done to introduce more in-depth analysis, including options for time splitting and search functionality for the receipts.

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Section A. Problem Statement

Many people face challenges keeping track of spending and are often unaware of how much they are actually spending versus how much they think they're spending. With many often spending more than what they can afford leading to credit card bills racking up. The manual processes of storing, searching, and analyzing physical receipts is time-consuming, inefficient, and prone to errors. Financial receipts are also often lost, disorganized, or difficult to analyze, making it challenging for individuals to track their spending and make informed financial decisions. This project will allow individuals to keep track of their spending by digitally uploading receipts so they are able to make informed financial decisions. It will also allow individuals to know just exactly how much they are spending and where they are spending it.

Capital One is an American financial services company known for their innovative approach to banking and credit card services. Capital One offers many different credit cards to fit the needs of many different customers. The company follows a data-driven approach with a "reverence for insights derived from data" (Bean, 2024) and "adopted a "You Build, Your Data" approach to give our data users greater ownership and accountability over their data" (Lebonitte, 2024).

The problem has currently been addressed through applications that allow users to track their expenses through connecting their accounts to track spending and income. One well known application is Rocket Money. Rocket Money "is a personal finance app…that helps you manage your money, lower your bills, and even cancel unwanted subscriptions" (Hamilton, 2022). Other banking companies, like Bank of America, have similar expense and spending insights. Bank of America has "Category-specific interactive charts and longer-term spending trends help you identify where you are frequently over or under budget" (*Use the spending & budgeting tool to get a clear view of your finances*). One study found that "financial literacy helps people make informed and responsible financial decisions, boosting financial stability and reducing financial worries" (Bai, 2023).

Section B. Engineering Design Requirements

B.1 Project Goals (i.e. Client Needs)

The goals and design objectives presented in this section were constructed with the help of mentors from Capital in order to meet their expectations by the end of the year.

- Digitally store receipts (physical and digital)
- Ability to search through receipts efficiently
- Ability to query receipts at the item level
- Insights and trending for the consumer spending

B.2 Design Objectives

- The design will utilize AWS and other appropriate technologies to store receipt and receipt metadata
- The design will allow for the capture of both digital and physical receipts
- The design will allow for the categorization of receipts by receipt type (eg Gas, Groceries, Candles)
- The design will include functionality for searching
- The design will provide insights and trending for consumers

B.3 Design Specifications and Constraints

Some of the design specifications for the project are as follows:

- Design must have the ability to receive images (jpg, png, etc.) of receipts for extraction. (Functional constraint)
- Design must have the ability to process receipts of varying layouts and formats. (Functional constraint)
- Design must have accurate OCR results when extracting text from receipts (Functional constraint)
- Design must have the ability to extract key information (Functional constraint) – examples include date, vendor, total, etc.
- Design must be able to automatically and/or manually categorize receipts for organization (Functional constraint) – Categorical examples include grocery, shopping, entertainment, medical, utilities, dining out, transportation, travel, etc.
- Design must have the ability to search for receipts (Functional constraint) – examples include search by date, vendor, cost, category, etc.
- Design must analyze spending based on time periods and categories. (Functional constraint)
- Design must show trend analysis to identify spending patterns. (Functional constraint)
- Design must include at least one open-source project (Cost constraint)
- Design must be cyber secure, in order to provide protection for users

B.4 Codes and Standards

       As of now, there are no notable codes or standards. Current project milestones focus on the creation of the database, front end, and back end. As the team shifts focus towards cyber security more research will be done into what standards are applicable to the design.

Section C. Scope of Work

C.1 Deliverables

As of writing, the final deliverable is a functioning web page hosting the analyzer that consumers are able to access, even if locally. This includes integration into the back end so that users may see their receipts and visualization of their spending is provided. Code and research will be posted into the GitHub repository of the team.

C.2 Milestones

Figure 1.1

Project Roadmap

Semester 1: MVP	Milestone 1: Convert receipts image into metadata, create data model, wiremock UX flow.
	Milestone 2: Search functionality using various search criteria. For example: By category, by date-range.
Semester 2: Refinement	Milestone 3: Insight features includes spending trends based on categories and identify deals from similar purchases across other consumes.
	Milestone 4: Integrate features on web interface for Upload, Search, and Insight features.
Final: Demo!	Present / demo and celebrate your accomplishment!

Project milestones are divided into four larger milestones, intended to facilitate the design process. As of writing, Milestone 1 is still in progress as the team works to design an OCR model capable of processing receipts accurately with a low computational and financial cost.

C.3 Resources

- ExpressExpense Receipt Database: Five-thousand US receipts of various types for training and testing purposes
- AWS Lambda: API calls to access the database.
- AWS DynamoDB: NoSQL database to store receipt information for the users
- AWS S3: Capturing images is not possible within Dynamo, so an additional storage system is necessary
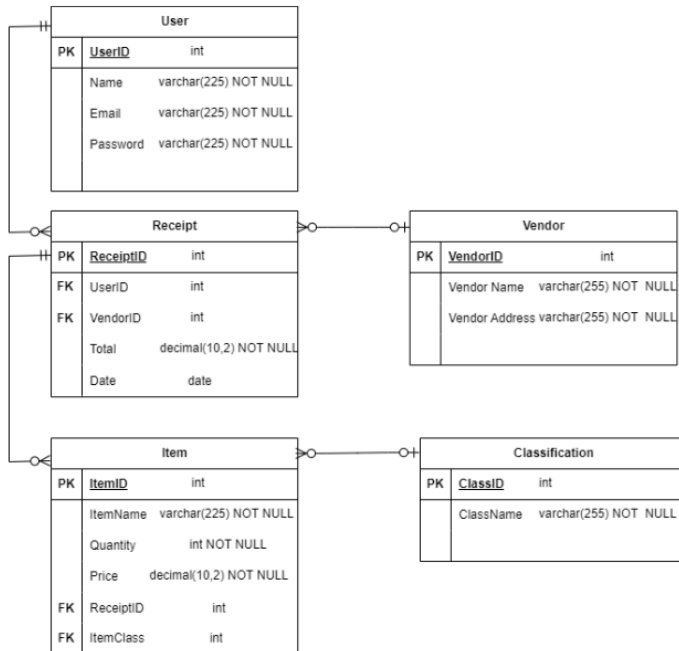
Section D. Concept Generation

Figure 2.1

Figure 2.2

Figure 2.1 depicts a relational table between various entities within the environment of the team. Though the team has shifted away from a relational database and towards NoSQL, the diagram demonstrates the thought process of what will need to be accessible for users. Figure 2.2 depicts a mock user interface including a dashboard, navigation, various ways to view and analyze the receipts a user uploads, and a nearby deals tab.

Section E. Concept Evaluation and Selection

The use of a systematic decision-making process, such as a Decision Matrix or Pugh Matrix, is often valuable for evaluating and comparing design concepts. However, in this context, the workflow and project dynamics involve weekly meetings and close communication with the sponsors. This iterative collaboration allows for continuous refinement of design concepts based on direct feedback.

Through this approach, design objectives and constraints are addressed dynamically, ensuring alignment with the client's preferences and priorities. Consequently, the structured use of a Decision Matrix is deemed unnecessary. Instead, frequent discussions enable the integration of client input and progressive adjustments to the design, achieving the desired outcomes efficiently and effectively while maintaining flexibility in the decision-making process.

Section F. Design Methodology

F.1 Sprint Validation

The development process follows a sprint-based approach managed in Trello. Each sprint consists of specific tasks that are worked on collaboratively by the team. The following steps outline the sprint validation process:

1. **Sprint Initiation:** Tasks for each sprint are defined and tracked using Trello. Tasks include design improvements, functionality development, and testing milestones.
2. **Progress Monitoring:** Team members work on sprint tasks, bringing up challenges or blockers during group discussions or meetings with sponsors.
3. **Demo and Review:** Upon completing a sprint, the outcomes are demoed to the team for internal validation. After team approval, the results are presented to the sponsors for feedback and further validation.

F.2 Testing Methods

Testing is an integral part of the development process to ensure functionality, accuracy, and security. The following methods are used to validate the system:

- **Database Testing:** A labeled dataset of receipts is used to test the analyzer's ability to extract and organize relevant data accurately. The testing involves a variety of receipt formats to account for variability.
- **Edge Case Testing:** The system is tested against unusual or unexpected input scenarios to ensure robust performance. Examples include malformed receipts, incomplete data, and corrupted files.
- **Security Testing:** The website's security is evaluated through targeted testing, including:
    - Attempting to inject malicious inputs into the database.
    - Testing for vulnerabilities in data storage and retrieval to prevent data breaches.
    - Ensuring proper encryption and authentication protocols are in place.

F.3 Validation Procedure

Validation is an ongoing process, with key steps at both the team and sponsor levels:

1. **Team Validation:** Each sprint deliverable is reviewed and approved by the team after internal testing and demos.
2. **Sponsor Validation:** Validated deliverables are presented to the sponsors for feedback and approval.
3. **Final System Validation:** Once the receipt analyzer is deployed online, final validation will include:
    - Comprehensive testing of all features.
    - Security testing to safeguard user data.
    - Functional testing with real-world receipts.

The validation procedure ensures the final design meets client expectations and adheres to all specified objectives.

Section G. Results and Design Details

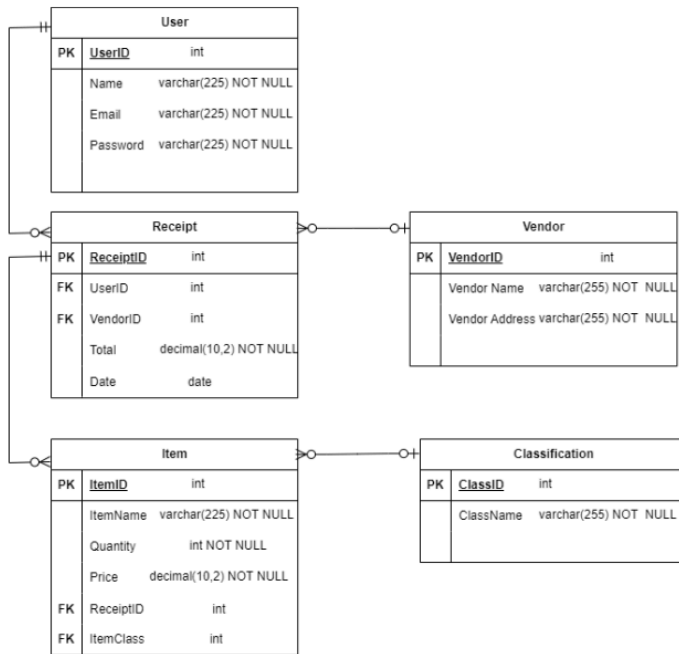## G.1 Modeling Results

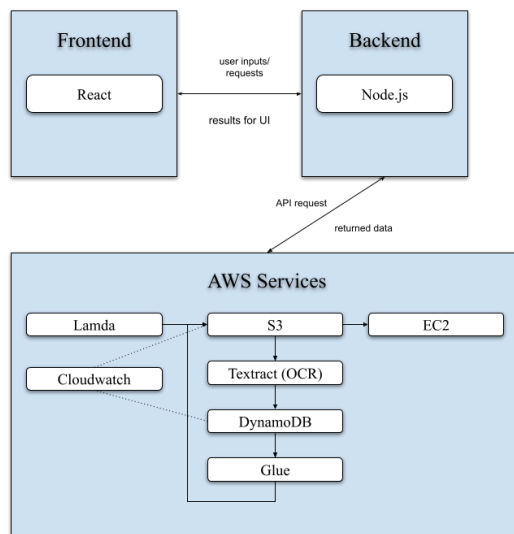Figure 3.1 Relational Table

Figure 3.2 DataFlow

Figure 3.3 UI Mock
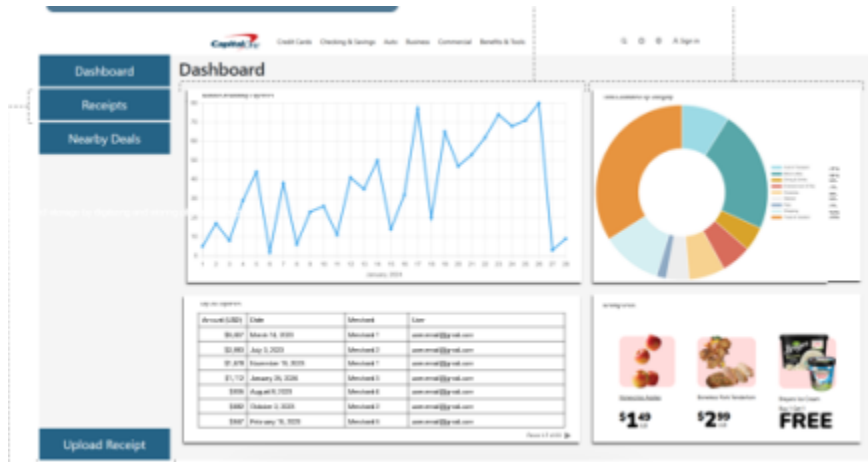
G.2 Testing Results (Informal)

Figure 3.4 Current UI Model
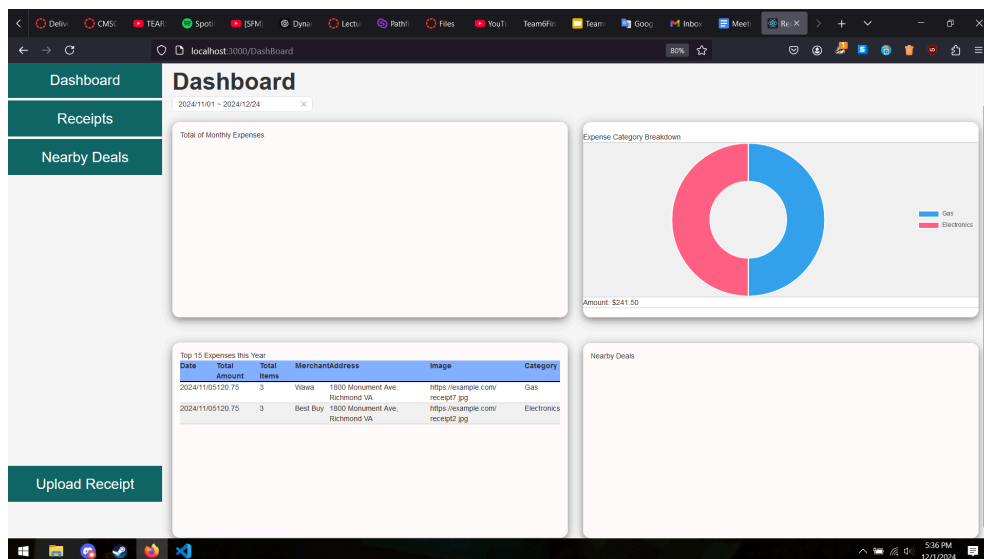
Testing using the original OCR model from Tesseract along with a custom NER model proved ineffective in accurately extracting relevant information from testing receipts. Research is being conducted on machine learning opportunities within Tesseract's model, though this appears to be quite time intensive. Currently, the user interface has some functionality, and can display some relevant information from the database, demonstrating communication between front end and back end.

G.3. Validation Report

Currently, the project is within Milestone 1. All code has been validated during weekly meetings, and Capital One Sponsor continues to help the team towards success. Current goals include utilizing Amazon's Textract to provide real time data for deeper visualization, with plans to move back into Tesseract once the database is more complete. Integration with a Tesseract machine Learning model will then take place to lower the operating costs of the analyzer.

Section H. Societal Impacts of Design

H.1. Ethical Considerations

As the team works to complete the project, ethics and consumer safety must be considered. Personal information and spending habits, as well as geolocation, are all being recorded into the database to provide the metrics back to the user. To bad faith actors, such data could be seen as valuable, and as such it is paramount to ensure that users as well as the client of the project are well protected and secured.

Section I. Cost Analysis

- ExpressExpense Database: Estimated $250 (not yet approved)\
- AWS Services Rendered: $0. As the team continues to utilize the services provided by AWS, this is expected to rise. As of December, the team is still within the free thresholds for all services while utilizing mock data

Section J. Conclusions and Recommendations

The receipt analyzer project represents a focused effort to develop a robust system for extracting, organizing, and securely storing receipt data. The design team employed an iterative engineering design process to refine the concept and achieve key milestones, balancing technical challenges with client feedback.

The initial project goals were to:

1. Provide an easy-to-use interface for uploading receipts.
2. Accurately extract key data, including item names, prices, and vendors.
3. Ensure secure data storage to protect sensitive information.

To date, the team has successfully:

- Designed a preliminary database schema to manage receipt data efficiently.
- Developed UI mockups showcasing core features of the system.
- Conducted initial testing with a labeled dataset of receipts, identifying areas for improvement.

Key obstacles encountered included:

- Variability in receipt formats, which necessitated iterative refinements to the data extraction algorithm.
- Combatting cost with open source software, as oftentimes these softwares lack some functionality

While significant progress has been made, the project remains in its early stages. Several opportunities for further advancement have been identified:

- Improve data extraction accuracy by training on a larger, more diverse set of receipts.
- Incorporate machine learning models for enhanced recognition of non-standard layouts.
- Increase the scope of edge case testing to malformed receipts.
- Perform stress testing on the system to ensure scalability for larger datasets.
- Transition from mockups to a functional interface with live data integration.
- Conduct usability testing with target users to identify areas for improvement.

Appendix 1: Project Timeline

	Receipt Analyzer Time Chart								
Milestone 1	██████████████								
Milestone 2									
Milestone 3									
Milestone 4									
	September	October	November	December	January	February	March	April	May

Appendix 2: Team Contract (i.e. Team Organization)

Step 1: Get to Know One Another. Gather Basic Information.

Task: This initial time together is important to form a strong team dynamic and get to know each other more as people outside of class time. Consider ways to develop positive working relationships with others, while remaining open and personal. Learn each other's strengths and discuss good/bad team experiences. This is also a good opportunity to start to better understand each other's communication and working styles.

Team Member Name	Strengths each member bring to the group	Other Info	Contact Info
Will Southerland	Organized, excellent communicator, punctual	I'm open to new perspectives and ideas, and work best with organization and a deadline.	southerlandw@vcu.edu
Josh Tarongoy	Early starter, worker, I do things.	Communicates with others to ensure everyone's on the same page.	tarongoyj@vcu.edu
Joshua Whitchurch	Hard-worker, punctual.	I love to find creative solutions to problems and value communication with teams.	whitchurchjm@vcu.edu
Lindsey Marandina	Organized, Communicative	Open to any ideas	marandinalc@vcu.edu

Other Stakeholders	Notes	Contact Info
Thang Dinh (Faculty Sponsor)		*tndinh@vcu.edu*
Mehul Garnara (Capital One Sponsor)		mehul.garnara@capitalone.com

Step 2: Team Culture. Clarify the Group's Purpose and Culture Goals.

Task: Discuss how each team member wants to be treated to encourage them to make valuable contributions to the group and how each team member would like to feel recognized for their efforts. Discuss how the team will foster an environment where each team member feels they are accountable for their actions and the way they contribute to the project. These are your Culture Goals (left column). How do the students demonstrate these culture goals? These are your Actions (middle column). Finally, how do students deviate from the team's culture goals? What are ways that other team members can notice when that culture goal is no longer being honored in team dynamics? These are your Warning Signs (right column).

Resources: More information and an example Team Culture can be found in the Biodesign Student Guide "Intentional Teamwork" page (webpage | PDF)

Culture Goals	*Actions*	*Warning Signs*
Make sure every team member is aware of progress on the project	-Communicate when work is being done, either via our Discord server or email -Upload progress to our github repo	-Progress is not communicated -Repo is not updated clearly
Alert others about upcoming delays.	- A simple message telling the others about their schedule is enough. (I.e. Busy due to a club meeting, exam, etc.)	- Other members will question if you have done your part of the work.
Foster an environment where all ideas are valued	-Make sure team members who want to approach a problem their own way have the space to do so	-If you disagree with another team members approach, communicate it with respect and an open mind

Step 3: Time Commitments, Meeting Structure, and Communication

Task: Discuss the anticipated time commitments for the group project. Consider the following questions (don't answer these questions in the box below):

- What are reasonable time commitments for everyone to invest in this project?
- What other activities and commitments do group members have in their lives?
- How will we communicate with each other?
- When will we meet as a team? Where will we meet? How Often?
- Who will run the meetings? Will there be an assigned team leader or scribe? Does that position rotate or will the same person take on that role for the duration of the project?

Required: How often you will meet with your faculty advisor advisor, where you will meet, and how the meetings will be conducted. Who arranges these meetings?
See examples below.

Meeting Participants	Frequency Dates and Times / Locations	Meeting Goals Responsible Party
Students Only	Saturdays at 10 am, voice call on discord	Update group on day-to-day challenges and accomplishments, progress on the project, scheduling future meetings etc
Students + Faculty advisor	Fridays at 11 am on Slack and as needed	Update faculty advisor and get answers to our questions
Project Sponsor	Fridays at 11 am on Slack	Update our sponsor on progress, receive feedback, hear expectations

Step 4: Determine Individual Roles and Responsibilities

Task: As part of the Capstone Team experience, each member will take on a leadership role, ***in addition to*** contributing to the overall weekly action items for the project. Some common leadership roles for Capstone projects are listed below. Other roles may be assigned with approval of your faculty advisor as

deemed fit for the project. For the entirety of the project, you should communicate progress to your advisor specifically with regard to your role.

- **Before meeting with your team**, take some time to ask yourself: what is my "natural" role in this group (strengths)? How can I use this experience to help me grow and develop more?
- **As a group,** discuss the various tasks needed for the project and role preferences. Then assign roles in the table on the next page. Try to create a team dynamic that is fair and equitable, while promoting the strengths of each member.

Communication Leaders

Suggested: Assign a team member to be the primary contact <u>for the client/sponsor</u>. This person will schedule meetings, send updates, and ensure deliverables are met.

Suggested: Assign a team member to be the primary contact <u>for faculty advisor</u>. This person will schedule meetings, send updates, and ensure deliverables are met.

Common Leadership Roles for Capstone

1. **Project Manager:** Manages all tasks; develops overall schedule for project; writes agendas and runs meetings; reviews and monitors individual action items; creates an environment where team members are respected, take risks and feel safe expressing their ideas.
   Required: On Edusourced, under the Team tab, make sure that this student is assigned the Project Manager role. This is required so that Capstone program staff can easily identify a single contact person, especially for items like Purchasing and Receiving project supplies.
2. **Logistics Manager:** coordinates all internal and external interactions; leads in establishing contact within and outside of organization, following up on communication of commitments, obtaining information for the team; documents meeting minutes; manages facility and resource usage.
3. **Financial Manager:** researches/benchmarks technical purchases and acquisitions; conducts pricing analysis and budget justifications on proposed purchases; carries out team purchase requests; monitors team budget.
4. **Systems Engineer:** analyzes Client initial design specification and leads establishment of product specifications; monitors, coordinates and manages integration of subsystems in the prototype; develops and recommends system architecture and manages product interfaces.
5. **Test Engineer:** oversees experimental design, test plan, procedures and data analysis; acquires data acquisition equipment and any necessary software; establishes test protocols and schedules; oversees statistical analysis of results; leads presentation of experimental finding and resulting recommendations.
6. **Manufacturing Engineer:** coordinates all fabrication required to meet final prototype requirements; oversees that all engineering drawings meet the requirements of machine shop or vendor; reviews designs to ensure design for manufacturing; determines realistic timing for fabrication and quality; develops schedule for all manufacturing.

Team Member	Role(s)	Responsibilities
Will Southerland	Project Manager	- Facilitate communication between the group, advisors, and sponsor - Schedule meetings - Keep group members on task and make sure work is being accomplished on time
Lindsey Marandina	Logistics Manager	- Documents meetings and goals - Keeps track of upcoming meetings and tasks - Follow up with task progress
Joshua Whitchurch	Test Engineer	- Facilitate planning for sprints as they occur - Research necessary software, data mining algorithms, etc as needed and provide information to other team members
Josh Tarongoy	Systems Engineer	- Analyzes client initial design specification and comes up with product specifications for the team. - Manages internal subsystems in developing prototype - Develops system architecture and manages product interfaces.

Step 5: Agree to the above team contract

Team Member: Will Southerland   *Signature:* Will Southerland__

Team Member: Josh Tarongoy   *Signature:* ___*Josh Tarongoy*___

Team Member: Joshua Whitchurch   *Signature:* Joshua Whitchurch 09/03/24

Team Member: Lindsey Marandina   *Signature:* **Lindsey Marandina**

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