# Software Requirements Specification for ParkingLotHawk

MECHTRON 4TB6 Capstone Design Project

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# Revision History

| Date | Version | Notes |
|---|---|---|
| Oct 5, 2022 | 1.0 | Team Finalized SRS |

# 1 Introduction

## 1.1 Purpose

The purpose of the project will be to design an aerial drone, called ParkingLotHawk, that can detect how many parking spots are available in any given parking lot. ParkingLotHawk can be operated by property personnel to allow drivers how many spots are available at a parking lot. ParkingLotHawk will over any parking lot designated by the user and will aggregate visual information and output the amount of parking spots available. Many parking lots today do not have this data and this data can be used for many reasons. The data can be used by retailers to know how long customers stay at specific stores or location. This data can also be used for drivers to know if there are parking spots available in a specific location allowing for drivers to not waste time and resources in a full parking lot.

## 1.2 Scope

The product specified in this SRS is about an autonomous aerial drone for helping parking lot operators understand the state of their parking lot. The product specified does not require the operator to manually control or move the drone, rather the requirement describes various autonomous flight modes. The specified drone shall support the ability to both create a path to reach is specified location, as well as create and follow a path to explore large parking lot sections autonomously. During flight, the specified drone shall transmit live information about the parking lot sections it detects. The completed product, a combination of the physical drone and any equipment/application intended to be kept by the parking lot operator to communicate with the drone, is called the ParkingLotHawk. A solution that implements the requirements will help parking lot authorities of outdoor lots quickly gain valuable information without requiring permanent solution, large monetary and time investments or complex training.

## 1.3 Definitions, Acronyms, and Abbreviations

## 1.4 References

## 1.5 Overview

The SRS is organized to follow the IEEE 1998 template. Introduction contains the purpose of the SRS as well as the scope of the product and the problem it solves. Overall Description refines the scope of the product further. It provides more detail about the products environment, primary functions, intended users, constraints and finally assumption. Specific requirements contains a detailed description of all requirements, organized into sections for readability. Finally the appendix contains reflection regarding new knowledge and skills the team needs to create the specified product, along with approaches to how the team will acquire the knowledge.

# 2 Overall Description

General factors that affect the product and the requirements are described in the following subsections. A high-level overview of the product functions are also described (see Product Functions).

## 2.1 Product Perspective

The system specified is an independent and stand-alone parking lot tool. It does not fit into or interface with a larger system of parking lot and security technologies the operator may have available.

The environment consists of an outdoor parking lot and the operator's PC. The operator's PC shall be running with Windows 10 or Windows 11.

## 2.2 Product Functions

This subsection describes the behaviour overview of the ParkingLotHawk by splitting its functionality into various interconnected states of operation. These states are further refined within Section Functional Requirements.

### 2.2.1 Idle State

The product is powered on and communicating with the operator application, but all motors are turned off.

### 2.2.2 Hover State

The product maintains its current longitudinal and latitudinal position, and hovers at a pre-defined operator selected height.

### 2.2.3 Manual Location Move State

The product shall move to an operator specified location, and hover at a pre-defined operator selected height. Note that this height does not need to be the same as the height specified in the Hover State.

### 2.2.4 Autonomous Explore State

The product shall autonomously explore within the current parking lot without operator input.

### 2.2.5 Configure State

During this state, the operator is able to define parameters of operation that are not configurable in other states.

### 2.2.6 Off State

The product shall be unpowered and stops communication with the operator application.

### 2.2.7 Land State

### 2.2.8 Desired Location Error State

This error state occurs when the operator specifies an invalid desired position and shall provide the appropriate error message to the operator.

### 2.2.9 No Parking Lot Detected Error State

### 2.2.10 Malfunction State

This error state occurs when an internal/external malfunction occurs in such a way that nominal performance is not possible. The resulting action by the product will be further specified within Section Functional Requirements.

## 2.3 User characteristics

The stakeholders are Dr. Spencer Smith, the MECHTRON 4TB6 teaching assistants, property managers, security personnel and anyone who is an active driver. All demographics mentioned would find the data of the ParkingLotHawk useful. The knowledge expected for using the ParkingLotHawk is to be able to understand how to use a computer and how to switch a device on and off. The user will need to turn the drone on and place it close to a parking lot. The user will also need to send an ON command using a

computer that will be sent to the drone using radio communication. The ParkingLotHawk is made mindful of the community, therefore, no air or noise pollution will occur, and no invasion of privacy will ensue.

### 2.4 Constraints

The purpose of the system is to provide parking spots availability to property managers and/or security personnel and this information could be relayed to customers or guests of a property. As the user can come from a non-technical background, the constrain on the usability of the product should be considered. The system will be used using radio communication from a computer and turned on and off using one button. Radio communication can only work within about 2 km from one point to the other. The project constraint present is a maximum budget of $ 750. Canadian regulatory policy does not allow for drone flight within 1 nautical mile (about 2 km) from heliports and 3 nautical miles (5.6 km) from airports. If the drone weighs over 25 kg the team will need to get special permission from Transport Canada before flying.

### 2.5 Assumptions and Dependencies

The assumptions of the project are:

- Functional Autopilot Software
- Long lasting battery

The dependencies of the project are:

- Operator does not fly the drone exceeding a specified amount of time
- Birds do not interfere with the drone
- Operator has a Windows 10 or 11 OS
- Parking lot lines are visible
- Operation done under non-inclement weather

## 3 Specific requirements

This section of the SRS should contain all of the software requirements to a level of detail sufficient to enable designers to design a system to satisfy those requirements, and testers to test that the system satisfies those requirements.

### 3.1 External Interfaces

Input Variables: Input variables are set/configured before normal operation. They are constant throughout the drones normal operation.

Monitored Variables are variables that are continuously monitored by the drone.

Controlled Variables are variables that are output by the system. Some are visible to the operator on their application, while others help to indirectly accomplish functional requirements.

### 3.2 Functional Requirements

#### 3.2.1 General Functional Requirements

foo

Figure 1: System Context Diagram

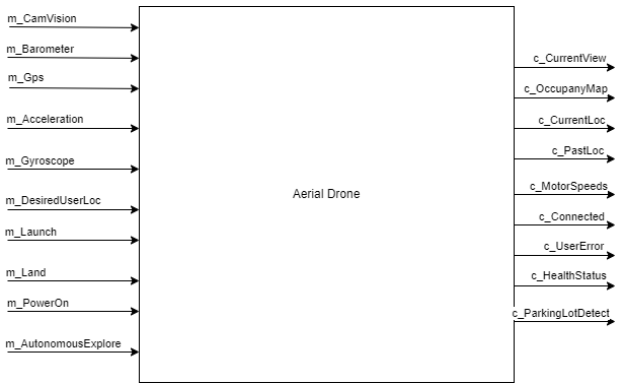


Table 1: Input Variables

| Variable Name | Type | Unit | Description |
|---|---|---|---|
| i_Mode | Enumeration | 0 - Normal, 1 - Configure | Set by the user to choose whether they want to configure internal parameters or if they want regular operation. |
| i_MinHoverHeight | float | m | Minimum aerial hover height set by user |
| i_MaxHoverHeight | float | m | Maximum aerial hover height set by user |
| i_DesiredHover-Height | float | m | Desired aerial hover height set by user |

#### 3.2.2 State Implementation Requirements

foo

#### 3.2.3 State Transition Requirements

foo

### 3.3 Performance Requirements

foo

### 3.4 Logical Database Requirements

There is no requirement for databases, as the problem requires no long-term storage of data.

### 3.5 Design constraints

### 3.6 Standards Compliance

### 3.7 Software System Attributes

none

Table 2: Monitored Variables

| Variable Name | Type | Unit | Description |
|---|---|---|---|
| m_Acceleration | Vector | $m/s^2$ | three-dimensional vector containing acceleration relative to frame of the drone. |
| m_Gyroscope | Vector | Rad | three-dimensional vector containing orientation relative to frame of the drone. |
| m_Gps | Tuple | GPS coordinates (degrees-minutes-seconds (DMS)) | current GPS coordinates of the drone. |
| m_Barometer | Float | atm | Altitude detection using atmospheric pressure measurement |
| m_DesiredUserLoc | GPS Location | GPS coordinates (DMS) | Desired location of the aerial drone set by user. |
| m_Launch | Boolean | - | Indicates if the operator desires the drone to begin operation and turn on all peripherals. |
| m_AutonomousExplore | Boolean | - | Indicates if the operator desires the drone to autonomously explore the parking lot. |
| m_powerOn | Boolean | - | Indicates if the operator desires the drone to be On or Off. |
| m_Land | Boolean | - | Indicates if the operator desires the drone to land. |
| m_CamVision | Image | Array of Pixels | Latest image of the section of the parking lot currently visible to the drone. |

### 3.8 Reliability

### 3.9 Availability

### 3.10 Security

### 3.11 Maintainability

### 3.12 Safety

### 3.13 Usability

### 3.14 Portability

None.

Table 3: Controlled Variables

| Variable Name | Type | Unit | Description |
|---|---|---|---|
| c_CurrentView | Image | Array of Pixels | Live visual display of parking lot section the drone's currently sees, as well as any further annotations and text. |
| c_OccupancyMap | Image | Array of Pixels | Map of available parking spots based on the drone's previous paths. |
| c_CurrentLoc | Tuple | {GPS coordinates (DMS) , height (m)} | GPS coordinates are stored at the first index, height is stored in the second index. Estimated longitudinal coordinate, lateral coordinate and height of the drone. |
| c_PastLoc | Vector | 1/ Degrees, minutes, and seconds (DMS) | Trace of the drone's location in the past 60 seconds (vector of GPS locations). |
| c_MotorSpeeds | Vector | $rad/s^2$ | n-dimensional vector containing the motor speeds of however many motors the drone chooses to use (2 for helicopter, 4 for quadcopter, 6 for hexcopter, etc.). The vector contains speeds of each motor clockwise from front of the drone. |
| c_Connected | Boolean | - | Indicates if connection between the drone and the operator's application is established |
| c_ParkingLotDetected | Boolean | - | Indicated if a parking lot is detected in the c_CurrentView. |
| c_UserError | Enumeration | 0 - None, 1 - Desired_Location_Out_Of_Bounds, 2 - No_Lot_Detected_State | Indicates if a command the user requested is not feasible. |
| c_HealthStatus | Enumeration | 0 - Healthy, 1 - Unhealthy | Indicates if the drone's mechanical and electrical state allows it to safely fly. For example if there is mechanical damage, the value should be Unhealthy. |

# 4 Supporting information

## 4.1 Appendixes

### 4.1.1 Appendix A: Reflection

Although the team has a solid education in the foundation in Mechatronics, they lack practical experience in building drones and robots in general. The knowledge the team currently does not have is identified in the table below. Each discipline of knowledge was assigned to a specific team members who would become the expert in the subject. They may use any resources to gain the knowledge, such as books, blogs, YouTube

Table 4: GEN_001

| | |
|---|---|
| Description | The product shall be able to recognize **??**. This requirement is a refinement of the Autonomous Explore State. |
| Rationale | This requirement ensures that the product is able to implement basic autonomy, such as not traveling past the parking lot boundaries. |
| Phase | II |
| Likely to Change | No. This requirement is required to implement the Autonomous Explore State. |
| Associated Inputs and Outputs | m_CamVision. |

Table 5: GEN_002

| | |
|---|---|
| Description | The product shall provide live update of c_CurrentLoc, c_CurrentView and c_OccupancyMap during all normal and non-configurational operation states. This requirement is a refinement of the normal and non-configuration operation states specified in Section 2.2. |
| Rationale | This requirement ensures that the product always provides the latest controlled variable information to the operator. |
| Phase | II |
| Likely to Change | No. This requirement is a part of the MVP and must be present to make the product achieve its product functions. |
| Associated Inputs and Outputs | m_CamVision, c_CurrentLoc, c_CurrentView, and c_OccupancyMap. |

Table 6: GEN_003

| | |
|---|---|
| Description | The product shall allow the operator to configure the i_MinHoverHeight, i_MaxHoverHeight, and i_DesiredHoverHeight. This requirement is a refinement of the Configure State. |
| Rationale | The value of these parameters depends on the operators view preferences and parking lot conditions. For example a parking lot with a lot of large trucks may be better suited to higher hovering heights. |
| Phase | I |
| Likely to Change | No. This requirement is vital to the operation of the product, as it must be suited to different parking lot environments. |
| Associated Inputs and Outputs | i_MinHoverHeight, i_MaxHoverHeight, and i_DesiredHoverHeight. |

videos, and other websites available to them.

The team has also defined what it means to be an expert in their domain:

- In depth understanding of how the component works physically (if applicable).
- Proper reasoning as to why specific component/firmware was chosen.
- In depth understanding of the key parameters and specifications of the product/firmware.
- In depth understanding of the inputs and outputs to the domain.

Table 7: GEN_004

| | |
|---|---|
| Description | The condition i_MinHoverHeight ¡= i_DesiredHoverHeight ¡= i_MaxHoverHeight shall always be true. This requirement is a refinement of the Configure State. |
| Rationale | This requirement ensures logical values for the parameters are set by the operator. |
| Phase | I |
| Likely to Change | No. This requirement is required to check the inputted values by the operator. |
| Associated Inputs and Outputs | i_MinHoverHeight, i_DesiredHoverHeight, and i_MaxHoverHeight. |

Table 8: GEN_005

| | |
|---|---|
| Description | The product shall be able to identify non-occupied parking spots. This requirement is a refinement of the normal and non-configuration operation states specified in Section 2.2. |
| Rationale | This requirement ensures that the product is able to create the occupancy map. |
| Phase | III |
| Likely to Change | No. This requirement is required to create the occupancy map, which is one of the main functions of the product during the Phase III Release. |
| Associated Inputs and Outputs | m_CamVision, c_ParkingLotDetected, and c_OccupancyMap. |

Table 9: GEN_006

| | |
|---|---|
| Description | The product shall be shall highlight non-occupied parking slots on the operator's display. This requirement is a refinement of the normal and non-configuration operation states specified in Section 2.2. |
| Rationale | This requirement ensures that the product is able to create the occupancy map. |
| Phase | III |
| Likely to Change | No. This requirement is a key feature of the occupancy map in order to efficiently communicate the data to the operator. |
| Associated Inputs and Outputs | m_CamVision, c_CurrentView, c_ParkingLotDetected, and c_OccupancyMap. |

- In depth understanding of the integration of the domain into the project.

For many of the technical domains, the team has opted to partake in a dual-expert system where two experts are present for the domain. This ensures that in the absence of an expert, the effects on the team are minimized. Furthermore, this promotes collaboration between the experts during their research of their domain. Git, programming languages and Linux are already well understood by team members.

Table 10: STA_000

| | |
|---|---|
| Description | The product shall implement an Idle state. During this state, the solution is powered on but motors are stationary. This requirement is a refinement of the Idle State. |
| Rationale | This state is used to ensure that the operator can safely hold the drone and access the mechanical switch that controls m_PowerOn. |
| Phase | I |
| Likely to Change | No. This requirement is required for the safety of the operator. |
| Associated Inputs and Outputs | m_PowerOn and c_Connected. |

Table 11: STA_001

| | |
|---|---|
| Description | The product shall implement a Hover State. During this state, the solution shall fly and hover to height i_MaxHoverHeight. The drone shall keep the same lateral location it is currently at. This requirement is a refinement of the Hover State. |
| Rationale | This state is used for when the product is waiting for further operator commands. Hover height is selected to be i_MaxHoverHeight, so that the drone can see as much of the parking lot section as it can. This makes the transition to Autonomous Explore State more likely. |
| Phase | II |
| Likely to Change | No. This requirement is a key feature of the MVP, and is required in order to gather any useful information to the operator. |
| Associated Inputs and Outputs | m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, i_MaxHoverHeight, and c_MotorSpeeds. |

Table 12: STA_002

| | |
|---|---|
| Description | The product shall implement a Manual Location Move State. During this state, the drone moves to the m_DesiredUserLoc, and hovers at that location with height i_DesiredHoverHeight. This requirement is a refinement of the Manual Location Move State. |
| Rationale | This state is used for when the the product needs to provide the operator the ability to move the drone to a specific location. |
| Phase | II |
| Likely to Change | No. This requirement is a key feature of the product, and is required in order for the operator to make changes to the product's path. |
| Associated Inputs and Outputs | m_DesiredUserLoc, m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, i_DesiredHoverHeight, and c_MotorSpeeds. |

| Domain | Assigned Experts | Description of Domain | Recommended Resources |
|---|---|---|---|
| Latex | Zaid | The Latex domain expert is responsible for understanding the Latex syntax and generation process. | Google |
| Power Management and Motors | Fady and Zaid | This domain relates to the powering of the individual components of the drone, and the control of the motors. Example components include the battery, Power Distribution Board, and the Electronic Speed Controller. | Motor datasheet, Google, Youtube |
| Mechanical Design | Winnie and Ali | Included within this domain is the creation of the custom drone frame, in addition to minimizing vibrations while maximizing structural integrity. | Google, Youtube |
| External Sensors and Peripherals | Fady, Winnie and Ali | This domain includes the external sensors that connect to the flight controller, including the camera, radio transmitter, and any other sensors that may | Google, Youtube, Datasheet of |

Table 13: STA_003

| | |
|---|---|
| Description | The product shall implement an Autonomous Explore State. During this state the drone will create its own path to explore and remain within the parking lot it currently detects. This requirement is a refinement of the Autonomous Explore State. |
| Rationale | This state is used for when the operator does not need to constantly instruct the drone to move. |
| Phase | III |
| Likely to Change | No. This requirement is an important part of the Phase III Release, as it allows for automated creation of the occupancy map. |
| Associated Inputs and Outputs | m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, m_Autonomouse-Explore, m_CamVision, c_CurrentView, and c_MotorSpeeds. |

Table 14: STA_004

| | |
|---|---|
| Description | The product shall implement a Configure state. During this state settings and parameters that cannot be changed during flight can be changed. The Input Variables i_MinHoverHeight, i_MaxHoverHeight and i_DesiredHoverHeight can be changed in this state. The product is powered on but motors are stationary. This requirement is a refinement of the Configure State, and references GEN_003. |
| Rationale | This state is used to allow parameters that are unsafe to change during flight operation, to be safely changed through a special process. During this state the operator can safely hold the drone. Such parameters are outlined in **??**. |
| Phase | II |
| Likely to Change | No. This requirement is required to ensure safety of the operator, as well as the product from unsafe changes during operation. |
| Associated Inputs and Outputs | i_Mode, i_MinHoverHeight, i_MaxHoverHeight, and i_DesiredHover-Height. |

Table 15: STA_005

| | |
|---|---|
| Description | The product shall implement an Off state. All modules are powered off. No battery power is consumer. c_UserError is set to None, c_Health-Status is set to Unhealthy, and c_Connected is set to false. All values in the matrices c_MotorSpeeds, c_PastLocations, c_OccupancyMap, and c_CurrentView are set to 0. This requirement is a refinement of the Off State. |
| Rationale | This state is used to explicitly state what it means for the drone to be off. |
| Phase | I |
| Likely to Change | No. This requirement is required for the safe operation, transport, and handling of the product. |
| Associated Inputs and Outputs | c_UserError, c_HealthStatus, c_Connected, c_MotorSpeeds, c_PastLocations, c_OccupancyMap, and c_CurrentView. |

Table 16: STA_006

| | |
|---|---|
| Description | The product shall implement a Land state. In the land state the solution first travel laterally to the initial launch location, and then lands vertically downward. Once physically landed, the drone enters the Idle state. This requirement is a refinement of the Land State. |
| Rationale | This state is used to explicitly designate a landing path and command. |
| Phase | II |
| Likely to Change | No. This requirement is required for stopping the operation of the product. |
| Associated Inputs and Outputs | m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, and c_MotorSpeeds. |

Table 17: STA_007

| | |
|---|---|
| Description | The product shall implement an Desired Location Error state. Upon entry to this state, the c_UserError variable is set to Desired_Location_Out_Of_Bounds. The drone proceeds to Hover at its current location. Upon exit of this state, the drone shall set c_UserError to None. This requirement is a refinement of the Desired Location Error State. |
| Rationale | This state is used to indicate explicitly that the operator's request cannot be met. |
| Phase | II |
| Likely to Change | No. This requirement is required for clear communication with the operator to handle unsupported requests. |
| Associated Inputs and Outputs | m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, c_UserError, and c_MotorSpeeds. |

Table 18: STA_008

| | |
|---|---|
| Description | The product shall implement a No Parking Lot Detected Error state. Upon entry to this state, the c_UserError variable is set to No_Lot_Detected_State. The drone proceeds to Hover at its current location. Upon exit of this state, the drone shall set c_UserError to None. This requirement is a refinement of the No Parking Lot Detected Error State. |
| Rationale | This state is used to indicate explicitly that the product cannot detect a parking lot. |
| Phase | II |
| Likely to Change | No. This requirement is required for clear communication with the operator to handle unsupported requests. |
| Associated Inputs and Outputs | m_Barometer, m_Acceleration, m_Gyroscope, m_Gps, c_UserError, and c_MotorSpeeds. |

#### 4.1.2 Appendix B: Formal Transition Table

Table 19: STA_009

| | |
|---|---|
| Description | The product shall implement a Malfunction state. During this state the drone sets the c_HealthStatus to Unhealthy. It then tries to land at its launch location, which if is not possible the drone instead lands vertically on the land below. After landing the drone enters the Off state. This requirement is a refinement of the Malfunction State. |
| Rationale | This state is used to ensure that the product can handle large malfunctions that can occur during operation. |
| Phase | II |
| Likely to Change | No. This requirement is required to handle malfunctioning components during operation. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, c_healthStatus, and c_motorSpeed. |

Table 20: PERF_001

| | |
|---|---|
| Description | The product shall explore ¿ 90% of the detected parking lot during the Autonomous Explore State. This is a refinement of STA_003. |
| Rationale | The requirement ensures that Autonomous Explore State is able to accurately survey the majority of the parking lot in order to provide accurate information to the operator. |
| Phase | III |
| Likely to Change | Yes. Based on algorithm performance of autonomous exploration and the limitations of the hardware, the threshold may be required to change. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, m_AutonomousExplore, and c_MotorSpeeds. |

Table 21: PERF_002

| | |
|---|---|
| Description | The product shall takeoff to i_MaxHoverHeight and land from i_MaxHoverHeight within 25 seconds. This requirement are refinements of STA_001 and STA_006. |
| Rationale | The requirement ensures that minimal time is required for the product to start transmitting useful data to the operator, and that it does not take excessive time to cease operation once finished. |
| Phase | II |
| Likely to Change | No. This requirement refines the Minimum Viable Product and should not be modified. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, and c_MotorSpeeds. |

Table 22: PERF_003

| | |
|---|---|
| Description | The product shall move to a specified location with an average speed exceeding 4km/hour. This is a refinement of STA_002. |
| Rationale | The requirement ensures that the operator spends minimal time waiting for the product to move to the desired location, and that it is quicker than the average speed of a person walking. |
| Phase | II |
| Likely to Change | No. This requirement refines the movement of the product to ensure that the product is more optimal than a human. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, and c_MotorSpeeds. |

Table 23: PERF_004

| | |
|---|---|
| Description | The product shall transmit all data to the operator at a rate exceeding 0.5 frames per second. This is a refinement of the functions specified in Section Product Functions. |
| Rationale | The requirement ensures the operator is receiving real time data from the product. |
| Phase | I |
| Likely to Change | No. This requirement constitutes the MVP, and ensures that the operator is able to receive the information in a timely manner. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, m_CamVision, c_CurrentView, c_CurrentLoc, c_PastLocations, and c_MotorSpeeds. |

Table 24: PERF_005

| | |
|---|---|
| Description | The product shall maintain a longitudinal and lateral position within a 1.5m radius during the Hover State. This requirement is a refinement of STA_001. |
| Rationale | The requirement ensures that the product does not drift to a different location when the operator expects it to be stationary. |
| Phase | II |
| Likely to Change | No. This requirement is required to allow proper operation of the product, as excessive drifting will cause inaccurate data to the operator. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, c_CurrentLoc, and c_MotorSpeeds. |

Table 25: PERF_006

| | |
|---|---|
| Description | The product shall always maintain an altitude between i_MaxHoverHeight and i_MinHoverHeight, within a tolerance of ±5%. This requirement are refinements of STA_001, STA_002, and STA_003. |
| Rationale | The requirement ensures that the operator specified altitude limits are respected during operation of the product. |
| Phase | II |
| Likely to Change | No. This requirement ensures that the operator's commands are respected during operation. |
| Associated Inputs and Outputs | m_barometer, i_MaxHoverHeight, i_MinHoverHeight, and c_MotorSpeeds. |

Table 26: PERF_007

| | |
|---|---|
| Description | The product shall be operable within requirements within non-inclement weather. Inclement weather includes precipitation, fog, or gusts exceeding 40km/h. This requirement are refinements of all the functions stated in Section Product Functions, and the assumption of the weather in Section Assumptions and Dependencies. |
| Rationale | The requirement ensures that the product is usable in the majority of the environmental conditions, such that its availability is maximized. |
| Phase | III |
| Likely to Change | Yes. Based on hardware limitations, this requirement may need to be modified to include less adverse weather conditions. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, c_CurrentView, c_CurrentLoc, c_PastLocations, and c_MotorSpeeds. |

Table 27: DES_001

| | |
|---|---|
| Description | The product shall cost less than $750 to manufacture. This requirement refines the constraint specified in Section Constraints. |
| Rationale | The requirement ensures the constraint of the design is met, and ensures that it is not costly for users to implement or replace the product. |
| Phase | I |
| Likely to Change | No. This requirement must be met in order to satisfy the externally imposed constraint. |
| Associated Inputs and Outputs | N/A. |

Table 28: STD_001

| | |
|---|---|
| Description | The product shall weight a total of less than 25kg. This requirement refines the constraint specified in Section Constraints. |
| Rationale | The requirement ensures the constraint of the design is met, and ensures that the product abides by Canadian regulatory laws. |
| Phase | I |
| Likely to Change | No. This requirement must be met in order to satisfy the externally imposed constraint. |
| Associated Inputs and Outputs | N/A. |

Table 29: STD_002

| | |
|---|---|
| Description | The product shall use radio communication only within the 2.4MHz range. This requirement refines the constraint specified in Section Constraints. |
| Rationale | The requirement ensures the constraint of the design is met, and ensures that the product abides by Canadian regulatory laws. |
| Phase | I |
| Likely to Change | No. This requirement must be met in order to satisfy the externally imposed constraint. |
| Associated Inputs and Outputs | N/A. |

Table 30: SAFE_001

| | |
|---|---|
| Description | The product shall not influence or interact with dynamic actors positioned in the parking lot. This requirement is a refinement of the product functions stated within Section Product Functions. |
| Rationale | The requirement ensures the product does not negatively impact the safety of visitors in the parking lot. |
| Phase | I |
| Likely to Change | No. One of the fundamental product goals is to assist in parking lot traffic. If the product negatively impacts the traffic, there is no use in the product. |
| Associated Inputs and Outputs | N/A. |

Table 31: SAFE_001

| | |
|---|---|
| Description | The product shall not influence or interact with dynamic actors positioned in the parking lot. This requirement is a refinement of the product functions stated within Section Product Functions. |
| Rationale | The requirement ensures the product does not negatively impact the safety of visitors in the parking lot. |
| Phase | I |
| Likely to Change | No. One of the fundamental product goals is to assist in parking lot traffic. If the product negatively impacts the traffic, there is no use in the product. |
| Associated Inputs and Outputs | N/A. |

Table 32: SAFE_002

| | |
|---|---|
| Description | The product shall not allow the operator to set i_MaxHoverHeight, i_MinHoverHeight, or i_DesiredHoverHeight to be below 7m. This requirement is a refinement of SAFE_001. |
| Rationale | The requirement ensures that the product does not interfere with existing traffic and that the flight path is above the majority of obstacles. |
| Phase | I |
| Likely to Change | No. A selected height of below 7m drastically increases the amount of potential obstacles, which will further increase the complexity of the product. |
| Associated Inputs and Outputs | i_MaxHoverHeight, i_MinHoverHeight, and i_DesiredHoverHeight. |

Table 33: SAFE_003

| | |
|---|---|
| Description | The product shall not require the operator to physically manipulate the product in any way in any states outside of Off State. This requirement are further refinements of all the states outlined in Section Product Functions. |
| Rationale | The requirement ensures that the operator does not interfere with the functions of the product, and that the operator is kept safe from any malfunctions of the product. |
| Phase | I |
| Likely to Change | No. To maintain operator safety, the operator must never be required to be near the product during operation. This ensures that in the case of product failure, the operator is not harmed. |
| Associated Inputs and Outputs | N/A |

Table 34: SAFE_004

| | |
|---|---|
| Description | The product shall not cause distractions or negatively impact greater than 2% of the visitors in the parking lot. This requirement is a refinement of SAFE_001. |
| Rationale | The requirement ensures that the usage of the product does not negatively impact the visitors in the parking lot. |
| Phase | I |
| Likely to Change | No. One of the fundamental product goals is to assist in parking lot traffic. If the product negatively impacts the visitors, there is no use in the product. |
| Associated Inputs and Outputs | N/A |

Table 35: SAFE_005

| | |
|---|---|
| Description | The product shall include a mechanical Off switch to the product. This requirement is a refinement of the Off State. |
| Rationale | The requirement ensures that the product can be turned off even in the case of electronic failures, and can double as a kill switch. |
| Phase | I |
| Likely to Change | No. A kill switch independent from the electronics is essential to the safe operation of electromechanical products, and must be required within the product. |
| Associated Inputs and Outputs | N/A |

Table 36: USE_001

| | |
|---|---|
| Description | The product shall provide a visual trace of its location for the past 60 seconds +- 1 second. This requirement is a refinement of the c_CurrentView data. |
| Rationale | The requirement ensures that the operator is able to keep track of the product's past movement to understand which areas of the parking lot have been explored. |
| Phase | II |
| Likely to Change | Yes. Although a method of visualizing the past path is required, the method at which it is done may be changed in future revisions. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, c_CurrentView, c_CurrentLoc, and c_PastLocations. |

Table 37: USE_002

| | |
|---|---|
| Description | The product shall allow the operator to save the current visual and raw data into a folder. This requirement is a refinement of the c_CurrentView data. |
| Rationale | The requirement ensures that the operator can save the current data for future reference and analysis, and provides a digital record of its operation. |
| Phase | III |
| Likely to Change | Yes. The method of which the operator saves the data, or which data is saved, may be changed in future revisions. |
| Associated Inputs and Outputs | m_barometer, m_acceleration, m_gyroscope, m_gps, c_CurrentView, c_CurrentLoc, and c_PastLocations. |

Table 38: USE_003

| | |
|---|---|
| Description | The product shall be able to operate and provide data to the operator for ¿ 5 minutes without the need to recharge. This requirement is refines the functions stated within Section Product Functions. |
| Rationale | The requirement ensures that the product is able to explore the entire parking lot without the need to recharge in between. |
| Phase | II |
| Likely to Change | Yes. This requirement may be changed due to hardware limitations of the product, and is not required for the MVP. |
| Associated Inputs and Outputs | N/A. |

Table 39: USE_004

| | |
|---|---|
| Description | The product shall require less than 2 hours of training for the operator to use. This requirement is a refinement of the assumptions stated within Section Assumptions and Dependencies. |
| Rationale | The requirement ensures that no technical knowledge is required for the operator to use, allowing for widespread adoption of the product. |
| Phase | I |
| Likely to Change | No. Due to the user characteristics of the product, this requirement is required in order for use by the targeted user. |
| Associated Inputs and Outputs | N/A. |

Table 40: Internal State Machine Variable: These variables are defined in order to help to simplify the Transition Table 41

| Variable Name | Type | Unit | Description |
|---|---|---|---|
| k_ConnectionLost-Thresh | float | sec | Constant of 5 seconds. Used to define what it means for connection to be weak and/or lost. |
| k_DesiredLocCha-nged | bool | - | Indicates if the desired location has been changed by the user. |
| k_OnGround | bool | - | Indicates if the drone is currently on the ground. |

Table 41: State Transition Matrix: This is a formal specification of the finite state machine. The current states are written along the top row, and the transitions along the leftmost column. Other cells indicate the next state.

| - | Idle | Hover | Manual Location Move | Autonom ousExplo re | Confi gurati on | Off | Desired Loca- tion Out of Bounds Error | Malfuncti on | Land | No Park- ing Lot Error De- tected |
|---|---|---|---|---|---|---|---|---|---|---|
| m_PowerOn | - | - | - | - | - | Idle | - | - | - | - |
| !m_PowerOn | Off | - | - | - | - | - | - | - | - | - |
| m_Launch & i_- Mode == Nor- mal | Hover | - | - | - | - | - | - | - | - | - |
| m_Launch & i_- Mode == Confi gure | Confi gurati on | - | - | - | - | - | - | - | - | - |
| m_Autonomou- sExplore & c_ParkingLot- Detected | - | Auton omous Explo re | Autonom ousExplo re | Autonom ousExplo re | - | - | Auton omous Explo re | - | - | Auton omous Explo re |
| c_UserError == Desired_Loca- tion_Out_Of_- Bounds | - | - | Desired Location Out of Bounds | - | - | - | - | - | - | - |
| m_Land | - | Land | Land | Land | - | - | Land | Land | Land | Land |
| (c_Connected) held for k_Con- nectionLost- Thresh | Malfu nction | Malfu nction | Malfuncti on | Malfuncti on | Malfu nction | - | Malfu nction | Malfuncti on | Malfu nction | Malfu nction |
| c_ParkingLot- Detected | - | Autonomous Ex- plore | - | - | - | - | - | - | - | - |
| k_DesiredLoc- Changed | - | Manual Loca- tion Move | Manual Location Move | Manual Location Move | - | - | Manual Loca- tion Move | Manual Location Move | Manual Loca- tion Move | Manual Loca- tion Move |
| k_OnGround | - | - | - | - | - | - | - | Off | Off | - |

## 4.2 Index