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June 14, 2020

Dr. Craig Scratchley
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Re: ENSC 405W/440 Requirements Specification for the Urban Needle Locator Mark I

Dear Dr. Scratchley:

The attached requirements specification is for the Urban Needle Locator Mark I, a RFID based tracking solution for identifying the location and ID of syringes from needle exchanges that are carelessly discarded in urban environments.

Our goal is threefold: create a substantial efficiency increase in locating and removing used syringes, reassure citizens their public areas are needle-free, and hold exchanges accountable that the syringes leaving their operations are properly discarded.

To be successful in achieving these goals the Mark I requires concurrent identification of multiple passive tags while estimating their location GPS coordinates using a combination of sensors and time-displaced triangulation. This requirement specification outlines the various subsystems which work together to achieve our key objectives while staying within safety guidelines and ensuring that the Mark I is built to considerable sustainability standards.

Verifynd's team has six dedicated engineers in three disciplines: biomedical engineers Liam Goundrey and Matthew Schilling; electronics engineers Madhumeetha Udayakumar and Bella Xu; computer engineers Eric Kwok and Alex Makasoff.

If you have any comments or questions please contact Liam Goundrey by phone (604-445-7651) or email (lgoundre@sfu.ca).

Regards,

Matthew Schilling
Chief Executive Officer
Verifynd

Enclosed: Requirements Specification for the Urban Needle Locator Mark I

Outdoor Asset Tracking Solutions

Requirements Specification

Urbaln Needle Locator Mark I

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Abstract

The Urban Needle locator Mark I is a mapping and tracking system which reads syringes discarded in an environment and stores their unique-ID, GPS coordinates, and time-stamped data. Dirty needle refuse represents a modern problem and requires a modern solution. By using a combination of passive RFID tags, mobile antenna system and GPS sensors the Mark I will be able to produce a map of current needle refuse to be referenced by cleanup crews. Due to the immense scope of the problem - PHS mobile needle exchange estimates they retrieved 1.6 million used syringes in 2012 alone in Vancouver[1] - even small efficiency increases can produce large reductions in time spent on cleanup. For these reasons, it is critical that the Mark I is able to accurately locate syringes and produce reliable data that workers can use effectively. Additionally, as the Mark I is an engineered product operating in an urban environment, it is essential that it conforms to safety and engineering standards mandated by local governments. The following document quantitatively outlines all of the necessary requirements for the system to operate successfully in Canada.

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1 Introduction

The Urban Needle locator Mark I, abbreviated UNLmkI, represents a philosophy that tracking urban assets makes increasingly busy cities function better for everyone. Needle exchanges represent a general health benefit [2], but syringes left behind in public urban spaces are a cost. In order to keep track of syringes after they have left exchange centres, we propose a system of passive RFID tags embedded in syringes which are read by a roaming mobile antenna system. A set of sensors on the mobile system records the GPS, tag ID and timestamp of syringes within a radius of 30ft. By travelling through neighbourhoods (likely attached to a vehicle) the system is able to quickly read syringe locations and save this information to a cloud map database to be used by cleanup crews.

Current syringe cleanup crews generally rely on hotlines, these hotlines need to be staffed by either additional workers or volunteers and represent a slow and cumbersome process for identifying refuse hotspots. For example, a single needle exchange in Vancouver operates a cleanup service 20hrs per day, seven days a week, year-round [3].

By reducing the current random-search method of syringe cleanup we expect to see big increases in efficiency. There is also an important benefit in having accountability that syringes leaving needle exchanges have been properly accounted for, as a common argument [4] against having these programs is bio waste ends up in public spaces where it is both unsightly and dangerous to citizens. Another benefit is being able to quantify that not only are particular hotspot areas syringe-free, but wide areas of the city can be quantified on the same time-stamped basis. A general overview of how the system functions is illustrated in **Figure 1.1**.

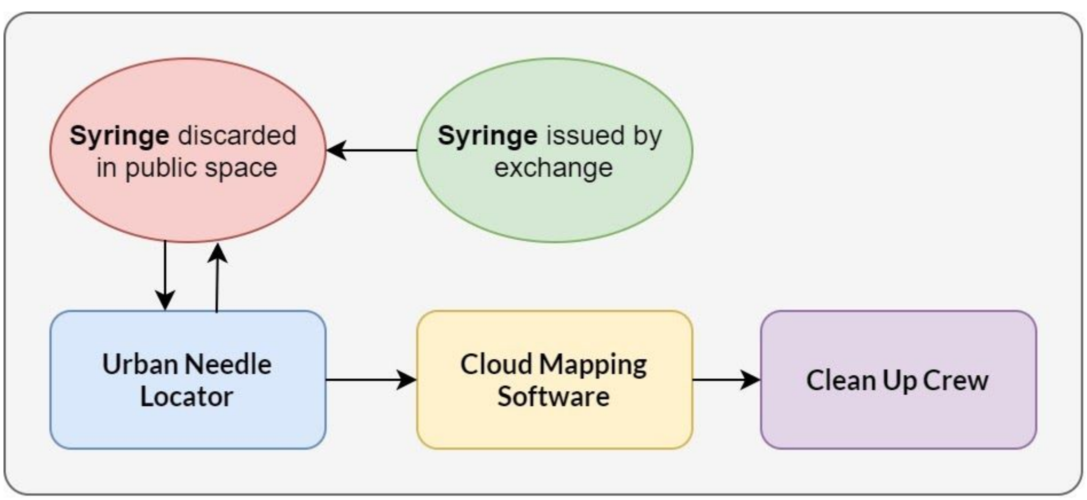

Figure 1.1: General System Function

1.1 Scope

The purpose of this document is to highlight the functional needs of the subsystems and specify relevant engineering standards plus safety and sustainability of both the device components / design and its implementation in the urban environment.

1.2 Requirement Classification

Requirements are listed as follows:

Req {document Section}.{Requirement Number}-{Design Stage}

The design stage is divided into three sections: proof of concept, minimal viable product and beta - **C,M,B**. An example hardware requirement for proof of concept is written:

Req 3.1.10 - C

2 System Overview

The UNLmkI consists of two components: the hardware to communicate with RFID tags and software to display the location of these tags. The hardware consists of an RFID antenna/reader system, supporting sensors and a GPS module. The software system consists of retrieving information from the microcontroller unit, Raspberry Pi, and storing it in an SD card for upload to cloud storage.

The antenna and reader will be responsible for transmitting and reading radio waves as tags are encountered, the time of flight sensor and accelerometer will give the precise distance to the tag in coordination with the RFID and a GPS module will be used to pinpoint the tag location on a map.

All the information from sensors and the reader will be funneled through the microcontroller and uploaded to an SD card and sent via Wi-Fi/Bluetooth to other platforms (mobile and/or cloud based). **Figure 2.1** displays the high level overview of the hardware and software components of UNLmkI.

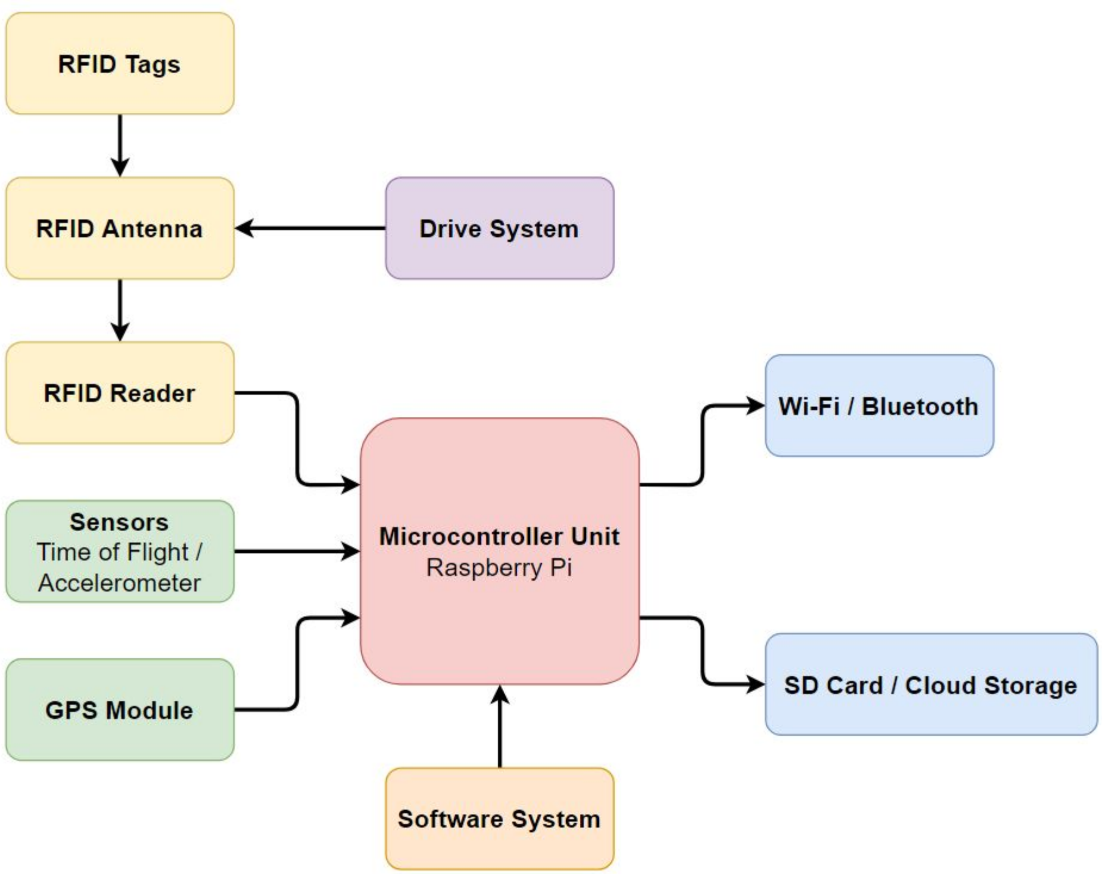

Figure 2.1: Hardware and Software Overview

3 High-Level Requirements

Fundamentally the UNLmkI identifies a syringe, locates it with respect to a GPS system and stores those values at a specific time. These three pieces of data are stored to be utilized on a cloud mapping solution which can be accessed by workers on location to efficiently remove used syringes from public spaces. The next set of chapters will detail the various subsystems and their respective requirements.

3.1 Beta Phase High-Level Requirements

In order to move into a real-world testing phase, certain key metrics need to be established as successful.

Table 3.1: Beta Phase High Level Requirements

Req 3.1.1 - B	UNLmkI shall operate on a battery-powered system.
Req 3.1.2 - B	UNLmkI shall operate on a mobile transport solution (car, bike, or person).
Req 3.1.3 - B	UNLmkI shall locate a syringe with respect to the mobile antenna GPS coordinate to within 4 feet of accuracy.
Req 3.1.4 - B	UNLmkI shall ID multiple syringes simultaneously.
Req 3.1.5 - B	UNLmkI shall store location, ID and time information to a database which can be utilized by mapping software (i.e. Open Street Maps).

4 Mechanical Requirements

Mechanical Requirements will be illustrated with motor system restrictions in the following section.

4.1 Drive System

Table 4.1: Drive System Requirements

Req 4.1.1 - C	The motor system shall maintain a constant rotational speed of 4π/3 rads/second.
Req 4.1.2 - C	The motor system shall return to the current angle when requested.
Req 4.1.3 - M	The motor will have sufficient torque to return to operational speed within a reasonable time when interrupted.
Req 4.1.4 - M	The bearings used will provide stable operation when the system is moved.
Req 4.1.5 - M	The motor system will operate efficiently off of the chosen power supply.
Req 4.1.6 - B	The motor system will operate over a reasonable lifespan of the unit.

Depending on the form factor of the final product, this drive system may not be necessary. However, since directional circular polarized antennas have a cone-like RF emitting shape they provide longer read distances [5] but do not cover a large area and therefore some means of sweeping the antenna may be required. This motor system would need to be of sufficient power to maintain the rotational velocity of approximately 4π/3 rads/second.

The chosen rotational velocity is designed to accommodate RFID readers with a sampling rate in the order of 200 reads per second. While the torque required to overcome the friction of the bearing system is low, it will also need to provide additional torque to bring the antenna up to the required velocity within a reasonable time.

As this component would be one of the few mechanical parts of the system, it is important to use appropriate materials and building techniques to minimize the effect of wear on the system.

5 Hardware Requirements

The following session will provide hardware requirements for UNLmkI with precise explanations regarding decisions.

5.1 RFID System

The RFID system consists of RFID tags, RFID readers, and RFID antennas, **Figure 5.1**. Tagging syringes with passive RFID tags allows identification. The Ultra-High Frequency band ranges from 300 MHz to 1 GHz [6]. For the UNLmk1 UHF RFID is required due to the much higher read range compared to low-frequency and high-frequency tags. The maximum read range of UHF RFID could be up to 50 feet, however, in this case 30 feet is a good range to maintain reliable reads as well as read accuracy. Furthermore, the high data transfer rate makes the UHF RFID tags suitable as there will be the need to detect multiple tags in a small physical area.

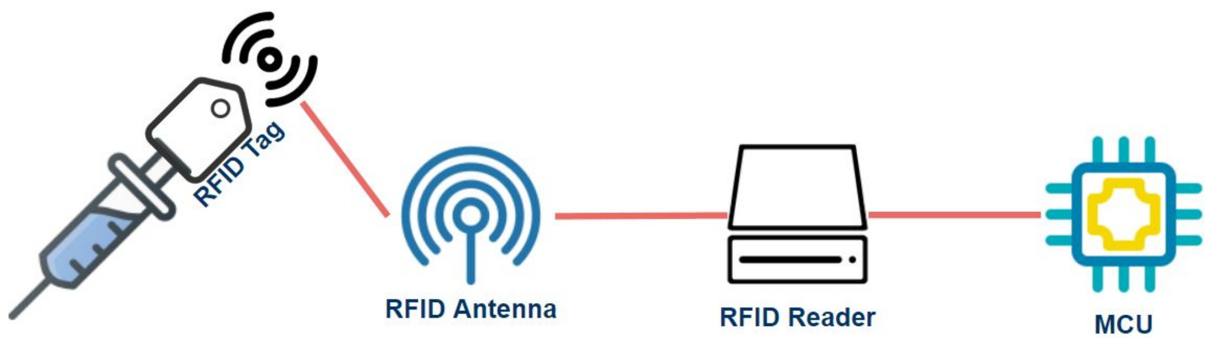

Figure 5.1: Schematic Diagram of a Basic RFID System

5.2 RFID Tags

Table 5.2: RFID System Requirements

Req 5.2.1 - C	RFID Tags shall operate in the Ultra-High Frequency (UHF) range in 860 - 960 MHz.
Req 5.2.2 - C	Each tag's EPC number shall be unique. The EPC number of each tag is read to identify the tag as well as the syringe.
Req 5.2.3 - C	RFID Tags shall be passive, not containing battery power.

5.3 RFID Reader

Table 5.3: RFID Reader Requirements

Req 5.3.1 - C	The RFID Reader shall be connected via TTL/USB/UART with Android, Arduino, and Raspberry Pi.
Req 5.3.2 - C	The reader shall provide 3.0 W to antennas to maximize the read range.

5.4 RFID Antenna

Table 5.4: RFID Antenna Requirements

Req 5.4.1 - C	A circularly polarized antenna shall be used since the tag orientation is unknown.
Req 5.4.2 - C	The antenna shall have the read range of at least 30 feet.
Req 5.4.3 - C	The frequency range of the antenna shall be within 902 - 928 MHz[7], [8] to comply with the Canadian Radio-television and Telecommunications Commission (CRTC) regulation.
Req 5.4.4 - C	The antenna shall have an azimuth angle of at least 45 degrees to[7] provide a large read area.
Req 5.4.5 - C	The antenna shall have an IP rating of 65 for outdoor use. This rating protects it from liquids and ambient moisture.
Req 5.4.5 - B	The antenna shall not be placed in an environment where it contains metal or water.
Req 5.4.6 - B	The antenna shall not pass a 4W Effective Isotropic Radiated Power (EIRP) as it must conform to CRTC regulations. [9]

5.5 Sensor System

To update the geo-location of the RFID tag, it is important to find a way of determining the distance between the RFID antenna and tag. When a reader receives a signal from an RFID tag, it can report the tag's Received Signal Strength Indicator (RSSI) value. However, RSSI values are not reliable for calculating the distance of the tag from the antenna in a passive RFID system due to environmental sensitivity constraints. For instance, metal reflects the energy and water absorbs the energy. There are alternative ways of measuring distance, including differences in phase between antenna readings, however, for the purposes of the UNLmkI a backup sensor system has been chosen to calculate a more accurate geo-location.

Table 5.5.1: Time of Flight (ToF) Sensor Requirements

Req 5.5.1.1 - C	The sampling rate of the ToF sensor shall be 4 kHz which can cover a 15 m range.
Req 5.5.1.2 - C	The ToF sensor will be able to detect distance independent of reflectivity interference.
Req 5.5.1.3 - C	The ToF sensor shall have a clock frequency of at least 45 MHz to maintain proper data acquisition.

Table 5.5.2: Accelerometer Sensor Requirements

Req 5.5.2.1 - C	The accelerometer shall have digital output values to determine the tilt and speed of the reader to exactly determine where the antenna found the tag as the antenna is moving.
Req 5.5.2.2 - B	The accelerometer shall be mounted easily to the antenna.

The Time of Flight sensor is able to measure the distance between an object and itself based on the time delay. A typical laser will be emitted from the sensor and bounced back after hitting the target. A periodic modulated signal is emitted and a phase shift in the reflected light is measured to attain depth information of the target object.

To manipulate the operation of motors, an accelerometer is chosen to measure the change in velocity.

5.6 GPS Module

Table 5.6: GPS Module Requirements

Req 5.6.1 - C	The module must have a serial port with a baud rate of 9600.
Req 5.6.2 - C	The module shall have a hot start which means all of the satellites are up to date and are close to the same positions as they were in the previous power-on state.
Req 5.6.3 - B	The module shall upload coordinates in real-time and shall be synchronized with the RFID reader.

The UNLmkI will be equipped with RFID antennas which will transmit appropriate UHF frequency radio waves to passive tags. In order to provide the antenna with a maximal power of 4W, the reader must be power efficient and connectors should be a low loss. The GPS module must be able to lock immediately when new tags are found. A directional antenna has a longer read range than an omnidirectional antenna; therefore, a rotating mechanism would be essential to scan the entire area. The general sensor data integration system is illustrated in **Figure 5.6**.

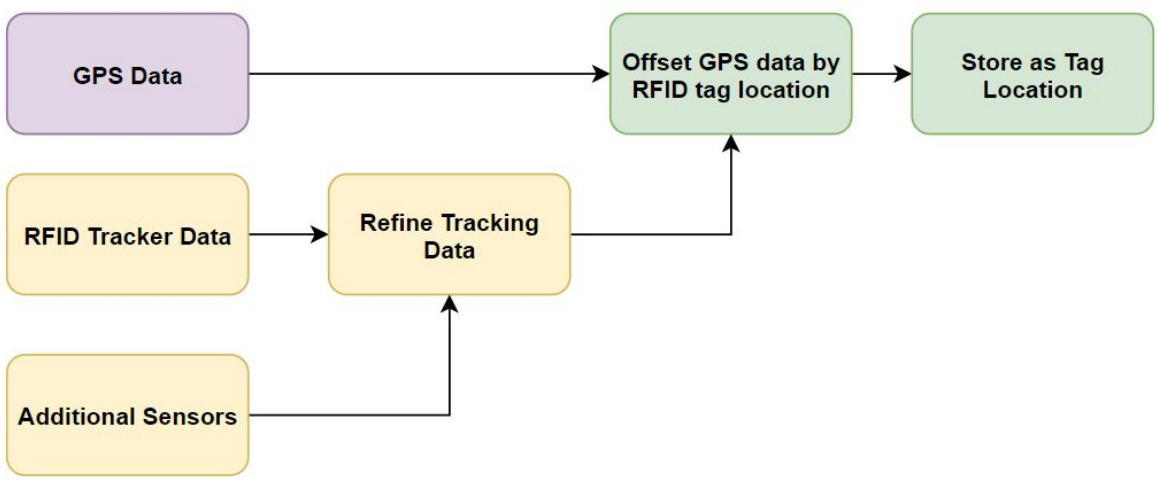

Figure 5.6: Sensor Data Integration.

6 Electrical Requirements

6.1 Power Supply

Table 6.1: Power Supply Requirements

Req 6.1.1 - C	The power supply will be able to effectively power all components in the system, with the capability to deliver 4W to the antenna for maximum read distances.
Req 6.1.3 - B	The power supply will be able to provide continuous working time for a minimum of 4 hours.
Req 6.1.4 - B	The power supply will have a turnaround time of 1 hour.

The UNLmkI will be required to traverse the city on a shift based schedule. This requirement specifies a 4-hour shift followed by a 1 hour turnaround time. Whether this turnaround time is accomplished by a replaceable battery pack or a fast charging solution will be determined at a later date.

6.2 Wiring

Table 6.2: Wiring Requirements

Req 6.2.1 - C	Any high power wires will be fully insulated to ensure working safety for team members and the equipment
Req 6.2.2 - B	The casing will be isolated to protect the user from any potential microshocks
Req 6.2.3 - B	The Wiring will be neat and secured with clear wiring diagrams provided.

The wiring of the system allows for easy troubleshooting of the final build and ensures that users and technicians are safe from potential shocks. To maximize read range the cable should be a higher insulation rating.

7 Software Requirements

7.1 General

Table 7.1: General Software Requirements

Req 7.1.1 - C	UNLmkI shall detect and differentiate individual RFID tag IDs.
Req 7.1.2 - C	After detecting the same RFID tag at least once, UNLmkI shall triangulate an estimate of the location of the syringe for each new detection.[10]
Req 7.1.3 - C	UNLmkI shall record GPS coordinates and heading when requested.
Req 7.1.4 - M	UNLmkI shall operate and manage all processes in real-time.
Req 7.1.5 - M	UNLmkI shall log any errors encountered.
Req 7.1.6 - M	UNLmkI will manage faults without needing a full power cycle.
Req 7.1.7 - M	There shall be enough ports on the selected MCU to accommodate GPS, RFID reader, and any other required components.
Req 7.1.8 - B	UNLmkI shall write location data, time of measurement, and syringe triangulation estimate to non-volatile memory.
Req 7.1.9 - B	UNLmkI will boot up within 60 seconds after power-up.
Req 7.1.10 - B	UNLmkI shall power off and save all data in less than 45 seconds after the user shuts the device down.
Req 7.1.11 - B	UNLmkI will be able to process 10 requests per second.
Req 7.1.12 - B	UNLmkI will attempt to save power by using a microcontroller that has specific low-power features.[11]
Req 7.1.13 - B	In the event that a firmware upgrade fails the UNLmkI will revert back to its previous firmware version and still be functional.
Req 7.1.14 - B	The UNLmkI will notify the user when the battery needs to be recharged.

Req 7.1.15 - B	The UNLmkI software will provide a command interface to allow for debugging.

The Urban Needle Locator Mark I must be able to integrate RFID information, GPS coordinates and heading, and any other sensors in order to triangulate syringe locations. Each syringe will have a unique RFID identifier. When UNLmkI receives an RFID ping from a syringe, it will record time and GPS information. Then, if this ID has been recorded before, UNLmkI will use the previously recorded location to generate an estimate of the syringe location. If there is a previous estimate averaging will be used to create a new estimate. The general algorithm is illustrated in **Figure 7.1**.

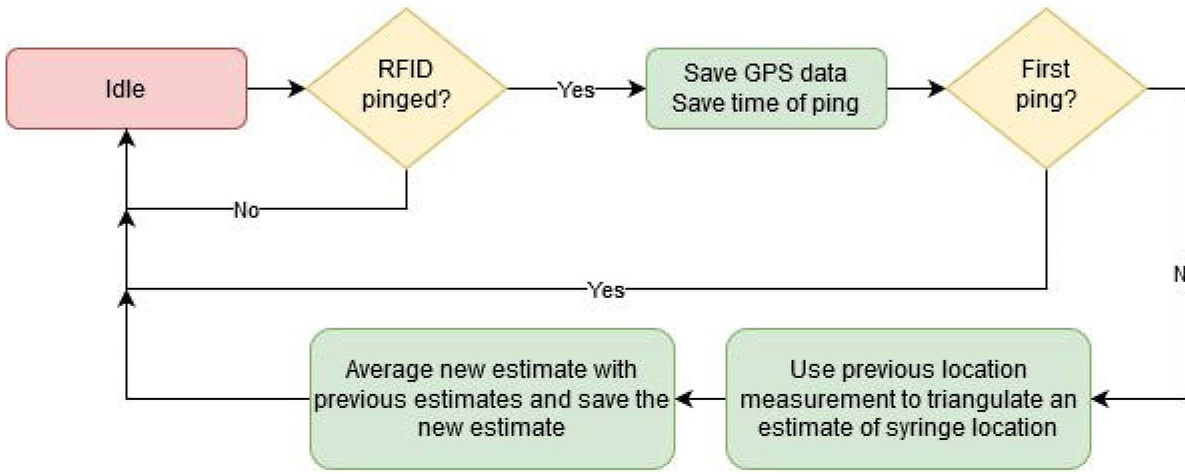

Figure 7.1: Triangulation Algorithm

In order to respond to events in real time the UNL software will utilize the FreeRTOS kernel [12] to write application code for servicing events and tasks. This kernel has a well documented API to use for handling both software and hardware interrupts triggered during the operation of the device. Due to FreeRTOS being well supported open source software there are many resources available to the software team to help with debugging issues that come up during development.

To minimize the power consumption of the device a low power microcontroller will be used. This MCU will add another level of constraint to the development of the device, however, by choosing a low-power MCU battery drain issues that could come up during testing may be mitigated.

The amount of peripherals required to determine the distance of the RFID tag from the reader requires that the MCU have a suitable number of GPIO ports, as well as potential adaptors to accommodate for the connections required by the sensors.

8 Engineering Standards

Although the UNLmkI is not a medical device, it is important to consider general medical standards as outlined by Health Canada with respect to syringes. Since syringe manufacture is not part of Verifynd's goals, it is not necessary to follow strict adherence to medical device standards. However, when considering how the passive tags will be placed on syringes for maximum single strength it is important that medical device standards are referenced.

RFID, in this case UHF, operates in a crowded spectral bandwidth and regulations around radiofrequency exposure and bandwidth usage are important to ensure that the device does not cause harm to people exposed to the antenna. It is also critical for successful operation that signals from other devices operating in the same frequency range are not causing interference and vice versa.

These engineering standards are focussed on Canada as that is the expected test market for the UNLmkI, however, upon successful testing of the product and further prototype design, expanded standards considerations including the US and Europe would be explored. Adhering to the below standards ensures the device can be used by consumers in the Canadian market.

8.1 Safety & Legal

Table 8.1: Safety and Legal Standard Requirements

Req 8.1.1 - C	For consideration of syringe design and potential RFID embedding, Verifynd shall use CSA ISO 595-2:1987. [13]
Req 8.1.2 - C	To explore alternative syringe options Verifynd shall ensure any potential product comply with ISO 11040-6:201. [14]
Req 8.1.3 - C	Personal Privacy protections shall adhere to CSA-Q830-03 (R2014). [15]
Req 8.1.4 - C	All design aspects shall be considered with respect to potential legal risk in operating the device and gathering data as outlined in ISO 31022:2020.[16]

8.2 RFID

Table 8.2: RFID Standard Requirements

Req 8.2.1 - C	UHF RFID identification and capture techniques shall comply with CAN/CSA-ISO/IEC 29143:14. [17]
Req 8.2.2 - M	Data and data management of RFID passive tags shall comply with ISO/IEC 15961-3:2019. [18]
Req 8.2.3 - M	The design parameters of item tagging information shall take into consideration ISO 17367:2013. [19]
Req 8.2.4 - M	Radio Frequency band usage in the 800-900Mhz range will comply with ICES-003. [20]

8.3 Electrical

Table 8.3: Electrical Standard Requirements

Req 8.3.1 - M	Computing and electrical design shall comply with ICES-003. [20]
Req 8.3.2 - B	If system design encapsulates a wearable device it shall comply with IEC TR 63071:2016. [21]
Req 8.3.3 - M	Batteries shall conform to 1625-2004 - IEEE. [22]

8.4 Environment

Table 8.4: Environment Standard Requirements

Req 8.4.1 - C	Electronic components shall be chosen and designed in compliance with IEC TR 62824:2016. [23]
Req 8.4.2 - C	Electronics enclosure shall adhere to CAN/CSA-C22.2 No. 94.2-07 (R2012). [24]

8.5 Software

Table 8.5: Software Standard Requirements

Req 8.5.1 - M	Any software used in the device or end user shall comply with ISO/IEC TR 25060:2010. [25]
Req 8.5.2 - B	Any open source software used in the device shall adhere to the open standard outline by the open source initiative. [26]
Req 8.5.3 - M	Design of the cloud computing service will be written with respect to ISO/IEC TR 23188:2020. [27]

9 Sustainability & Safety

9.1 Sustainability

Table 9.1: Sustainability Requirements

Req 9.1.1 - C	UNLmkI shall use 3D printing with Polylactic acid (PLA), which is biodegradable and can be produced from renewable resources.
Req 9.1.2 - C	UNLmkI shall use a rechargeable power supply.
Req 9.1.3 - B	Electronic components shall be recycled by the Electronic Recycling Association [28]

Cradle to Cradle (C2C)[29] production system adheres to the principle that all components can be used for the next production process. In order to maintain sustainability, UNLmkI will follow the C2C model and primarily select environmentally friendly components.

In order to ensure the sustainability of the UNLmkI, the components should be made of materials that provide a durable chassis for the system. For effective recycling and manufacturing compliance of chassis components, ABS plastic is selected due to its high strength and impact resistance. Additionally, as a thermoplastic, recycling operations involving ABS plastics are well established [30]. In prototyping the UNLmkI, PLA will be used for structural components produced with 3D printing.

Electronic components in the PoC will be used on a breadboard and fully recoverable. Extra components will be recycled by the Electronic Recycling Association.

9.2 Safety

Table 9.2: Safety Requirements

Req 9.2.1 - C	High power systems will be insulated to maintain safety during development
Req 9.2.2 - B	Electrical components will be isolated to prevent any risk of shock to the user
Req 9.2.3 - B	Mechanically moving parts will have good clearance and additional barriers as needed to protect the user.
Req 9.2.4 - B	The data obtained will be maintained in a secure manner allowing for authorized user access.

The safety concerns around the UNLmkI are two-fold. First, there are mechanical and electrical safety concerts which require the elimination of potential shock hazards as well as the mitigation of any risk of moving parts striking the operator.

Second, the data generated by this product provides a map of hazardous materials in an environment. As a result, it is necessary to ensure that the data is kept secure and only qualified individuals are given access to the data. There are also privacy concerns of sharing this sensitive data causing some syringe users to attempt to avoid being recorded by the system and resort to unsafe methods to remain hidden. Hence, it is paramount that any data collected is stored with the care of utmost privacy to maintain confidence that no data is being leaked.

10 Conclusion

This requirement specification outlines the various subsystems which function together to produce GPS data for use on a cloud mapping service for tracking and identifying needle refuse in urban environments. The success of the system is predicated on how well these components work in parallel to triangulate the location of passive RFID tags scattered randomly. In addition to the functional requirements, adherence to engineering standards ensures the UNLmkI performs reliably and to governmental standards expectations.

Below is a summary of the key requirements:

1. **Mechanical**
    - The drive motor will fulfill the needs of moving the antenna to cover the necessary range of spatial areas for searching purposes.
2. **Hardware**
    - The antenna will provide a sufficient read range to detect tags of any orientation with secondary sensors assisting triangulation.
    - GPS coordinates timestamped simultaneously as tags are read and located.
3. **Electrical**
    - The power supply will provide sufficient power to the entire system while being able to run continuously for four hours.
4. **Software**
    - The UNLmkI will require a system that can respond to events in real-time and this will shape the development of the embedded software.
    - The UNLmkI must be serviceable to the user at all times when it is in the field and this places specific requirements on the robustness of the device's software.
5. **Engineering Standards**
    - Consideration of relevant medical standards with regard to syringes will be observed even if not directly implemented.
    - Privacy of data will be a fundamental consideration when making any decisions around data storage and security.
6. **Sustainability and safety**
    - The power supply will be rechargeable to reduce environmental waste.
    - The material will be made by 3D printing with PLA.
    - The electronics waste will be recycled by the Electronic Recycling Association.

Development of the UNLmkI will occur over three phases: a proof of concept during which key research milestones will be evaluated, minimal viable product during which the system will be tested in a controlled setting and a beta phase which will involve real-world testing.

Through each of these stages, the requirement specifications above lay out a roadmap to the successful engineering of a demonstrable product.

11 Glossary

API	Application programming interface
EIRP	Effective Isotropic Radiated Power
EPC	Electronic Product code
FreeRTOS	Real-time operating system that has been ported to 35 microcontroller platforms.
GPIO	General purpose input/output
GPS	Global Positioning System
IP	Ingress Protection rating
MCU	Microcontroller Unit
PHS	Portland Hotel Society. A Canadian non-profit organization dedicated to advocacy and support of homeless individuals.
PLA	Polylactic acid, or polylactide is widely used as 3D printing material.
RFID	Radio Frequency Identification
TTL	Time to live, mechanism that limits lifespan of data in a computer and/or network.
UART	Universal Asynchronous Receiver/Transmitter
UHF	Ultra High Frequency. The RFID band at 800-900 MHz used for long range passive tags
UNL	Urban Needle Locator
UNLmkI	Urban Needle Locator Mark I
USB	Universal Serial Bus

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Appendix: Acceptance Test Plan

Test Purpose: The attached test plan aims for checking if the Proof of Concept prototype of the UNLmkI meets the requirements during the ENSC 405 demo.

Test condition: There must be as little metal and water as possible in the testing environment.

The tests performed with different options of motors and antennas will be evaluated on price and performance. Unit testing will take place through black box evaluation, extensive coverage of source code and separate testing of all interfaces.

Testing will occur over a series of experiments. First, a basic functionality test will determine if the tag location data is accurate. This can be done by placing a tag at a distance of 5m from the reader in different directions and verifying the output of the tag location data.

Further testing can then be done to verify the range finding ability of the system. Placing a tag at a known distance from the reader, two reads will be taken to verify the functionality of the triangulation algorithm.

Final PoC testing will require that the GPS data be offset by the tag location data and stored and mapped.

User Interface tests can include refreshing the page to check for updated timestamps and accurate data from the GPS module.

The interface between the following subsystems will be tested:

1. Motor
2. RFID reader/antenna
3. Secondary sensors
4. UI

The most critical performance measures to test are :

1. Read range of antenna given the appropriate amount of power from a reasonable power source.
2. Response time of the sensor system and GPS module when tags are pinged by the reader.
3. Accuracy of the subsystem to pinpoint the location of the needle in an outdoor environment.
4. Response time of the MCU to calculate the position of the RFID tag.

Test sheet	
	Date:
Mechanical Requirements	
1. Motors	Comments:
Motors have a constant rotational speed of 4π/3 rads/second. ☐Yes (pass) ☐No (fail) Motors can return the current angle. ☐Yes (pass) ☐No (fail)	
Hardware Requirements	
1. RFID System	
The RFID tag operates in the UHF range. ☐Yes (pass) ☐No (fail) Each tag's EPC number is unique. ☐Yes (pass) ☐No (fail) The RFID tag is passive and does not require a power supply. ☐Yes (pass) ☐No (fail)	Comments:
The RFID reader is connected with the software system. ☐Yes (pass) ☐No (fail) The reader provides 3.0 W power to antennas. ☐Yes (pass) ☐No (fail)	Comments:
The antennas used are circularly polarized. ☐Yes (pass) ☐No (fail) The antenna has a 30 feet read range. ☐Yes (pass) ☐No (fail) The frequency range of the antenna is within 902 - 928 MHz. ☐Yes (pass) ☐No (fail) The antenna has an azimuth angle of at least 45 degrees. ☐Yes (pass) ☐No (fail) The antenna has an IP rating of 65. ☐Yes (pass) ☐No (fail)	Comments:

2. Sensor System	
The sampling rate of Time of Flight sensor is up to 4kHz ☐Yes (pass) ☐No (fail) The Time of Flight sensor can detect distance independent of object reflectivity. ☐Yes (pass) ☐No (fail) The Time of Flight sensor can have a clock frequency of at least 45 MHz. ☐Yes (pass) ☐No (fail) The accelerometer has digital output to detect motor motions. ☐Yes (pass) ☐No (fail)	Comments:
Electrical Requirements	
The power supply is able to provide sufficient power for the system. ☐Yes (pass) ☐No (fail)	Comments:
Software Requirements	
The system has an algorithm to detect and differentiate individual RFID tag IDs. ☐Yes (pass) ☐No (fail) After detecting the same RFID tag, the system is able to estimate the location of the syringe by triangulation. ☐Yes (pass) ☐No (fail) The system can record GPS coordinates and heading when requested. ☐Yes (pass) ☐No (fail)	Comments: