incrediBOWL™

Final Report

Group Number: 13

Members:

Rufus Caple (rufus1.caple@famu.edu)

Kiernan Farmer (kpf12@my.fsu.edu)

Maria Perez (mp13@my.fsu.edu)

Mateo Quintanilla (mq12b@my.fsu.edu)

Eddie Gibson (eg15g@my.fsu.edu)

Faculty Reviewers:

Dr. Linda DeBrunner

Dr. Chris Edrington

Sponsor:

Dr. Michael Devine

Advisor & Course Instructor:

Dr. Jerris Hooker

Date Delivered:

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ABSTRACT

Dr. Michael Devine, the Entrepreneur in Residence and an Adjunct Professor at the FAMU-FSU College of Engineering, is sponsoring the Incredibowl Team in its efforts to develop a consumer prototype of a Radio Frequency Identification Selective Feeder. The team intends to create a product that utilizes a personal RFID chip as identification to seal an animal's food and protect it from intruding animals as well as environmental conditions. The effectiveness of the selective feeder will be based on the ability to both allow the desired pet to retrieve the contents of the bowl when it has reached a close proximity as well as the ability of the bowl to protect the contents of the container from foreign elements. The team has gathered preliminary research about similar products in order to understand common strengths and weaknesses of existing competitors.

ACKNOWLEDGMENTS

The Incredibowl team would like to thank Dr. Devine for sponsoring the project and providing the group with the entrepreneurial guidance to create a successful product. The team would also like to recognize Dr. Linda DeBrunner and Dr. Edrington for their collective guidance through the group presentations. In addition, the Incredibowl team would like to thank Dr. Hooker for guiding the group through the obstacles faced in Senior Design and offering feedback on design ideas throughout the semester.

1. Introduction

The Incredibowl team has proposed this RFID Sensor Selective Feeder to allow pet owners the ability to manage their pet's food consumption without constant observation. A selective feeder is a device that contains either food or water in a bowl within it. The device protects the contents of the bowl from both invasive species and environmental damages. However, the selective feeder will open the lid to the food bowl upon sensing the presence of a particular radio frequency identification (RFID) chip within a close proximity. The chip will be attached to the consumer's pet collar, allowing for mobility and constant access to food and water. The identification chip will contain a personal code which will be used to open a specific selective feeder. This gives the consumer the ability to customize their feeding experience to fit the needs of their own pets.

Often times, pet owners with multiple pets struggle to feed a particular animal without the others attempting to steal one's food. A pet owner may also wish to leave a food bowl or water bowl outside for a dog or cat, but risks vermin or environmental issues contaminating the contents of the bowl. With the Incredibowl sealing lid design, a pet owner can now protect the contents of a particular pet's bowl. The embedded RFID chip in the pet collar allows a particular pet access to the bowl, without risking other pets or wildlife from attempting to steal the food.

The design team has been tasked with researching existing products on the market in order to determine the effectiveness of existing selective feeders. The success of the group will largely be based upon developing a product that fits the needs of the majority of consumers. This will be done by identifying common problems with existing technology, determining solutions for those problems, and engineering a final product that effectively corrects the oversights left by competitors.

2. Problem Statement

Currently, pet owners struggle to maintain a proper feeding pattern for their pet using a traditional food bowl. External factors, such as pests, other pets, and environmental conditions prevent pet owners from leaving a pet's food unattended for any extended period of time. The contents of the food bowl, whether it be dry food, wet food, or even water, is subjected to the risk of contamination when left unattended. Many pet owners would prefer to feed their animals outside, but cannot afford to because unconsumed food will draw the attention of invasive animals, such as birds or raccoons. On the other hand, pet owners that would like to leave food inside for an extended time bring the risk of bringing bugs into the house from the exposed odor of the food in the air.

In addition, pet owners cannot control the nature of their pets, no matter how hard they try. It is nearly impossible to train a dog or cat to eat all of its food before leaving if the animal simply does not want to. However, some animals enjoy eating all too much and often steal food from neighboring pet bowls when the owner is unaware. This is a problem for households with multiple pets as it leads to territorial issues as well as unregulated diets. Many pets cannot fend for themselves and can lose their food to animals if the owner is not around.

The Incredibowl team has proposed a selective feeder that operates for a selective animal, thus eliminating the problems mentioned above. The Incredibowl team is designing an attachment chip that can be mounted to nearly any collar. This chip will contain a personal identification for the pet that can be interpreted by the selective feeder. Multiple sensors around the bowl will sense when the pet with the desired collar is near, and allow only that particular animal to eat. The contents of the bowl will be enclosed with a sealable lid. The lid will only open up when the pet collar with a chip is within the proximity of the bowl, allowing a specific animal to eat from it. After the animal has finished eating and left, the lid will close and reseal the contents of the bowl.

3.Background and Literature Review

3.1 Related Competitors

There are a variety of products in the pet supplies market that work as automated feeders and selective feeders. Many of these products use RFID chips as well, although some use the microchip that many pet owners have surgically implanted in their pet. Companies, such as OnePets and SureFlap have utilized a similar method of scanning for food retrieval. However, the OnePets Wonderbowl has notoriously been known have malfunction. Consumers have listed a myriad of complaints about the product's lid closing on their pet's head or the lid not opening at all. Further research indicated that the inability to open could be caused from a short battery life, or an error in RFID detection. Likewise, the SureFlap SureFeed has listed problems directed towards the product's initial design. The contour scanner encloses the animal completely and is too small to be used by any pet larger than the average house cat.

Along with the reviews gathered from similar products on the market, the Incredibowl team worked to understand how an RFID chip can be used to in an innovative way. Researching the structure of an RFID chip lead the team to discover the range of designs in which the chip can be implemented. During this stage of preliminary research, the group was able to discover the Invengo Tome, a balance RAIN RFID inlay that meets the design specifications the group was looking for in order to fit to a universal pet collar, rather than a collar tag.

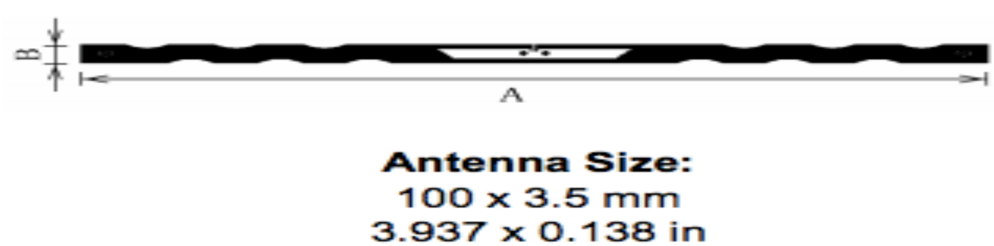

Figure 1: Invengo Tome Product Specification Size

3.2 Microcontroller Considerations

The initial consideration for hardware development was to use a microcontroller or microprocessor to handle the logic of the selective feeder. The inputs and outputs for the hardware are relatively simple so cost effective resources were appropriate considerations. The first idea for the central processing unit was a Raspberry Pi 2 microprocessor.

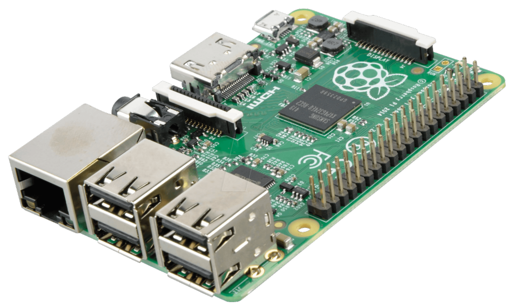

Figure 2: Raspberry Pi 2 Microprocessor

This board leads the electronics hobbyist community with its ability to run a Linux environment and control simple programs that will suit a wide array of needs. The Raspberry Pi contains many connection ports, such as: HDMI, microSD, 4 USBs, Ethernet, Audio, 40 GPIO, and an SD card slot. It also contains a 900 MHz 32-bit quad-core central processing unit. The board has access to the internet of things (IoT) through the Ethernet connection as well as wireless Bluetooth capabilities. The board is driven by a 5 Volt supply and how a power rating of 800mA (4.0 Watts).

Another consideration for handling the functionality of the Incredibowl selective feeder was the Arduino Uno micro controller.

Figure 3: Arduino Uno Microcontroller

The Arduino Uno has gained a lot of popularity in recent years for its innovation and simplicity. The board is designed with a logical approach that makes it a popular choice for novice controller users. The native integrated development environment (IDE) for the Arduino Uno is based off of the C programming language and is remarked as very intuitive. The board consists of a 32-bit AVR microcontroller with a 5 V linear regulator and 16MHz crystal oscillator. The board has 14 digital inputs to send and receive signals as well. The board typically runs a consumer around $35 if purchased brand new.

The final consideration for the controller of the selective feeder was the Texas Instruments MSP-430.

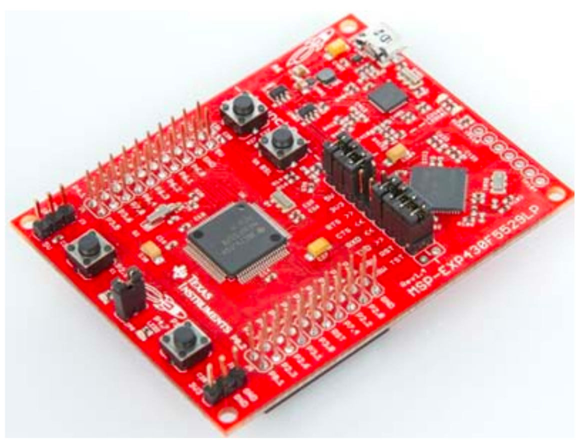

Figure 4: Texas Instruments MSP-430 Development Board

This board features minimal architecture at a minimal price. The average price for the development board, when purchased in a singular quantity, is around $13. However, the individual microprocessor can be purchased without the board for only $3. The microcontroller features a powerful 16-bit RISC CPU, 16-bit registers and constant generator registers, which allow the board to operate more efficiently. The board operates at a frequency of 25 MHz and contains 128 KB of nonvolatile memory and 10 KB of RAM. The board also feature 63 GPIO pins for sending and receiving signals.

3.3 DC Motors

A DC motor is essential for the design of the lid mechanism for the Incredibowl selective feeder. A brushed DC motor contains a pair of oppositely charged permanent magnets. Within the gap between the magnets is a metal coil that contains a flow of electrons when connected to a power supply. As the electrons flow through the metal coil within the magnetic field, a magnetic force is produced orthogonal to the coil electron flow and permanent magnet. This causes the coil to spin and thus generates a magnetic torque. As the magnetic field reaches equilibrium (after completing a 180-degree spin) a commutator reverses the flow of electrons within the coil. Therefore, the direction of torque will be reversed as the induced magnetic coil force is now attracted to the coils original position. The commutator effective causes the motor to rotate fluidly in one direction. A DC motor can also rotate in the opposite direction if the power supply leads are reversed. A DC motor only has two connection points, so a power supply can be directly connected to the motor. DC motors come in a wide range of sizes in order to supply different rotational speeds and torques at different power consumption levels. The motors can also be calibrated to operate a relatively low voltage, which is useful for the development of the selective feeder. The DC motor is also extremely lightweight, adding to the portability of the feeder’s design.

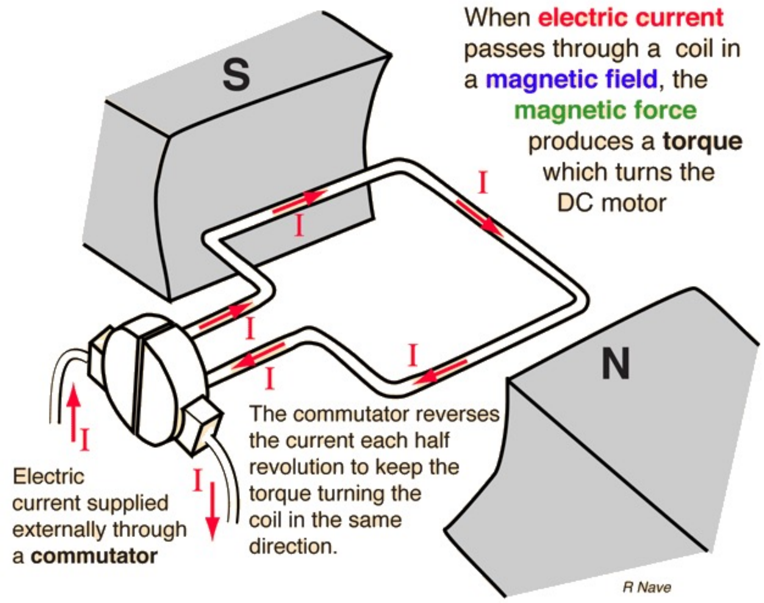

Figure 5: DC Motor Demonstration

4. Needs Statement

Incredibowl would like to introduce a prototype for a new selective feeder to the consumer market. Other products on the market fail to provide a selective pet feeding experience that works for both the pet owner and pet itself. The Incredibowl team, along with the guidance of Dr. Hooker and Dr. Devine, aims to deliver a feeder that is can reliably provide food to the consumer's pet without upsetting the cat or failing to protect the contents inside the feeder.

- Needs
    - Project Box
        - To house our design components
    - Two Step DC Motor
        - To control the lids movement
    - Texas Instruments MSP430 Launchpad
        - Controller of power objects
    - RFID/NFC Reader
        - To sense incoming/outgoing data
    - NFC/RFID Tags
        - Send data to reader for lid to open
        - Imbedded in collars
    - Two LED lights
        - Power (low battery flash)
        - Working processes (pairing collars, open/close)
    - Push Buttons
        - To signal functions on processor
    - C series battery holder
        - For batteries to power components
    - Wheels

        - So the lid can open/close smoother
    - Failsafe (non powered)
        - To be able to open lid without power

- Requirements
    - Reader senses RFID/NFC pet collar
    - Lid must stay open whilst pet is present within the proper distance
    - Lid opens/closes
    - Slightly Shockproof
    - Water resistant

5. Objectives and Goals

The Incredibowl team has developed a hierarchical approach to identifying the objectives and goals of the design project. The three primary objects that the feeder will need to satisfy are: portability, functionality, and durability. On the way to gain success with our product we would like to go through prototype building and secure the process steps with our software to confirm accuracy. The success of the product predominantly depends on the success of these three objectives.

In order to measure an achievable objective, secondary goals were created among the primary set of objectives. The feeder's portability will be achieved through a lightweight design with a rechargeable battery as well as a small, attachable RFID chip. The functionality of the feeder will be determined by the sensor range of the RFID chip, the ability for the lid to retract and remain open while the pet eats, a manual backup in case the battery dies, and a noise free implementation. The durability of the product will be measured by the water and shock resistance of the feeder, the strength of the lid, and the weatherproofing of the RFID/NFC chips and reader.

Figure 6: Incredibowl Objectives and Goals Chart

6. Constraints

Multiple constraints must be factored into the design process of the selective feeder. The three primary constraints that have been factored into the development are the mechanical aspects of production, time, and creating a durable yet portable device.

Mechanical Aspect:

Given the fact that we do not have a Mechanical Engineer on our team, we must learn how to use AutoCAD to create a prototype for our project. We will also have to figure out the design aspect of the lid and how exactly we will create a seal to provide freshness to the pets' food.

Time:

The construction of the selective feeder must be finished in time to test it for any oversights in design. The project must be completed and presented by the end of the Spring 2017 semester.

Durability/Portability:

The design of both the selective feeder and the RFID chip must be portable yet durable. Optimizing the design of one of these components sacrifices the other. The RFID chip must be able to be integrated into the collar of the pet and be able to function at a reasonable distance. The feeder must be able to withstand the environmental issues outside as well as be transportable from place to place. Therefore, compromises must be made in both objectives in order to create an ideal product for the consumer.

Power Supply Longevity:

The primary engineering constraint for the project is budgeting the lifetime of the power supply. The electrical system must be designed to minimize consumption from the batteries. The MSP-430 is being used to optimize current consumption with its lower power mode options. This will allow the microcontroller to operate and only consume 2 uA of current as opposed to 200uA. The sensors and motor must also be driven by the same battery connection. Fortunately, the motor will only consume power when it opening or closing the lid, which occurs for very short intervals of time. The sensors, on the other hand, must continually operate to ensure a proper functionality of the product. Therefore, operating the sensors will have the largest toll on the longevity of the power supply

7. Decision Making

The Incredibowl team considered a lot of factors before ultimately making a final decision. The team decided to go with an NFC chip versus other RFID chips because it met all the requirements that were needed for the feeder. NFC uses low power, has a range of 30 cm and size of the chip is fairly small. The range allows an optimal height for the pet to be able to trigger the bowl to open. The size of the chip allows the team to integrate the tag into the actual dog collar. Due to the fact that the NFC tags have a bending limit, we decided to encase the chip in the locking mechanism of the collar. Knowing that the pet's collar might spin around the pet's neck, we concluded that the locking mechanism must be weighted heavily so that the weight allows for the dog collar to be always pointed downwards.

Another decision the Incredibowl team had to make was how were we going to encase the electronics and mechanic devices. The encasing is going to be 3D printed in-home using Florida State University’s resources. This will also allow us to cut down on our budget. As for the lid, we have decided to have a retractable lid that moves at a speed where the pet would not get spooked. With this decisions, we get closer and closer to achieving our goal.

8.Deliverables

8.1 Task List

Level 1	Level 2	Level 3
Incredibowl	1 Initiation	1.1 Obtain SureFeed 1.2 Obtain RFID tags, inlays 1.3 Take apart Wonderbowl 1.4 Meet with advisor for question/answer 1.5 Project final materials for build
	2 Planning	2.1 RFID vs NFC 2.2 Interview potential customers 2.3 Design final bowl 2.4 Obtain all materials 2.5 Create task plan, timesheet 2.6 Distribute tasks
	3 Execution	3.1 START WORK 3.2 Verify and Validate User Requirements 3.3 Get system manufactured 3.4 Procure Hardware/Software 3.5 Install Development System 3.6 Testing Phase 3.7 Install Live System 3.8 User Training 3.9 True Testing
	4 Control	4.1 Project Management 4.2 Project Status Meetings/Presentations 4.3 Risk Management 4.4 Update Project Management Plan
	5 Closeout	5.1 Audit Procurement 5.2 Document Lessons Learned 5.3 Update Files/Records/Website 5.4 Peer Review 5.5 Archive Files/Documents

Figure 7: Incredibowl Task List

The figure above is the task list the Incredibowl team developed in order to organize the milestone objectives and goals that must be completed throughout the semester. The work was divided into five primary milestones: Initiation, Planning, Execution, Control, and Closeout. Each milestone contains tasks which must be finished before the milestone can be considered completed.

8.2 Work Breakdown Structure

The Incredibowl team used the information provided in the take list to develop a work breakdown structure (WBS). This was done in order to view the layout of each task and understand the dependencies of different goals. The work was broken down by milestone and each milestone has the necessary goals listed beneath it. Each division contains multiple tasks which must be completed before the milestone can be considered completed. The following is the work breakdown structure for the Incredibowl team:

Figure 8: Incredibowl Work Breakdown Structure

8.3 Gantt Chart

The task list and work breakdown structure were critical resources needed to develop a schedule for the group. After completing the two design elements, the team was able to format a timeline of events needed to complete the entire project. The five milestones that were outlined in the task list and work breakdown structure are mutually exclusive. However, they all have parallel portions in which tasks from different categories can be completed simultaneously. The Incredibowl team used this idea of parallel work to develop a Gantt Chart, consisting of the tasks outlined above, in order to schedule the completion of each milestone throughout the remainder of the year. The Gantt Chart highlights the concept of parallel planning by layering multiple tasks from the work breakdown structure. Sticking to the following schedule will allow the group to understand when each deadline should be met in order to keep a fluid progression of success throughout the year.

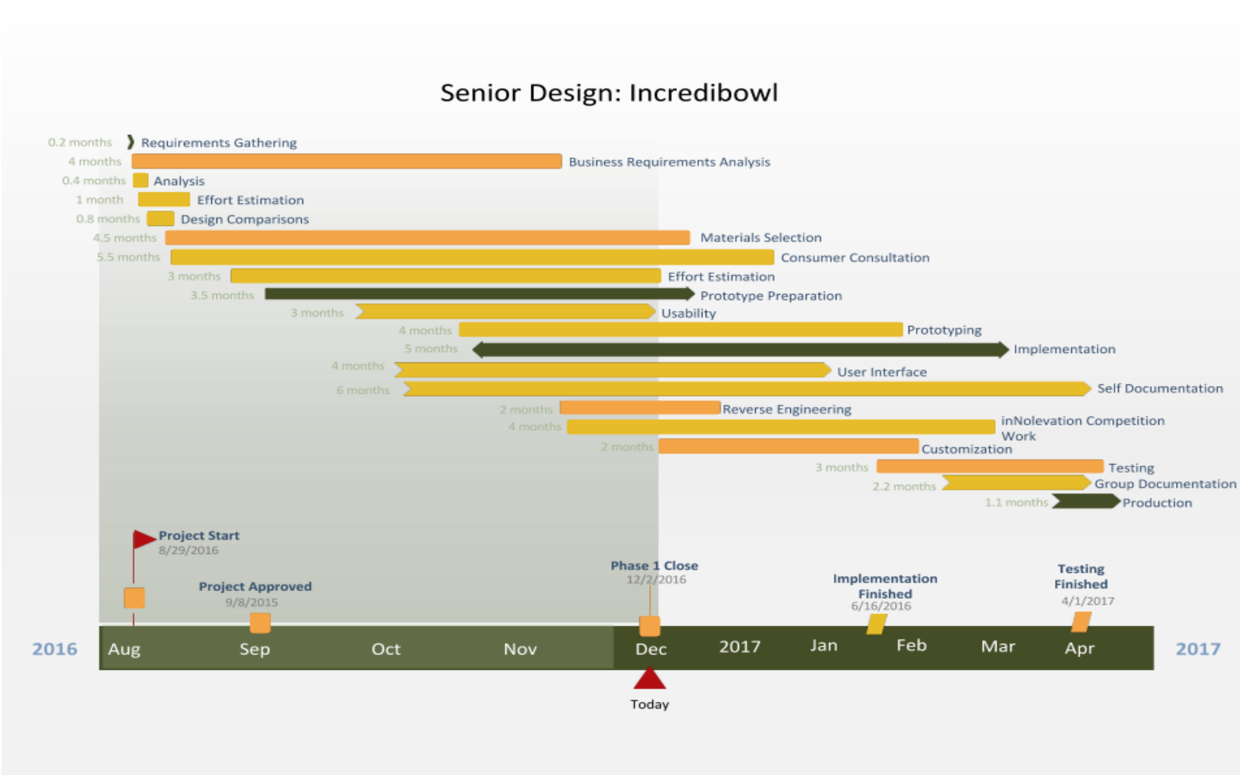

Figure 9: Incredibowl Gantt Chart

9. Resource Assignments

Rufus Caple – Rufus is the project manager for the Incredibowl team. He developed the initial concept and design for the selective feeder with the guidance of Dr. Devine. Rufus is in charge of delegating responsibilities to the other team members as well as providing them with the necessary information needed to complete each task. In addition, Rufus manages the overall timeline for the group's work breakdown structure. After an initial collection of background research has been obtained, Rufus determined the necessary time frames needed to complete each milestone and manages the completion along the way.

Kiernan Farmer – Kiernan is the lead ECE for the Incredibowl team. He has researched and developed a model for interpreting the information from the system's sensors and implementing the appropriate design aspects of the feeder. Kiernan has researched different products in the marketplace to narrow the scope of power supplies, microcontrollers, and motors needed for the project. Kiernan will also be responsible for programming the system to handle different identifications from the chip as well as control the rotation rate of a stepper motor to control the opening of the sealed lid. In addition, Kiernan was responsible for developing the needs analysis of the group as well as compiling the information gathered during meetings for a midterm report.

Mateo Quintanilla – Mateo is the financial director for the Incredibowl team. Mateo has developed an initial budget for the team. Mateo has does background research on existing products in order to find a similar product that can be reverse engineered. Also, Mateo was responsible for understanding the RFID technology, initially, in order to determine a product that the group planned to use for the pet collar. This knowledge has lead Mateo to understand the costs of each purchase, relative to the total budget, and determine where budget cuts were necessary.

Maria Perez – Maria is the secretary for the Incredibowl team. Maria has been responsible for organizing the group's conversations and efforts, both in and out of official meetings, and documenting the information discussed. Maria created accounts on a Google Drive in order to create a database for the group's workflow and necessary documents. The drive is also the hosting location for the notes

Eddie Gibson – Eddie is the lead Website developer for the Incredibowl team. Eddie is responsible for compiling the deliverables and meeting notes and organizing the content onto a visually appealing website. Eddie will be hosting the website through his blackboard account and is designing a layout that will also highlight the contributions of other team members.

10. Product Specifications

10.1 Design Specifications

Due to the entrepreneurial nature of this design project, the Incredibowl team has decided that common household batteries should drive the system. Four C batteries will be used to deliver a voltage of 3 Volts, when combined in a series-parallel connection to the microcontroller. The initial consideration for a power supply consisted of a rechargeable Lithium Ion battery pack, however the nature of an outdoor food bowl left suggested towards more practical power devices. Also, a rechargeable power supply would limit the use of the product to indoor pet owners. The battery supply can have a lifetime of approximately 15600 mAh (given that the consumer uses the popular Alkaline battery options).

The MSP430 can operate on a range of 1.8 - 3.3 Volts, but can function in a low power mode that take very minimal power. When in low power mode, the MSP430 microcontroller can draw as little as 0.6 mA of current. When the board is active, it can draw up to 300 uA. It is reasonable to assume that the board will be active for roughly 1% of the day, which equates to a total time of about 15 minutes a day for the animal to eats the contents of its food. This means that the other 99% of the day will consist of the controller operating in standby mode. If the board were to operate at this ratio of active/standby then it will consumer 0.6uA 99% of each hour and 300uA 1% of each hour, leading to 0.0036mA of consumption an hour. Dividing the capacity of a battery (using the approximation of 15600 mAh) by both the number of hours per year and the charge consumer per hour will leave you with an approximate lifetime of the battery supply. Therefore,

(Lifetime of Power Supply [years])

= (Supply Charge Capacity [mAh]) / (current [mA]) / (24 [hours/year]) / (365 [days/year])

= (15600 mAh]) /(0.99 X 2.1 [μA] + 0.01 X 290 [μA]) / (24 [hours/year]) / (365 [days/year])

= 15600 / 0.004979 / 24 / 365

= 358 years (with no load)

Therefore, the batteries used in the Incredibowl are not expected to due to the regular operation of the microcontroller alone. Although, the controller would normally play a large impact if it operated in an active mode 100% of the time.

The Incredibowl team plans on using a Series-Parallel connection of batteries to drive the internal electronics in the feeder. The battery holders will connect two batteries in series. Two sets of these batteries will be connected in parallel. This allows the system to operate with twice the voltage of a single battery and twice the charge, according to Kirchhoff's Laws. A schematic for the battery supply is included below to represent the connections and total values using C batteries.

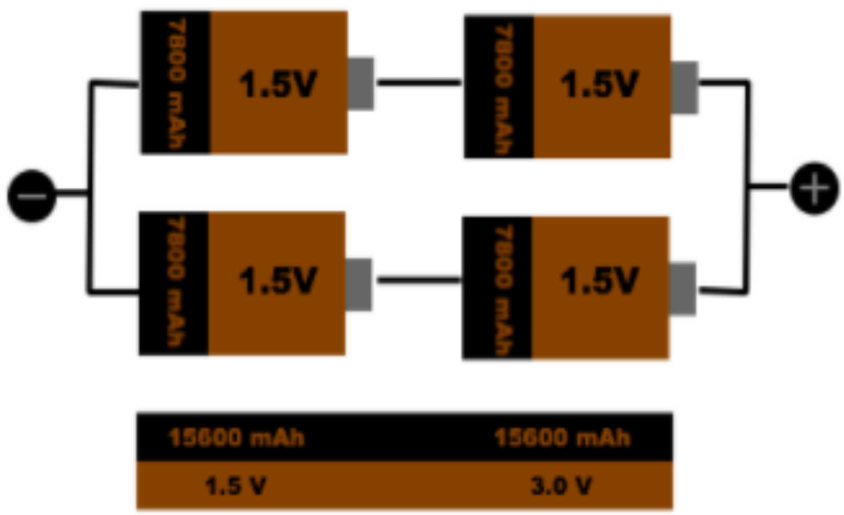

Figure 10: Series-Parallel Battery Supply Connection

The Incredibowl team has also determine that the selective feeder should be contained within a 16"X16" enclosure that is no more than 10" tall, as to conform with the average sizes of current food bowls that consumers would be familiar with. The enclosure must contain the feeding bowl, power supply, sensors, microcontroller, motor for the lid, and wire for connecting peripherals to the central processor.

10.2 Performance Specifications

The Incredibowl team aims to offer a product with optimal accuracy and ranges for the selective feeding needs. The RFID technology can offer readings up to 25 meters away for passive tags that require no power source. The passive tag is the ideal design for the collar as it would be difficult to keep a power supply attached to the consumer pet at all times. The Incredibowl team aims to limit the range of the sensor to 1.5 meters from the bowl. This performance specification should give the animal a comfortable amount of time to approach the bowl and give the bowl enough time to open at a slower rate. This range of 1.5 meters also allows the bowl to close very shortly after the animal leave the proximity of the bowl. This design will inhibit pests and environmental issues from reaching the contents of the bowl.

The lid of the selective feeder is arguably the most important mechanic in terms of performance design. Many competitors were discredited by the opening and closing speed of the feeders' lids. The Incredibowl team will make use of hardware delays (as they are slightly more efficient) within the microcontroller in order to control the movement rate of the lid. The ideal time for the lid to open and close is approximately one second. This will lead to a movement rate that will not scare the pet. This rate is also a happy medium that will not bore the animal by taking too long and possibly cause he/she to get distracted and leave the bowl without eating.

The data for the Incredibowl can be sent using RFID technology and handled within the microcontroller. The sensors can be programmed to handle different identification values from the RFID. The bowl will be designed to interpret up to ten different values, as most consumers are not expected to need more than ten separate Incredibowl feeders. A single bowl will be able to sense up to ten ID's from the pet collar, allow the consumer to have different bowls with different food contents for individual animals. This also allows the consumer to have a shared bowls for multiple pets to access. The values will be contained in the microcontroller and can be easily programmed with the use of two external pushbuttons.

11. Conceptual Design

The Incredibowl team has brainstormed many design considerations for different aspects of the selective feeder. These include subsets of the design, such as the way the lid should open, the microcontroller used to control the system, and the use of RFID or NFC sensors.

The primary mechanics of the selective feeder is opening the lid for the animal to eat. However, the Incredibowl team has looked deeply into the most user friendly option for opening the lid and narrowed it down to having the lid slide back and fold up. The Wonderbowl competitor uses the latch logic with a vertical opening and have received negative review for the design. Many consumers were dissatisfied by the mono-directional approach the lid gives animals. With a lid opening in one direction, the feeder is limited in space that surround the bowl, therefore only one animal may eat at a time. Although, this is a positive design feature for some users, it takes away from the users that intended to use the bowl to allow multiple pets, whom all have the RFID chips, to eat together. It also tends to scare the pet if the sensor is not read properly. Often times, consumers complained that the bowl would hit the animal in the head if the animal approached too quickly or the RFID chip was not faced in the correct orientation. For these reasons, the Incredibowl team has decided to use and accordion style lid that opens and compresses in size.

The functionality of the feeder is primarily dependent on the microcontroller used for processing the sensor information. After considering the product specifications of the Raspberry Pi B 2, Arduino Uno, and TI MSP430, the group has decided to implement the TI MSP430. The primary reasons for the decision are consistent with the needs analysis for the project. The TI MSP430 is the cheapest of all 3 choices, by a significant margin, allowing the development of a massive scale product with larger profit margins. Also, the low power mode feature of the MCU allows the board to draw fractions of a micro-amp at a time. This allows the user's battery supply to last longer. Therefore, by using the TI MSP430, the Incredibowl feeder is able to operate using four C batteries, which are easily accessible to the consumer.

The Incredibowl team has decided to use near field communication (NFC) instead of radio-frequency identification (RFID). The decision was based on the performance specifications of the product. NFC uses low power, has a range of 30 cm and size of the chip is fairly small. The range allows an optimal height for the pet to be able to trigger the bowl to open. The size of the chip allows it to be integrated into the actual dog collar. The NFC chip will be in cased within the locking mechanism of the collar. The latch will be weighed a bit heavier to ensure that it will swing back down around the pet's neck and will always be hanging down. This will ensure that the sensors will be able to receive the signal from the NFC chip.

12. Block Concepts

The block diagram portion for the Incredibowl team has been divided into three stages: hardware, software, enclosure, and lid operations. These four sections (blocks) of the project will be developed independently, but function together to complete the entire product. Each of the four sections will be worked on by all team members, but certain individuals will take the lead on the four aspects. A structure for the implementation process has been outlined in the diagram below:

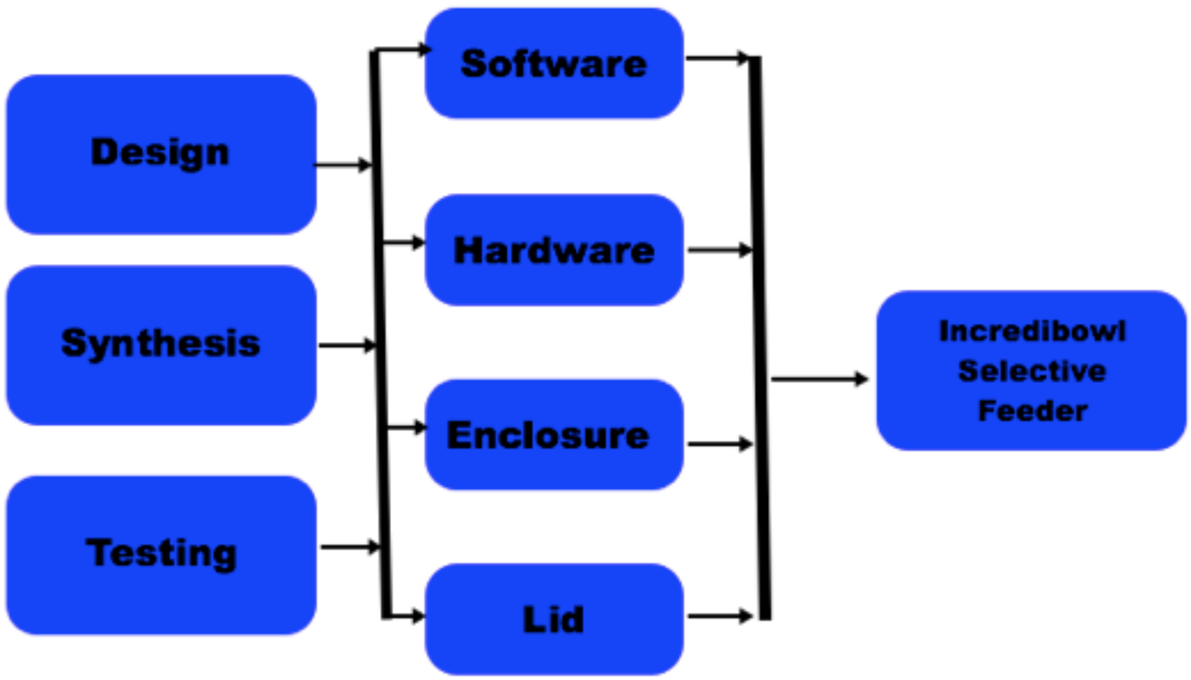

Figure 11: Block Design

Each section of the diagram must be planned, developed, and verified separately. This ensures that each aspect of the design can function on its own.

For the software block of the project, the MSP-430 must be utilized to handle information and call functions appropriately. A block diagram has been developed to further explain the functionality of the software:

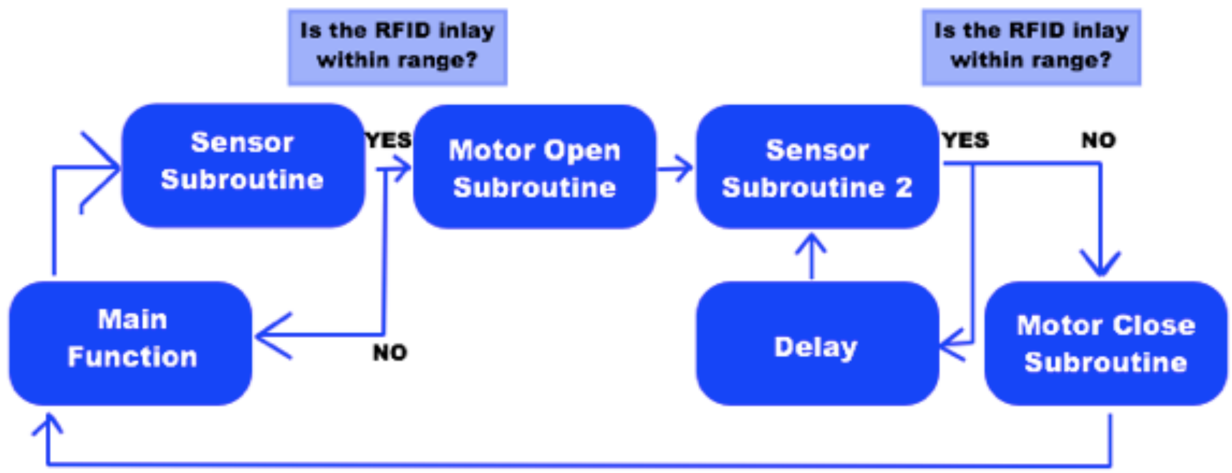

Figure 12: Software Block Diagram

This image represents a flowchart for the embedded microprocessor. The code is displayed using the "polling" technique in order to demonstrate the functionality clearly. In this approach, the microcontroller checks the output from the sensors and sees if an RFID tag has been sensed. If the tag hasn't been detected, the program continues its cycle of checking the sensor. However, once a tag has been detected, the program executes a function that initiates the motor to open the lid. The voltage output will be handled using the MSP430 for a calculated duration. Once the lid is open, the program will check the sensors again. Once the tag is no longer read, the main function will call another motor function that outputs a voltage to a second enable pin from the MSP430. This will enable the motor to rotate the opposite direction for the same amount of rotations. Once the entire process is complete, the function will begin checking for a tag again. However, the flowchart demonstrates this process simply to show how the functions will be called. The actual design of the feeder will include interrupts, instead of polls. This allows the MSP430 to operate in standby mode, drawing less power. The controller will wake up from this mode only once an interrupt has been triggered by the RFID sensor. This will save the user a great deal of battery life.

The hardware for the product has been designed using the following flowchart:

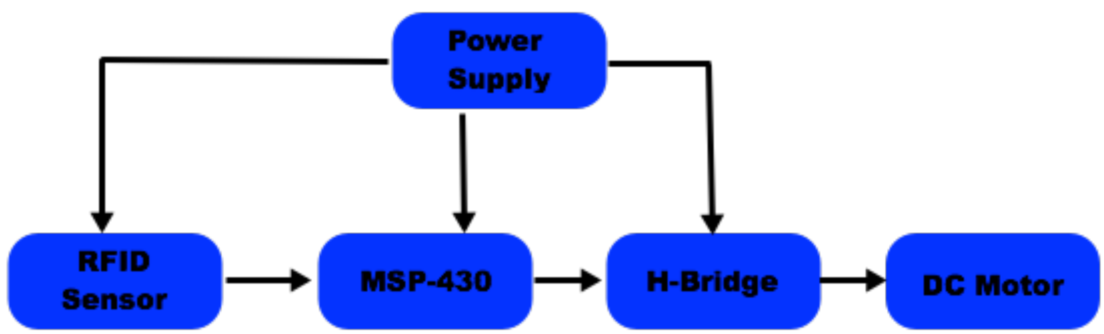

Figure 13: Hardware Block Diagram

The diagram demonstrates how the Series-Parallel connection of C-batteries will be used to drive the sensors, microcontroller, and h-bridge. Connections will also be made between the sensor and microcontroller in order to send the information from the RFID tag to the controller, which is used to interpret the RFID tag. From this point, the microcontroller outputs a voltage to the h-bridge. This acts as an electrical switch which allows current to flow through the h-bridge to the motor. When a particular pin on the IC is enabled, current will flow in a direction that causes the motor to rotate a particular direction. When the other pin is enabled, the current will flow the opposite direction and create torque in the motor that rotates the opposite direction. The IC bridge also serves to protect the microcontroller from back voltage damages. In order to verify the implementation of the hardware design, a multimeter will be used during all phases of the software block, to ensure that current flows to the motor and controller only at specified times. This verification will also lend a better outlook on the precise lifetime of the power supply.

The enclosure block has been developed with considerations to possible oversights. Instead of attempting to blindly develop a CAD model and get it fabricated, the Incredibowl team has taken a prototyping approach to the enclosure. The team has order a project box, which can house all the electronics and components for the project. This will allow the team to make measurements for holes that need to be drilled into the enclosure. It will also allow the team to develop an internal layout for the electrical and mechanical components of the feeder. Once the initial prototype has been completed, a complete design can be fabricated through 3-D printing. At this point, all the design specifications will be known and taken into consideration for the 3-D model. In all, the project box ensures a proper testing solution for the final model.

The final block for developing the product is the lid for the bowl. This section has many mechanical considerations that the Incredibowl team are prepared to design, implement, and verify. The team has decided to use an accordion style opening system for the lid. The lid must connect to the motor, lay flat when opened, condense when closed, and take stress when sealed. The lid will be developed using a CAD model as well and mockups will be created in parallel with the other design blocks. The team aims to finish the production of the lid before the electrical hardware is complete, so the group can know how much torque the motor must supply to move the lid. The design of the lid will be tested as the product is completed and the team can see how the lid opens and closes.

13. Analysis

The software portion of the block design was prepared based around the concept of power consumption optimization. The MSP-430 has a standby mode that allows the controller to operate on 2.1 uA at 3V. This means that the controller will only consumer 6.3 uW of power, which is a necessity for the longevity of the power supply in the selective feeder. In order to achieve this consumption, the Incredibowl feeder must spend the majority of its life in standby mode. The group has estimated the bowl will only be actively used for about 15 minutes a day. This accounts for 1% of the total day, meaning the bowl will operate in active mode for 1% of its life and standby mode for the other 99%. In order to maintain this feature, the software design must be based around register manipulation, rather than sequential polling. The MSP-430 has a register bit dedicated to interrupts. The value can be controlled with a peripheral, such as an external RFID sensor. When the value is low, the chip draws minimal power, but can fully operate and still receive information if an interrupt has been triggered from the sensor. The controller will be brought to active mode once the interrupt flag has been activated and the board will sufficiently operate to determine whether a valid RFID value was returned to the sensor.

The hardware block of the design was developed around the premise of the motor. The bowl requires a motor that can safely rotate in either direction, provide sufficient torque, and provide sufficient speed. An h-bridge integrated circuit (IC) will be used to link the controller to the MSP430, in order to prevent a harmful back voltage. This bridge also acts a logic element for the motor. The IC acts as a switch that allows current to flow from a source (the battery) when one of two inputs has been triggered as high (as output of the controller). A schematic of the integrated circuit shows how the logical enable pins connect to the motor, along with diodes and MOSFETS.

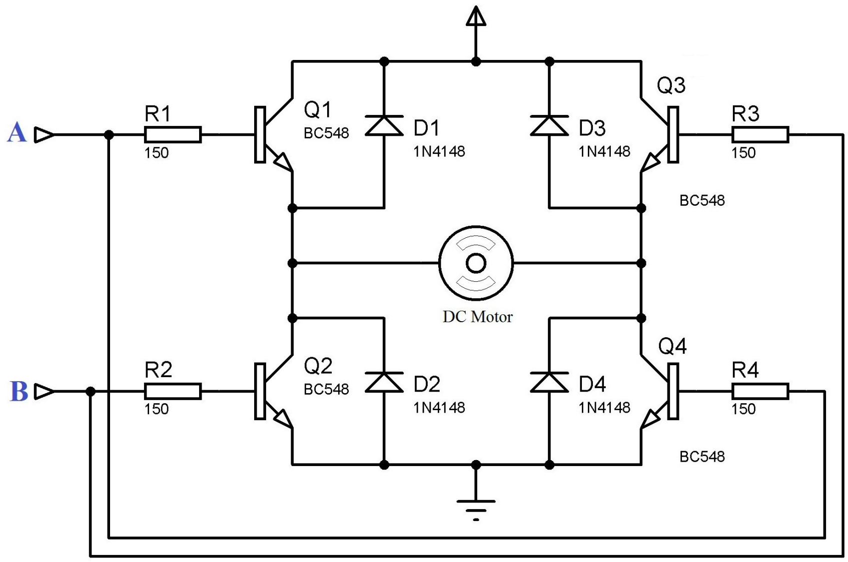

Figure 14: H-Bridge Schematic

The hardware design also focusses on the movement of the lid, which will ultimately be controlled by a DC motor. The motor requires minimal voltage (which is a necessity when using low voltage battery supplies). The motor also needs to drive a sufficient amount of torque to the lid, which is estimated to be approximately 50 oz-in given a 5 oz and 10 in lid design. The following chart has been used to help understand the relationship between torque, current, and rotational speed.

			118740	118741	118742	118743	118744	118745	118746	118747	118748
Motor Data											
	Values at nominal voltage										
1	Nominal voltage	V	4.5	8.0	9.0	12.0	15.0	18.0	24.0	32.0	48.0
2	No load speed	rpm	5350	5310	5230	4850	4980	4780	5190	5510	5070
3	No load current	mA	79.6	44.3	38.6	26.2	21.7	17.2	14.3	11.6	6.95
4	Nominal speed	rpm	4910	4510	4230	3820	3940	3740	4150	4470	4030
5	Nominal torque (max. continuous torque)	mNm	11.4	20.9	24.0	29.1	28.8	28.9	28.8	28.6	28.7
6	Nominal current (max. continuous current)	A	1.50	1.50	1.50	1.26	1.03	0.823	0.668	0.529	0.325
7	Stall torque	mNm	138	139	126	137	138	133	144	152	140
8	Starting current	A	17.2	9.73	7.72	5.82	4.83	3.72	3.28	2.76	1.56
9	Max. efficiency	%	87	87	86	87	87	87	87	88	87
	Characteristics										
10	Terminal resistance	Ω	0.261	0.822	1.17	2.06	3.10	4.84	7.31	11.6	30.9
11	Terminal inductance	mH	0.0275	0.0882	0.115	0.238	0.353	0.551	0.832	1.31	3.48
12	Torque constant	mNm / A	8.00	14.3	16.4	23.5	28.6	35.8	44.0	55.2	90.0
13	Speed constant	rpm / V	1190	667	584	406	333	267	217	173	106
14	Speed / torque gradient	rpm / mNm	39.0	38.3	41.6	35.6	36.1	36.0	36.1	36.3	36.4
15	Mechanical time constant	ms	4.74	4.15	4.12	4.00	3.98	3.97	3.97	3.97	3.97
16	Rotor inertia	gcm^2	11.6	10.3	9.45	10.7	10.5	10.5	10.5	10.4	10.4

Figure 15: Maxon Motor Data Sheet

According to this chart, the current the motor draws is linearly related to the torque that the motor provides. The torque is also linearly related to the rotational speed of the motor. The chart, provided by Maxon Motors, demonstrates these dependencies and has helped the team in selecting components that fits the needs of this project design.

14. Risk Assessment

The Incredibowl team has taken into consideration the risks involved with manufacturing the feeder. Since the prototype of the feeder will be made using a project box, there is risk of injury while cutting the hole on the top of the box for the lid and the food bowl. A sharp knife will be used in this process, so the team members will have to be sure to be mindful of the blade. Even after the hole has been cut out, the possibly sharp edges will have to be sanded down to prevent team members from getting cut on them. After this process, the electrical components will have to be soldered and wired together. The risks involved with the soldering and wiring are the risk of being burned by the soldering iron, being cut with the wire cutters, and being shocked once the connections have been made. Each team member that has not had soldering experience will watch an instructional video on how to solder, and all team members will wear long sleeve shirts and pants while soldering. While wiring the electrical components, team members will need to be mindful of connections being made to reduce risks of shocks. Protective eyewear and clothing will be worn throughout the manufacturing process to avoid any unforeseen injuries.

Aside from risks of injury during production, there are also scheduling and budget risks involved. As of December 5, the projected cost of completing the feeder is below $300; this leaves the team with around $200 to cover unexpected costs. These costs include but are not limited to needing to buy replacement components, or the costs of manufacturing are more than expected. When the project was started, it was scheduled to be completed before the Senior Design class deadline. Now the team has taken into account the deadlines for the InNOLEvation challenge and the College of Engineering Shark Tank. The schedule is being updated so that the feeder will be finished by these deadlines, but there is the risk of running into manufacturing delays.

15. Conclusion

The intent of the Incredibowl design project is to develop an RFID selective pet feeder with practical features for the consumer. This will be achieved by meeting the needs and requirements that the general population calls for. As outlined above in the “Objectives and Goals” section, the selective feeder must be portable, function properly, and by durable. These overall objective will be satisfied by completing several benchmarks in the design process.

The group will achieve the design needs by satisfying numerous goals. Ensuring that the RFID chip is portable enough to fit a variety of collars, as well as ensuring that the feeder itself can easily be transported from place to place, will suffice the portability of the design. Meanwhile, the feeder must be able to withstand external factors such as pest, predators, and environmental damages. Ensuring the feeder enclosure, especially the lid, is weather resistant and shock resistant will prevent any damage to the food/water within the feeder. Creating a method for keeping the RFID chip on a pet collar while enduring a variety of attenuations will satisfy the durability needs for the RFID chip as well. The product must also perform the intended functions of a selective feeder. The intent of the feeder is to open quietly when the pet is within a logical proximity, remain open while the pet eats, and close securely shortly afterwards. In case of emergency, the product should also have a manual method for opening the container.

The Incredibowl team will spend the remainder of the Fall 2016 and Spring 2017 semesters collaborating with Dr. Hooker and Dr. Devine to meet the needs for the product. A schedule will be set up to make sure that benchmarks for the project are met in a timely manner. By the conclusion of the year, the Incredibowl team should be able to present a functional RFID selective feeder prototype.

14. References

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