**Proposal for a Cluster-based GPS GSM Wandering Sheep Tracking System**

Arielle Zhang, Tabitha Kim, Edwin Ma, Ethan Fong, Emre Cagin

University of Toronto

February 2022

**Table of Contents**

1. Opportunity Statement

2.0 Team

2.1 Meet Our Team

2.2 Team Values

3.0 Background and Design Goals

3.1 Understanding the Stakeholders

3.2 Team value proposition and scoping

3.3 Reference Designs

4.0 Design Requirements Model

4.1 Functional Requirements

4.2 Non-Functional Requirements

4.2.1 Cost-efficiency

4.2.2 Accessibility

4.2.3 Time efficiency

4.2.4 Portability

4.2.5 Durability

4.2.6 Safety

5.0 Design Considerations

5.1 Conceptual Design: Thermal Imaging and Identification System

5.2 Conceptual Design: Cluster based GPS GSM tracking method

5.3 Converging and Recommended Design

6.0 Proposed Outcomes and Deliverables

6.1 Expected Outcomes and Values Provided for Stakeholders

6.1 Requirements Validation

7.0 Project Management Plan Summary

8.0 References

**Executive Summary**

The purpose of this proposal is to provide an overview of the sheep wandering issue in the community of Rosedale, Mthatha, South Africa, to frame the opportunity within this local context, and finally to propose a widget solution that aligns the most with the stakeholder’s values as well as reflects our team values.

Our stakeholders’ financial depend heavily on their livestock, mainly sheep. The profit each sheep makes is their source of income. Therefore, sheep wandering off is an issue they cannot overlook. Here, grazing sheep can wander off due to various reasons. They could be scared, or their curiosity may lead them to following what catches their sight. Regardless of the reason, when a sheep leaves the flock, they can easily mix with other herds or get lost. Once a shepherd realizes a sheep is missing, they report the missing sheep to the owner and proceed to search for sheep in the vicinity. However, due to their lack of cars and the precarious relationship between shepherds and farmers, this process is rather tedious. Moreover, as all farmers own the same type of sheep – dorper sheep – it is hard to differentiate them with other homesteads.

Therefore, to address this issue, we propose a sheep tracking system using Global System for Mobile communication (GSM) network along with GPS and the Received Signal Strength Indication (RSSI) system which reports the location of each sheep to the owner, preventing sheep loss in the first place, and notifies them once the sheep goes missing. This design satisfies the requirements both proposed by the stakeholders and derived by us including functionality, accessibility, and more.

The highlighted functionalities of the design include the notification system that goes off almost immediately after a sheep wanders off. This significantly decreases the time and effort it takes for the owners and shepherds to acknowledge that a sheep went missing and to find them. Moreover, this also makes the system easier to learn as it does not require the stakeholders to try and interpret the location of the sheep every second, since all they need to do is simply wait for a notification. Another outstanding feature of this design is its long range and signal strength. Our proposed design’s range ensures that no matter how large the grazing area is, the tracking system should still work, while its signal strength ensures reliable results and heavily decreases the possibility of false alerts.

This design has only been developed conceptually along with some prototypes that represent functionality rather than for testing their feasibility. Therefore, our next steps will include high-fidelity prototyping and testing against the requirements, making sure that our design is as feasible and functional as expected.

**1.0 Opportunity Statement**

Mthatha’s economy is heavily dependent on livestock farming [1]. Most of the residents in Mthatha either own sheep or serve as shepherds. However, there is an ongoing issue of losing sheep mainly due to them wandering off, different owners’ sheep getting mixed up, or shepherds not showing up. When the sheep wander off within a 1-2 km radius, they may end up falling into ditches or being attacked by stray dogs, and more. When they mix with other sheep groups, they may end up in homesteads that are over 5km away. Searching for the sheep is tedious work due to their lack of cars. The issue of wandering sheep is made worse since many livestock farmers in South Africa live in poverty [2]. Consequently, the stakeholders require the solution to be not only highly functional but also economically accessible. In the overview, the stakeholders implied that an ideal solution would be tracking the exact location of a lost sheep, however, on the technical level tracking the exact location is more costly [3]. Therefore, to balance between the cost and functionality, we decided to reframe the opportunity to focus on *preventing* sheep loss and/or successfully finding the lost sheep. This framing provides more flexibility for our design team to experiment with different technologies to best meet the stakeholder’s needs. Therefore, we are looking for a solution that is cost-efficient, accessible, time-efficient, portable, durable, and safe. Moreover, our ideal solution will be able to differentiate the sheep from other herds, alert them once the sheep are missing, and/or provide a way to track and locate them.

**2.0 Team**

2.1 Meet Our Team

**Tabitha** has experience in team projects and engineering design/programming competitions. Her experiences and interests in various fields of engineering allow her to support technical aspects of designs and introduce new concepts. She also has experience in researching under design teams which helps the researching process to be more efficient and rigorous.

**Ethan** is interested in digital and analog systems and plans to specialize in that field. He has experience in design competitions and multiple team projects – all of which are related to engineering design and programming. His experiences and interests in the different fields of engineering allow for versatility when working as part of a team of engineering designers.

**Arielle** has project management and engineering research experience. She is good at organizing, scheduling, and communicating. Her research experience provides a background for developing innovative electronic solutions. With the provided skills as an asset, Arielle will be the project manager aiming to provide a solution that maximizes user experience.

**Yiqun** enjoys engineering design, documents, construction, and more. He had some experience in engineering design projects. His experiences and interests as a student engineer are in numerous domains such as mechanical design, computer hardware, software, research, and electrical design support him during the design process.

**Emre** has had experience in both 3D design and programming since middle school. When working in a group, he values communication, efficiency, and creativity. His experience, interests, and team values will help the team when working together, making prototypes for potential designs, circuits, and when making the widget itself.

2.2 Team Values

**Empathy**: Empathy is the ability to understand others’ feelings, which is important for engineers to understand demands from stakeholders. Empathy for the environment encourages sustainable production which aligns with the United Nations Sustainability Development Goals (UNSDGs) [4]. Empathy for stakeholders encourages strong functionality that meets all stakeholders' needs and accessibilities.

**Sustainability (UNSDG sustainable consumption and production patterns)**: Sustainability as a value means meeting our own needs without compromising the ability of future generations. Our design needs to be concerned about resource usage efficiency during fabrication and waste prevention through improving durability [5].

**Functionality:** As a team of student engineers, we value functionality. Our most basic goal is to meet the stakeholders' needs and provide a design to match their functionality requirements. We believe strong design functions with proper framing are the most important component in engineering design for an engineer to serve the stakeholder’s explicit and latent needs.

**Accessibility:** Empathy encourages us to value equity for everyone, we integrate this broad value into our design in the form of accessibility. We believe that the stakeholders deserve a design that is easily accessible to them in terms of **affordability** and **ease of learning.**

We as a team value empathy which is shown in our care and concern for achieving the UNSDG. This leads us to value sustainable production, which aligns with the needs of our stakeholders and helps refine our durability and cost requirements. We also empathize with the financial status and educational backgrounds of the stakeholders through research and communication which helps us to refine our accessibility requirements. Our investment in the stakeholder’s experiences helps to refine our requirements model into a specialized and well justified requirements model, which in turn will inform a relevant and functional design. This allows our team to provide the best design solution for the stakeholders.

**3.0 Background and Design Goals**

The opportunity is set in the town of Mthatha in Eastern South Africa. Sheep farming is popular in this region because sheep do not need specific soil or crops to eat, so when grazing they can freely roam around the area [6]. The grazing area is a mixture of rural village land and hilly plains as seen by images provided by the stakeholder. The climate of the region is moderately cold, with a yearly high of around 27 degrees, so for most of the year, the sheep will be grazing in the cold. In local communities in Mthatha, members generally have low income [7] and raise sheep to improve their income. The design should serve the stakeholder’s need to find the lost sheep and keep the cost less than the total profit of the lost sheep. There are two scenarios the product must work: when the sheep wander off by themselves within 1-2 km’s range, or the sheep ending up in another homestead that is 5km far away. With the local service environment described, the design functions should support successful tracking and finding sheep when they are lost while being easy and convenient for local owners and shepherds to operate. The durability and safety of the product should address local climate and environmental factors.

3.1 Understanding the Stakeholders

The sheep owners in the rural town of Rosedale, Mthatha are the primary stakeholders. The main factors that affect the stakeholders are the economic impacts due to the lost sheep, the effort required on their end for finding the sheep, and the accessibility of the product. The three corresponding values are economic, convenience, and accessibility. The stakeholders wish to secure their profit by finding the lost sheep, so it would be illogical to spend more funds on finding sheep compared to the gain. Furthermore, tracking the lost sheep takes effort on the owners’ end as currently, they need to search the vicinity usually 1-2 km away or nearby homesteads up to 5 km away without cars. Therefore, functionalities such as accurate tracking and locating of the lost sheep can bring the value of convenience to the stakeholders. Lastly, to maximize benefits for most sheep owners, accessibility is highly valued. Considering the technical abilities of the shepherds, implementing the solution should be easy for the shepherds to handle. In this proposal, we prioritize the needs and values of our primary stakeholders; however, secondary stakeholders such as shepherds and sheep are also important. The shepherds are underpaid and are often given a high workload; thus the owners have a precarious relationship with the shepherds. Reducing the shepherd’s workload by introducing high functioning designs that can motivate them to work, would secure the owners’ money by minimizing the chances of sheep getting lost. For the sheep, the solution should not reduce the economic value of the sheep both directly and indirectly, thus the solution should not harm the sheep.

3.2 Team Value Proposition and Scoping

With the internet and mobile network coverage, the assistance of shepherds, and the limitations on funding, the scope of this proposal is developing a solution to prevent sheep loss and/or find the lost sheep that is accessible to every community member in Rosedale to secure their money and reduce their efforts to find the lost sheep. Among the three important potential forms of values we identified, functionality and cost efficiency are a delicate balance. We focus on thinking innovatively to reduce the cost while maintaining the functionality of the system to maximize the value of our solution for our stakeholders. In our teams’ values, we incorporate empathy into the design in the form of accessibility. We focus on making the product accessible to everyone in the community by keeping the cost affordable and making it easy to learn and operate. Aiming to make the system highly automated and user-friendly streamlines the training process, providing ease of learning for shepherds and sheep owners. In keeping with the 12th goal of UNSDG, sustainable consumption and production in mind, we aim to make the design durable to improve resource usage efficiency. The extended lifetime of the product reduces the cost for the stakeholders and is identified as responsible consumption promotion.

3.3 Reference Designs

Fencing (sometimes electrified) is a popular option for animals wandering off problems. Fencing an area is simple and effective to prevent animals from leaving by creating a physical barrier. However, for our stakeholders, it is not a valid solution. Because many shepherds in Rosedale share a communal grazing area, the coordination of fencing would be complicated, and fencing would reduce the amount of grazing land the shepherds have. Price estimates to be 7500 – 15000 USD (9500-19000 CAD), which is very expensive when compared to the price requirements provided later [8]. Taking fencing as a reference design, the cost of our solution should be lower than this. Another option that has been used to find sheep is GPS tracking. This has been used for sheep tracking in countries such as Norway [3]. The Telespor system is the current “market-leading" solution and makes use of a GSM to locate sheep in real time. However, this is also costly at 290 CAD per sheep, and there may not be enough cell towers to cover all the land [9].

**4.0 Design Requirements Model**

To fulfill all the demands from our stakeholders and successfully find the lost sheep, we have developed functionality and non-functionality requirements that the design needs to meet. Besides the requirements of strong functions, we also want to incorporate values such as cost efficiency, accessibility, UNSDG sustainable production based on our main team values.

4.1 Functional Requirements

The primary functions of the design should include a lost sheep notification system and finding system to fully address the missing sheep issue. Although the approaches to the opportunity may vary in nature, the requirements are generic enough for testing protocols of different designs.

Table 1 Criteria, metrics, and constraints for the notification system

|  |  |
| --- | --- |
| Criteria: synchronization of notification creation | |
| Time used (mins) for data entry/extraction | Must < 10 mins, should < 7 min [10] |
| Criteria: reliability of the notification communication | |
| Lower percentage error of false alert (%) | |
| Be able to create and send notifications in various environments (land, ditches, homesteads, water, bushes, forests) | Must work with lands, ditches, homesteads. |
| Be able to identify: 1. when sheep wander off by themselves 2. when groups of sheep meet 3. when sheep follow other groups | Must identify 1 and 3 as sheep lost alert.  Should identify 2 as high sheep lost risk alert. [11] |
| Should allow notification documentation, record all the history notifications [11] | |

Table 2 Criteria, metrics, and constraints for the finding system

|  |  |
| --- | --- |
| Criteria: tracking range | |
| Farther is better (m) | Must ≥ 2000 m. Should ≥ 2000 m |
| Criteria: location accuracy: closeness of a measured location to the real location of the device at the time of measurement [12] | |
| Closer is better (m). GPS level accuracy is within 4.9m[13]. | Must not exceed 500m because after testing, 500 m radius searching area makes a person tired. |
| Criteria: signal persistence | |
| Longer pulse duration (s) and more frequent the pulse (time/s) is better [14]. | Must not be interrupted completely. |
| Criteria: signal strength. | |
| Should be easily perceptible to humans. | |
| Criteria: identification must be unique to each sheep | |
| Must correctly differentiate each individual sheep among a group of sheep. | |

4.2 Non-functional Requirements

4.2.1 Cost-efficiency:

The requirement that was emphasized the most by the primary stakeholders was cost-efficiency. The average purchase price of the sheep in South Africa is approximately R1,300 and the average sheep output of small livestock owners is approximately R3,000 [15]. The average profit efficiency of the sheep was estimated to be about 65.5% [15]. Therefore, the strict profit made by each sheep can be estimated to be around R2,000. On average, small livestock owners have 150 sheep, and the rates of sheep loss range between 3-13% [16]. On average, small livestock owners have 150 sheep and the rates of sheep loss range between 3-13% [16]. Hence, the minimum loss would be about 4.5 sheep where the maximum loss would be 28.5 sheep on average. Therefore, we set the constraints for the budget to be (the strict profit each sheep makes + the price of the sheep) \* (the number of sheep that get lost) as the design should be profitable in the end. Therefore, our hard constraint is that our design *must* not exceed (R2,000 + R1,300) \* 28.5 ≈ R94,000 per year or R630 per sheep per year, where calculated in a similar manner using the maximum loss, it also *should* not exceed R15,000 per year or R100 per sheep a year.

4.2.2 Accessibility:

One consideration of the solution is its ease of learning/operation. Since the main language that the stakeholders use is Xhosa, the device should have the option to display information in it [17]. Since the solution will be implemented with local shepherds, there also needs to be education in teaching them how to use the design solution. The less time it takes for the shepherds to learn how to use the design the better. We plan to simulate this time by asking a random trial of students to learn how to use a prototype of the design.

4.2.3 Time-efficiency

When identifying a missed sheep, it should take less time to find the sheep based on the tracking information provided by the system. The time does not have a specific constraint, however, the faster is the better, because the stakeholders have other stuff to do, the solution intends to minimize the time shepherds spend finding sheep.

4.2.4 Portability

As part of the design for travel and ergonomics, the solution needs to be able to move around freely to track the sheep at different locations. Portability requirements for handheld devices were taken from the 2005 US human factors guide for the design of handheld devices. Two of the main concerns for devices are the weight and dimensions of the device. Note that the dimensions of the device are specified as the stow-away size; some devices may unfold but must stow away to a good size.

Table 3 Criteria, metrics, and constraints for portability

|  |  |
| --- | --- |
| Criteria: Device needs to be easy to move around, and shepherds must be able to use the device over the range of the grazing area (~5km through hilly terrain and villages). | |
| A lighter device is preferred (weight in pounds) | Widget should be under 5.1 pounds if handheld. |
| A smaller stowaway volume is preferred (size of dimensions in mm) | Widget should stow away to under 100x125x255mm in size [18]. |

4.2.5 Durability

High durability reduces product costs for the stakeholders by reducing the amount of maintenance needed. Besides the cost, durability also encourages responsible production by increasing resource efficiency. Considering the grazing area is close to water sources, the product needs to be waterproof, dustproof and drop proof.

Table 4 Criteria and constraints for portability

|  |
| --- |
| Criteria: Device needs to work for an extended period without malfunctioning |
| The lifetime of design [19] |
| Must pass waterproof and dustproof test from IP5 to IP6 [20] |
| Must pass drop test for ANSI/ISEA 121-2018 [21] |
| Working at least two weeks without charging [22] |

4.2.6 Safety

There are two safety concerns identified with possible designs: hearing loss from loud noises and electrical shocks. These two risks were quantified using guidelines on sheep hearing sensitivities [23] and an international standard on handheld device electrical limits [24].

Table 5 Criteria, metrics, and constraints for portability

|  |  |
| --- | --- |
| Criteria: Sound safety | |
| Noise emitted in use (dB/frequency range) | The typical hearing range of sheep is 125 Hz - 40 kHz. Most sensitive at 7 kHz. The device must not operate in those frequencies [23]. Device should not operate over 90dB [23]. |
| A smaller stowaway volume is preferred (size) |
| Criteria: electrical safety | |
| Operational voltage | The operational voltage must not exceed 60V dc or 42.4 V peak ac. [24]. |

**5.0 Design Considerations**

5.1 Conceptual Design: Thermal Imaging and Identification System.

A picture containing electronics, printer

Description automatically generated A picture containing text, nature, screenshot

Description automatically generated

Figure A CAD design for the handheld device and the mock UI

Our first proposed solution is a handheld device that has both thermal imaging and barcode scanning capacities (Figure 2). The thermal imaging will work similarly to commercial FLIR technology used to find deer, making use of an infrared camera and a screen to display the thermal image. Using the thermal camera, the device can help shepherds locate lost sheep when they have wandered off by highlighting animal heat signatures in red. This contrast would allow shepherds to move on quickly if no heat signatures are found. Moreover, the barcode scanner component complements the thermal imaging by allowing shepherds to find their sheep when mixed in with other herds. We propose barcode ear tags on the sheep which the shepherds can scan to identify who the sheep belongs to. Prototyping in CAD has been used to see if the two components can be unified in a single handheld unit, and to provide a visual representation of what the device would look like. Since the high temperatures are around 27 degrees in Mthatha and commercial FLIR works up to 35 degrees, we can expect the thermal imaging component to work year-round [25] [26]. The range of thermal cameras is over 90 meters which are good for looking for sheep [27].

5.2 Conceptual Design: Cluster based GPS GSM Tracking Method

Our second design is a tracking collar. There are leader collars and follower collars. Both types have wireless transceivers to exchange unique sheep identification tags that are unique to each sheep. Only the leader collars have GPS GSM transceivers to communicate with the user. To reduce the cost and increase the GSM transmission speed, we reduce the number of GPS GSM transceivers by grouping the sheep into small clusters around a leader sheep (node) using the wireless transceiver’s received signal strength. Once the sheep are clustered, they send their unique id to the leader sheep. The leader sheep sends its GPS information and sheep ids in the cluster to the user. The number of leaders and updating cycle can be set manually. If an id is missing, then track the most recent cluster location this id has been in or track the GPS location if this id is a leader sheep. Shepherds will get the information of missing sheep and track them immediately.

Diagram

Description automatically generated

Figure Cluster based GPS GSM tracking method

5.3 Converging and Recommended Design

The thermal imaging and barcode identification method provide a cost efficient and time efficient way to search the missed sheep, however, it does not have a lost sheep notification system, the owner would not know when and where the sheep was lost. They still need to search the 2 - 5km radius area to find the sheep. We opt out of this method because it would need further development of a missing sheep notification system to meet the stakeholder’s requirements. The cluster-based GPS GSM tracking method adopts the advantage of its reference design Telenor, allowing the owner to track the location of each sheep, making it easier to find the sheep when lost. It is feasible for a hi-fi prototype because there are GPS GSM tracking Arduino projects available online [28], and the project cost is below the team budget of 150 CAD. The physical collar design and prototyping, and the backend algorithm programming would also be feasible for us. With the engineering rationale and justification provided, we converged to the cluster-based GPS GSM tracking method.

**6.0 Proposed Outcomes and Deliverables**

6.1 Expected Outcomes and Values Provided for Stakeholders

The cluster-based GPS GSM tracking method has the advantage of accurate and efficient tracking of sheep locations, and the customized color design of the collar allows efficiency in differentiating sheep from other sheep groups. However, one concern with this design is that the location accuracy decreases over time, if the shepherd does not go search the sheep immediately, it would be harder to find the sheep. But this design reduces the workload for the shepherds because they only need to search for the sheep when they receive lost sheep notifications, this can motivate them to be more responsible for their work. Another advantage of this design is that the cost is flexible because stakeholders can choose the number of GPS GSM nodes they want. The design is easy to learn and operate because all the information will be displayed for the user. The collar is designed for durability, and this not only brings economic value to the stakeholders but also supports responsible consumption and sustainability by maximizing resource usage efficiency according to UNSDG. The collar is safe for the sheep to use, not harming the sheep in anyways. The design validation chart for each requirement is listed below.

6.2 Requirements Validation

Table 6 Requirement comparison validation chart

|  |  |
| --- | --- |
| Criteria | Synchronization of notification creation |
| Update cycle can be manually set by the user to be as frequent as the 7 minutes constraint. However, the update cycle is limited by the GPS and GSM transmission speed, the actual total transmission time need further testing once we have all the components. | |
| Criteria | Reliability of the notification communication |
| If the sheep wireless transceiver is stable, the percentage error of false alert should be low. | |
| GSM can send signals from land, ditches, homesteads, water, bushes, forests. | |
| The algorithm can identify when sheep wander off for any reasons but cannot identify when two sheep groups meet. However, the shepherd is allowed to act immediately before the sheep wanders off too far, so a sheep lost risk alert is unnecessary in this case. | |
| Back end database allows record of all location history and alert history. | |
| Criteria | Tracking range |
| The tracking range of the leader sheep can be infinitely large, however, when follower sheep wander off their location accuracy would decrease over time. But this is not violating the constraint because if the shepherd acts immediately, the sheep can be found within the tracking range this meets the high-level requirements of preventing the loss of sheep. | |
| Criteria | Location accuracy |
| Location is GPS level accuracy for leader sheep. Location accuracy for follower sheep depends on cluster size, for 20% nodes, the average sheep cluster size is 5-10 making the location accuracy roughly be within one acre, 200m radius when the sheep wanders off [29]. The average sheep walking speed is 1.06m/s [30], and on average a sheep walks for 1 min and stops for 14 mins when wandering. Thus, the sheep will escape the updated cluster location by 254m/ hr. Thus, the location accuracy of the sheep would violate the constraint after 1-2 hours. If the sheep continuously walks, this time would be shortened to 5-8 minutes. | |
| Criteria | Signal persistence |
| GSM uses 2G network, which is stable enough to continuously send information to the user. | |
| Criteria | Signal strength. |
| The GPS signal strength is reliable enough to be continuously sent to the user when needed, thus it is very perceptible to human. | |
| Criteria | Identification must be unique to each sheep |
| The unique sheep ID on the collar allows differentiation of each sheep among sheep groups | |
| Criteria | Cost-efficiency |
| We plan to have at least 20% of the sheep to have GPS GSM nodes. The biggest drawback of this design is that it is less affordable compared to the other designs, but cheaper than the reference design. We estimate the costs based on the market prices. For cheap models, a wireless transceiver averages around 3 CAD [31], and a GPS GSM transceiver, is approximated to be around 30 CAD [32]. Therefore, a very rough estimate would be 3 \* 150 + 30 \* (150 \* 0.2) = 1350 CAD = R15,937 plus the cost of collar materials, which is below the hard constraint of R97,000 and close to the soft constraint. Once we receive a more solid budget from the stakeholders, we can either proceed with this or try to decrease the cost. | |
| Criteria | Accessibility |
| The system is highly automated to immediately provide the location of the lost sheep at the moment the sheep is lost. UI can be implemented in any languages stakeholder prefer. | |
| Criteria | Time-efficiency |
| If the shepherd departs to search the sheep immediately when notified, they can quickly find the missed sheep. However, if the shepherd waits until later, the searching range would be larger, and it would take longer to find the sheep. Collars can be made with customized colors to allow shepherd to quickly find their own sheep from another owner’s sheep group. | |
| Criteria | Device needs to be easy to move around |
| During fabrication, we can make the collar light and small enough to meet the requirements. | |
| Criteria | Device needs to work for an extended period without malfunctioning |
| The product we design can pass the waterproof test and dustproof test which we assigned in the section of requirement. The material we choose should have high stiffness and be eco-friendly to pass the drop test and fulfill the demand for sustainability. The battery that we choose is the maximum lifetime of this size. The principle of the tracker is based on the data provided from satellite and transmitted from GSM station, so the accuracy and lifetime are high since these tools are stable and accurate. | |
| Criteria | Sound Safety |
| Our design does not incorporate elements of sound to locate sheep. | |
| Criteria | Electrical Safety |
| GSM power classes are divided into power level numbers [33] and have maximum power outputs of 2W in power level 2. This falls within safety limits since raspberry pi modules can output up to 3W of power and they have a maximum voltage of 3.3V. Similarly, GPS modules are well researched and the operating voltage for many standard chips are between 2.7 and 3.6V [34] which is well under the constraint of 60V. The product fulfills safety requirement. | |

*(Chart is color coded, green means requirement is perfectly met, yellow means still need improvement)*

**7.0 Project Management Plan Summary**

Table 7 Project management progress up till today

|  |  |
| --- | --- |
| Week | Summary |
| 3 Team building | Completed the PM artefacts. Introduced to the opportunity overview. Non-functional research for framing, scoping and stakeholder analysis. |
| 4 Framing | Non-functional research and stakeholder analysis to finalize framing and scoping. Preventing sheep loss was identified as the actual need instead of tracking the lost sheep. Met the GSU student. Proposal outline was done. |
| 5 Conceptual Designs | Finalized framing, scoping, and requirements. Brainstormed different approaches to the solutions. Functional and technical research on different tracking methods and reference designs. |
| 6 Converge | Converged to three conceptual designs: thermal imaging, cluster-based GPS GSM tracking. More technical research on the feasibility and functionality of the three approaches. |
| 7 Low fi prototype and proposal | Refined the conceptual designs and the design requirements. Prototyped the two designs for comparison and converged to the final proposed design: cluster-based GPS GSM tracking method. Validated the proposed design by comparing to the requirements. Proposal was completed and submitted. |

Table 8 Technical milestones for the next 6 weeks, Gannt chart

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Tasks/Week | 8 | 9 | 10 | 11 | 12 | 13 |
| Collar design (Edwin) | Durability design, make selection on materials. | | Aesthetic design including color, shape, and size. Submit for 3D printing | | Put PCB into the design collar. | |
| Node electrical design (Ethan) | Wireless transceivers [35]. | RAM to store information. | GPS GSM tracking/ information transmission [36]. | Send PCB for fabrication (usually take 2 weeks). | | |
| Back-end (Emre) | Database to store the ids. | | Back-end app to compare and track the sheep ids. Connect to node for testing. | UI locating the sheep on google map. Connect this part to node for testing. | | |
| Other roles | PM and progress: Arielle  Communication and documentation: Tabitha | | | | | |

**8.0 References**

[1] Encyclopædia Britannica, inc. (n.d.). *Mthatha*. Encyclopædia Britannica. Retrieved February 23, 2022, from <https://www.britannica.com/place/Mthatha>

[2] Maziya, M., Tirivanhu, P., Kajombo, R. J., & Gumede, N. A. (n.d.). *Gender disparities in poverty among smallholder livestock farmers in South Africa*. South African Journal of Agricultural Extension. Retrieved February 23, 2022, from <http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0301-603X2020000200003>

[3] *The prevalence of lameness in the assessment of Transylvanian dairy herds by locomotion score and according to the Farmers' estimates*. Directory Indexing of International Research Journals. (n.d.). Retrieved February 22, 2022, from <https://www.citefactor.org/article/index/47309/pdf/>

[4] *What are the sustainable development goals and why should you care?* Our goals,our future - Plan International Canada. (n.d.). Retrieved February 22, 2022, from <https://plancanada.ca/stories/what-are-thesdgs?gclid=Cj0KCQiAjc2QBhDgARIsAMc3SqQXUiFx6XwfW5cDuwZd5laeEiUnrUqpXD5zsiZ71679kxNQl3s3llQaAm76EALw_wcB>

[5] Wikimedia Foundation. (2021, December 18). *Sustainable development goal 12*. Wikipedia. Retrieved February 22, 2022, from <https://en.wikipedia.org/wiki/Sustainable_Development_Goal_12>

[6] *Worldwide elevation finder*. Topographic Map - Altitude Map. (n.d.). Retrieved February 23, 2022, from <https://elevation.maplogs.com/poi/mthatha_south_africa.483767.html>

[7] *SOS Children's village mthatha*. SOS Children's Villages. (n.d.). Retrieved February 22, 2022, from <https://www.sos-childrensvillages.org/where-we-help/africa/south-africa/mthatha>

[8] *How much does an electric fence cost?* CostHelper. (n.d.). Retrieved February 22, 2022, from

<https://home.costhelper.com/electric-fences.html>

[9] *Radiobjella Inkl batteri*. Telespor. (n.d.). Retrieved February 22, 2022, from <https://nettbutikk.telespor.no/products/radiobjella-inkl-batteri>

[10] Lahausse, J. A., Fildes, B. N., Page, Y., & Fitzharris, M. P. (2008). The potential for automatic crash notification systems to reduce road fatalities. *Annals of advances in automotive medicine. Association for the Advancement of Automotive Medicine. Annual Scientific Conference*, *52*, 85–92.

[11] Lacson, R., O'Connor, S. D., Andriole, K. P., Prevedello, L. M., & Khorasani, R. (2014). Automated critical test result notification system: architecture, design, and assessment of provider satisfaction. *AJR. American journal of roentgenology*, *203*(5), W491–W496. <https://doi.org/10.2214/AJR.14.13063>

[12] *Location Data Accuracy - MMA*. (n.d.). Retrieved February 22, 2022, from <https://www.mmaglobal.com/files/documents/location-data-accuracy-v3.pdf>

[13] *GPS accuracy*. GPS.gov: GPS Accuracy. (n.d.). Retrieved February 22, 2022, from <https://www.gps.gov/systems/gps/performance/accuracy/>

[14] Chou, C. T. (2018). Detection of persistent signals and its relation to coherent feed-forward loops

*Royal Society Open Science*, *5*(11), 181641. <https://doi.org/10.1098/rsos.181641>

[15] Additional information Funding This work was supported by Intra-ACP Mobility Scheme: [Grant Number STRE1101630]. (n.d.). *Determinants of profit efficiency among smallholder sheep farmers in South Africa*. Taylor & Francis. Retrieved February 22, 2022, from <https://www.tandfonline.com/doi/full/10.1080/20421338.2021.1879510?casa_token=SSCu9HK5fpYAAAAA%3AFbjWeE5EVe70_OuQcgL_iR4TL7cvC7aUDx82dMzo6eqSRXTJZvsurbmlvasMTHCH4hUKqMuSYsvwg4E>

[16] *Developing alternatives to protect ... - escholarship.org*. (n.d.). Retrieved February 22, 2022, from <https://escholarship.org/content/qt58r1g4wj/qt58r1g4wj_noSplash_c05614f4da5bcb8ba3ab41e0a5266bc8.pdf?t=qf25mm>

[17] Wikimedia Foundation. (2022, January 14). *Mthatha*. Wikipedia. Retrieved February 22, 2022, from <https://en.wikipedia.org/wiki/Mthatha>

[18] FAA human factors (ang-E25) 2005-human factors guidance for the use of handheld computing devices. (n.d.). Retrieved February 23, 2022, from <https://hf.tc.faa.gov/publications/2005-human-factors-guidance-for-the-use-of-handheld/>

[19] *Blog*. Concox. (n.d.). Retrieved February 22, 2022, from <https://www.iconcox.com/blog/how-long-does-the-gps-tracker-last.html>

[20] *Waterproof testing*. Applied Technical Services. (2021, November 11). Retrieved February 22, 2022, from <https://atslab.com/environmental-testing/waterproof-testing/>

[21] *Dropped objects testing (ANSI/ISEA 121)*. Element. (n.d.). Retrieved February 22, 2022, from <https://www.element.com/product-qualification-testing-services/dropped-objects-testing>

[22] *Home*. How to Choose a GPS Tracker. (n.d.). Retrieved February 22, 2022, from <https://www.brickhousesecurity.com/gps-trackers/device-guide/>

[23] *Effect of noise on performance, stress, and ... - cvzv.sk*. (n.d.). Retrieved February 22, 2022, from <http://www.cvzv.sk/slju/14_2/8_Broucek.pdf>

[24] *International IEC standard 60950-1*. (n.d.). Retrieved February 22, 2022, from <https://webstore.iec.ch/preview/info_iec60950-1%7Bed2.0%7Den_d.pdf>

[25] *Frequently asked questions: Thermal imaging for elevated skin temperature screening*. Frequently Asked Questions: Thermal Imaging for EST | Teledyne FLIR. (n.d.). Retrieved February 23, 2022, from https://www.flir.eu/discover/public-safety/faq-about-thermal-imaging-for-elevated-body-temperature-screening/#:~:text=FLIR%20thermal%20camera%20with%20screening,F%20to%20113%C2%B0F).

[26] *Weatherspark.com*. Mthatha Climate, Weather By Month, Average Temperature (South Africa) We ather Spark. (n.d.). Retrieved February 23, 2022, from https://weatherspark.com/y/95239/Average-Weather-in-Mthatha-South-Africa-Year-Round

[27] *Explore at night or in lowlight conditions*. Thermal Vision for Outdoor & Law Enforcement | Teledyne FLIR. (n.d.). Retrieved February 23, 2022, from https://www.flir.ca/ots/thermal-vision/

[28] Admin, Says:, R., says:, M. A., says:, M., says:, N., says:, A., says:, K., says:, S. chaitanya C., says:, A. N., says:, M., says:, K. E., & Says:, I. (2022, January 21). *GPS+GSM based vehicle tracking system using Arduino*. How To Electronics. Retrieved February 22, 2022, from <https://how2electronics.com/gps-gsm-based-vehicle-tracking-system-using-arduino/>

[29] Written by Nicole Cosgrove Lead Pet Expert & Pet-ditor in Chief Nicole is the proud mom of Baby, by, W., Nicole Cosgrove Lead Pet Expert & Pet-ditor in Chief Nicole is the proud mom of Baby, Nicole Cosgrove Lead Pet Expert & Pet-ditor in Chief, Cosgrove, N., Lead Pet Expert & Pet-ditor in Chief, & Nicole is the proud mom of Baby. (2022, January 19). *How much space do sheep need to be happy?* Pet Keen. Retrieved February 22, 2022, from <https://petkeen.com/how-much-space-do-sheep-need-to-be-happy/>

[30] Agostinho, F. S., Rahal, S. C., Araújo, F. A. P., Conceição, R. T., Hussni, C. A., El-Warrak, A. O., & Monteiro, F. O. B. (2012, June 22). *Gait analysis in clinically healthy sheep from three different age groups using a pressure-sensitive walkway*. BMC veterinary research. Retrieved February 22, 2022, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3418207/#:~:text=The%20velocity%20used%2C%201.1%2D1.3,m%2Fs%20%5B19%5D.>

[31] *2.4G Wireless Serial Transceiver Module JDY-40 over 24l01 long-distance communication module*. Elecbee Factory. (n.d.). Retrieved February 22, 2022, from <https://www.elecbee.com/en-14177-24g-wireless-serial-transceiver-module-jdy-40-over-24l01-long-distance-communication-module?utm_term=&utm_campaign=goshopping_%E5%8A%A0%E6%8B%BF%E5%A4%A7&utm_source=adwords&utm_medium=ppc&hsa_acc=9958698819&hsa_cam=13478729888&hsa_grp=125180135964&hsa_ad=527159163777&hsa_src=g&hsa_tgt=pla-1076244340952&hsa_kw=&hsa_mt=&hsa_net=adwords&hsa_ver=3&gclid=CjwKCAiA6seQBhAfEiwAvPqu1ymBOR7qUDtdt7juUtYEikqnir9OKQuwqE2ubDhj7pawa9qIMAbbvBoCMMwQAvD_BwE>

[32] Elmwood Electronics. (n.d.). *GPS receiver - GP-20U7 (56 channel)*. Elmwood Electronics. Retrieved February 22, 2022, from [https://elmwoodelectronics.ca/products/13740?variant=28164953667¤cy=CAD](https://elmwoodelectronics.ca/products/13740?variant=28164953667%C2%A4cy=CAD)

[33] Notes, E. (n.d.). *GSM Power Control & Power class*. Electronics Notes. Retrieved February 22, 2022, from <https://www.electronics-notes.com/articles/connectivity/2g-gsm/power-amplifier-control-classes.php>

[34] Last Minute Engineers. (2020, December 18). *In-depth: Interface ublox NEO-6M GPS module with Arduino*. Last Minute Engineers. Retrieved February 22, 2022, from <https://lastminuteengineers.com/neo6m-gps-arduino-tutorial/>

[35] *2491*. DigiKey. (n.d.). Retrieved February 22, 2022, from <https://www.digikey.com/en/products/detail/adafruit-industries-llc/2491/5761206>

[36] Admin, Says:, R., says:, M. A., says:, M., says:, N., says:, A., says:, K., says:, S. chaitanya C., says:, A. N., says:, M., says:, K. E., & Says:, I. (2022, January 21). *GPS+GSM based vehicle tracking system using Arduino*. How To Electronics. Retrieved February 22, 2022, from <https://how2electronics.com/gps-gsm-based-vehicle-tracking-system-using-arduino/>