February 21, 2018

Andrew H. Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia V5A 1S6

Re: Capstone Project Functional Specifications for *SafeLift* and *AppAid*

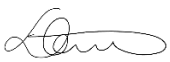
Dear Dr. Rawicz,

Enclosed is a document that provides the functional specifications for our Capstone Project, *SafeLift* and *AppAid*. *SafeLift* is a proximity alert system that aims to improve the overall safety of workplaces that utilize powered industrial trucks such as forklifts. *AppAid* is a risk management app that helps manage and mitigate risks before they become fatal.

The objective of this document is to provide the specifications, requirements and functionality of the design solution proposed for our system. It includes the system and component requirements, safety and engineering standards requirement, as well as reliability and sustainability issues. This document will be used as a guide and reference during the development of the project.

Our team consists of four senior engineering students with backgrounds in electronics, software, embedded systems, hardware and mechanical design. Please do not hesitate to contact the team in case you require any further information at fmose@sfu.ca.

Sincerely,



Fred Mose,
Chief Executive Officer
PowerLift Safe Solutions

Enclosure: Functional Requirements and Specifications for *SafeLift* and *AppAid*.

Functional Specification

SafeLift and *AppAid*

You don't have to be a statistic

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Submitted to

Dr. Andrew Rawicz

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Abstract

With the increasing use of forklifts for heavy material handling, the risks posed to the safety of drivers as well as pedestrians is significant. According to OSHA, one person dies due to forklift accident every three days [1]. Current methods to reduce forklift accidents include driver training, equipment maintenance and designated areas of operation. Looking at aforementioned statistic these strategies do not seem to be enough. In this report, we present a solution that we believe will improve workplace safety. Our product consists of a hardware component, *SafeLift* and a software component, *AppAid*.

This document contains the design requirements and functional specifications for *SafeLift*, a forklift proximity alert system and *AppAid*, a risk management app. The specifications define the system components, user interface, engineering standards, safety and sustainability of the product. All these will provide the basis for the design and building of the working model.

The design specifications to be implemented are divided into the following three phases of product development:

- Proof of Concept – in this stage we will demonstrate how the critical elements shall be integrated to give the desired functionality of the system
- Prototype – in this stage we will produce a product which will be tested
- Final Design – after thorough testing of the prototype the final product is expected to be delivered by end of August 2018

For each of these stages the processes involved are described, specifying their various elements and functions which will be tested vigorously to ensure the proper overall system functionality. All elements of the design shall adhere to safety standards and sustainability issues mentioned in this document.

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Glossary

AES	Advanced Encryption Standard
GUI	Graphical User Interface
ISO	International Standards Organization
RFID	Radio Frequency Identification
UART	Universal Asynchronous Receiver-Transmitter
UHF	Ultra-High Frequency

1. Introduction

1.1 Background

Accidents due to heavy industrial trucks in workplace are unfortunate events that can happen in the absence of proper safety procedures and affect several employees. These unsafe and hazardous working conditions can result in long-term psychological as well as physical consequences for the employee and the company. To control such incidents, workplace safety measures have been put in place.

Workplace safety refers to employee protection from illness, injury and hazard [2]. The primary objective to enforce workplace safety is to provide the employees with a safe, healthy and risk-free work environment. We believe our product, *SafeLift* is the perfect blend of safety and ease of use that will provide safer working conditions for the employees without being *too-much-work* for the employer.

PowerLift Safe Solutions offers two products to prevent casualties; *SafeLift* and *AppAid.*

1.2 Scope

In today's world, many corporations focus on the development and growth of employees. They believe in the ideology of benefiting the employee through different approaches yet safety at workplace is an important aspect that these organizations tend to ignore [2]. The wellbeing, health and safety of the employees should be among the top priorities of all firms. Our vision for *PowerLift Safe Solutions* is to design a product that can be integrated into existing industrial vehicles to exponentially increase the levels of safety at workplace.

This document provides a detailed explanation of the functionality and requirements that *PowerLift Safe Solutions* promises to implement in *SafeLift* and *AppAid*.

1.3 Intended Audience

This document is to be used by the engineers at *PowerLift Safe Solutions* as a guideline during the development stages of *SafeLift* and *AppAid*. This document can also be used by the TAs for grading purposes. The hardware and software engineers of the project can use this document as a reference at any time during the development and/or testing stages of the product.

1.4 Requirement Classification

For consistency purposes, the entire document follows the coding scheme mentioned below:

[Req {subsection #}.{requirement #} – Development Stage]

For example**: [Req 1.1.3 – PT]** refers to general requirement number 3 for prototype.

The development stages are abbreviated as:

PC – Proof of concept
PT – Prototype
FP – Final Product

The requirement section of the document is divided into 5 main categories:

1. *SafeLift* System Requirements
2. *AppAid* Requirements
3. Engineering Standards
4. Enviromental Standards
5. Safety and Sustainabilty

2. System Overview

2.1 *SafeLift* - Forklift proximity alert system

SafeLift is an obstacle detection sensory system with sensors mounted on key positions around the forklift. This sensory system has two components; an RFID system to detect employees and other vehicles and an ultrasonic system to detect objects. Employees will be required to carry their RFID tags at all times. The range for the sensors is a customizable radius of three to five meters set by the employer when installing the system. This is the range we believe is required for the forklift operator to avoid the accident. Figure 1 below shows the proposed positioning of the control system as well as the position of the sensors.

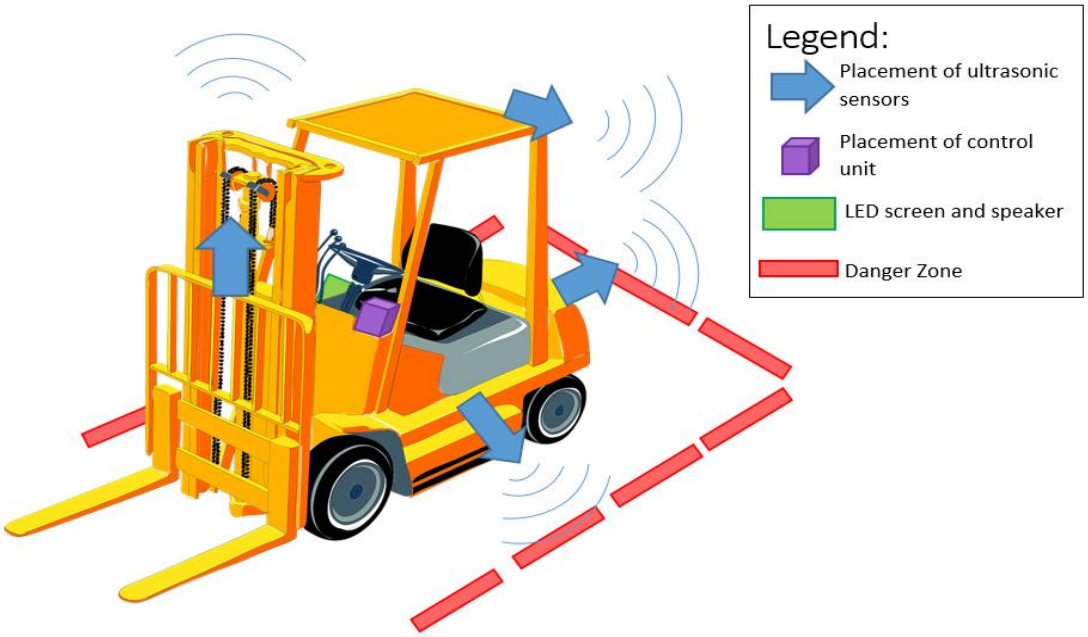

Figure 1. *SafeLift* control and sensory system placements

The sensory systems will be designed to set off an audio alarm as well as display a visual warning when the obstacle is in the danger radius of the forklift. The figure below shows a block diagram of the system.

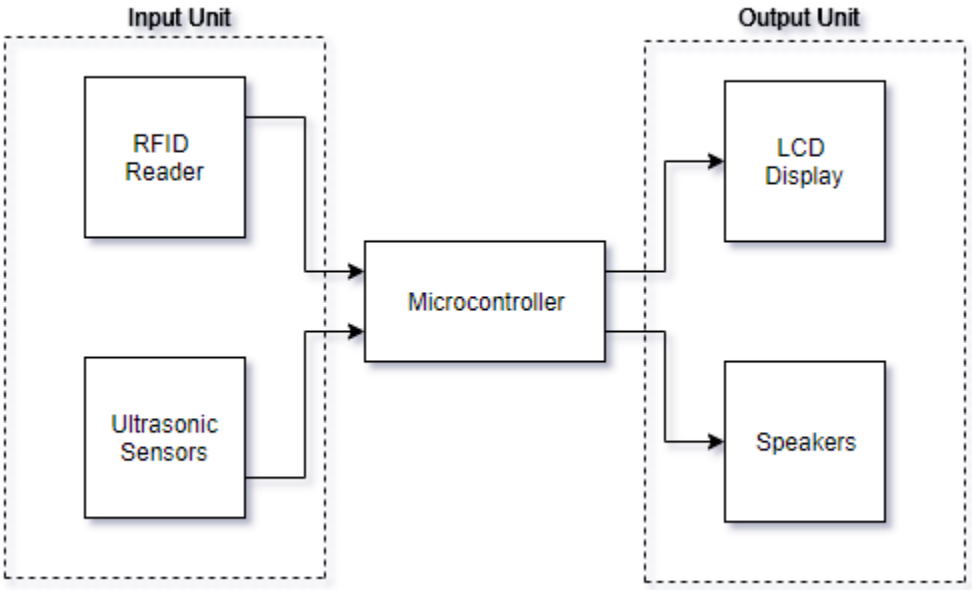

Figure 2. Block diagram of SafeLift system

2.2 *AppAid* – risk management app

The second product that *PowerLift* has to offer is a risk management application, called *AppAid*. *AppAid* is primarily being designed to identify and mitigate long term workplace risks by tracking and analyzing the recurrence of injuries and incidents. *AppAid* will keep a record of all injuries and near misses as well as track accident-prone locations in the workplace. The addition of the application will help authorities take appropriate measures to reduce accidents that could have been avoided. Furthermore, this app will also be used by employers to train employees. It will contain easy-to-access training modules with up-to-date health and safety standards. *AppAid* will also schedule and send reminders for regular review sessions.

3. *SafeLift* System Requirements

This section gives the specific requirement for our product. It has seven sections, some of which have sub-sections to provide further requirements.

3.1 General Requirements

[Req 3.1.1– PC]	Booting up of the system should be under a minute
[Req 3.1.2– FP]	Optimal for forklifts of speeds between 6 – 8 km/h
[Req 3.1.3– FP]	The system will be easy to install
[Req 3.1.4– FP]	The system will be long lasting i.e., it will have a service life of at least 5 years
[Req 3.1.5– FP]	The system will not cost more than $1500
[Req 3.1.6– FP]	User manual for the system will be in English
[Req 3.1.7– FP]	The system should go into power save mode when not in use
[Req 3.1.8– FP]	The system will be marketed as kit that can easily be installed by a forklift dealer or any existing forklifts
[Req 3.1.9– FP]	The system will be waterproof
[Req 3.1.10– FP]	Position of the components of the system should not be affected by motion of truck
[Req 3.1.9 – FP]	The app will come as a package with the purchase of *SafeLift*

3.2 Physical and Operational Requirements

[Req 3.2.1– PC]	The system should detect and report the correct distance of obstacle
[Req 3.2.2– PC]	The system should refresh distance every 3 seconds and report any changes

[Req 3.2.3– PT]	Power buttons and connections ports should be easily accessible and clearly labelled
[Req 3.2.4– PT]	System should auto calibrate when powered up or when obstacle leaves detection range
[Req 3.2.6– FP]	The components should have protective cases preventing dust accumulation
[Req 3.2.7– FP]	System should be simple to use even without much technical knowledge
[Req 3.2.8– FP]	The display device shall have a holding dock which will screwed at position on the truck whose angle can be adjusted
[Req 3.2.9– FP]	Placement of the RF antenna shall be clear of obstruction to allow for proper propagation of RF waves

3.3 Electrical requirements

[Req 3.3.1– PC]	System shall be powered by a 12V adapter
[Req 3.3.2– PT]	Display should alert user in case of low battery level
[Req 3.3.3– FP]	All voltage level for all components should be 3 -12 V
[Req 3.3.4– FP]	System should use a rechargeable battery sufficient to allow usage for at least 4 hours on single charge
[Req 3.3.5– FP]	Any electrical component including wires shall not interfere with forklift operation

3.4 Component Requirements

3.4.1 Microcontroller

The microcontroller is the core of the system. It translates and processes the data received from the input unit (RFID reader and Ultrasonic sensors) then sends it the output unit (LCD screen and speakers) to display the results.

[Req 3.4.1.1 – FP]	The microcontroller will have the capability to implement digital filtering
[Req 3.4.1.2 – FP]	The microcontroller should not lose information due to sudden loss of power.
[Req 3.4.1.4 – FP]	The microcontroller will take no longer than 3 s to power on and initialize.
[Req 3.4.1.5 – FP]	The microcontroller will be compatible with a 5 V rechargeable battery.
[Req 3.4.1.6 – FP]	The microcontroller will have low power consumption.

3.4.2 Ultrasonic Sensors

[Req 3.4.2.1– PC]	Maximum objection detection distance of 5 m
[Req 3.4.2.2– PC]	Minimum objection detection distance of 0.5 m
[Req 3.4.2.3– PT]	Operating voltage of 5 V, 3 mA Current draw
[Req 3.4.2.4– FP]	Automatic calibration to compensate for changes in temperature, voltage, humidity and noise
[Req 3.4.2.5– FP]	The dimensions of the sensors should not be larger than 35 x 20 x 3 cm.
[Req 3.4.2.6– FP]	Beam angle of at least 30 degrees.
[Req 3.4.2.7– FP]	Nominal Frequency of 40 Hz [5]

3.4.3 RFID System

The RFID system consists of three components: reader, tags and antenna. The reader generates electromagnetic waves via the antenna over the read range radius. When the tag enters this region, it interacts with waves and gets activated sending back a wave signal with the information on it, which is interpreted by the reader.

[Req 3.4.3.1– PC]	UHF 860 -956 MHz
[Req 3.4.3.2– PC]	Read range of up to 5m
[Req 3.4.3.3– PC]	Passive tags with unique ID
[Req 3.4.3.4– PC]	Have faulty tag detection system
[Req 3.4.3.5– PC]	RFID activated only when tag is in read range
[Req 3.4.3.6– PT]	Reader should operate with a regulated voltage between 5 -10 V
[Req 3.4.3.7– PC]	Read multiple tags simultaneously at least 200 tags/s
[Req 3.4.3.8– PC]	Tags should weigh less than 30 grams
[Req 3.4.3.9– FP]	RF power maximum: 1 W – transmitted and 4 W – EIRP (Equivalent Isotropically Radiated Power) [3]
[Req 3.4.3.10– FP]	Circularly polarized antenna to offer flexibility in the tag orientation
[Req 3.4.3.11– FP]	RFID reader shall use high speed USB or TTL Uart (RS232) communication with microcontroller
[Req 3.4.3.12– FP]	Reader software should be able to interact with microcontroller OS
[Req 3.4.3.13– FP]	The radio frequency waves should shall not cause interference with any other devices or components

3.4.4 LCD Screen

[Req 3.4.4.1– PC]	The display shall be a 10" screen
[Req 3.4.4.2– PC]	Display range and direction of obstacle this indicates ultrasonic sensor detection

[Req 3.4.4.3– PC]	Display number of RFID tags which indicated pedestrians in danger zone
[Req 3.4.4.4– PT]	Display color coded obstacle distance. For example, green is a far distance, yellow medium distance and red is close distance
[Req 3.4.4.5– FP]	The display should refresh the range data 3 to 4 times per second.
[Req 3.4.4.7– FP]	The display should be position on the forklift such that the operator has clear view and does not strain look at it.

3.4.5 Speakers (Buzzer)

[Req 3.4.5.1– PC]	Audible sound when an obstacle enters a danger zone
[Req 3.4.5.2– PT]	Sound with noise emission level between 60 dB – 87 dB (87 dB is Canadian exposure limit for 8 hours) [6]
[Req 3.4.5.3– PT]	Audible sound which beeps faster as obstacle gets closer then to a continuous tone at a distance of less than 0.5 m
[Req 3.4.5.4– FP]	Have an adjustable volume level

3.5 Software/ Firmware Requirements

[Req 3.5.1– PC]	Software for the reader should be compatible with the software on the microcontroller
[Req 3.5.2– PC]	Software should automatically detect the appropriate port connections example COM3, COM5, etc.
[Req 3.5.3– PT]	System should handle sudden run- time errors or interrupts from hardware components without affecting its functionality
[Req 3.5.4– FP]	All software should allow upgrades to improved versions

3.5 Environmental Requirements

[Req 3.6.1– FP]	All components should have operating temperature of -20°C to 55°C
[Req 3.6.2– FP]	All components should operate within humidity range of 5% - 45%
[Req 3.6.3– FP]	RFID tags should be able to operate properly in an environment of metal abundance.

4. Environmental Standards

CAN/CSA-ISO 14040-06 (R2016)	Environmental Management - Life Cycle Assessment - Principles and Framework [7]

CAN/CSA-ISO 14044-06 (R2016)	Environmental Management - Life Cycle Assessment - Requirements and Guidelines [7]
CAN/CSA-SPE-890-15	A Guideline for accountable management of end-of-life materials [7]
CAN/CSA-ISO 14001:16	Environmental management systems — Requirements with guidance for use [7]
CAN/CSA-ISO 14004:16	Environmental management systems - General guidelines on implementation [7]
CAN/CSA-ISO 20121:13	Event sustainability management systems - Requirements with guidance for use [7]

5. Engineering Standards

ISO/IEC 18000-6	Parameters for Air Interface Communications at 860-960 MHz [4]
ISO/IEC 15962	Information technology -- Radio frequency identification (RFID) for item management -- Data protocol: data encoding rules and logical memory functions [4]
ISO/IEC 15962	Deals with the processing of data and its presentation to the RF tag, and the initial processing of data captured from the RF tag. [4]
ISO/IEC 15963	Describes numbering systems that are available for the identification of RF tags [4]
CAN/CSA-Z107.56-M86	Procedures for the Measurement of Occupational Noise Exposure [7]

6. *AppAid* Requirements

6.1 General Requirements

[Req 6.1.1– PC]	Available on Android
[Req 6.1.2– PC]	Cover 90% of android operating systems
[Req 6.1.3– PC]	User sign in to access application.
[Req 6.1.4– PT]	Optional fingerprint log in
[Req 6.1.5– FP]	Separate login for employers and employees
[Req 6.1.6– FP]	Different user privileges on their clearance.
[Req 6.1.7– FP]	Available on iOS

6.2 Security Requirements

[Req 6.2.1– PC]	Encryption of the data
[Req 6.2.2– PC]	Log in time out
[Req 6.2.3– PC]	Secure log in
[Req 6.2.4– FD]	Encryption of the data

6.3 Usability and Reliability Requirements

[Req 6.3.1– PC]	Provide easy to use GUI
[Req 6.3.2– PC]	Have fast response time
[Req 6.3.3– PT]	Should be able to recover any work in progress in case of a crash
[Req 6.3.4– FP]	Will handle any improper data or operations without crashing

6.4 Operational and Reporting Requirements

Incident Reporting	[Req 6.4.1– PC]	Easy to fill out forms
	[Req 6.4.2– PC]	When the user requests a filing form, the app will automate filing of standard incident reporting forms
Statistics Reporting	[Req 6.4.3– PC]	Data analysis representation using graphs
	[Req 6.4.4– PC]	Statistical Relevance
Training Module	[Req 6.4.5– PT]	Training provide with infographics, and other documents to forklift operators
	[Req 6.4.6– FP]	Schedule bimonthly training sessions
	[Req 6.4.7– FP]	Alerts to remind operators for new training modules
	[Req 6.4.8– FP]	Track training progress of individual operators

Qualified Operator/ First Aid Attendant Tracker	[Req 6.4.9– FP]	Tracks qualified operators and first aid attendants
	[Req 6.4.10– FP]	Monitor incident rates of individual operators, which can be used to see which operators need additional training
	[Req 6.4.11– FP]	Tracks which operator is using which vehicle. This can be used during incident reporting
	[Req 6.4.12– FP]	Tracks qualified operators and first aid attendants
	[Req 6.4.13– FP]	Monitor incident rates of individual operators, which can be used to see which operators need additional training

7. Safety and Sustainability

At *Powerlift Safe Solutions* emphasis is placed on ensuring that the product as sustainable and safe for the use. *Powerlift Safe Solutions* is designed to improve the safety of workplace environments that incorporate the use of forklifts. *Powerlift Safe Solutions* will emphasize "cradle-to-cradle" design. Every product will be made from sustainable materials that can easily be recycled after the product's life cycle. Since this product is designed to interact with clientele, extensive measures must be taken to ensure the safety of the user. During sustainability and safety analysis, emphasis on reliability will be placed on the various products components to ensure that the product works according to design. Failure to do so would result in injury since the product is heavily based on safety. A list of safety requirements includes:

- Secure fastening of devices to avoid injuries
- The device should not collect excessive electrostatic charge that is harmful to humans and electronic circuits inside the device.
- All electrical devices/components shall be encased properly.
- Device should be non-flammable, non-explosive, and easily transported.
- Wires and board shall be properly insulated and grounded to prevent shocks and electrical fires
- The unit must be resistant to different physical forces such as being dropped or getting hit
- All components must withstand operation temperature, humidity, and currents
- The unit should not overheat under continuous usage
- The electronic components shall not cause interference with other devices

Due to safety concerns for the user base, non-toxic materials have been chosen as well as materials that are free of any lead contaminations. This will minimize any harmful exposures and make the

product as safe as possible. Due to the passive nature of the RFID tag as it does not have an in-built energy source, it emits no waves and poses no danger. The ultrasonic sensor will emit a low working frequency of 40Hz [5] which will pose no danger to the user. AppAid will include a secure login, a login time out and the encryption of data using a AES.

Another very important aspect of sustainability is the environmental footprint of our product. Environmental standards CSA-C22.2 No. 107.2.01- Battery Chargers and CSA-C22.2 No. 0.23-15 – General Requirements for Battery-Powered Appliances standards. These standards are applied to stationary battery chargers and battery powered devices for indoor and outdoor use as well as portable and mobile charges. Since batteries are the most common form of hazardous waste, an implementation is needed to mitigate the disposal of batteries after the end of their life cycle. This will be done by including workforce and competency training in *AppAid*.

8. Conclusion

SafeLift, in combination with *AppAid* is a robust, durable, compact and powerful system for reducing forklift injuries. By using both RFID and ultrasonic sensors mounted on strategic positions on the forklift, detection of bystanders and obstacles will be possible. *AppAid* will provide forklift drivers with infographics and other training sessions as well as remind operators when they need re-training. The system design consists of three major sections:

- Software development aimed to develop an application to keep track of workplace injury and help re-train forklift operators
- Hardware development aimed to provide a robust, durable, and compact solution for reducing forklift injuries and workplace accidents.
- Firmware development aimed to enable communication between the microcontroller and the RFID components.

To minimize scheduling slippage, the prioritization system will be implemented to allocate resources efficiently. The focus will be on basic functionality of the product, this includes detection of obstacles using the RFID and ultrasonic sensor. A basic functionality of the application is also necessary.

In this document, there is clear justification of the requirement specifications for both the hardware and software aspects of the product. Including a detailed outline of the requirements of the electrical, and computational aspects of the product

Although they are a few products out there that help improve the safety of forklift usage, *Powerlift Safe Solutions* has created a product that rivals the competition. It is the first product of its kind that combines both a hardware and software component. *Powerlift Safe Solutions* product will also

be one that is of low cost and easy to use. This document has also described and addressed sustainability, safety and environmental concerns. *Powerlift Safe Solutions'* goal is to ensure a hazard free working environment as well as to ensure the reliability and sustainability of the product and that starts with following the standards that have been outlined above.

9. References

[1] R. Bostelman, "Towards Improved Forklift Safety", *Nist.gov*, 2018. [Online]. Available: https://www.nist.gov/sites/default/files/documents/el/isd/ms/PerMIS-09-Forklift-Safety-WhitePaper.pdf. [Accessed: 21- Feb- 2018].

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Appendix

A. Proof of Concept

For the proof-of-concept *PowerLift Safe Solutions* will deliver the following features of *SafeLift*:

- Have the system boot up in less than a minute
- Have the system detect and report the correct distance of obstacle
- Have the microcontroller, which is the heart of the system, translate and process the data received from the input unit (RFID reader and Ultrasonic sensors) then sends it the output unit (LCD screen and speakers) to display the results
- Have the ultrasonic sensors detect objects that are a minimum distance of 0.5 m and maximum distance of 5 m away
- RFID will read up to 5m and have a faulty tag detection system
- RFID system will read simultaneously of up to 200 tags

We have chosen these features because, they are the core of *SafeLift*. To proceed further, these features must be implemented and proven to work reliably.

For the *AppAid* we will deliver the following features for the proof-of-concept:

- The incident reporting module
- The statistics reporting module

These two modules are the core of *AppAid.* While the other features are useful, they are not core to the operation of *AppAid. AppAid* at its core is an incident reporting and tracking software. The other modules only help to boost the effectiveness of *AppAid* but without the incident reporting and statistics reporting modules, they would lose much of their effectiveness.