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Team: Ground Control

Project: Sherpa Drone

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Last Updated: November 1, 2014 9:52 PM

Table of Contents

Document Revision History

Revision Number	Revision Date	Description	Rationale
0.1	10/8/14	Initial version for Rough Draft	n/a
0.2	10/24/14	Peer Review version of draft	Included modifications from Chance's feedback before distributing to sponsor and peer review team.
1.0	11/1/14	Gate Review version	Incorporated feedback from Mr. O'Dell, and peer review team as well as performing polishing for whole document.

List of Figures

List of Tables

1. Product Concept

This section describes the function, use, and audience for the Sherpa Drone product. The Sherpa Drone will be an autonomous flying drone available to customers in a retail store to guide them to specified products by flying a route through the store that the customer can follow. It may also work in a warehouse, guiding workers to products in a similar manner.

1.1 Purpose and Use

The purpose of the Sherpa Drone is automated guidance through a retail or warehouse environment. Users will be able to interact with the Sherpa Drone through a kiosk interface. There they will be able to search for or specify a product to locate. The drone will launch from a base station adjacent to the kiosk and fly through the store, guiding the user to the location of their item. Once the drone has completed its guidance, it will return to the base station. At the station, it will either accept a new item to provide guidance to or charge itself while waiting on use.

1.2 Intended Audience

This product is intended for use in any kind of retail outlet or warehouse. Primary users will be customers (or employees in a warehouse) of the establishment. Secondary users will be the administrators who program in floor plans and supervise the drone activity. If commercially sold, the drone would be targeted at business establishments rather than individual users.

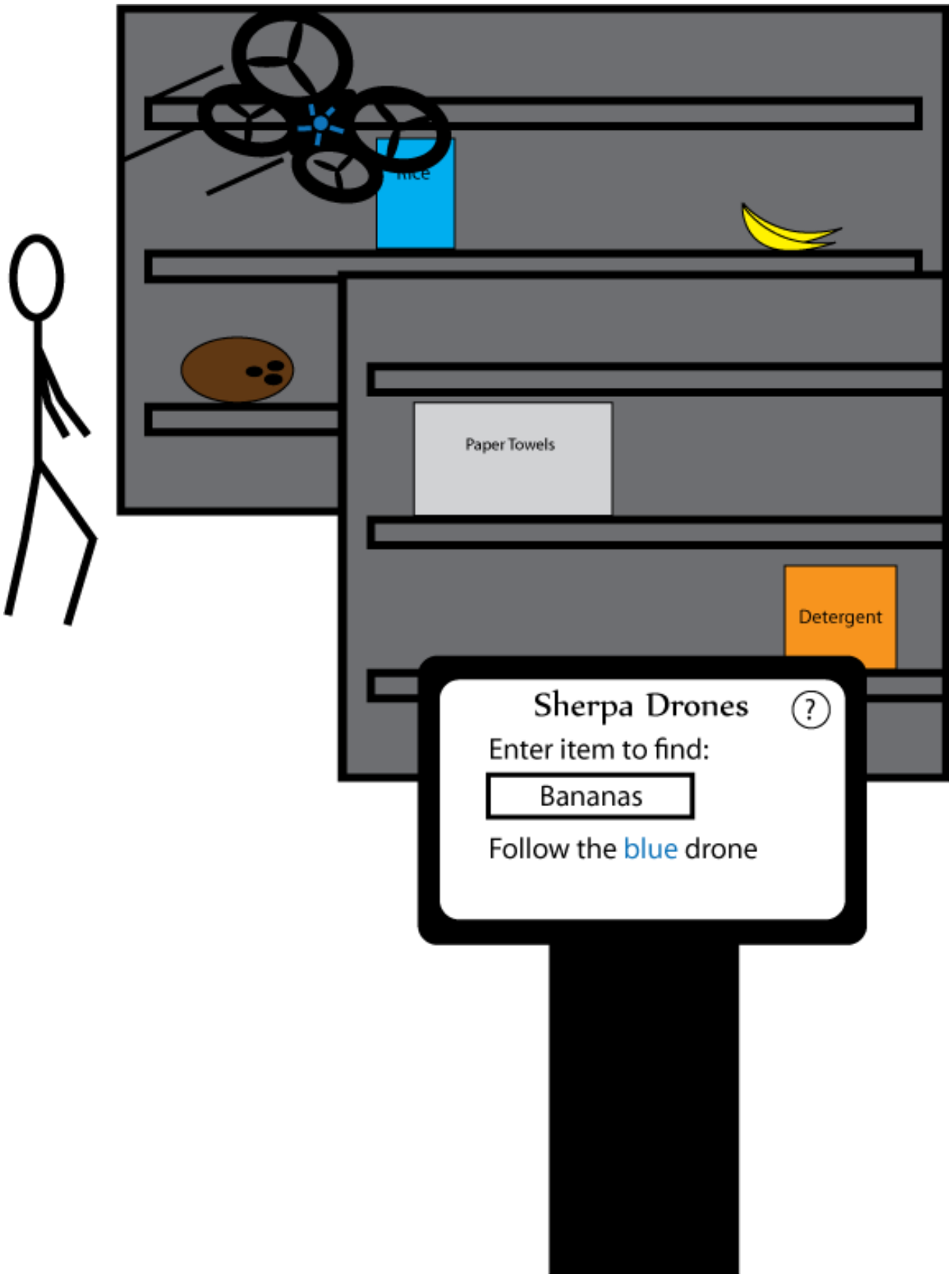

Figure 1-1 Product Concept

2. Product Description and Functional Overview

This section provides the reader with an overview of the Sherpa Drone. Defined here are the primary operations of the product, from the perspective of end users, maintainers and administrators. The key features and functions found in the product, as well as critical user interactions and user interfaces are described in detail.

2.1 Features and Functions

The Sherpa Drone will be a small aerial autonomous vehicle. It will communicate with nearby customers through a LED light and possibly a small speaker. In addition, the drone will have sensors that will allow it to detect the proximity of objects and its height above the floor. It will communicate to the kiosk over Bluetooth or another wireless standard. The kiosk will be built using a Raspberry Pi connected to a touch sensitive display. The base station shall include a place for the drone to land and recharge. The drone, the kiosk, and the base station will constitute a closed system sufficient to operate in the store.

The kiosk will allow customers to search for and select specific items in the store inventory. The items in the inventory will be stored on a database contained on the kiosk itself. The kiosk will provide the drone with a series of way points for navigation. The drone will launch from the base station and follow these way points thus leading the customer to the selected item. When the drone reaches the item, it will flash its LED light to alert the customer. After a short wait, the drone will return to its base station.

System administrators will be able to update the item database to add, delete, or modify inventory. This will allow the administrator to keep the system aware of what items are in the store and where they are located. These interactions will require the administrator to log in to a secure menu on the kiosk. This will prevent customers from modifying the store's information.

2.2 External Inputs and Outputs

Table 2-1 External Inputs and Outputs

Name	Type	Description	Use
Terminal	Input / Output Screen	The terminal will have the ability to access the database and send Bluetooth signals	Input: The terminal will allow the customer to select an item from the database. Output: The terminal will show the customer the items in the database.
Sensor	Input	The sensor will have the ability to detect the proximity of objects.	Input: The sensor will allow the drone to detect objects so it can avoid them.
Light/Speaker	Output	The light/speaker will be located on the drone.	Output: The LED light and speaker will allow the drone to be seen and heard.

2.3 Product Interfaces

This is the Home Screen shown when a customer or administrator first approaches the kiosk. Here are the main options, Search for an Item, Search By Category, and Administrator Login.

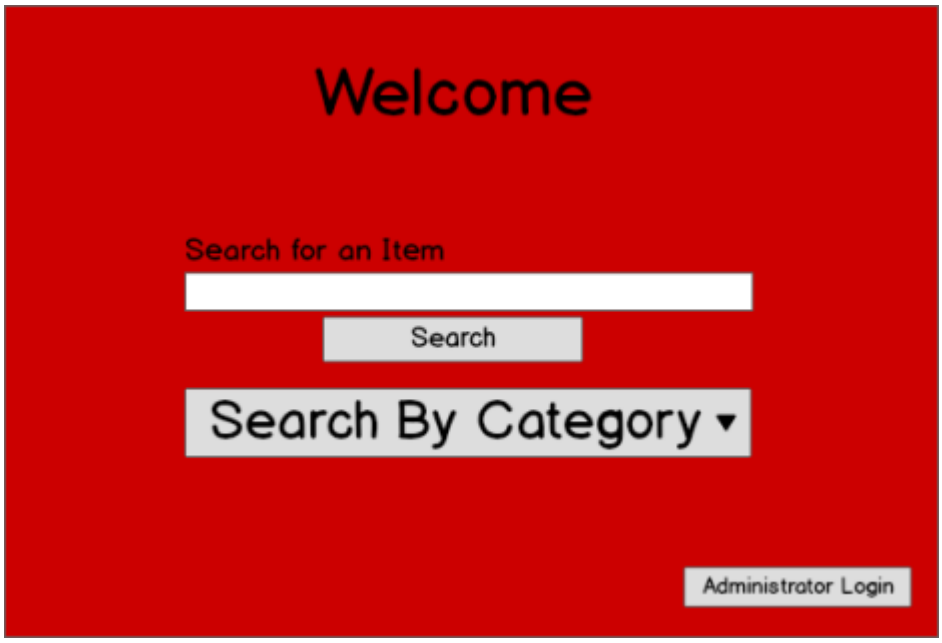

Figure 2-1 Home Screen

If the customer selects Search By Category they are taken to this screen where they can then choose the category. The sample categories are like those found in a university book store.

Figure 2-2 Search by Category

Once the customer selects a category they are taken to this screen which provides them with a list of the items in that category. Here they can select an item or try searching again by using either the Search for an Item input or Search By Category.

Figure 2-3 Category Results

This shows the input when typing a particular item into the Search for an Item input box. The onscreen keyboard will appear and accept input from the touch screen.

Figure 2-4 Search for an Item

This is the Results page for when a particular item is searched for. It shows any items that match the name that the customer entered in the system and allows them to be selected.

Figure 2-5 Search Results

This shows the item details for a particular item in the store. Here the name of the item and additional information such as the price is displayed along with the Find This Item button and a link back to the Home Page.

Figure 2-6 Item Page

This shows the screen if the Administrator Login button on the Home Screen is pushed. It requires a password to access the administrator console and also features a link back to the Home Page.

Figure 2-7 Admin Login Page

This shows the options of the Admin Console including Set Up Store, Update Store, Add Item, and Update Item. It also includes a link to Log Off which will return the administrator to the Home Page.

Figure 2-8 Admin Console

This shows the dialog for Set Up Store and Update Store. The administrator can control the locations of aisles, tables, and pillars in the store so that the system knows where the item locations are in the physical store.

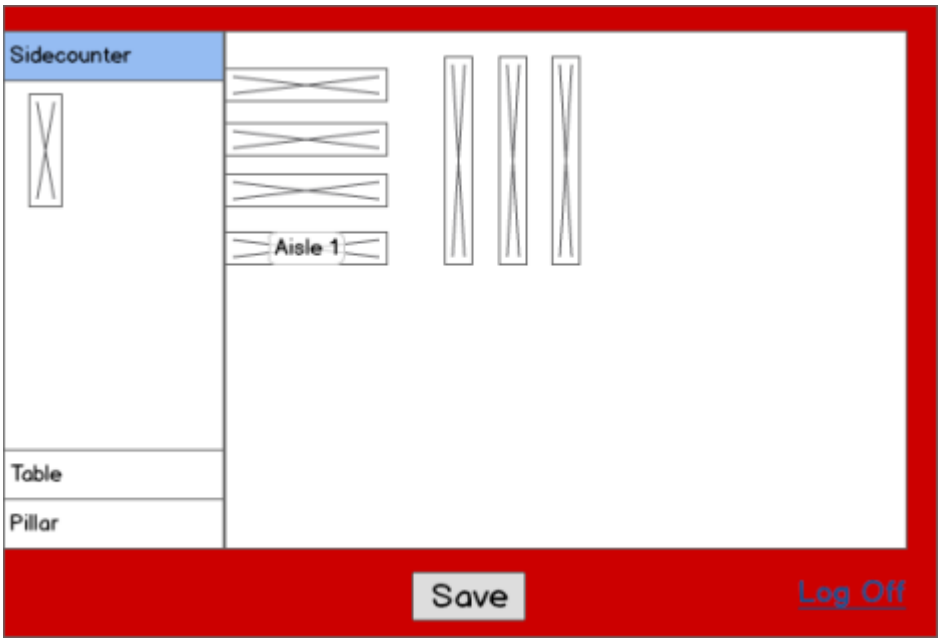

Figure 2-9 Update/Set Up Store

This shows the dialog when Add Item or Update Item is pressed. It allows the administrator to change the name, location, and details of the item. They have an option to Save the item as well as one to Remove.

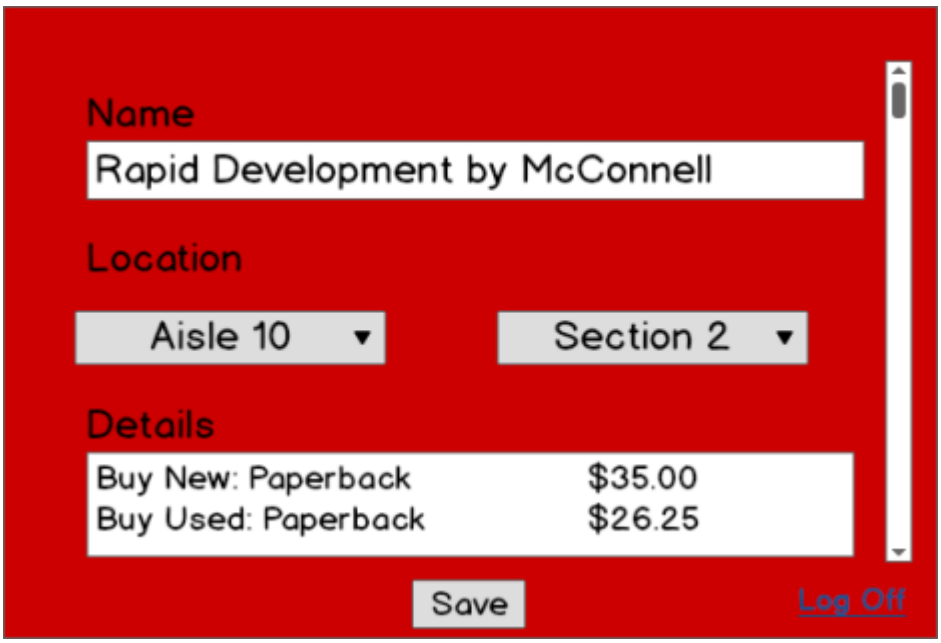

Figure 2-10 Add/Update Item

3. Customer Requirements

This section includes all of the end user functionality of our project. These requirements have been generated through the initial project description and the Ground Control team with input from the sponsor Paul Beaulieu the Store Director of the UT Arlington Bookstore. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

3.1 Search By Name

3.1.1 Description: The system shall allow a customer to type in the name of an item to search for at the kiosk.

3.1.2 Source: Ground Control

3.1.3 Constraints: None

3.1.4 Standards: SQL is the database standard.

3.1.5 Priority: 1 - Critical

3.2 Auto-Fill Search Bar

3.2.1 Description: The system shall suggest possible items to the customer as the customer types into the search bar at the kiosk.

3.2.2 Source: Paul Beaulieu (Sponsor)

3.2.3 Constraints: Latency in the database during search

3.2.4 Standards: SQL is the database standard.

3.2.5 Priority: 3 - Moderate

3.3 Search By Category

3.3.1 Description: The system shall allow a customer to select an item from the search list based on category at the kiosk. This will provide them with a list of all items in the store in that category that they can browse to select.

3.3.2 Source: Ground Control

3.3.3 Constraints: None

3.3.4 Standards: SQL is the database standard.

3.3.5 Priority: 2 - High

3.4 Follow Drone

3.4.1 Description: The system shall allow a customer to follow a drone around the store towards the desired item location. The drone must fly at a reasonable pace and travel a path that the customer can follow without difficulty.

3.4.2 Source: Ground Control and Paul Beaulieu (Sponsor)

3.4.3 Constraints: None

3.4.4 Standards: None

3.4.5 Priority: 1 - Critical

3.5 Stay with Customer

3.5.1 Description: The drone will match pace with the customer, slowing as necessary. If the customer falls behind, the drone must stop to wait. The drone must wait for the customer until the customer approaches again or thirty seconds have passed when the customer will be informed to start moving and if an additional fifteen seconds pass the system will cancel the search.

3.5.2 Source: Ground Control

3.5.3 Constraints: Drone must navigate against indoor air currents.

3.5.4 Standards: None

3.5.5 Priority: 5 - Future

3.6 Open Administrator Console

3.6.1 Description: The system shall allow an administrator to log in, with a password, to a special menu at the kiosk in order to add, remove, and move items in the store.

3.6.2 Source: Ground Control

3.6.3 Constraints: None

3.6.4 Standards: Protection of any passwords through hashing and/or encryption.

3.6.5 Priority: 1 - Critical

3.7 Manage Items in Inventory

3.7.1 Description: The system shall allow an administrator to add and modify items to the store with their name, category, and location at the kiosk.

3.7.2 Source: Ground Control and Paul Beaulieu (Sponsor)

3.7.3 Constraints: None

3.7.4 Standards: Location will be specified in terms of aisle, aisle side, and shelf.

3.7.5 Priority: 1 - Critical

3.8 Change Store Layout

3.8.1 Description: The system shall allow an administrator to change the layout of aisles and shelves within the store at the kiosk.

3.8.2 Source: Ground Control and Paul Beaulieu (Sponsor)

3.8.3 Constraints: None

3.8.4 Standards: None

3.8.5 Priority: 4 - Low

3.9 Track Inventory Changes

3.9.1 Description: The system shall allow an administrator to update the locations of items automatically using RFID or other inventory tracking technology.

3.9.2 Source: Paul Beaulieu (Sponsor)

3.9.3 Constraints: None

3.9.4 Standards: RFID or other tracking technology would be used.

3.9.5 Priority: 5 - Future

3.10 Make Drone Visible/Audible

3.10.1 Description: The drone will use an LED light and sound cues to announce its activity to surrounding customers including varied colors and sounds to distinguish which drone is helping which customer.

3.10.2 Source: Ground Control and Paul Beaulieu (Sponsor)

3.10.3 Constraints: None

3.10.4 Standards: None

3.10.5 Priority: 2 - High

3.11 Mobile App Access

3.11.1 Description: The system shall include a mobile app that allows customers to request the service of a drone while within the store.

3.11.2 Source: Ground Control

3.11.3 Constraints: None

3.11.4 Standards: None

3.11.5 Priority: 5 - Future

3.12 Service Drone

3.12.1 Description: The system shall allow an administrator or service personnel to perform maintenance on the drone, including charging the battery.

3.12.2 Source: Ground Control

3.12.3 Constraints: None

3.12.4 Standards: None

3.12.5 Priority: 1 – Critical

3.13 Drone automated charge

3.13.1 Description: The system will automatically charge the drone while it is not currently helping customers so that it will consistently have a full or near-full battery.

3.13.2 Source: Ground Control

3.13.3 Constraints: None

3.13.4 Standards: None

3.13.5 Priority: 3 - Moderate

4. Packaging Requirements

This section describes how the end system will be finalized, both with what the end user can see or cannot see and how the system will be shipped to customers. These requirements have been generated by the Ground Control team. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

4.1 Kiosk circuitry

4.1.1 Description: Kiosk enclosure will house all required circuitry, wires and components out of sight from the customer.

4.1.2 Source: Ground Control

4.1.3 Constraints: None

4.1.4 Standards: None

4.1.5 Priority: 4 – Low

4.2 Kiosk Power Source

4.2.1 Description: Kiosk will utilize a single external power cable. This cable will provide the correct DC power to components from an AC plug.

4.2.2 Source: Ground Control

4.2.3 Constraints: None

4.2.4 Standards: The cable will plug into a standard three prong wall outlet.

4.2.5 Priority: 5 – Future

4.3 Drone Circuitry

4.3.1 Description: Drone circuitry, including the control board, will be housed entirely out of sight of the customer.

4.3.2 Source: Ground Control

4.3.3 Constraints: None

4.3.4 Standards: None

4.3.5 Priority: 4 - Low

4.4 Drone Wires

4.4.1 Description: Drone will enclose most wires from customer vision. The only acceptable exposed wires are those to the motors and from the batteries.

4.4.2 Source: Ground Control

4.4.3 Constraints: None

4.4.4 Standards: None

4.4.5 Priority: 3 - Moderate

4.5 Drone Sensors

4.5.1 Description: The drone will include ultrasonic sensors for the detection of objects in its vicinity.

4.5.2 Source: Ground Control

4.5.3 Constraints: Ultrasonic sensors are not able to detect all possible hazards, such as a strong wind current.

4.5.4 Standards: None

4.5.5 Priority: 2 – High

4.6 System Installation

4.6.1 Description: The system designers will install the necessary product pieces at the retail environment.

4.6.2 Source: Ground Control

4.6.3 Constraints: None

4.6.4 Standards: None

4.6.5 Priority: 2 - High

5. Performance Requirements

Performance requirements for the Sherpa Drone will govern the response time, workload, and scalability. Features covered by performance include flight speed, flight pattern, wake time, travel time, battery life, and algorithm efficiency. These requirements have been generated by the Ground Control team and the sponsor Paul Beaulieu. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

5.1 Drone Response Time

5.1.1 Description: The drone will demonstrate responsive behavior through a light that turns on to indicate a message received. Messages from the base station to the drone will be delivered in an interval of under a second to allow prompt drone response.

5.1.2 Source: Ground Control

5.1.3 Constraints: Interference might cause the drone to lose connection to the base station or cause intermittent drone response.

5.1.4 Standards: None

5.1.5 Priority: 1 - Critical

5.2 Drone Wake Time

5.2.1 Description: The system will respond to a new item selection and wake the drone from a dormant state on the base station within fifteen seconds. Total time to calculate route, communicate with the drone, and begin travel must fall within this time.

5.2.2 Source: Ground Control

5.2.3 Constraints: The drone must have sufficient power to activate and initiate flight.

5.2.4 Standards: None

5.2.5 Priority: 3 - Moderate

5.3 Drone Travel Time

5.3.1 Description: The drone will complete its travel in a reasonable time span as appropriate to the size of the store and the maximum number of items allowed in a single trip.

5.3.2 Source: Ground Control

5.3.3 Constraints: Appropriate path time will vary depending on the layout of a store and the nature of the customer. The five minute limit assumes a relatively small store of 2000 square feet or less.

5.3.4 Standards: None

5.3.5 Priority: 1 - Critical

5.4 Return After Completion of Guidance

5.4.1 Description: The drone will return to the base station once travel has been executed for the customer. The drone will not be expected to wait on customer input. It may follow a path that is not appropriate to customers.

5.4.2 Source: Ground Control

5.4.3 Constraints: The drone must maintain enough battery power to return to the base station and follow a path that avoids collisions and hazards.

5.4.4 Standards: None

5.4.5 Priority: 2 - High

5.5 Base Landing Upon Completion

5.5.1 Description: The drone will execute a landing on the base station when guidance is complete. If the drone loses connectivity with the base station it will land in a designated safe zone in the store.

5.5.2 Source: Ground Control

5.5.3 Constraints: None

5.5.4 Standards: None

5.5.5 Priority: 1 - Critical

5.6 Base Station Charging

5.6.1 Description: The drone will execute a landing on the base station in the correct orientation to charge. If unable to charge, it will attempt a second landing. If this landing fails, the drone will land on the base station and notify the administrator.

5.6.2 Source: Ground Control

5.6.3 Constraints: The drone will only operate while battery life remaining is sufficient to complete another full trip. Charge time is dependent on customer frequency of use and amount of travel per trip.

5.6.4 Standards: None

5.6.5 Priority: 3 - Moderate

5.7 Max Items Per Trip

5.7.1 Description: The system will require that users specify no more than an allotted number of items per guidance operation. This number will be set by the administrator as part of system set up. Customers who wish to follow the drone to more items must return to the base station and complete another request. This limit will prevent a single customer request from monopolizing the use of the drone.

5.7.2 Source: Ground Control and Paul Beaulieu (Sponsor)

5.7.3 Constraints: None

5.7.4 Standards: None

5.7.5 Priority: 3 - Moderate

5.8 Minimum Operational Time

5.8.1 Description: The drone will be able to maintain operational flight time of at least thirty minutes from a fully charged state.

5.8.2 Source: Ground Control

5.8.3 Constraints: None

5.8.4 Standards: None

5.8.5 Priority: 2 - High

5.9 Number of Drones Supported

5.9.1 Description: The system will support the full operation of a single drone at a time. This drone will be responsible for guiding all customers.

5.9.2 Source: Ground Control

5.9.3 Constraints: None

5.9.4 Standards: None

5.9.5 Priority: 1 - Critical

5.10 Operational Range

5.10.1 Description: The drone will maintain operational contact with the base station at all times through a wireless signal. Any drone that loses contact with the base station through exceeding the operational range or interference will immediately land and power down in the designated safe zone.

5.10.2 Source: Ground Control

5.10.3 Constraints: Interference in the work environment might shorten the effective operational range. Environment features such as concrete walls may also shorten range.

5.10.4 Standards: None

5.10.5 Priority: 2 - High

6. Safety Requirements

These are the requirements specifying how the project must be constructed in order to maintain the safety of the customers and administrators using the product. These requirements have been generated by the Ground Control team and the sponsor Paul Beaulieu. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

6.1 Drone Rotors

6.1.1 Description: The drone rotors shall not harm a person or damage property.

6.1.2 Source: Ground Control

6.1.3 Constraints: The rotors must allow the drone to fly.

6.1.4 Standards: None

6.1.5 Priority: 1 - Critical

6.2 Drone Weight

6.2.1 Description: The system shall be light enough to avoid damage to person or property if it were to fail.

6.2.2 Source: Ground Control

6.2.3 Constraints: None

6.2.4 Standards: The system must not cause harm to anyone or thing when it fails.

6.2.5 Priority: 1 - Critical

6.3 Property Damage

6.3.1 Description: The system shall be designed so that it does not cause property damage. A collision with another object does not cause property damage.

6.3.2 Source: Ground Control

6.3.3 Constraints: None

6.3.4 Standards: None

6.3.5 Priority: 1 - Critical

6.4 Eye and Ear protection

6.4.1 Description: The system shall not cause damage to peoples' eyes through its LED or to peoples' ears through the speaker.

6.4.2 Source: Ground Control

6.4.3 Constraints: The system may not be operable by customers who have significant handicaps.

6.4.4 Standards: None

6.4.5 Priority: 1 - Critical

6.5 Drone Avoids Collisions

6.5.1 Description: The drone shall fly in such a manner to avoid pedestrians or objects.

6.5.2 Source: Ground Control

6.5.3 Constraints: The drone cannot dodge fast impacts such as if a customer’s child were to throw an object directly at it.

6.5.4 Standards: None

6.5.5 Priority: 1 - Critical

6.6 Altitude Control

6.6.1 Description: The system shall control its flight altitude to avoid hazards to customers or the environment. The flight altitude shall be set in the initial configuration of the product for a store. At this time the altitude shall be limited to a single level, i.e. a store with two floors would require separate drones for each floor.

6.6.2 Source: Ground Control

6.6.3 Constraints: None

6.6.4 Standards: None

6.6.5 Priority: 1 - Critical

6.7 Down Draft

6.7.1 Description: The system shall be designed so that rotor down draft does not cause damage or harm to person or property.

6.7.2 Source: Ground Control

6.7.3 Constraints: Drone rotors must produce enough thrust to lift the drone to the desired altitude.

6.7.4 Standards: None

6.7.5 Priority: 1 - Critical

6.8 Damage Avoidance

6.8.1 Description: The system shall be designed to fail safely. Damaged parts shall not pose an immediate hazard to person or property.

6.8.2 Source: Ground Control

6.8.3 Constraints: The system cannot control actions of customers or predict the result of malicious tampering.

6.8.4 Standards: None

6.8.5 Priority: 1 - Critical

7. Maintenance and Support Requirements

This section includes all requirements for both maintaining and supporting the Sherpa Drone after delivery. This will entail having both a User Manual and Troubleshooting Guide, as well as, how the maintenance team should handle software updates and hardware failure for both the drone and kiosk. These requirements have been generated by the Ground Control team. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

7.1 Source Code and Documentation Availability

7.1.1 Description: All source code developed by Ground Control will be made available to the maintenance team and future development teams. This source code will include adequate comments to document its functionality. The team will make available all schematics and technical documentation, including: System Requirements Specification, Architectural Design Specifications, Detailed Design Specifications, and System Test Plan.

7.1.2 Source: Ground Control

7.1.3 Constraints: None

7.1.4 Standards: JavaDoc for in code comments.

7.1.5 Priority: 3 - Moderate

7.2 User Manual

7.2.1 Description: The User Manual will contain instructions for operation of the system. It will instruct administrators in maintaining an accurate layout of their store and inventory of the items in the store. Another section will instruct customers on how to use the kiosk, which will be accessible from the kiosk itself.

7.2.2 Source: Ground Control

7.2.3 Constraints: Will only be available in English (US).

7.2.4 Standards: None

7.2.5 Priority: 3 - Moderate

7.3 Drone Maintenance

7.3.1 Description: Standard maintenance of the drone, such as checking for damaged parts, will be included in the User Manual. The Ground Control team will train technicians to take over maintaining the system after completion of the project. If a software update is needed for the drone, the trained technicians will complete installation.

7.3.2 Source: Ground Control

7.3.3 Constraints: None

7.3.4 Standards: None

7.3.5 Priority: 4 - Low

7.4 Kiosk Maintenance

7.4.1 Description: Standard maintenance of kiosk will be included in User Manual. The Ground Control team will train technicians to take over maintaining the system after completion of the project. For software updates, administrators will be able to download the update onto a flash drive and install it on the kiosk.

7.4.2 Source: Ground Control

7.4.3 Constraints: None

7.4.4 Standards: None

7.4.5 Priority: 4 - Low

7.5 Troubleshooting Guide

7.5.1 Description: The troubleshooting guide will include solutions to commonly detected problems discovered during system testing and from users of the Sherpa Drone.

7.5.2 Source: Ground Control

7.5.3 Constraints: The troubleshooting guide cannot include instructions for all possible issues with the product.

7.5.4 Standards: None

7.5.5 Priority: 4 - Low

8. Other Requirements

There are a few small additional requirements about how the product will be delivered to the final customer. The Sherpa Drone is intended to be operated by the customer without any input from the original programmers. To this end there are some set up steps that must be preformed to deploy the product in a particular store. These requirements are ranked by numbers 1 through 5 with 1 being highest priority. The number 5 low priority requirements will not be implemented and are considered as future improvements to the system.

8.1 Configuration of Store

8.1.1 Description: The system will allow the installation team to input the layout of the store into its memory. This will include where the aisles and other locations (tables, racks, etc.) where items are located in the store.

8.1.2 Source: Ground Control

8.1.3 Constraints: The system can accept only one layout. Additional layout changes would require the input of the developers.

8.1.4 Standards: None

8.1.5 Priority: 2 - High

8.2 Data Storage

8.3.1 Description: The system will store inventory information in a database. This database will include the location data necessary for drone path-finding. It will also include category and subcategory of each item to assist in user searches.

8.3.2 Source: Ground Control

8.3.3 Constraints: None

8.3.4 Standards: The database will use a SQL distribution for storage.

8.3.5 Priority: 2 – High

8.3 Protected Administrator Console

8.3.1 Description: The system will hide the administrator console from access by the customer by using a special code or sequence to bring up the log in page.

8.3.2 Source: Ground Control

8.3.3 Constraints: None

8.3.4 Standards: None

8.3.5 Priority: 5 – Future

9. Acceptance Criteria

While it is understood both by Ground Control and the sponsor, Paul Beaulieu, that the version of the Sherpa Drone currently under development shall be a proof of concept, the prototype must demonstrate key functionality for proof of concept. These acceptance criteria shall be tested in a mock store layout consisting of aisles with items marked visibly at their appropriate locations. The parts that must be demonstrated shall be demonstrated through a recorded session in this mock store. We have not included "4 - Low" or "5 - Future" requirements in this section as they will not be verified for acceptance of the product.

9.1 Sample store item lookup

9.1.1 Requirement(s) addressed: Requirement 3.1 Search by Name: the system shall allow an item to be searched by name.
Requirement 3.4 Follow Drone: the drone shall lead a customer through the store.
Requirement 3.10 Make Drone Visible/Audible: the drone shall appear visible/audible through a light/sound.
Requirement 5.9 Number of Drones Supported: the system shall consist of only one drone.

9.1.1 Verification Procedure: System testers will allow a sample customer to approach the kiosk, enter an item by name to find, and then follow the single launched drone, which is obvious through visual/audible cues, to the item they entered in the kiosk.

9.2 Search auto-fill

9.2.1 Requirement(s) addressed: Requirement 3.2 Auto-Fill Search Bar: the system shall automatically fill the search bar with suggested items.

9.2.2 Verification Procedure: System testers will start to enter an item into the kiosk and will then observe if it suggests the item they were searching for after only entering two to three letters.

9.3 Search by category

9.3.1 Requirement(s) addressed: Requirement 3.3 Search by Category: the system shall allow an item to be searched by category.

9.3.2 Verification Procedure: System testers will allow a sample customer to approach the kiosk, enter an item by category to find, and then follow the launched drone to the item they selected in the kiosk.

9.4 Add item to store

9.4.1 Requirement(s) addressed: Requirement 3.6 Open Administrator Console: the system shall allow an administrator to open a console to control the drone.
Requirement 3.7 Modify Items in Inventory: the system shall allow an administrator to add and modify items in the store.

9.4.2 Verification Procedure: System testers will allow a sample administrator to approach the kiosk and log into the administrator's console. They will then add an item to the store using the menu options in the console using an items name, category, and location.

9.5 Allow service of drone

9.5.1 Requirement(s) addressed: Requirement 3.12 Service Drone: the system shall allow an administrator to access the drone and service it.

9.5.2 Verification Procedure: System testers will allow a sample administrator to approach the drone and open its base station in order to service the drone.

9.6 Drone returns to base station

9.6.1 Requirement(s) addressed: Requirement 5.4 Return After Completion of Guidance: the drone shall return to the base station once guidance has been completed.
Requirement 5.5 Base Landing Upon Completion: the drone shall execute a landing on the base station in the correct orientation.

9.6.2 Verification Procedure: System testers will observe the drone while it attempts a landing on the base station automatically. For acceptance the drone must make full contact with the ground, stop its rotors, and be in the correct orientation to commence battery charging.

9.7 Installation of system

9.7.1 Requirement(s) addressed: Requirement 4.6 System Installation: they system shall not be an "off the shelf" product and will require installation.
Requirement 8.1 Configuration of Store: the system shall allow a set-up team to enter the configuration of a store.

9.7.2 Verification Procedure: System testers will install the system in the mock store and start the system with a blank slate of information and will then add the aisles of the sample store into the system so that it knows the layout.

9.8 Verify response time

9.8.1 Requirement(s) addressed: Requirement 5.1 Response Time: the system shall respond in under a second.

9.8.2 Verification Procedure: System testers will communicate a message from the base station to the drone. They will measure time of response for drone operation and accept if within parameters.

9.9 Verify wake time

9.9.1 Requirement(s) addressed: Requirement 5.2 Wake Time: the system shall respond to a new selection and wake the drone within fifteen seconds.

9.9.2 Verification Procedure: System testers will communicate a selection from the base station to the drone. They will measure time taken for the drone to launch and begin flying a path and accept if within parameters.

9.10 Verify path time

9.10.1 Requirement(s) addressed: Requirement 5.3 Path Time: the drone shall complete a guidance within the allotted time.

9.10.2 Verification Procedure: System testers will create a request for the drone and complete a full circuit. They will measure time for the drone to complete the path and accept if within parameters.

9.11 Drone charges at base station

9.11.1 Requirement(s) addressed: Requirement 5.6 Base Station Charging: the drone shall recharge its batteries while seated on the base station.

9.11.2 Verification Procedure: System testers will observe the battery charge of the drone while seated on the base station. Battery charge must increase over time for acceptance.

9.12 System restricts the items per trip

9.12.1 Requirement(s) addressed: Requirement 5.7 Max Items Per Trip: the system shall not allow the user to request more than the administrator's defined maximum items per trip.

9.12.2 Verification Procedure: System testers attempt to create a guidance list with more than the defined maximum items. For acceptance, the system must reject this list.

9.13 Drone maintains operations over time

9.13.1 Requirement(s) addressed: Requirement 5.8 Minimum Operational Time: The drone shall maintain operational flight for a time of at least thirty minutes from a fully charged state.

9.13.2 Verification Procedure: System testers will launch a fully charged drone and keep it in operational use such that it will not land on the base station to charge for thirty minutes. If the drone maintains power, they will accept.

9.14 Drone operational range failure behavior

9.14.1 Requirement(s) addressed: Requirement 5.10 Operational Range: the drone shall maintain operational contact with the base station at all times.

9.14.2 Verification Procedure: System testers will block drone communications with the base station. For acceptance, the drone must immediately suspend operation, land, and stop.

9.15 Drone safety precautions

9.15.1 Requirement(s) addressed: Requirement 6.1 Rotors: The system shall have rotors that will not harm a person or damage property.
Requirement 6.3 Property Damage: The system shall be designed so that it does not cause property damage.
Requirement 6.4 Eye and Ear Protection: The system shall be designed so that it does not cause harm to anyone's sight or hearing.
Requirement 6.5 Avoids Collisions: The system shall be designed so that it avoids pedestrians or objects when in use.
Requirement 6.8 Damage Avoidance: The system shall be designed so that when it is damaged, it nor the damaged parts will become a hazard or danger to anyone or thing.

9.15.2 Verification Procedure: System testers shall ensure that the drone will be designed to be an object that has safety as the highest priority. The rotors will not harm or cause damage to objects or people. The drone will avoid collisions and will be designed so that any damage sustained will not cause it to become dangerous. The drone will not cause damage to anyone through the use of its lights and speakers.

9.16 Drone weight limit

9.16.1 Requirement(s) addressed: Requirement 6.2 Weight: The system shall weigh enough so that if it should fail that it will not cause damage to anyone or thing.

9.16.2 Verification Procedure: System testers shall ensure that the drone will not weigh so much that it will cause damage or harm if it were to fail and crash on anyone or anything.

9.17 Drone altitude restriction

9.17.1 Requirement(s) addressed: Requirement 6.6 Altitude Control: The system shall be designed so that it does not reach an altitude were it could become a hazard.
Requirement 6.9 Ceiling Avoidance: The system shall be designed so that it will not interfere with any object on the ceiling of any building it is used in and will avoid the ceiling itself.

9.17.2 Verification Procedure: System testers shall ensure that the drone will not reach a height were it could harm anyone and will not reach a height were it could damage the ceiling.

9.18 Drone down draft limit

9.18.1 Requirement(s) addressed: Requirement 6.7 Down Draft: The system shall be designed so that it's down draft does not cause damage or harm to anyone or thing.

9.18.2 Verification Procedure: System testers shall ensure that the drone rotors will not produce a down draft that will cause harm or damage to anyone or anything.

9.19 Drone physical inspection

9.19.1 Requirement(s) addressed: Requirement 4.4 Drone Wires: The system shall be designed so that there are limited exposed wires on the body of the drone

9.19.2 Verification Procedure: System testers shall conduct an inspection of the drone shows that there are no exposed wires.

10. Use Cases

These use cases address the main user functionality that the Sherpa Drone will have to implement. There are two main types of users: customers and administrators. The customer will be the end user of the product, interacting with the kiosk and drone. The administrator will be a member of the store's staff who will be responsible for modifying the drone's knowledge of the store through the kiosk. These use cases will cover any interaction that either the customer or administrator should have with the product, including both interactions with the kiosk and the drone itself.

10.1 Search for Item in Store

10.1.1 Scenario: The customer approaches the kiosk and taps it to start up. They are then presented with a keyboard and an option to "Search by Category." They either type in the name of the item they are looking for, or select "Search by Category" and choose the item form a list. They then press a "Find this Item" button and the system shows a message that a drone is on its way and which color its LED will shine.

10.1.2 Actor(s): Customer, Database Service

10.1.3 TUCBW: The customer taps on the kiosk to display the search page.

10.1.4 TUCEW: The customer sees a message saying a drone is on its way and which LED color it will show.

10.2 Follow Drone to Item

10.2.1 Scenario: The customer sees the drone approach. They then follow the drone to the item they are looking for. The drone light will turn off after ten seconds and fly back to the home station or returns to the kiosk for the next customer.

10.2.2 Actor(s): Customer

10.2.3 TUCBW: The customer sees the drone with their indicated LED color approaching.

10.2.4 TUCEW: The customer sees the item they are looking for and the drone leaves.

10.3 Request Help with System

10.3.1 Scenario: The customer approaches the kiosk and taps it to turn it on and display the search page. They do not know how to use the kiosk and so the tap on the help button indicated by a question mark. The system then provides them with a basic tutorial for locating items.

10.3.2 Actor(s): Customer

10.3.3 TUCBW: The customer taps on the kiosk to display the search page.

10.3.4 TUCEW: The customer sees the tutorial of how to use the search functionality.

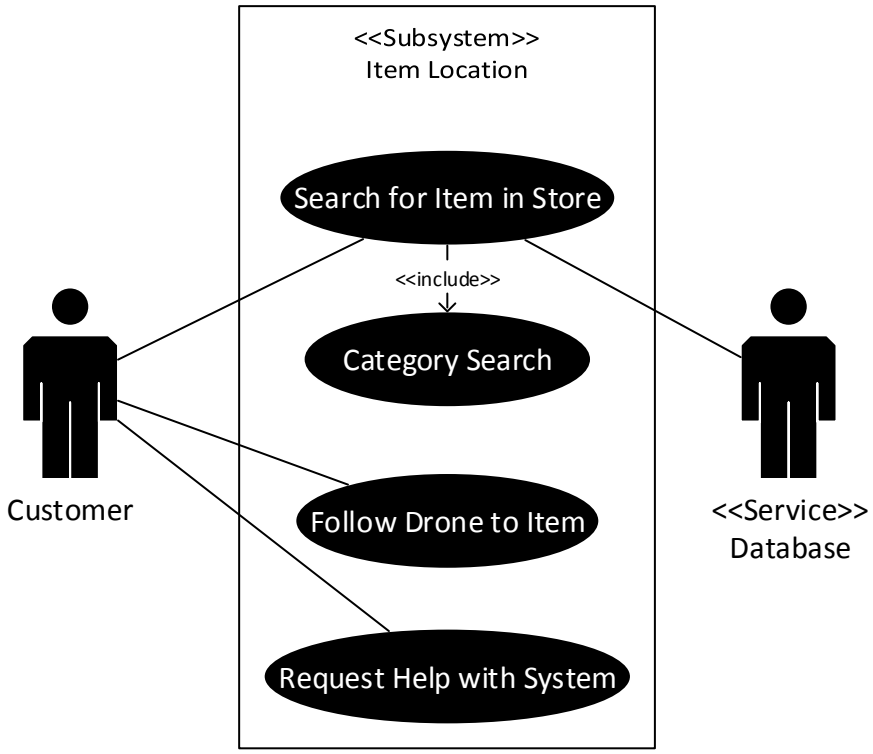

Figure 10-1 Use Case: Item Location Subsystem

10.4 Set Up Store Layout

10.4.1 Scenario: The administrator logs into the "Administrator Console" and taps on "Setup Store" button. They then enter in the size of the store and location of the aisle in the store. Then they tap the "Save" button and sees the confirmation of the store layout setup and are returned to the "Administrator Console."

10.4.2 Actor(s): Administrator, Database Service

10.4.3 TUCBW: The administrator enters login information and taps "Login" button.

10.4.4 TUCEW: The administrator sees the confirmation that the store layout was set up.

10.5 Update Store Layout

10.5.1 Scenario: The administrator logs into the "Administrator Console" and taps on "Update Store" button. They then enter in the aisle locations that they wish to change, including adding and removing aisles as well as moving them. They then tap the "Save" button and sees the confirmation page and are returned to the "Administrator Console."

10.5.2 Actor(s): Administrator, Database Service

10.5.3 TUCBW: The administrator enters login information and taps "Login" button.

10.5.4 TUCEW: The administrator sees the confirmation that the store layout was updated.

10.6 Add Item

10.6.1 Scenario: The administrator logs into the "Administrator Console" and taps on "Add Item" button. They then enter the item information and which aisle, and where on the aisle the item is located. They then tap on the "Save" button, are shown a confirmation page, and are prompted if they want to add another item or to return to the "Administrator Console."

10.6.2 Actor(s): Administrator, Database Service

10.6.3 TUCBW: The administrator enters login information and taps "Login" button.

10.6.4 TUCEW: The administrator sees the confirmation that the item was added.

10.7 Update Item

10.7.1 Scenario: The administrator logs into the "Administrator Console" and taps on "Update Item" button. They then enter the name of the item to update. They then add the new item details including the location and the category of the item. There is also an option to remove. They then tap on the "Save" button, are shown a confirmation page, and are prompted if they want to update another item or return to the "Administrator Console."

10.7.2 Actor(s): Administrator, Database Service

10.7.3 TUCBW: The administrator enters login information and taps "Login" button.

10.7.4 TUCEW: The administrator sees the confirmation that the item was updated.

10.8 Shut Down System for Maintenance

10.8.1 Scenario: The administrator logs into the "Administrator Console" and taps on the "Shut Down" button. They then see a confirmation message that the system will shut down and taps on the "Yes" button. The system then will shut down the drone and kiosk.

10.8.2 Actor(s): Administrator

10.8.3 TUCBW: The administrator enters login information and taps "Login" button.

10.8.4 TUCEW: The administrator sees the confirmation that the system is shutting down.

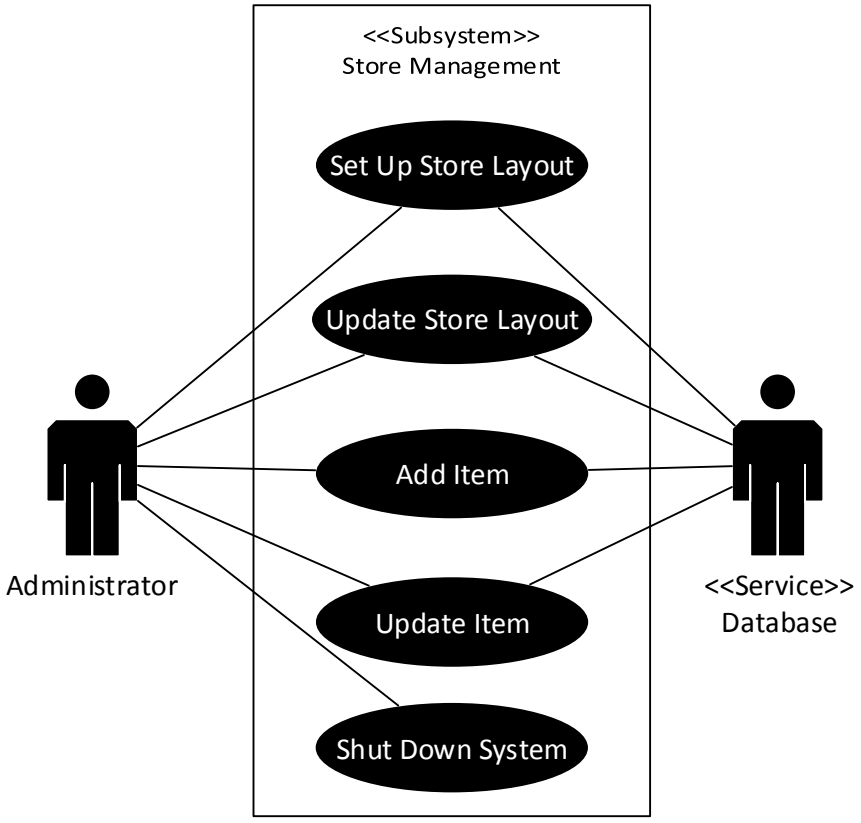

Figure 10-2 Use Case: Store Management Subsystem

11. Feasibility Assessment

Feasibility analysis, as used here, consists of an assessment of the following six components: scope analysis, research completed/remaining; technical analysis; cost analysis, resource analysis; and schedule analysis. The purpose of this section is to analyze whether the Sherpa Drone is feasible to complete within the time-frame and budget. At this stage, the assessments are made based on the team's judgment, knowledge, and experience.

11.1 Scope Analysis

The team has come to the agreement that a proof of concept prototype is feasible within the scope and requirements of the project. Based on prior experience and research, the team has limited the scope to include the system's basic functionality. The drone will show a single customer at a time to a single item, completing a return trip to the kiosk before accepting a new mission. Critical requirements include the construction of a database, the drone, the kiosk, and the software interfaces. These together will account for the majority of the project. Requirements will be completed according to priority to ensure that critical requirements are completed first.

11.2 Research

The team has researched platforms for the kiosk, induction chargers, and components for the drone. For the terminal, we have considered the Raspberry Pi with a 5 to 7 inch touch screen in addition to a more traditional keyboard, monitor, tower set up. We have found induction chargers that will meet our power requirements within budget.

The research we need to complete is into the software components of the project. We have come to the agreement that the software will primarily be written in C for the drone and Java for the kiosk and will transmit packets between them by Bluetooth. We also need to research database options and path finding algorithms.

For the hardware, Aaron Windham's technical experience in drone construction and unmanned vehicle sensors, through university classes and personal drone ownership, forms the basis for our research. To supplement this knowledge the team will research power sources, rotors, frames, and sensors for the drone. The team will need to further familiarize ourselves with the communication over Bluetooth, for the link between the drone and the kiosk.

11.3 Technical Analysis

The system will be split in to two major parts: the construction of the drone and kiosk, and the networking and software portions. The drone will require that the team continue to research similar drones and the components of these examples in order to allow for the best quality at the lowest price. The kiosk will be either a touch screen running off a Raspberry Pi or a more conventional design. The team has members that are familiar with both of these paradigms so construction of the kiosk will be relatively simple. The network connectivity and Bluetooth router will have to be researched further as well.

Several team members have experience with database implementation from class work and internships that will aid in the project. Similarly, team class work in networking and artificial intelligence assists in the construction of the path finding algorithm. This should allow the team to build an effective but simple system to run the application side.

11.4 Cost Analysis

System and drone hardware pose a risk of overrunning the operational budget of the project. However, analysis shows that individual components are available at reasonable prices. Research has shown that items such as touch screens, motors, processors, and sensors are all available for prices under a hundred dollars. Bluetooth communication and ultrasonic sensors are both cheap and widely available alternatives to costly computer vision cameras and an in-built wireless transmitter.

Available drones range in expense from low-cost toys to professional systems used by enthusiasts. Smaller, less sophisticated drones have lowered in price immensely over the past few years. As these requirements scale down, so does cost. Existing technical expertise will also allow save budget by assembling hardware in house. Therefore, we expect to build a small prototype within our cost constraints.

Table 11-1 Cost Estimates

Part	Quantity	Total Cost
Drone Frame	2	$50
Rotor	4	$40
Props	12	$48
Controller Board	1	$75
Batteries	1	$35
Induction Charging Circuits	1	$20
Touch Screen with Driver	1	$100
Raspberry Pi	1	$35
Kiosk Enclosure	1	$50
	Total:	$453

11.5 Resource Analysis

The project calls for expertise in software, hardware, and project management domains. Analysis shows that team members have the expertise to meet these challenges.

The first challenge is planning and project management. Every team member has participated in a waterfall project before due to the class prerequisite in software engineering. Additionally, the two software engineers on the team, Justin Crist and Frank Robinson, have completed additional class work in project management and testing that will further aid efforts. Awareness of risk management and potential complications allows the team to properly allot both time and manpower resources to weak points. Dakota Slay has been assigned to monitor risks throughout the project.

The second challenge will be software design and implementation for the base station and kiosk. While the program design of both are as yet unknown, the team has freedom to implement in a familiar language, cutting the time necessary to learn new tools. The most likely candidate is Java, a language that comes with multiple libraries for ease in building graphic user interfaces. Java also has touch screen

APIs that would make building a touch based interface easier. The entire team has experience with C as well, the most likely candidate for drone programming.

The third challenge will be drone construction. The team's most scarce resource in this domain is expertise. Only the team computer engineer, Aaron Windham, has direct experience with constructing hardware to specification in a technical project. The team must assign extra time and manpower to the construction of the drone and assisting Aaron in its completion.

The fourth challenge will be drone navigation. While physical control of drone systems is handled internally by most available drone models, navigation instructions arrive from the base station. The base station must create an appropriate schema of the physical landscape and transmit the path-finding algorithm to the drone in actionable steps. Two team members, Justin Crist and Matthew Leonard, have experience in artificial intelligence algorithms which are a good fit for path-finding in a simulated environment.

Given the broad expertise of team members, we expect to be able to operate within the existing resource constraints.

11.6 Schedule Analysis

11.6.1 Jones First Order Estimation

First we will complete an estimate by function points. We assemble a list of processes according to requirements and partition them by program characteristic.

Table 11-2 Program Characteristics

Function	Processes
Inputs	Search by category; search by name; administrator updates to store layout; administrator updates to inventory; start drone guide; cancel drone guide
Outputs	Drone status report; desired item list; wait screen; user information
Inquiries	Search by category; search by name; ask drone status
Logical Internal Files	Navigation; store layout; collision detection; status monitoring; item scheduling
External Interface Files	User interface; drone signals; administrator interface

We translate these tasks into function points by estimating the complexity for each.

Table 11-3 Unadjusted Function Point Estimation

Function	Low Complexity	Medium Complexity	High Complexity	Totals
Inputs	6 x 3	0 x 4	0 x 6	18
Outputs	4 x 4	0 x 5	0 x 7	16
Inquiries	2 x 3	1 x 4	0 x 6	10
Logical Internal Files	1 x 7	1 x 10	3 x 15	62
External Interface Files	1 x 5	2 x 7	0 x 10	19
Unadjusted function point total		125		

Separately, we tally the influence multipliers based on the projected needs of the project.

Table 11-4 Jones First Order Influence Multipliers

Data Communications	2
Distributed Data Processing	0
Performance	2
Heavily used configuration	4
Transaction Rate	1
On-Line data entry	0
End-user efficiency	5
On-Line update	1
Complex processing	5
Reusability	5
Installation Ease	1
Operational Ease	3
Multiple Sites	0
Facilitate Change	5
Total	34

The Adjustment Factor is based on the formula AF = 0.65 + (Total * 0.01). We multiply this by the influence multiplier for the final adjusted function-point total.

Table 11-5 Final Function Points

Unadjusted Function-Point	125
Influence Modifier	0.99
Adjusted Function-Point	123.75

We may use this result with Jones First-Order procedure to create a schedule estimate. The formula uses Adjusted Function-Point raised to the factor below for the "Systems" category.

Table 11-6 Time Estimates

	Best in Class	Average	Worst in Class
Factor	0.43	0.45	0.48
Total (months)	7.94	8.74	10.10

Thus the team may expect a best case finish in slightly less than eight months. This estimate is longer than the actual scheduled time of the project especially given the fact that each team member cannot commit 40 hours each week. As such, the team agreed that requirements ranked as low priority will be cut as necessary to ensure schedule compliance.

11.6.2 Simple CoCoMo

A second schedule estimate with simple CoCoMo will help the team check the validity of the result above. First, we will convert size into CoCoMo from function points. The team expects to use Java, which Capers Jones estimates to approximate 55 lines of code per function point.

Table 11-7 Lines of Code from Function Points

Adjusted Function Points	Lines of Code/Function Point	Source Lines of Code
123.75	55	6806.25

Let us round that to 7 KLOC for the following calculations. Effort in simple CoCoMo is calculated as 1.4 * KLOC.

Effort = (1.4 * KLOC) = 9.8

For the time estimate, we will use the Rule of Thumb: duration = 3 * Person Months ^ 1/3

Time (months) = 6.42

Thus, simple CoCoMo provides a schedule estimate under that of Jones First Order estimation. While this is a flattering impression, the team should lean towards pessimism in scheduling.

11.6.3 Discussion

Both methods provide estimates of project schedule that exceed the time constraints given. By inspecting the function points in Jones' First Order Estimation, we note that fully half of the function points relate to the internal logical file category. Thus, internal logic is a critical area for the team to reduce requirements. Low priority requirements need to be removed from project expectations for the sponsor, and the team should cast a critical eye on software complexity risks during architectural and detail design. This is an area where additional attention to detail may result in the most significant savings in terms of time and effort. By reducing the requirement workload and managing the complexity of the software processing, we will be able to bring the project within constraints.

12. Future Items

These are the requirements that will not be included in the proof of concept version that is being developed by the team at this time. The requirement and reason for each item's exclusion is provided for record keeping.

12.1 Customer Requirement: 3.5 Stay with Customer

12.1.1 Requirement Description: The system shall allow a customer to stay close to the drone, with it slowing down or stopping if they fall behind.

12.1.2 Constraint: Technology: Current system does not include a device carried by the customer to use for distance measuring.

12.2 Customer Requirement: 3.9 Track Inventory Changes

12.2.1 Requirement Description: The system shall allow an administrator to update the locations of items automatically using RFID or other inventory tracking technology.

12.2.2 Constraint: Technology: Current store does not use technology to track location of items in the store. Schedule: Incorporation of this would likely double time to complete project. Cost: The chips and readers to track inventory would have a high cost that our project does not have the flexibility for.

12.3 Customer Requirement: 3.11 Mobile App Access

12.3.1 Requirement Description: The system shall allow a customer to download an app onto their device to ask for a drone to find an item.

12.3.2 Constraint: Schedule: Development of a mobile app would have a high time cost, especially when the issue of finding the location of the customer with the device for the drone to begin guidance is considered.

12.4 Packaging Requirement: 4.2 Kiosk Power Source

12.4.1 Requirement Description: Kiosk will have one single power cable going in to the enclosure.

12.4.2 Constraint: Cost: Would require a device to power the kiosk contained within the kiosk enclosure which would raise the cost of the kiosk and enclosure beyond what the team has the budget for.

12.5 Other Requirement: 8.3 Protected Administrator Console

12.5.1 Requirement Description: The system will hide the administrator console from access by the customer by using a special code or sequence to bring up the log in page.

12.5.2 Constraint: Schedule: Team will not have the time to develop a special way of opening the console because this would take an additional month to complete to research a proper way to hide and implement.