The University of Tulsa, Oklahoma

CattleLog Cattle Management System

<u>University of Tulsa Team</u>

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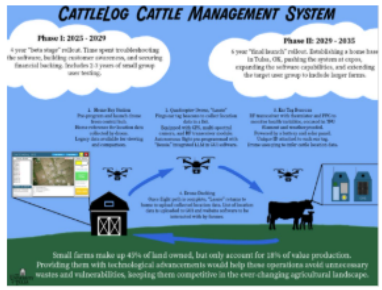
Quad Chart

CattleLog

Project Summary:

- Selected agricultural area/management practice:
    - Cattle/Livestock Management within Small Farms
- Team-identified use case (*i.e., challenge to solve*):
    - *Reduce/Eliminate Lost/injured Cattle/Livestock and increase production/efficiency in small farms*
- System(s) overview:
    Modified drone to autonomously log data from Cattle tags such as location, age, temperature, health records, and food sources

Project Image:



Team Composition/Roles:

- Senior Design Capstone Project
- Nate Husen | *Co-Project Manager, Completing Bachelor's in Mechanical Engineering*
- Kaylee Kapche | *Co-Project Manager, Completing Bachelor's in Mechanical Engineering*
- Anthony Fatigante | *Team Member, Completing Bachelor's in Mechanical Engineering*
- *Katie Eugenio | Team Member, Completing Bachelor's in Mechanical Engineering*
- *TJ Knight | Team Member, Completing Bachelor's in Mechanical Engineering*

"Dedicated to giving our best in everything we do!"

Proposed deployment timeline:

Table of Contents

0.0 ABSTRACT/SUMMARY

This proposal presents a solution to long-standing insufficiencies in agricultural monitoring methods, particularly, cattle tracking systems. A lack of comprehensive monitoring has resulted in cows becoming lost and facing various injuries, costing farmers thousands of dollars. In answer to these issues which need addressing, our team has developed an affordable, drone-based cattle tracking and management system in answer to these issues and shortcomings. Using a drone equipped with a radio transceiver, in addition to technology commonly found on drones such as radio frequency (RF) communication, Global Positioning System (GPS) receivers, Light Detection and Ranging (LiDAR) sensors, and cameras, the system can locate cattle quickly, monitor their positions in real time, track cattle health/biometrics for disease and distress, and provide farmers with a bird-eye view of their food source availability. This approach significantly reduces the time, labor, and costs of traditional cattle management, enabling farmers to operate with greater efficiency and increase their profit margins. Utilizing innovative solutions to barriers such as regulatory approval, system durability, and user adoption, the proposed solution overcomes hurdles by using familiar technologies such as rotor-wing drones and cell phones as the building blocks for the new airborne cattle management system. By improving cattle tracking, reducing accidental losses, and streamlining operations, this system provides small farmers with a practical and sustainable way to thrive in an evolving agricultural landscape.

Unique application of an aviation platform allows CattleLog not only to compete with other cattle tracking systems, but to offer new possibilities for agriculture that can serve to benefit the whole industry. Since the proposal, the team has further refined the assessment of the proposed technology including a scaled-down version of the system for the team’s Capstone project. In this way, the team has undertaken additional research and expanded the scope of the proposed system. Further analysis was performed with the understanding that any additional features and developments must be natural extensions of the technologies used, requiring little additional modification and minimal increase in cost. Feasibility of the design and an in-depth analysis of implementation barriers have been performed. To conform to current regulatory restrictions, the operation of the system has been significantly updated. A more accurate cost analysis of the system has been developed, including software developments and labor overhead.

1.0 SITUATIONAL ASSESSMENT

The first task in identifying a need was characterizing the agricultural industry and identifying a user group who would benefit the most from the integration of new technology. To narrow the scope of the research, focus was directed on livestock farms, as they make up 81% of agricultural products by value in Oklahoma[1]. Additionally, research targeted small farms, defined as those that make $350,000 or less a year and hold less than 100 acres, as they own 45% of the land used for agricultural production[1]. USDA census data shows a 64% discrepancy in production between large and small farms, which amounts to almost 350 billion dollars of difference[2]. The proposed solution must be cost-effective and accessible to these small farms. The price ceiling of $5000.00 dollars was determined by interviews with farmers, based on the price of one head of cattle (~$4000[3]) with $1000.00 overhead, this limit allows *CattleLog* to have the lowest initial cost of any cattle tracking system currently on the market (Figure 1).

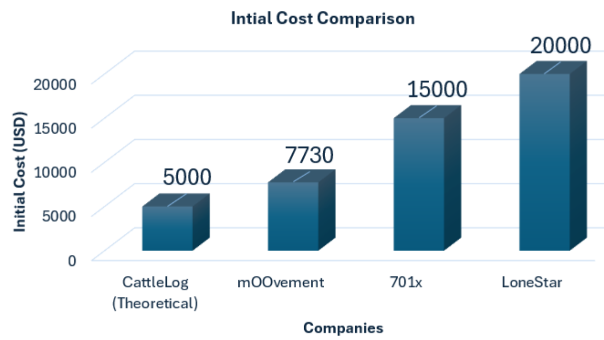


Figure #1 - Initial Cost Comparison of Cattle Tracking Systems[4],[5],[6]

The team worked with a small family farm in Haskell Oklahoma to gain firsthand knowledge of the day-to-day operations of a cattle farm, helping to herd, feed, band, and tag their small herd. Small farms struggle most with labor and defects, as was discovered through applying the lean manufacturing principle called the 8 Wastes[7]. We found through hands-on experience that upwards of two hours of time and labor is wasted trying to locate cattle before herding them. Being able to locate cattle and travel directly to them, as opposed to sweeping the entirety of the farm, would save upwards of $4500 dollars of labor annually (APPENDIX B). In addition, 1.5 billion dollars[8] worth of adult cattle were lost in 2016 alone to non-predator causes such as disease, injury, and circumstances such as wandering off and never returning. Better cattle management and closer monitoring of location and health help to mitigate the risks to livestock from these various causes. While the occasional defect in large-scale manufacturing may not

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[1] Christine Whitt, Noah Miller, and Ryan Olver, "In 2021, About 89 Percent of U.S. Farms Were Small Family Farms," *Charts of Note*, U.S. Department of Agriculture, Economic Research Service, accessed [date of access], https://www.ers.usda.gov/data-products/charts-of-note/chart-detail?chartId=105916#:~:text=In%202021%2C%20about%2089%20percent,farms%20were%20small%20family%20farms.

[2] U.S. Department of Agriculture, National Agricultural Statistics Service, *Farm Economics: 2022 Census of Agriculture Highlights*, February 2024, https://www.nass.usda.gov/Publications/Highlights/2024/Census22_HL_FarmEconomics_FINAL.pdf.

[3] Oxbow Cattle Company, "Whole Beef," Oxbow Cattle Co., accessed February 6, 2025, https://www.oxbowcattleco.com/product/whole-beef/#:~:text=The%20estimated%20final%20price%20is,hooves%2C%20lower%20legs%20and%20entrails.

[4] "Products." Accessed February 15, 2025. https://www.moovement.com.au/product.

[5] 701x. "701x - Livestock GPS Ear Tags - United States." Accessed February 15, 2025. https://www.701x.com/.

[6] LoneStar Tracking LLC, "GPS Cattle Tracking," accessed May 4, 2025, https://www.lonestartracking.com/gps-cattle-tracking/.

[7] Lean Construction Institute, "8 Wastes of Lean," Lean Construction Institute, accessed February 6, 2025, https://leanconstruction.org/lean-topics/8-wastes-of-lean/#:~:text=What%20Are%20the%208%20Wastes,%2C%20Motion%2C%20and%20Extra%20Processing.

[8] U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), "Cattle and Calves Death Loss in the United States—2015," U.S. Department of Agriculture, September 2016, 29, https://www.aphis.usda.gov/sites/default/files/cattle_calves_deathloss_2015.pdf.

pose a significant financial threat to a business, losing a cow represents an investment of thousands of dollars with no return. Saving one cow can make a substantial difference for these small farms.

The original proposal identified that another area of concern for small cattle farmers was environmental impact. Unchecked grazing and the ecological devastation it can cause is a major threat to the long-term viability of cattle operations. Soil erosion is something carefully monitored in Oklahoma, epicenter of the “Dust Bowl,” a period of environmental collapse induced by both natural drought and man-made factors[9]. In March of 2025, Oklahoma faced widespread wildfires and dust storms with widespread impact, even darkening the skies above the University of Tulsa campus for several days[10]. While this erratic weather was the result of natural causes, ensuring that man-made factors do not exacerbate these events is crucial to preventing catastrophe. Monitoring grazing and ensuring herds do not decimate the surface foliage that prevents soil erosion is an additional undertaking, which would help to protect Oklahoma’s farms in the long term and ensure they can continue to operate profitably for years to come.

2.0 CONCEPT OF OPERATIONS AND IMPLEMENTATION ANALYSIS

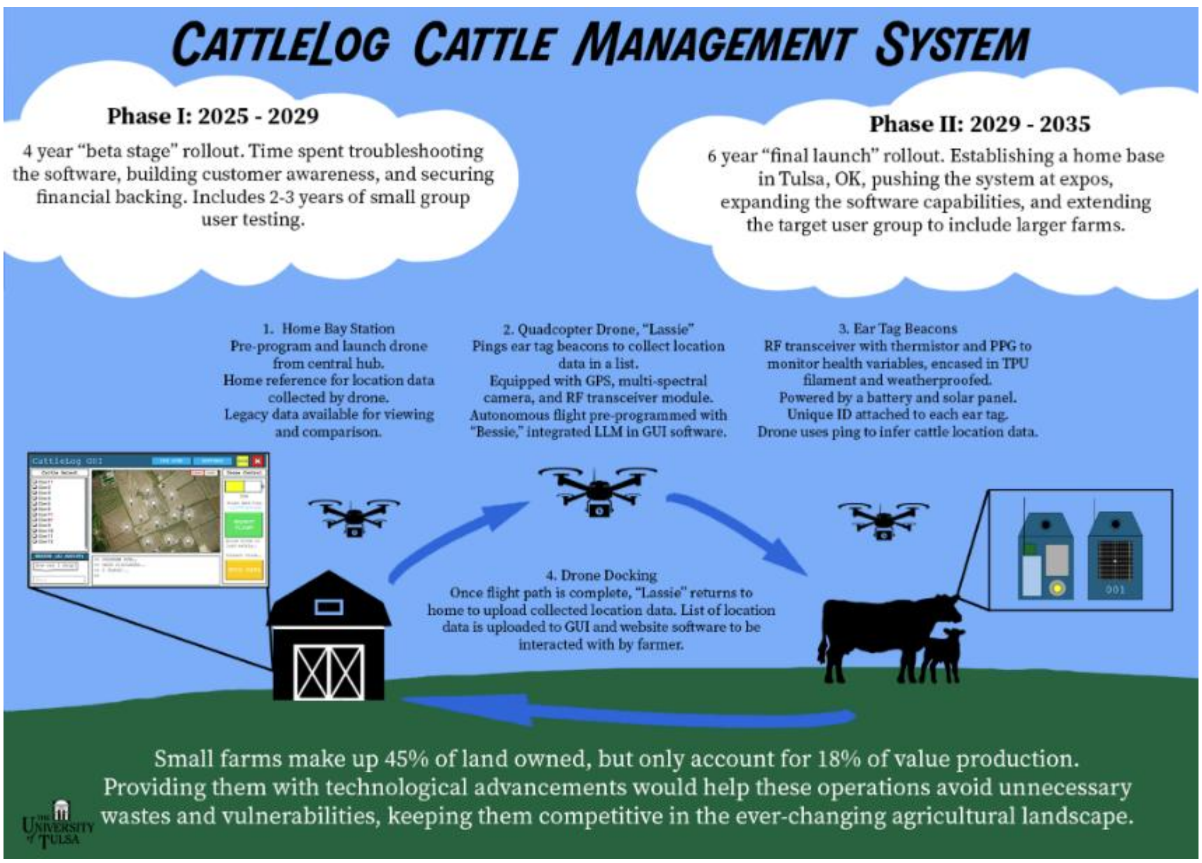

Figure #2 – Infographic Overview

[9] National Drought Mitigation Center, "The Dust Bowl," accessed May 4, 2025, https://drought.unl.edu/dustbowl/.

[10] Adam Voiland, “Dusty Inferno Hits Oklahoma,” *NASA Earth Observatory*, March 18, 2025, https://earthobservatory.nasa.gov/images/154054/dusty-inferno-hits-oklahoma.

The *CattleLog* system designed by The University of Tulsa team addresses these varied needs. Four primary components comprise the system: the tag beacons, a drone-mounted receiver, graphical user interface (GUI) software, and a website. The function of each of these systems is explored individually, with implementation analysis specific to each technology of interest.

2.1 DRONE

The aviation component of the system is the modified quad-copter drone, nicknamed “Lassie.” Using a lightweight RF transceiver mounted on the drone allows it to send a wake signal to the tags, prompting the tags to initialize their beacons and send a signal in response. By surveying rangeland and with the unique perspective that a drone is capable of, the system allows users to make informed decisions about their herds, plan grazing, and gain insight into cattle habits. Using the drone as a repositionable, self-locating antenna for tracking allows the system to have a high degree of flexibility and ease of use. Key features of a drone make it the ideal platform for the receiver (Table 1).

Drone Feature	Description	Benefit
Inherent GPS Integration	Drones use GPS to track their own location while in flight.	Provides a reference point for cattle locations from receiver.
Reprogrammable Flight Path	Different flight paths can be programmed for the drone.	The system can adapt to the varied shapes and sizes of small farms and can meet more varied needs.
Altitude/Terrain Modes	Drones typically have LIDAR sensors, barometers, and GPS, all of which allow the drone to maintain constant elevation. [10]	Maintains constant elevation above ground and allows for cattle locations to be projected on a 2D plane.
Integrated Multispectral Camera	Cameras are common on many drones, large and small, to capture aerial footage across multiple spans of EM wavelengths.	Allows for a “bird’s-eye view” of the farm, imaging the farm and approximating foliage density using near-infrared waves.

Table #1 - Drone Features and Benefits

A small drone such as this could still manage to fly in most weather conditions and could be repaired cost-effectively by the operators themselves. The drone collects two types of data as it flies. When a user wants to survey their farm with the drone, they send a request through the *CattleLog* online service to initiate a programmed flight path and—contingent on approval from a licensed operator—the drone is launched to collect data. Autonomous flight is a critical component of the system, allowing for versatility across farm geographies and ease of use for farmers. The RF transceiver collects each tag’s ID, latency, sensor data, and the corresponding GPS coordinates from the drone’s GPS at the moment of greatest signal strength. Farmers can also request a flight to inspect a particular cow of interest, such as one known to be pregnant or sick. In this case, the drone would run a normal flight path and once the signal from the proper tag is received, the drone narrows in on the cow’s location to image its location. In addition, integrating a multi-spectrum camera pointed towards the ground below as it flies builds a bird-eye view of the farm that can be processed to assess food source availability. As the images are transmitted to the GUI, it builds an interactable map of the farm that can alternately display cattle locations and available foliage for grazing. Inspired by techniques using infrared imaging for precision farming at the bleeding edge of the industry[11], the drone could approximate the healthy foliage based on the proportion of near-infrared waves reflected by foliage. Healthy plants reflect more green light and near-infrared wavelengths than other objects, and the amount of these wavelengths absorbed is used to provide a Normalized Difference Vegetation Index (NVDI), ranging from -1 to 1. Assigning segments of the rangeland different NVDI values would allow for the farmers to have unprecedented insight into the health of their land. The images and tag data are transmitted to the computer with the GUI software, and once the flight path is completed, the drone returns to the launch position and lands.

Several different types of drones have been compared for use in this application (Table 2), considering several key factors: ease of use, power efficiency, and --a criteria brought to our attention by real world testing-- cattle response.

Drone Type/Description	Advantages	Disadvantages
Quadcopter Traditional drone using propellors to generate thrust.	Simple maintenance, small and light, used in autonomous applications.	Power inefficient, short range, noisy and can disturb livestock at low elevations.
VTOL Hybrid Fixed Wing Drone with vertical takeoff and landing propellors as well as fixed wing geometry that creates lift while flying.	Flexible landing and takeoff using propellers, power efficient flight from fixed-wing lift.	Complex maintenance of two propulsion systems, expensive up front cost.
Fixed Wing Drone that uses fixed wings to generate lift much like an RC Airplane.	Unmatched battery efficiency, relatively quiet.	High difficulty of flight and operation, expensive to purchase and maintain, inability to hover
Avian Drones[12] Novel drone design that mimics the physical appearance of birds and uses fixed wings to generate lift.	Undetectable to cattle, lightweight and quiet.	Novel technology and not extensively used, susceptible to attack from real birds of prey.

Table #2 - Drone Type Comparison

Our comparisons of these varied drone designs yielded two candidates for the best type of drone for our application: the standard quadcopter drone and the avian drone. The former is the most common type of drone used today and is a versatile, comparatively accessible aviation platform. A quadcopter drone such as the DJI Air 3S[13] could be used to effectively cover a 100-acre farm on one or two battery's charge, and the CattleLog team determined that at a minimum of 50-foot elevation effectively reduces the impact of frightening cattle and signal distortion from multi-body diffraction near the ground. However, further research has indicated a new possibility that could be a feasible alternative. A new type of fixed wing drone designed to mimic the physical characteristics of a bird would allow for subtle observation vastly closer to the herd. Most efforts to develop drones like this are still in early stages of development,

[11] GISGeography, "What is NDVI (Normalized Difference Vegetation Index)?", accessed May 4, 2025, https://gisgeography.com/ndvi-normalized-difference-vegetation-index/.

[12] The Drone Bird Company, "The Drone Bird Company," accessed May 4, 2025, https://www.thedronebird.com/.

[13] DJI, "DJI Store," accessed May 4, 2025, https://store.dji.com/.

but projects such as the "Drone Bird" have garnered attention for their innovative designs, and merit further exploration as they are improved.

2.2 TAG BEACONS

The tag beacons are attached to the cow's ear and contain a transceiver which sends out a signal containing an ID and sensor values. The system was inspired by wildlife tracking technology such as the Motus system used by the California Department of Fish and Wildlife[14], which uses similar RF beacons to track animals in state parks to monitor population and behavior. Radio frequency beacons are far less expensive than using individual GPS trackers, and in areas like the flat farmland of the Great Plains, there are typically few obstacles that would inhibit signal reception. Repeatedly sending a signal from the drone-mounted transceiver, the tag beacons would respond with their unique ID and sensor value signals. The tag circuitry would be contained within a small plastic shell, injected molded using Thermoplastic Polyurethane (TPU) and used in place of the tags already used by most farmers. The material is chosen for its proven qualities in mass-produced cow tags, UV resistance, and weather resistance[15], allowing the tags to survive extended periods of time exposed to the elements and protect the enclosed circuitry. A small 2 Ah LiPo battery would power the beacon. Each tag must be equipped with a small solar panel to supplement the battery power, passively recharging the battery while the beacons wait for the wake signal (APPENDIX D). The battery will provide active power while the beacon transmits, ensuring the proper current output is achieved to send a usable signal. While the team was initially opposed to the implementation of solar panels due to the additional per-tag cost it would incur, a closer analysis has yielded that these panels would not just be crucial to the effective functioning of the *CattleLog* system but would also reduce the labor cost required to maintain the system. Changing 100 tag batteries every 14 weeks would be a significant endeavor, likely taking a team of 3 farmers upwards of 5 hours, an additional labor cost of approximately $1137.00. This is compared to the additional cost of adding 100 solar panels, calculated to be approximately $950.00. Implementing solar power to recharge the batteries is clearly justified, maintains the price under the set limit, and increases the ease of use of the system.

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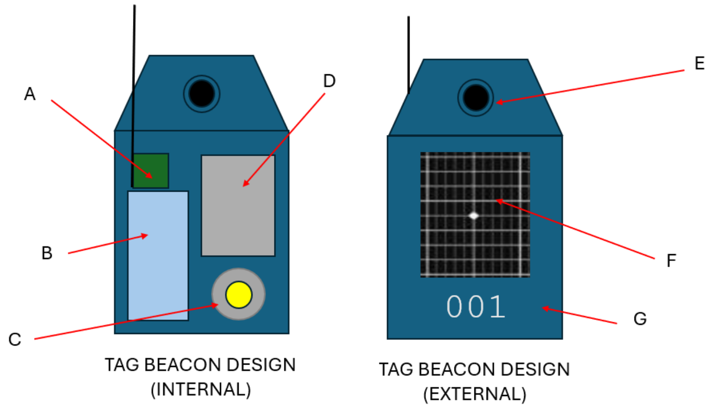
[14] California Department of Fish and Wildlife, "Motus Wildlife Tracking System," *California Department of Fish and Wildlife*, accessed February 6, 2025, https://wildlife.ca.gov/Science-Institute/Climate-Biodiversity-Monitoring/CDFW-Motus#:~:text=Motus%20is%20a%20radio%20telemetry,animals%20from%20any%20registered%20project.

[15] PRL Resins, "ASA's Role in Outdoor Applications Through Weather Resistance," *PRL Resins*, accessed February 6, 2025, https://prlresins.com/asas-role-in-outdoor-applications-through-weather-resistance/#:~:text=Weatherability%3A%20Beyond%20UV%20resistance%2C%20ASA,it%20suitable%20for%20demanding%20applications.



A	RF TRANSCEIVER	E	THERMISTOR
B	MICROCONTROLLER	F	SOLAR PANEL
C	PPG SENSOR	G	TPU CASE
D	2AH LIPO BATTERY		

Figure #3 – Simplified Tag Design with Labels and Legend, based on the components used to build our working prototype.

In addition to the tag sending the cow's location to the drone, the tag also functions as a health monitor. Tracking vital signs from an ear tag is feasible and widely done on larger farms in industry, allowing them insight into the health of their herd. The basic function of a thermistor involves running a current through an element with a temperature-dependent resistance and approximating the temperature based on the difference of current intensity from a reference value. A thermistor located near where the cow's ear interfaces with the tag could provide a rough estimate of the cow's temperature and would provide an early warning for health emergencies like overheating or calving. A PPG sensor uses light to detect differences in the volume of blood present in the microvascular network of arterioles, capillaries, and venules just beneath the skin, which can be related to the heart rate and blood oxygen level of the subject. The electronic components that comprise a PPG sensor are simple and cheap, relying largely on an LED and a photoresistor, and the thin skin of a cow's ear provides an optimal location for a valid sensor reading, and is a feasible application of the technology at its current level[16]. Farmers have a particular interest in tracking the blood oxygen level of their cattle, as respiratory disease is a common cause of death for cattle, and an early warning would allow them to treat affected individuals and isolate them from the rest of the herd before further spread. Both sensors rely on changes in current through a variable resistor, returning current values that can be easily sent in RF transmissions. Actual processing of the data will occur in the software component of the system, conserving battery life and memory demands in the tag's microcontrollers.

2.3 GUI AND WEBSITE

The third component of the system is used to display the data: the GUI software. The software will receive data from the drone as it flies, and update with cattle location and food source availability in

[16] Luwei Nie et al., "Is Continuous Heart Rate Monitoring of Livestock a Dream or Is It Realistic? A Review," *Sensors* 20, no. 8 (April 17, 2020): 2291, https://pmc.ncbi.nlm.nih.gov/articles/PMC7219037/.

real time. It will show the approximate region each cow is in, centered on the drone's GPS location at the time of recording, and flag cows that show early warning signs of disease such as elevated body temperature, increased heart rate, or erratic movements. As images are transmitted from the drone, they are uploaded to the map and assigned a value corresponding to their NVDI index, calculated using data collected by the multi-spectrum camera. Flags for depleted regions and signs of soil erosion are provided to help farmers understand the impact of their herds and plan to prevent overgrazing. Included in the software is “Bessie,” an LLM designed to serve as a 24/7 help resource that users can speak with. Trained in the GUI Software and PX4, users can ask simple questions through a chat window and get the fast help they need at any time of the day or night.

With an extensive log of legacy data, farmers could make inferences about how their cattle behave under different environmental conditions, noting where they graze and how much they eat. Using this data wisely would not only allow the user to help optimize their operation, but minimize their impact on the land they use, ensuring they can stay successful and profitable for years into the future.

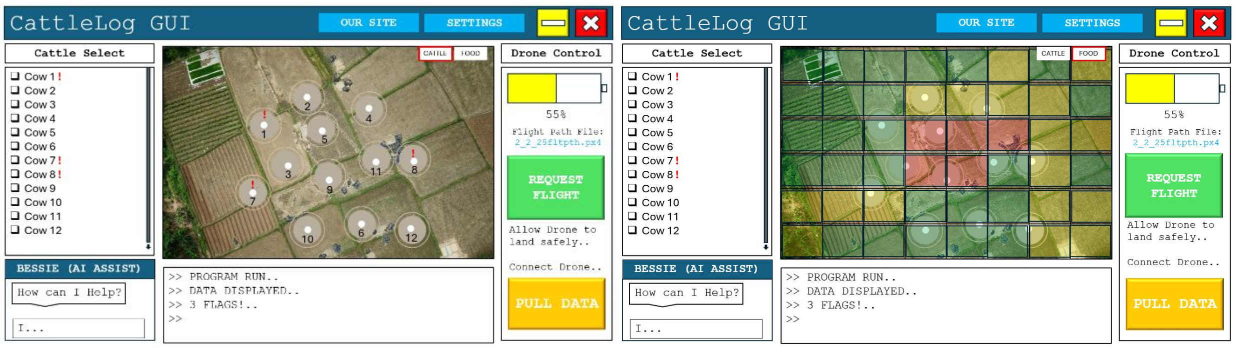


Figure #4 – Wireframe Mockups of the GUI Software Displaying Location and Grazing Data

The fourth and final component of the system is the mobile device compatible website, which would serve as both the hub of support and user collaboration, but it would also provide users with access to Bessie and data printouts from the computer on the go. The site will also host a forum for users, with message boards for Frequently Asked Questions (FAQs) that can be addressed collaboratively by both *CattleLog* staff and other users.

The development cost of the software and website was the subject of our implementation analysis. Altogether, the time and labor required to develop this software would amount to $76,800-$92,200 (APPENDIX C). This is a significant investment and would require an additional overhead cost. Assuming the system achieves its ten-year sales goal of 17,000 systems, about $30.00 of overhead per system would be added to the price to recoup the maximum possible development cost.

2.4 COST ANALYSIS

The base system will be sold as a package, with a pre-built drone with a mounted receiver, and as many beacons as needed by the customer.

Tag			Receiver			Drone			GUI/Website	
Component	Cost	Vendor	Component	Cost	Vendor	Component	Cost	Vendor	Item	Cost
ATmega328	2.89	Sparkfun	Arduino x3	32.85	Sparkfun	Drone + Controller	1274.00	DJI	Software Overhead	$30.00
Battery x1	6.48	EEMB	Battery x2	12.96	EEMB	Battery x3	85.98	Hobby King	TOTAL	$30.00
RF Module	6.5	Sparkfun	RF Module	6.5	Sparkfun	MultiSpectrum Camera	55.99	Amazon		
Thermistor	0.032	Digikey	GPS Module	49.95	Sparkfun	TOTAL	1415.97			
PPG	4	Amazon	SD Card Module	5.5	Sparkfun					
Solar Panel	9.5	Sparkfun	Button x2	0.2	Digikey					
Case	1.00	N/A	Piezobuzzer	0.7	Digikey					
Misc	5	N/A	Case	1.00	CattleLog					
TOTAL	31.37		Misc	5.00	CattleLog					
TOTAL X100	3137		TOTAL	114.66						
						SYSTEM TOTAL COST		$4,697.63		

Figure #5 – Component Breakdown of Total System Cost

The total cost of the system has been updated to reflect the changes since the initial proposal and has increased to $4,697.63, still well under the proposed cost ceiling.

3.0 PATHWAY TO IMPLEMENTATION

The 10-year rollout of the system involves two stages of development: a 4-year "beta stage" and a 6-year "launch period." The beta stage is focused on troubleshooting the system, building customer awareness, and securing financial backing. The launch stage will focus on selling the system to the intended user group, establishing a company location and hiring a team of support staff, ultimately concluding with an expansion of the technology to meet the needs of a broader user group (APPENDIX H).

3.1 TIMELINE

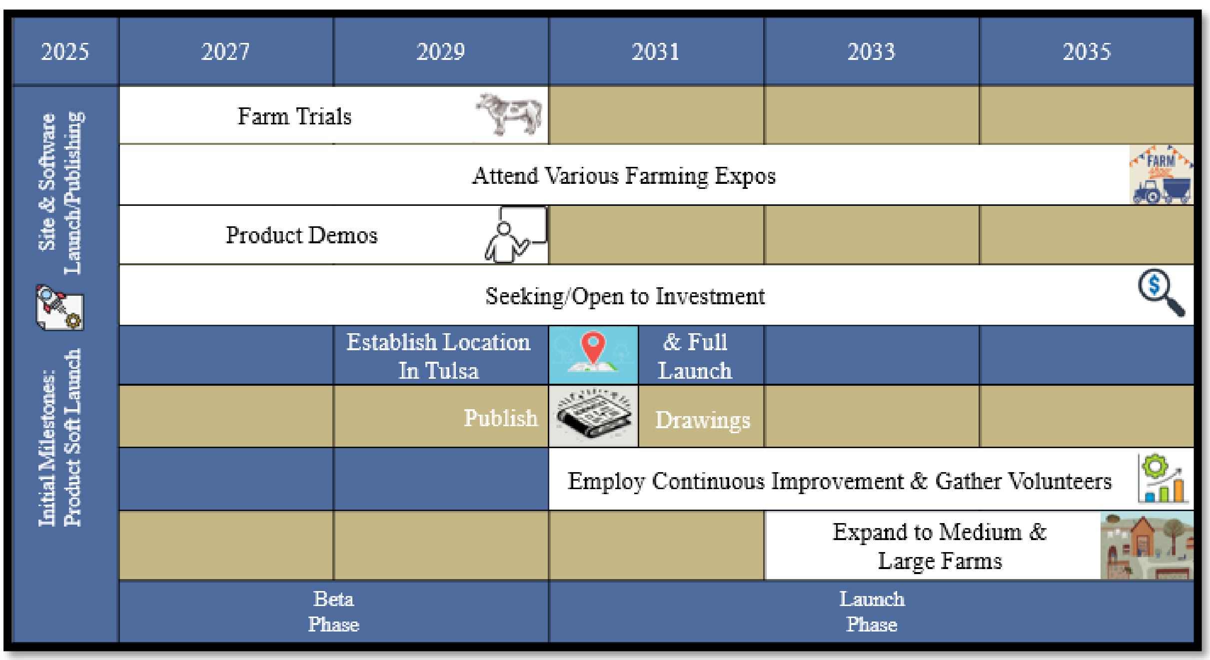


Figure #6 – Product Timeline for the CattleLog System

Setting a long-term goal for the 10-year development period will serve to gauge success and manage scope. System sales will dictate outreach, with the goal of 1% of small cattle farms adopting the system by the end of the 10-year period, a total of 17,000 systems. During the “beta” stages of development, the drone and tag system will be demonstrated at livestock exhibitions. A website will additionally be launched with information on service capabilities. This will aid farmers in learning through demo-trials and will serve as a means of feedback acquisition. This gathers interest from farmers and provides comfortability in contacting *CattleLog’s* Help Desk.

Following 2-3 years of trials, the system can be launched on the wider market, marking the beginning of the launch phase of deployment. The tag/drone/software package would be sold from the website, operated from a small facility located in Tulsa - the prospective drone capital of the US[17]- for ease of shipping and access to farms. Cities like Tulsa are seeking to increase economic growth by incentivizing tech startups with additional funding, and the city of Tulsa received a 51-million-dollar grant[18] for development of a “Tech Hub” focusing on development and application of autonomous technologies such as drones. Additionally, the website would be expanded significantly, including a forum for collaboration and Q&A by and for users, a dedicated service portal, and a mobile site that allows users to upload their data and access it on the go. Social media would also play an important role in increasing awareness of the product, with community engagement also helping reach users who are less tech-savvy, allowing them to ask for help in a familiar environment.

The last planned development during the launch phase is the introduction of a line of product packages designed to allow CattleLog to reach larger farms. While small farms are an underserved majority, larger farms also share the need to track their herds and grazing. While other systems allow for farmers to track their herd’s location and health, the additional function of our system as a grazing tracker allows larger farms to reduce their impact on the environment.

3.2 TECHNOLOGY READINESS LEVELS AND BARRIERS

	TRL LEVEL	TRL DESCRIPTION	BARRIERS
DRONE	6	Prototype demonstrated in a relevant environment.	Part 108 Legislation must be written.
TAG BEACONS	6	Prototype demonstrated in a relevant environment.	Prototypes do not account for battery life or long-term function.
GUI	8	Real world examples in use today.	While functionality is similar to real world applications, must still be developed.
WEBSITE	9	Real world examples in use today.	Website must be built and maintained.

Table #3 – TRL Analysis

The most unique barrier the CattleLog system must overcome is the issue of flight regulations for drones. Compliance with FAA guidelines is necessary to ensure the safety and function of the system, but the guidelines that an application like this requires are still in development. Part 108 is a set of policies

[17] City of Tulsa, “Tulsa Officials Release Blue Ribbon Commission Report Aimed at Making Tulsa the Drone Capital of the World,” *City of Tulsa*, accessed February 6, 2025, https://www.cityoftulsa.org/press-room/tulsa-officials-release-blue-ribbon-commission-report-aimed-at-making-tulsa-the-drone-capital-of-the-world/#:~:text=These%20factors%20have%20primed%20Tulsa,Drone%20Capital%20of%20the%20World

[18] Oklahoma Department of Commerce, "Oklahoma Celebrates $51 Million Investment in Tulsa Region’s Tech Hub," July 5, 2024, https://www.okcommerce.gov/oklahoma-celebrates-51-million-investmen-in-tulsa-region-s-tech-hub/.

designed to accommodate large-scale, commercial, autonomous flight, currently being written and developed in a dialogue with companies like Amazon who seek to use autonomous drones for package delivery[19]. This new legislation would allow operators off-site to remotely launch and monitor the drones for their system at the request of users. The likelihood of individual farmers wanting a tracking system enough to travel to a testing center and get approved for a Part 107 pilot certification is slim, so CattleLog will take a new approach still under development. Piloting the drones remotely allows for greater flexibility and increases the ease of use of the system. Of course, if desired a farmer can still opt to complete the Part 107 training and control the system themselves, at any approved testing center. Placing drone control in the hands of a trained professional assigned to plan and monitor the flight is the safest option for this system and balances the flexibility of having an individual drone for each system with the logistical difficulty of possibly having dozens of drones in the air at once.

4.0 KEY FINDINGS AND CONCLUSION

1	There is urgent need for the implementation of affordable technology in the cattle and livestock industry. Vast discrepancies in production between small farms and larger corporate farms display this need.
2	Common wastes in livestock include lost and sick cattle, representing billions of dollars in losses.
3	The cattle industry needs technology not only to help optimize their operation as a business, but to assist in sustainability to help mitigate environmental impact.
4	A quadcopter drone-based platform offers unique advantages in addressing these needs, with integrated technology that allows it to collect a variety of data from the sky.
5	The small form factor and location of tags on cattle make them the ideal housing for radio beacons and vital sign-monitoring sensors.
6	Development cost and time for the GUI software used to process data provides $30 of overhead per unit sold.
7	A total system cost of $5000 remains within the established price range, while including the new features and equipment needed.
8	The safest, simplest method of operating the system is with a remote pilot, covered under Part 108 legislation.

Table #4 – Key Findings Summary

In conclusion, the *CattleLog* team has developed an affordable, drone-based cattle tracking and management system to help small livestock farmers, who risk losing thousands of dollars annually to preventable causes. In doing this, the project was developed by combining four main components: a drone, tags, software, and a website. Successful implementation of the proposed system could save farmers hours of labor and costs upwards of $8000.00, while helping to curtail the environmental impact of livestock farms, ensuring that these farms can be successful and sustainable for years to come.

[19] Advexure, "Part 108: Is It Still Happening? What We Know So Far," accessed May 4, 2025, https://advexure.com/blogs/news/part-108-is-it-still-happening-what-we-know-so-far.

5.0 ANNOTATED BIBLIOGRAPHY

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   – Demonstrates the disparity between large and small farms in terms of production and illustrates the disconnect of land ownership of the smaller farms, the lower producers of the two.

2. U.S. Department of Agriculture, National Agricultural Statistics Service. *Farm Economics: 2022 Census of Agriculture Highlights*. February 2024. https://www.nass.usda.gov/Publications/Highlights/2024/Census22_HL_FarmEconomics_FINAL.pdf

   – Used to quantify the discrepancy between small and large farms, using the total value of production from agriculture in USD.

3. Oxbow Cattle Company. “Whole Beef.” *Oxbow Cattle Co.* Accessed February 6, 2025. https://www.oxbowcattleco.com/product/whole-beef/#:~:text=The%20estimated%20final%20price%20is,hooves%2C%20lower%20legs%20and%20entrails.

   – Used to quantify the cost of one head of cattle, which combined with user-group interviews defined our price ceiling.

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   – Cattle tag price reference for a rival company.

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   – Cattle tag price reference for a rival company.

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   – Cattle tag price reference for a rival company.

7. Lean Construction Institute. "8 Wastes of Lean." *Lean Construction Institute*. Accessed February 6, 2025. https://leanconstruction.org/lean-topics/8-wastes-of-lean/#:~:text=What%20Are%20the%208%20Wastes,%2C%20Motion%2C%20and%20Extra%20Processing.

   – Defines the 8 wastes of lean manufacturing used to analyze the agricultural industry from an engineering perspective.

8. U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS). *Cattle and Calves Death Loss in the United States—2015*. U.S. Department of Agriculture, September 2016. https://www.aphis.usda.gov/sites/default/files/cattle_calves_deathloss_2015.pdf.

   – Establishes the amount of cattle lost to various causes in 2015, used to illustrate that defects are the largest waste.

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   – Characterizes the environmental conditions caused by the Dust Bowl, and identifies their causes as both natural and manmade.

10. Adam Voiland. “Dusty Inferno Hits Oklahoma.” *NASA Earth Observatory*. March 18, 2025. https://earthobservatory.nasa.gov/images/154054/dusty-inferno-hits-oklahoma.

    – NASA source noting the significant weather events that have recently struck Oklahoma.

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    – Explains a technique for using Infrared imaging to approximate health and density of foliage already in use in high-tech precision farming.

12. The Drone Bird Company. *The Drone Bird Company*. Accessed May 4, 2025. https://www.thedronebird.com/.

    – An example of an avian drone, a novel aviation platform identified as a potential substitute for the quad copter drone.

13. DJI. *DJI Store*. Accessed May 4, 2025. https://store.dji.com/.

    – Highlights the price of a DJI Air 3S drone, chosen as the ideal platform for our modification, balancing price and ease of use.

14. California Department of Fish and Wildlife. *Motus Wildlife Tracking System*. Accessed February 6, 2025. https://wildlife.ca.gov/Science-Institute/Climate-Biodiversity-Monitoring/CDFW-Motus#:~:text=Motus%20is%20a%20radio%20telemetry,animals%20from%20any%20registered%20project.

    – Example of RF based wildlife tracking, with an explanation of its function.

15. Luwei Nie, Daniel Berckmans, Chaoyuan Wang, and Baoming Li. “Is Continuous Heart Rate Monitoring of Livestock a Dream or Is It Realistic? A Review.” *Sensors* 20, no. 8 (April 17, 2020): 2291. https://pmc.ncbi.nlm.nih.gov/articles/PMC7219037/.

– Used to justify use of PPG sensor in tag beacons, showing that it is feasible and possible given the limitations of the technology.

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– City of Tulsa Press release detailing the city’s goal to become the drone capital of the world, and therefore a prime location for *CattleLog*’s business ventures.

17. Oklahoma Department of Commerce. "Oklahoma Celebrates $51 Million Investment in Tulsa Region’s Tech Hub." July 5, 2024. https://www.okcommerce.gov/oklahoma-celebrates-51-million-investmen-in-tulsa-region-s-tech-hub/.

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18. Advexure, Part 108: Is It Still Happening? What We Know So Far Advexure, https://advexure.com/blogs/news/part-108-is-it-still-happening-what-we-know-so-far (accessed May 2025).

– Information on Part 108, the incomplete regulations concerning autonomous drone flight beyond line of sight.

APPENDICES

APPENDIX A: UPDATED SYSTEM TOTAL COST ANALYSIS

Tag		
Component	Cost	Vendor
ATmega328	2.89	Sparkfun
Battery x1	6.48	EEMB
RF Module	6.5	Sparkfun
Thermistor	0.032	Digikey
PPG	4	Amazon
Solar Panel	9.5	Sparkfun
Case	1.00	N/A
Misc	5	N/A
TOTAL	31.37	
TOTAL X100	3137	

Receiver		
Component	Cost	Vendor
Arduino x3	32.85	Sparkfun
Battery x2	12.96	EEMB
RF Module	6.5	Sparkfun
GPS Module	49.95	Sparkfun
SD Card Module	5.5	Sparkfun
Button x2	0.2	Digikey
Piezobuzzer	0.7	Digikey
Case	1.00	CattleLog
Misc	5.00	CattleLog
TOTAL	114.66	

Drone		
Component	Cost	Vendor
Drone + Controller	1274.00	HolyBro
Battery x3	85.98	Hobby King
MultiSpectrum Camera	55.99	Amazon
TOTAL	1415.97	

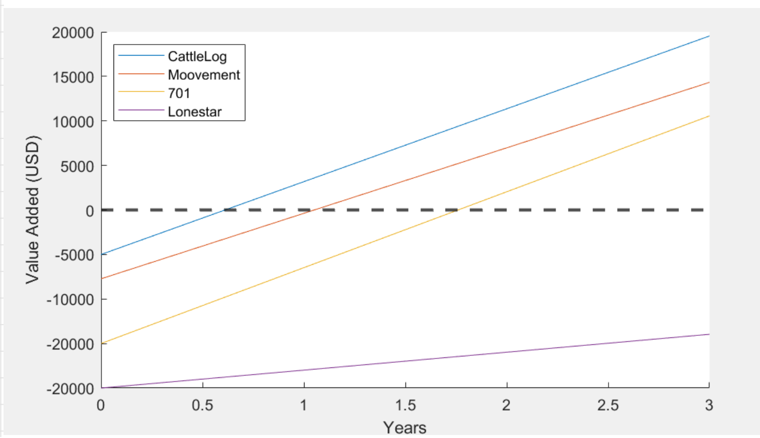
GUI/Website	
Item	Cost
Software Overhead	$30.00
TOTAL	$30.00

SYSTEM TOTAL COST	$4,697.63

APPENDIX B: LONG TERM COST PROJECTIONS AND ANNUAL SAVINGS

- Each system incurs negative value at the time of purchase and slowly recoups cost as it saves farmers money.
- A “worst case scenario” is assumed in which the system only saves one cow a year ($4000 dollar savings value), saves an hour of labor per herding, and incurs a $500 repair cost annually.
- Each competing system is assumed to function without needing repair and save one cow as well.
- Using these calculations, a MATLAB model is created to display the time needed to recoup the cost of the system.

Hours spent herding a week:	4
Herdings a week:	2
Number of Ranchhands needed	3
Dollars/Hr	15
Weeks/Yr	52
Cost Before System	18720
Hours spent herding a week:	3
Herdings a week:	2
Number of Ranchhands needed	3
Dollars/Hr	15
Weeks/Yr	52
Cost After System	14040
$ Saved in labor	4680



- Under these assumptions, the system pays for itself in under a year, and saves a total of $8680.00.

APPENDIX C: SOFTWARE DEVELOPMENT TIMELINE AND TOTAL COST

The following is a brief summary of how the software development time was estimated, given the scope of the project.

- 5 Man Development Team
    - Project Lead AND QA Lead (@ $45.00/hr)
    - 2 UX/UI Designers
    - 2 Back-End Developers
    - Designers and Devs for small projects are hired at a fixed rate, set for a project of this scope to be $7500-$10000.
- Total Time for Project: ~26-29 Weeks
    - ~3 Weeks for Project Discovery
        - Concept is already validated, research complete, but implementation and concept generation will take some time.
    - ~7 Weeks for Software Design
        - 2-3 Weeks UX
        - 3-4 Weeks UI
    - ~12-15 Weeks for Software Development
        - 3-7 Weeks for Front-End
        - 3-7 Weeks for Back-End
    - ~4 Weeks Testing and Debug
        - Reduce team to 3 man testing team (Lead and 1 Dev @ increased rate of $45.00)
- Total Cost for Development = $76800-$92200
    - Fixed Rate Labor = ~$30000-$40000
    - Project Lead Labor = ~$46800-$52200
- Software Overhead ~$30.00
    - ~$100,000 development cost
    - ~17,000 systems sold if 1% of small livestock farms adopt the system
    - $Overhead = \frac{Cost}{\#\ of\ Sales} \rightarrow \sim\$30.00 = \frac{\$100000}{17000}$

APPENDIX D: LABOR SAVED USING SOLAR POWER

Theoretical calculations show that supplementing the battery with a solar panel would be feasible, given our assumptions previously, the batteries would last about 14 weeks.

Battery Transmission Power (RFM69)	Transmission Time per hour	Sleep Power (RFM69)
0.13	1	0.000001

Battery Capacity (AH)	Self Discharge	Actual Capacity (AH)	Weeks/Battery Capacity	Total Power/Week	Total Sleep Time/Week in hours
2	0.08%	1.84	14.13569	0.130167	167

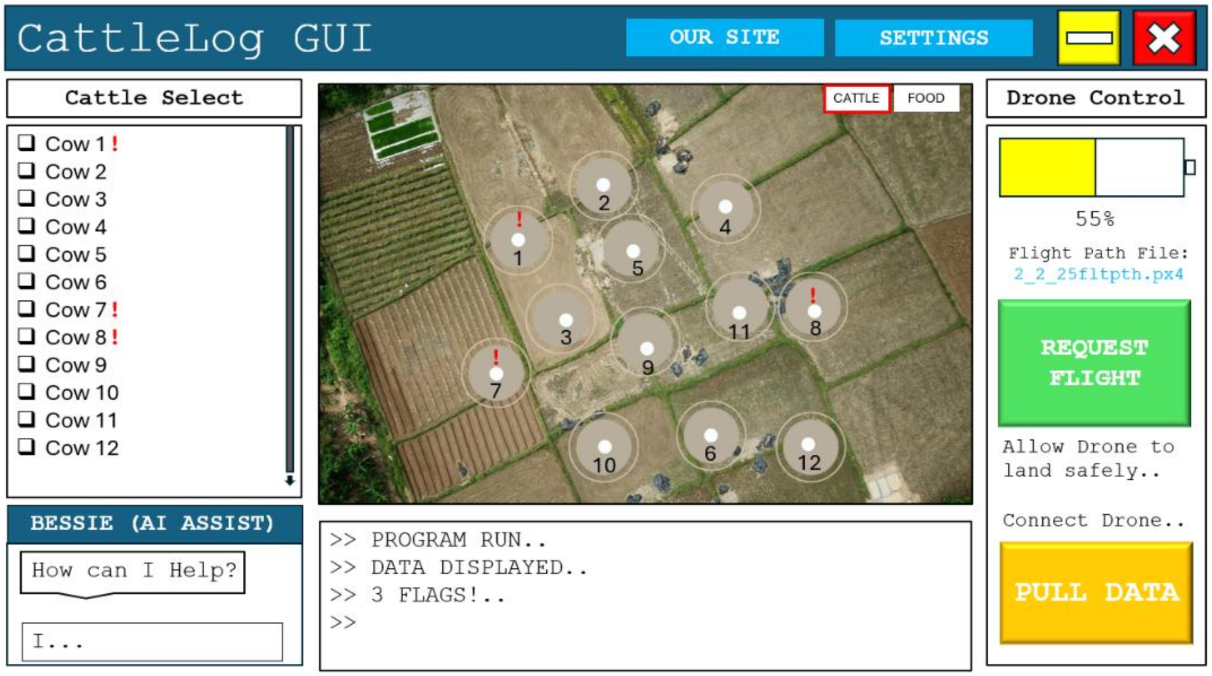
The power generated by a solar panel of the size selected for the tag would generate enough power to recharge the battery within ~3.5 days, enough to ensure it remains charged, eliminating the need for a battery change.

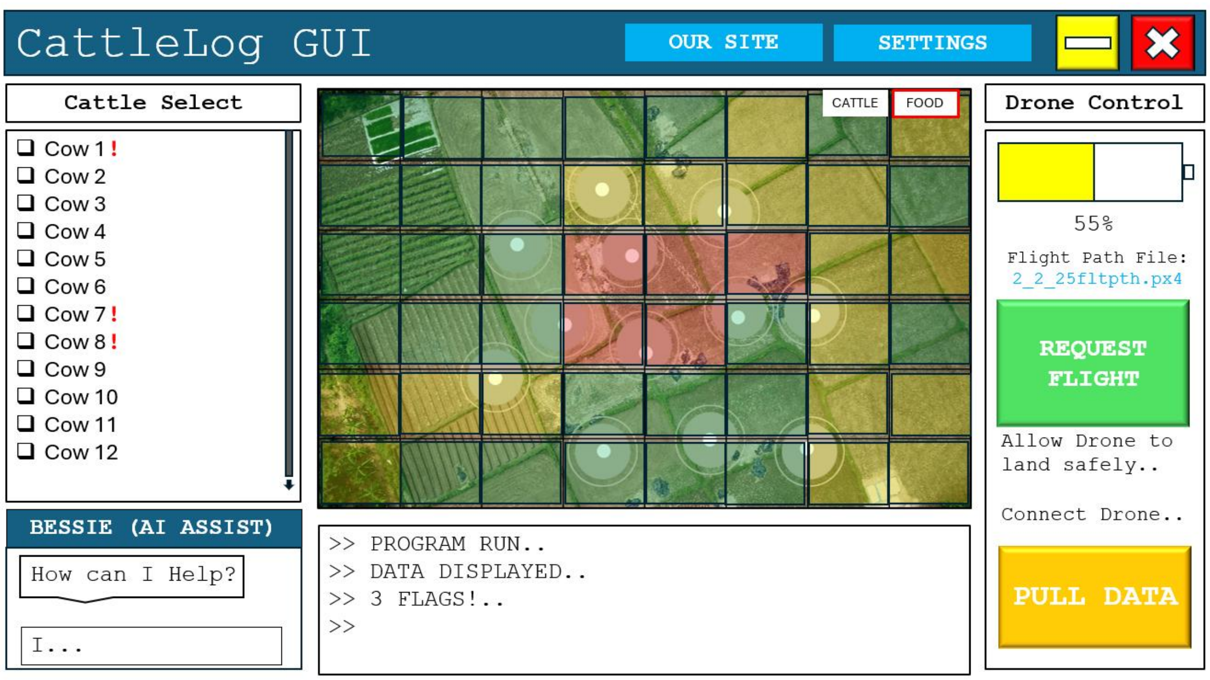
Solar Panel Power (W) per panel	Peak Sun Hours in Tulsa, OK (average)	Power each Solar Panel can generate (Wh/Week)	Hours for the Solar Panel to Fully Charge the Battery	Days for the Solar Panel to Fully Charge the Battery
0.3	5.1	10.71	82.27891862	3.428288276

Assuming a farmhand is paid $18.95/hr, spending 5 hours per battery change, 4 times a year, the total labor for a team of 3 farmhands is found to be $1137.00, compared to $950.00.

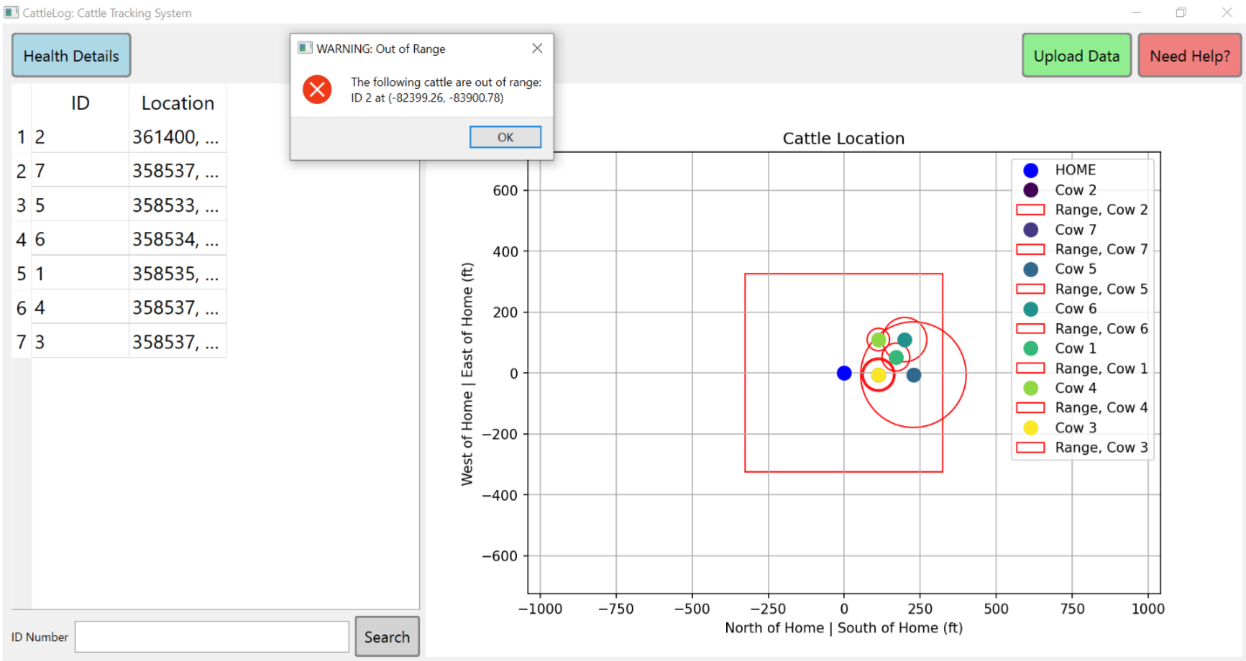
Labor Time to Change Battery on Ear Tag every year	Labor cost/Year ($)	Money saved from using Solar Panel/Year ($)	Total Price for solar panels ($)	Profit from using Solar Panels (Years)
20	379	379	950	2.5

APPENDIX E: SOFTWARE WIREFRAME

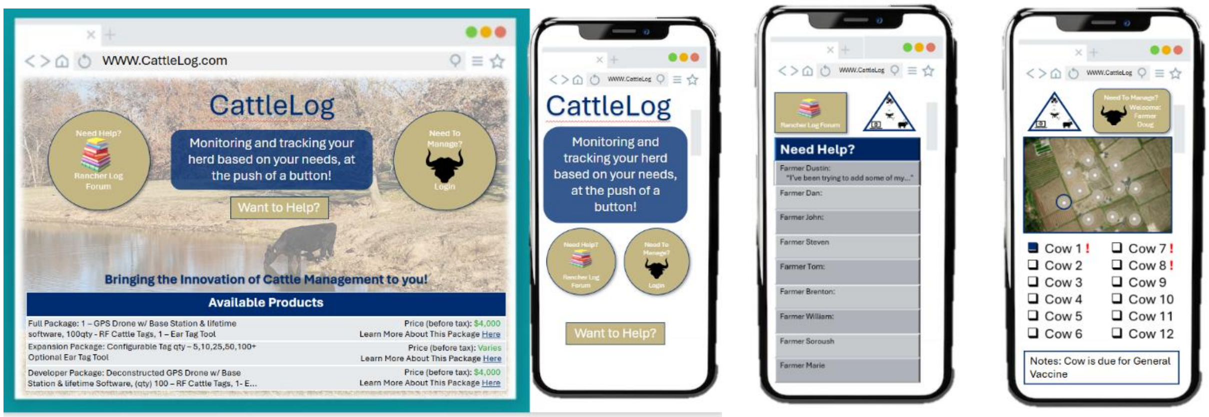




APPENDIX F: SOFTWARE PROTOTYPE CONSTRUCTED USING PYQT



APPENDIX G: WEBSITE WIREFRAME



APPENDIX H: SYSTEM RECONFIGURATIONS FOR LARGER FARMS

	Small Farms		Medium-Large Farms	
Component	Description	Cost	Description	Cost
Drone	DJI Air 3S or Equivalent	$1,415.97	Drone Fleet - Assume x5	$6,370.00
Tags/Beacons	x 100	$3,137.00	x 350	$8,844.50
Software	Software package with capabilities up to 100 cattle	$30.00	Software package with capabilities up to 1000 cattle - Customer Help Available	$30.00
Drone Modifications	x 1	$114.66	Assume x 5	$573.30
Total	$4,697.63		$15,817.80	