Long-Range UAV RFID Reader for Use with RFID Cattle Tags

ECE4011 Senior Design Project

Raising The Steaks
Dr. Manos Tentzeris
CattleTime (or RTC Cattle Tag)

Jesse Baker	jesserbaker02@gmail.com
Neil Dahlqvist	ndahlqvist3@gatech.edu
Ashley Hrebik	ahrebik3@gatech.edu
Santiago Juarez	santi@gatech.edu
George Tzintzarov	gtzintzarov22@gatech.edu

Submitted April 15, 2016
Revised September 11, 2016

Contents

Executive Summary

The purpose of this project is to design, build, and test a Radio-Frequency Identification (RFID) system for use in the cattle industry which tracks various cattle and recognizes if a cow is lost. The project is focused on improving the read range and reading capabilities of the RFID technology through a system level optimized design. A system of this caliber will reduce the day to day labor of counting cattle in various herds from a multi-hour procedure down to only one hour. In order to meet these specifications, the transmitter/receiver components of a typical RFID system will be researched, redesigned, and optimized. Higher frequencies will be used due to the fact that they are known to increase the read range of the system and allow multiple tags to be read at once. RFID systems with longer read ranges also require more sophisticated power management solution, so a secondary effort will go into designing the platform on which this system will be built upon. The proposed solution will seek to investigate the design of a mobile reader mounted on an unmanned aerial vehicle (UAV) for inventory and field rotation of cattle with possible location capabilities. The development of readers with these capabilities will depend on (1) frequency of operation, (2) antenna structure and size, and (3) power management. The expected outcome of the design is a fully functional prototype that will cost $3,000.

Long-Range UAV RFID Reader for Use with RFID Cattle Tags

1 Introduction

The "Raising the Steaks" team will design a long range RFID sensing system for the purpose of taking inventory of cattle on a pasture. The team is requesting approximately $3,000 USD to develop a fully functioning prototype.

1.1 Objective

The objective is to design a stand-alone system for use on cattle ranches which will take inventory of herds of cattle. This procedure has historically been done manually by physically counting and recording cattle. It is also not unusual for cattle to miss pasture rotations because they are sleeping, injured, or have wandered off. This solution will allow quick and easy cattle inventory management, as well as distinguishing which cows are not where they are supposed to be. The entire system will be mounted on a drone or unmanned aerial vehicle (UAV) and will consist of an RFID transmitter/receiver, a 1 Watt electromagnetic radiation source to excite the tags as per FCC regulations, a central processor such as an Arduino, Raspberry Pi or CuBox, and an LCD display which will populate a list of cattle ID's in real time while the UAV is flown around the pasture.

1.2 Motivation

The main motivation for this project is to revolutionize the cattle industry technology in the US and allow ranchers to quickly and reliably count and track their cattle. This will be a new product for exclusive use by CattleTime on its ranches. Currently there is no quick way to take inventory of cattle because RFID technology has a limited range of a few feet. This requires a rancher to physically get close to each animal to identify it. The team will offer a more efficient way of taking inventory by increasing the RFID tag reader range through design and offering a full inventory system integrated with a database.

1.3 Background

In 2004, the US Government asked cattle farmers to tag their animals with RFID for the purposes of tracking the lifetime and health of cattle [1]. This effort would help control various diseases and serve as an authentication to any animal in question after the discovery of mad cow disease. However, due to the extreme limited range of RFID technology, this effort was unsuccessful and only 30% of cattle producers adopted this technology. The current market is moving towards Ultra High Frequency (UHF) RFID tags in an effort to try to increase readability distance.

Raising the Steaks's industry partner, CattleTime, is using UHF RFID tags along with mobile readers which achieve a distance of a few feet. Workers walk up to each animal and brandish a reader which is in the shape of a large wand and either receive information from the tag or program the chip in the tag using the mobile reader's interface. The mobile reader was designed and manufactured by Motorola, while the physical tag itself (not the RFID chip) was designed and tested by a Mechanical Engineering Senior Design group from Georgia Tech. The RFID chip itself was designed and manufactured by a third party prior to the team beginning this project. The RFID tag uses ultra-high frequencies (around 900 MHz) and is a passive tag, meaning that is uses incident electromagnetic radiation to reflect back out a signal to the reader. The key building blocks are the RFID tag and chip, which are fixed in the scope of our project unless the sponsors desire changes with the testing in the following weeks.

2 Project Description and Goals

The team will design a UAV mounted system which will take inventory of cattle with RFID tags from a range of several meters and populate a list of cattle on an LCD screen. The UAV will be flown by a rancher over each herd. Once the UAV has passed within the read range of each animal, a processor will check to see if any animals are missing. If they are missing, the operator will have the ability to input a search ID for that specific animal. The UAV can then be flown around the pasture again and will notify the operator if it picks up the RFID signature of the desired animal.

The targeted user is ranchers on large-scale cattle farms around the continental United States. The target price is roughly $3,000, but will save our sponsor, CattleTime, money in the long run from reduced labor time. The features of the UAV system include:

- Maximized read range of the UHF RFID tags.
- Reader mounted to the UAV to fly around and activate the RFID tags
- Ability to read multiple tags quickly and populate a list on an LCD screen
- Ability to export the list on a USB stick

3 Technical Specifications

The tags will have to be excited by an incoming electromagnetic signal of ~900MHz, they will reflect at best half the received power. Once the signal is reflected back the receiver must read each tag and populate a list and check for missing animals.

Feature	Specification
Tag Operating Frequency	900 MHz
Output Power to activate passive tag	≤1 W
Read-Range of each RFID tag	≤4 m
Size of System	All aboard a UAV
Weight (mobile reader)	<5kg
Power Source for UAV system	Rechargeable battery pack
Battery Life of Mobile Reader	>1hrs
Communication with Database	USB/WiFi/Bluetooth
Flight time of UAV	Up to 28 min

Table 1. System Specification

4 Design Approach and Details

4.1 Design Approach

The entire system consists of a UAV, a mobile reader, a central processor, and an LCD display.

The schematic is shown below in Figure 1.

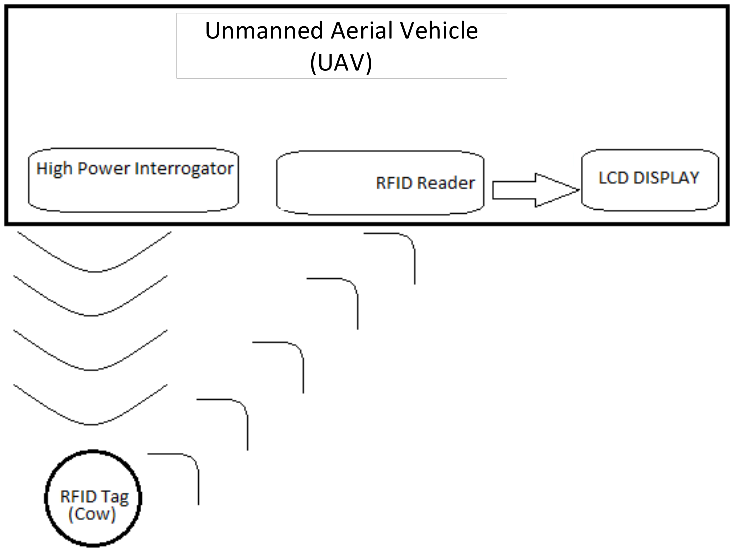


Figure 1. Simple schematic of the inventory system

The mobile reader will be mounted on the under-side of the UAV and angled down towards the cattle. This will be done in an effort to reduce the amount of interference between the interrogator and the RFID tag. For example, a cow may have its head down behind another cow while it is pasturing, the interrogator signal would have to travel through the first cow to get to the desired tag. Figure 2 shows a picture of the interrogator the team is testing.

Figure 2. Motorola FX7500 Fixed Reader [2]

Once the interrogator's signal arrives at the tag, a reflection will occur and the tag will send out a signal with information pertaining to the particular animal. An example of a mobile reader shown in Figure 3 will receive the tags' signal and populate a list of all received tags.

Figure 3. Motorola MC9190-Z Handheld RFID Reader [2]

The list will then be sent to a larger LCD display through wireless connection. The team has not yet determined exactly how this will be done. This communication specification will have to be set once the reader technology is developed and data rates are tested. However, the list will be available to transfer with a USB stick for analysis in the offices on the ranch.

If this plan does not work, our contingency project will be to post fixed readers at exits of different pastures. Since all cattle have to pass through the same gate to get from pasture A to pasture B, this bottleneck will provide a great opportunity for the team to set up closer range readers and take inventory there.

4.2 Codes and Standards

ISO 11784: (The international standard defining frequencies, baud rate, bit coding and data structures of transponders used for animal identification) will be used for bit patterns to identify animals, bit pattern country code, manufacturer code [3].

Class 2/Class 3 RFID tag standards (for semi-passive tags) will be used in research for semi-passive tags [4]. As of now the team must work with the provided passive tags.

Data content codes for 64-bit identification code (15 digit numeric) will be used to identify birth, herd, range, and other ranch variables [5].

Air interface protocol [6] defines the physical and logical requirements for an RFID system of interrogators and passive tags, operating in the 860 MHz - 960 MHz UHF range.

FCC Rule Section15.247 defines the maximum output RF energy for RFID systems to be 4 Watts.
(https://apps.fcc.gov/kdb/GetAttachment.html?id=QRSnt%2BM%2Fe%2BNFOLVllOMypQ%3D%3D)

4.3 Constraints, Alternatives, and Tradeoffs

4.3.1 Alternatives

The team explored using a separate high powered interrogator to increase read range. The high powered reader can draw much more power from a car battery. However, read range is largely limited by the use of passive tags, regardless of what reader is used.

The team also explored the idea of using semi-passive tags instead of the provided passive tags. Semi-passive tags gather electromagnetic radiation from the environment to charge up small capacitors and help boost the output signal. In contrast passive tags rely entirely on the strength of the interrogators signal to power outputting its RFID information.

4.3.2 Constraints

This system has several constraints, the first is the amount of power we can use in the interrogator. While 40 Watts of power would greatly improve the range we could read at, anyone caught in the path of the reader would be physically damaged. Cost of the tags is also a large constraint: active tags have a battery source and do not require an interrogator signal in addition to having much farther read ranges. However they cost anywhere from $50 to $100 in contrast to the $0.05 passive tags cost. Since this will be applied to large herds of 200 or more cattle, the high cost tag is not an option.

4.3.3 Tradeoffs

If the system is to be mobile, then a part of the system must be battery powered. This means less power available to interrogate the tags, which translates into a smaller read range. If the system was fixed at the gate exit of each pasture as our contingency plan details, then the team could run a power line from a 120 V outlet to power the system. The tradeoff here is that the ranchers would only be able to take inventory while doing pasture rotation. The type of tag depends on the amount of money the team and sponsor company are willing to spend. There are some tags which are designed differently to allow farther innate read ranges. To switch to different tag technology would require great manufacturing costs and may not leave enough time to complete other parts of the project.

5 Schedule, Tasks, and Milestones

Raising the Steaks will be designing and implementing an RFID reader prototype from April 2016 to December 2016. Appendix A contains a GANTT chart that outlines the timeline of major tasks and milestones. Appendix B contains a PERT chart that shows the progression of the tasks and how they are interconnected. Appendix C contains a spreadsheet that reveals the probabilities associated with each task with a final calculation of the completion of the prototype at least one week earlier than the Capstone event in December 2016.

6 Project Demonstration

The demonstration of this prototype will take place on a ranch in Rydal, GA where multiple hundred cattle have previously been tagged with RFID. The UAV will be provided by Dr. Tentzeris' lab. A standard ATV will be provided from by whomever is in charge of the ranch at that time to drive around the pasture and test the UAV.

6.1 Integration with UAV

The first part of the demonstration will be to mount the developed RFID reader prototype on a UAV. The RFID system will have to be able to work off an additional mounted battery, and be secure enough as to withstand reasonable flight maneuvers.

6.2 Counting Cattle

The next part of the demonstration will involve driving up to a herd of cattle. Once at a distance of up to 5 meters, the operator holding the UAV RFID system will try to "scan" the herd by flying the UAV over the herd. The operator will then confirm that all of the cattle in that herd are physically present and their information has populated the LCD screen of the reader system.

6.3 Finding Lost Cattle

The final part of the demonstration will be to find a lost cow. The operator will come up to a herd of cattle and scan the herd to count the cattle. This time, however, there will be a cow that is missing from the herd and will be off to the side. The operator has to 1) note that there is a cow that missing, 2) search for that specific cow using the handheld, and 3) find the cow.

7 Marketing and Cost Analysis

7.1 Marketing Analysis

Tracking and maintaining cattle using UHF RFID systems is not a new concept. However, most of these concepts exist in other countries outside the United States. These existing concepts also have a very limited range and capability compared to the prototype proposed in this project.

Item	Allflex Cost	Agrident Cost
Mobile Stick Reader	$1,100.00 [7]	$790.00 [8]
Read Range	50 cm [7]	35 cm [8]

Table 2. Allflex and Agrident mobile reader costs.

7.2 Cost Analysis

7.2.1 Opportunity Cost Savings

Assuming that the average rancher salary is $60,000 per year in the state of Georgia [9], this equates to about $30 per hour. From talking to people in this field, on average, the rancher will spend about 15 hours per week counting cattle and looking for lost cattle. This comes up to $23,400 per year per rancher of money spent finding and counting cattle. Using the proposed prototype, it will severely cut this opportunity cost down to the retail price of the reader system and a small fraction of time spent driving around and counting cattle.

7.2.2 Parts/Materials

Raising the Steaks will develop a working RFID reader system prototype that will be mounted on a UAV. To accomplish this, multiple handheld readers and fixed readers will have to be acquired, characterized, and modified to accomplish this effort. Most of the RFID technology, as far as readers and tags go, will be provided by CattleTime on its budget by prior agreement, so prices for those specific components are not listed. The rest of the materials cost is listed in Table 3. An MBED will be used as the central microcontroller to handle the system. An LCD display will be used to display useful information. Some type of structure will need to be made to secure the reader to the UAV. This structure will also need to be somewhat durable for prototype purposes. The value for this structure is estimated.

Item	**Cost**
MBED LPC1768 Microcontroller [10]	$50
LCD Display [11]	$49.95
Structure	$50

Table 3. Costs to prototype.

7.2.3 Costs of Labor and Profits

There are 5 engineers on Raising the Steaks. The labor hours spent per engineer is predicted in Table 4 for a whole semester.

TASK	**HOURS**
Weekly Meetings	22
Paper Reports and Summaries	30
Presentation	1
Testing	25
Transportation	15
TOTAL	**93**

Table 4. Hours of labor.

The total labor costs are calculated using the hours per engineer for a semester and an annual average salary of an entry level Electrical Engineering graduate from Georgia Tech which is currently around $68,000. At 93 hours of labor, the cost per engineer is $3,162. Assuming 30% fringe benefits of labor and 120% overhead for unexpected costs, the total development cost for the RFID reader system is shown in Table 3. The total development cost is estimated to be around $45,545.50.

DEVELOPMENT	**COST**
Parts	$149.50
Labor	$15,810
Fringe Benefits	$4,743
Overhead	$24,843
TOTAL	**$45,545.50**

Table 5. Total development costs.

If the assumed selling price of the reading system was $3,000, then only 16 readers need to be sold to break even from all of the development costs. With the expected impact of such a reader in the cattle industry, the chances of selling more than 16 is highly likely since there are numerous ranches around the United States. Maintenance costs are currently undefined due to the fact that the design is still in its initial phase and sources of failure in physical parts have not been identified nor tested.

8 Current Status

All of the ECE 4011 requirements are complete. This includes initial project scheduling, project cost analysis, project summary, and project proposal. The proposal is currently being redefined to capture a more realistic approach to the initial proposed solution. Hardware, as far as RFID transmitter and receiver, is in the process of being acquired and testing/characterization shall begin shortly. This proposal will be presented on September 1st, 2016 to the project sponsor CattleTime, the Georgia Tech faculty advisor Dr. Tentzeris, and anyone else who is interested in this product.

9 References

[1]"EID Tags - Electronic Identification Ear Tags", *Cattleidentification.org*, 2016. [Online]. Available: http://cattleidentification.org/ear-tags/eid-tags. [Accessed: 10- Apr- 2016].

[2]"Motorola RFID Handheld Readers & Portals", *Barcode Printers Scanning for Warehousing Healthcare Mobile Workforce*, 2016. [Online]. Available: http://www.rmsomega.com/products/hardware/motorola-rfid-handheld-readers-portals/. [Accessed: 10- Apr- 2016].

[3]"ISO 11784:1996 - Radio frequency identification of animals -- Code structure", *Iso.org*, 2016. [Online]. Available: http://www.iso.org/iso/catalogue_detail?csnumber=25881. [Accessed: 10- Apr- 2016].

[4]"RFID Tags - EPC-RFID", *EPC-RFID*, 2016. [Online]. Available: http://www.epc-rfid.info/rfid_tags. [Accessed: 10- Apr- 2016].

[5]*Animal Identification & Information Systems Reference Guide*, 1st ed. National Institute for Animal Agriculture, 2016.

[6]"EPC UHF Gen2 Air Interface Protocol | GS1", *Gs1.org*, 2016. [Online]. Available: http://www.gs1.org/epcrfid/epc-rfid-uhf-air-interface-protocol/2-0-1. [Accessed: 10- Apr- 2016].

[7]"7020 - Aleis » Allflex USA", *Allflexusa.com*, 2016. [Online]. Available: http://www.allflexusa.com/our-products/readers/product/7020. [Accessed: 10- Apr- 2016].

[8]"Buy Online, Sheep Software for PC & PDA, Electronic Tag reading equipment, Psion, Agrident, Stick readers, Accessories- TGM Software Solutions Ltd", *Tgmsoftware.com*, 2016. [Online]. Available: http://www.tgmsoftware.com/buy/sterling.htm. [Accessed: 10- Apr- 2016].

[9]"Rancher", *Sokanu.com*, 2016. [Online]. Available: https://www.sokanu.com/careers/rancher/salary/. [Accessed: 10- Apr- 2016].

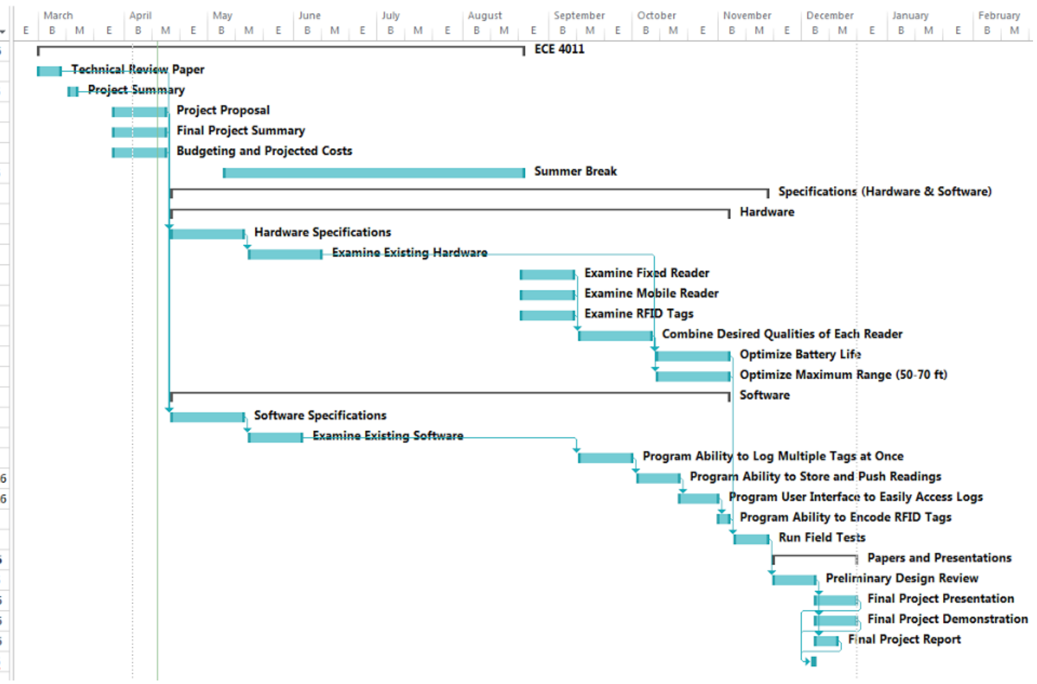
[10]"OM11043,598 NXP Semiconductors | Mouser", *Mouser Electronics*, 2016. [Online]. Available: http://www.mouser.com/ProductDetail/NXP/OM11043598/?qs=WluGR1XeskOiY15%252bhYn5cQ%3D%3D&gclid=Cj0KEQjwosK4BRCYhsngx4_SybcBEiQAowaCJY2lygKBY5QOd8ZebA1oU7qk_umW-BlApTlqKC6wEPkaAmx28P8HAQ. [Accessed: 12- Apr- 2016].

[11]"Graphic LCD 160x128 Huge - LCD-08799 - SparkFun Electronics", *Sparkfun.com*, 2016. [Online]. Available: https://www.sparkfun.com/products/8799. [Accessed: 12- Apr- 2016].

Appendix A: Project GANTT Chart

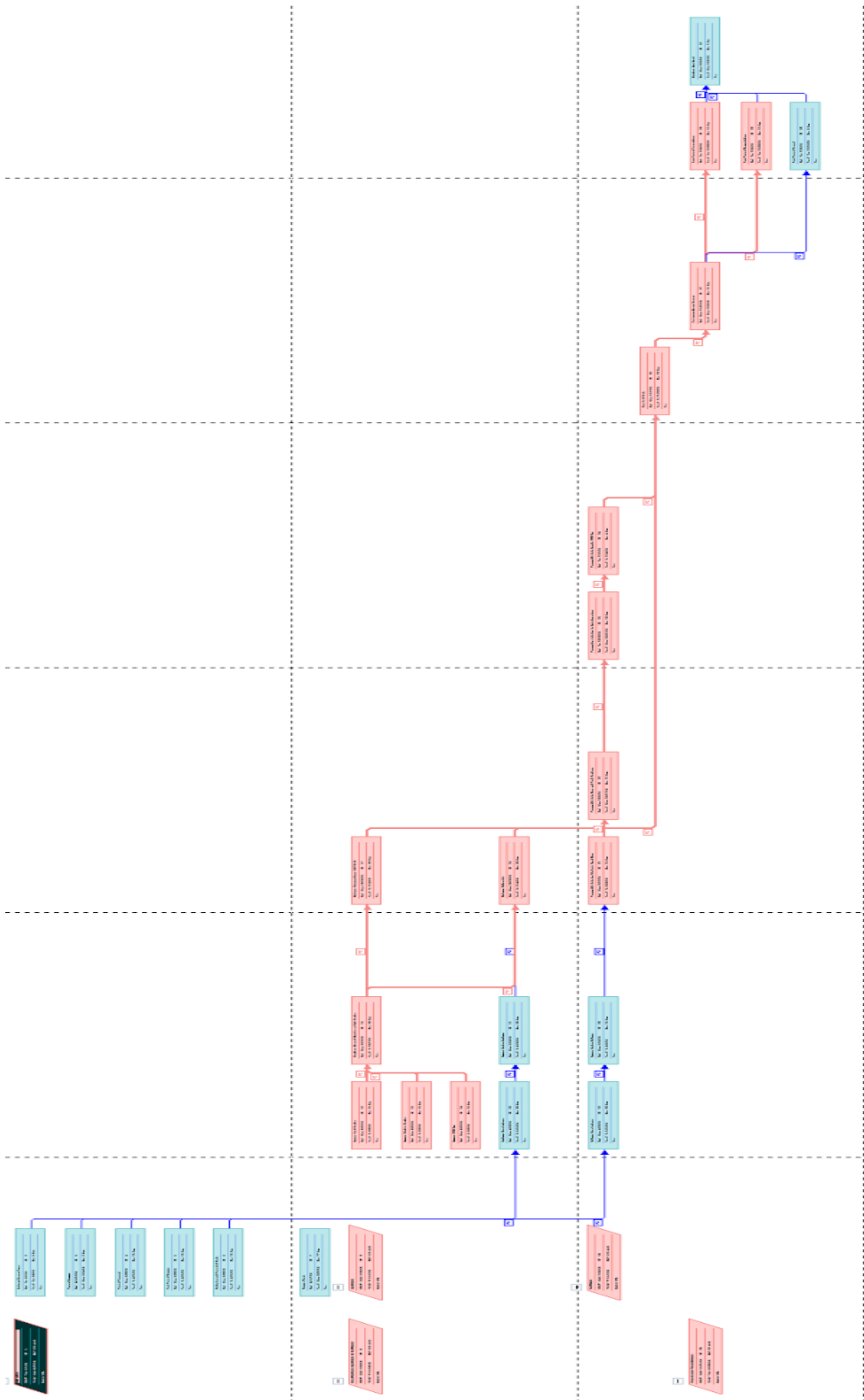
See next page for project GANTT chart.

	Task Mode	Task Name	Duration	Start	Finish
1		1 ECE 4011	125 days	Tue 3/1/16	Mon 8/22/16
2		1.1 Technical Review Paper	6 days	Tue 3/1/16	Tue 3/8/16
3		1.2 Project Summary	2 days	Sat 3/12/16	Mon 3/14/16
4		1.3 Project Proposal	15 days	Mon 3/28/16	Fri 4/15/16
5		1.4 Final Project Summary	15 days	Mon 3/28/16	Fri 4/15/16
6		1.5 Budgeting and Projected Costs	15 days	Mon 3/28/16	Fri 4/15/16
7		1.6 Summer Break	77 days	Sat 5/7/16	Mon 8/22/16
8		2 Specifications (Hardware & Software)	155 days	Mon 4/18/16	Fri 11/18/16
9		2.1 Hardware	145 days	Mon 4/18/16	Fri 11/4/16
10		2.1.1 Hardware Specifications	20 days	Mon 4/18/16	Fri 5/13/16
11		2.1.2 Examine Existing Hardware	20 days	Mon 5/16/16	Fri 6/10/16
12		2.1.3 Examine Fixed Reader	15 days	Mon 8/22/16	Fri 9/9/16
13		2.1.4 Examine Mobile Reader	15 days	Mon 8/22/16	Fri 9/9/16
14		2.1.5 Examine RFID Tags	15 days	Mon 8/22/16	Fri 9/9/16
15		2.1.6 Combine Desired Qualities of Each Reader	20 days	Mon 9/12/16	Fri 10/7/16
16		2.1.7 Optimize Battery Life	20 days	Mon 10/10/16	Fri 11/4/16
17		2.1.8 Optimize Maximum Range (50-70 ft)	20 days	Mon 10/10/16	Fri 11/4/16
18		2.2 Software	145 days	Mon 4/18/16	Fri 11/4/16
19		2.2.1 Software Specifications	20 days	Mon 4/18/16	Fri 5/13/16
20		2.2.2 Examine Existing Software	15 days	Mon 5/16/16	Fri 6/3/16
21		2.2.3 Program Ability to Log Multiple Tags at Once	15 days	Mon 9/12/16	Fri 9/30/16
22		2.2.4 Program Ability to Store and Push Readings	11 days	Mon 10/3/16	Mon 10/17/16
23		2.2.5 Program User Interface to Easily Access Logs	10 days	Tue 10/18/16	Mon 10/31/16
24		2.2.6 Program Ability to Encode RFID Tags	4 days	Tue 11/1/16	Fri 11/4/16
25		2.3 Run Field Tests	10 days	Mon 11/7/16	Fri 11/18/16
26		3 Papers and Presentations	22 days	Mon 11/21/16	Tue 12/20/16
27		3.1 Preliminary Design Review	11 days	Mon 11/21/16	Mon 12/5/16
28		3.2 Final Project Presentation	11 days	Tue 12/6/16	Tue 12/20/16
29		3.3 Final Project Demonstration	11 days	Tue 12/6/16	Tue 12/20/16
30		3.4 Final Project Report	6 days	Tue 12/6/16	Tue 12/13/16
31		3.5 Capstone Expo Event	1 day	Mon 12/5/16	Mon 12/5/16



Appendix B: Project PERT Chart

See next page for project PERT chart.



NETWORK DIAGRAM

Appendix C: Project PERT Analysis

See next page for project PERT analysis.

	A	B	C	D	E	F	G	H	I	J
1	Tasks	Dur_Optimistic (days)	Dur_Expected (days)	Dur_Pessimistic (days)	Std_Dev	Var	Crit_Path_Mean	Crit_Path_Std_Dev	Z_transform	Prob_Finish_Week_Early (Percentage)
2	**ECE 4011**		**125**							
3	Technical Review Paper	x	x	x						
4	Project Summary	x	x	x						
5	Project Proposal	14	15	15	0.17	0.03				
6	Final Project Summary	14	15	15	0.17	0.03				
7	Budgeting and Projected Costs	13	15	18	0.83	0.69				
8	Summer Break	77	77	77	0.00	0.00				
9	**Specifications (Hardware & Software)**		**155**							
10	**Hardware**		**145**							
11	Hardware Specifications	17	20	21	0.67	0.44				
12	Examine Existing Hardware	17	20	25	1.33	1.78				
13	Examine Fixed Reader	13	15	16	0.50	0.25				
14	Examine Mobile Reader	13	15	18	0.83	0.69				
15	Examine RFID Tags	12	**15**	16	0.67	0.44				
16	Combine Desired Qualities of Each Reader	18	20	24	1.00	1.00				
17	Optimize Battery Life	17	20	22	0.83	0.69				
18	Optimize Maximum Range (50-70 ft)	18	20	23	0.83	0.69				
19	**Software**		**145**							
20	Software Specifications	17	20	21	0.67	0.44				
21	Examine Existing Software	17	15	23	1.00	1.00				
22	Program Ability to Log Multiple Tags at Once	13	15	16	0.50	0.25				
23	Program Ability to Store and Push Readings	13	11	16	0.50	0.25				
24	Program User Interface to Easily Access Logs	8	10	13	0.83	0.69				
25	Program Ability to Encode RFID Tags	3	4	5	0.33	0.11				
26	Run Field Tests	9	10	13	0.67	0.44				
27	**Papers and Presentations**		**22**							
28	Preliminary Design Review	10	11	12	0.33	0.11				
29	Final Project Presentation	9	11	13	0.67	0.44				
30	Final Project Demonstration	11	11	11	0	0				
31	Final Project Report	6	6	6	0	0				
32	Capstone Expo Event	1	**1**	1	0	0				
33							135	2.15	1.39	91.77
34		**Key**								
35		x = already completed								
36		**BOLD** = simply for organization								
37		(not included)								
38										