IoT Smart Doggy Door

Group 15 - Dr. Chan

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Goals and Objectives

- Create a doggy door that is rich with features, easy to use and capable of implementing new ideas
- Enable remote user control with a mobile application
- Have long lasting, affordable, and easy to replace collars
- Make the door as compact as possible
- Supply the door with two power sources
- Allow offline operation
- Create a responsive system
- Add an auditory cue for the dog to learn from

Requirement Specifications

- Door dimensions (flap and overall size)
- Strength of flap
- Detection/reading distance
- System processing time
- Door flap locking distance
- Buzzer noise level
- Duration of external battery life

Description	Parameter	Specification
Door flap dimensions	Dimensions of the door flap	W: 0.25” L: 12” H: 19”
Door frame dimensions	Dimensions of the whole door setup	W: 8”, L: 12”, H: 22”
Durability of flap	How much force the door flap can withstand	63 N/mm^2
Tag/collar reading distance	How far the tag should be read from the door	0.5 m - 1 m
Infrared detection distance	How far the infrared sensor detects movement	0.5 m - 1.5 m
Tag process and door unlock time	The duration at which the tag should be read, processed, and the door unlocked	< 4.5 seconds
Door flap locking distance	How far the locks should be placed from the door flaps resting position	< 4”
Sound pressure level of buzzer	How loud the buzzer should be	70 dB - 90 dB
External battery life	Duration of the battery life	1 hour - 1.5 hour

House of Quality

- Strived for ease of use and reliability
- Willing to compromise on aesthetics and cost to create a better product overall

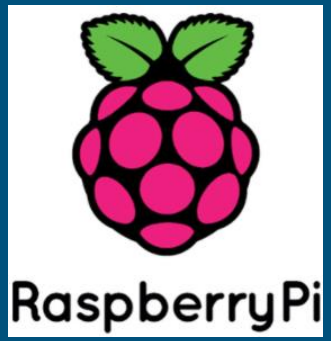
Correlations	
Positive	+
Negative	-
No Correlations	

Relationships	
Strong Positive	▲
Positive	△
Neutral	○
Negative	▽
Strong Negative	▼

Column #	1	2	3	4	5	6
Customer Requirements (Explicit and Implicit) \ Engineering Requirements	Accuracy	Operation Time	Quality	Smartphone Operations	Size	Cost of Production
Aesthetics	▲	○	○	○	▽	▽
Ease of Use	○	○	▲	▲	○	○
Reliability	○	○	△	△	○	▼
Range	○	▽	△	○	▽	▼
Security	▽	▽	△	△	○	▽
Cost	○	○	▼	○	▽	▼
Target	Beamwidth +/- 20°	< 4.5 seconds	Withstand for 1-2 years	Query database < 4 seconds	< H:22", W:4:, L:12"	< $700

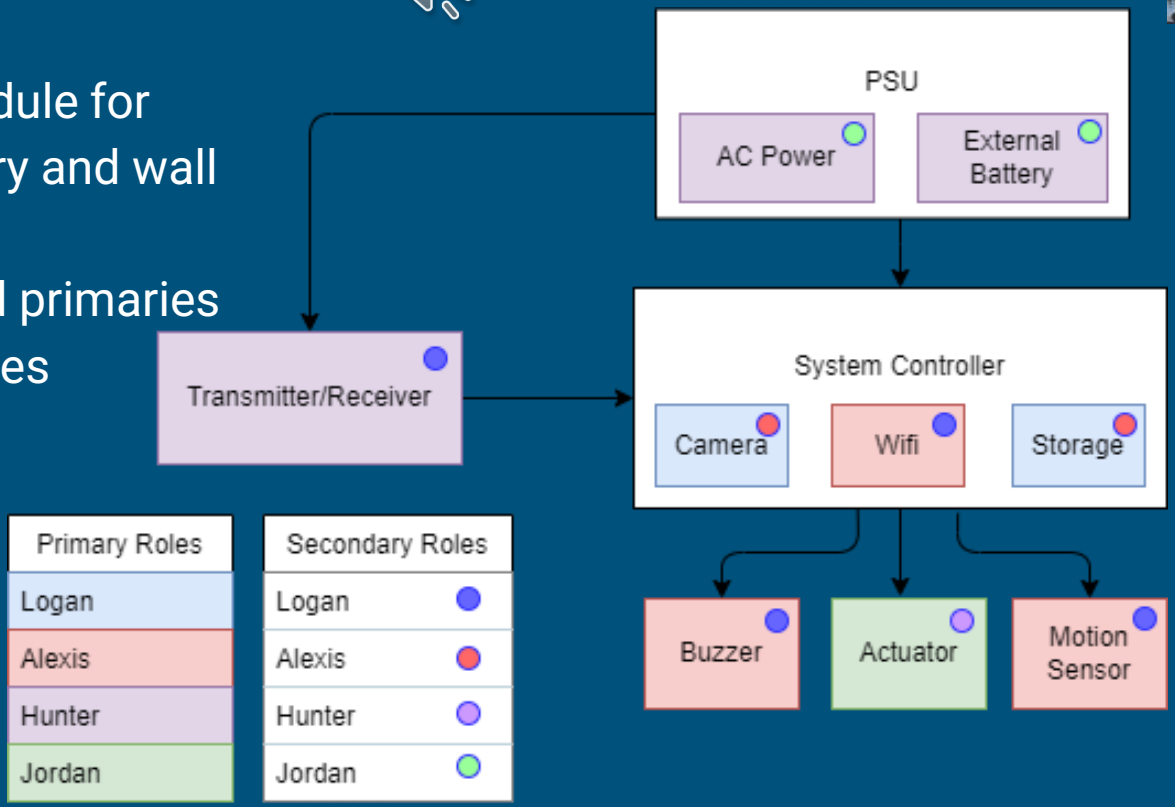
Plan of Approach

- Compartmentalize the system into individual parts
  - Mechanical
    - Precise measurements
  - Electrical
    - PCB
  - Software
    - Raspberry Pi
    - Database
    - Mobile Application



Hardware Diagram

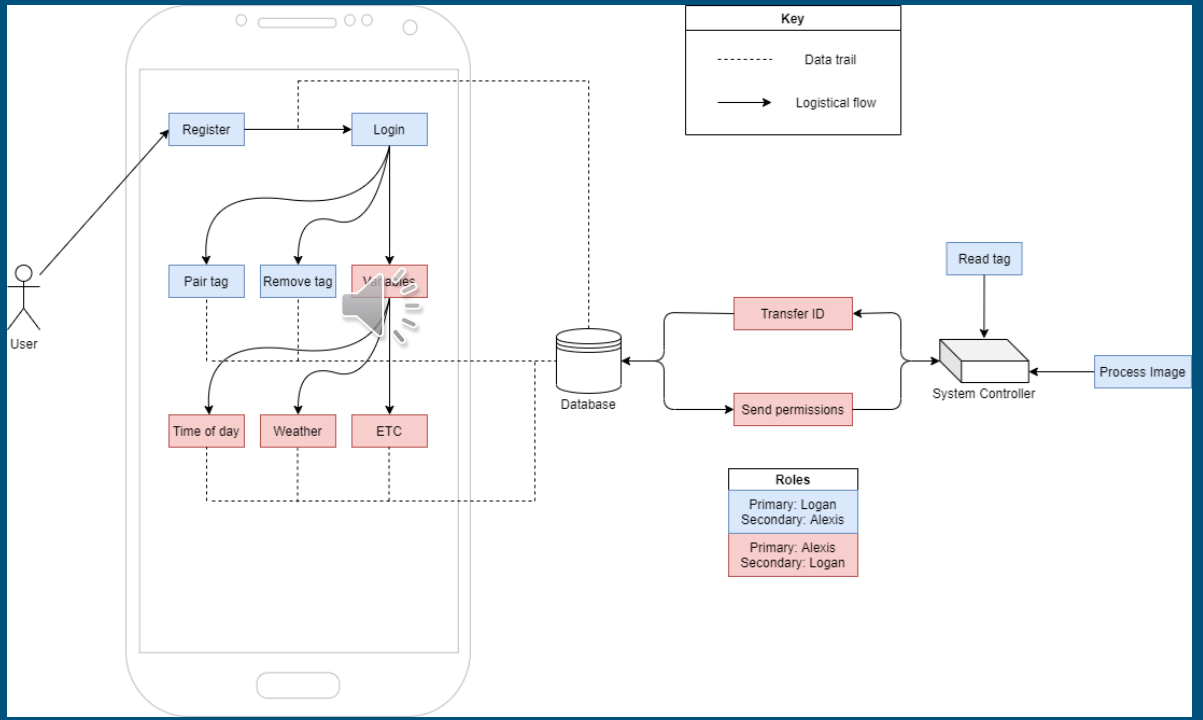
- Switching module for external battery and wall adapter
- Each assigned primaries and secondaries



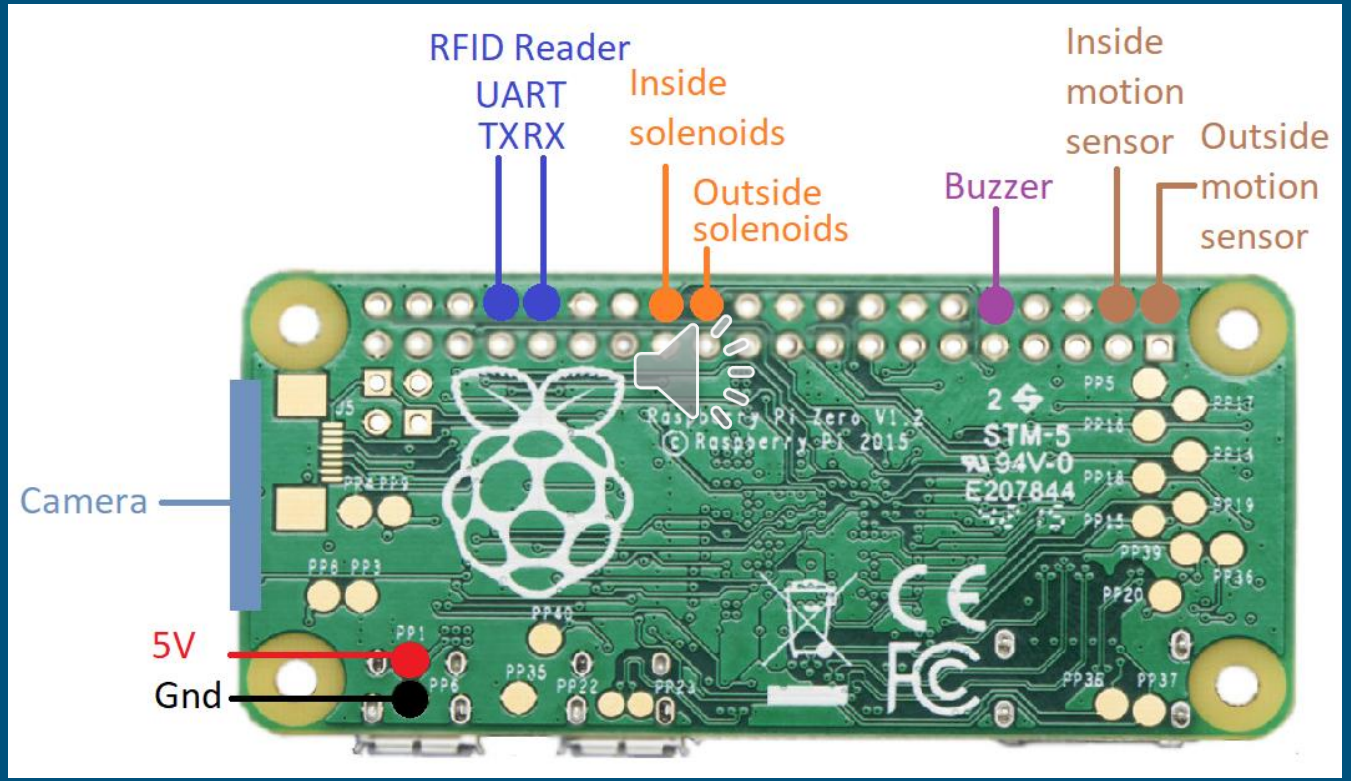
Primary Roles	Secondary Roles
Logan	Logan
Alexis	Alexis
Hunter	Hunter
Jordan	Jordan

Software Diagram

- Software setup using database and mobile app for IoT integration
- Workload split between front end and back end tasks



Raspberry Pi Pinout



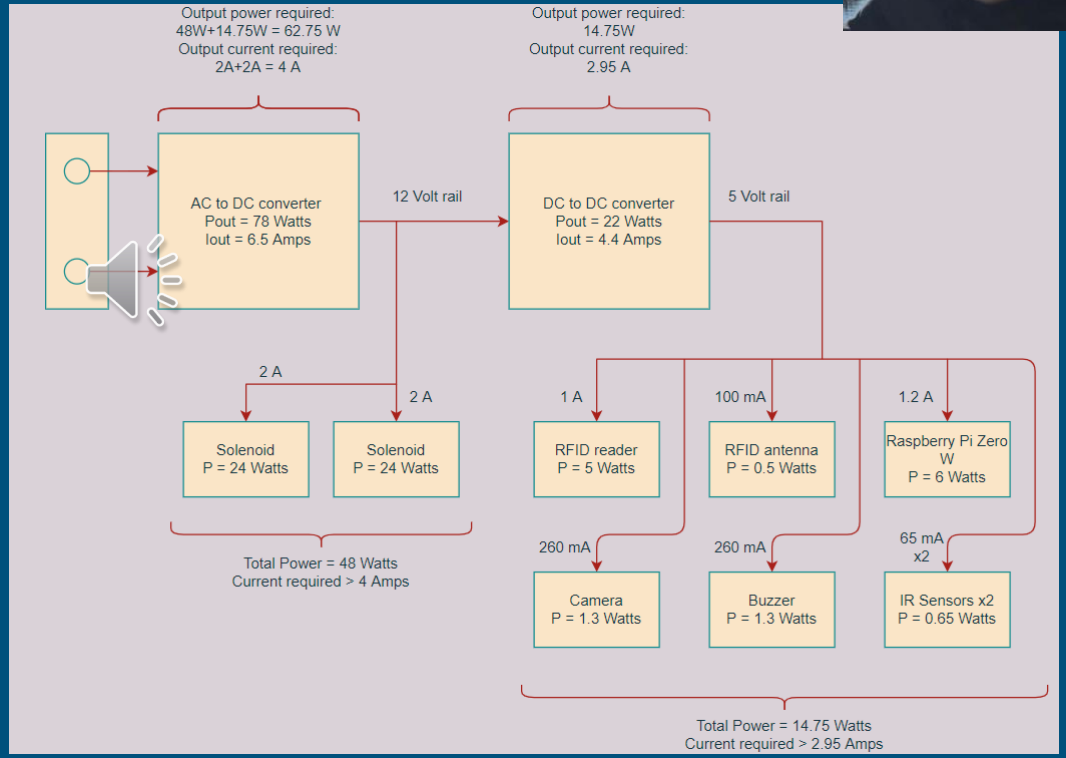
Significant PCB Design

- PSU AC/DC converter topologies
- Tradeoffs between efficiency and simplicity
- LLC controllers introduced many luxuries, but the complexity was unnecessary
- PFC controllers' disadvantages outweighed the simplicity
- Flyback was an acceptable compromise between what we were looking for

Topology	Advantages	Disadvantages
Flyback Controllers	• Mutually coupled inductors isolate the input from the output (no need for additional circuitry) • Capable of providing multiple different output voltages, each separated from input • Simplistic design (very few components required)	• Unable to produce too high of an output current/power • The transformer gap results in more EMI • Greater ripple current
LLC controllers	• Reduced EMI, ZVS, ZCS • High efficiency • Large range of output power and output current • Lower BOM cost in regards to output inductors	• Complex/sophisticated design, requiring extensive research for design and control • Difficult frequency tuning
(PFC) Controllers	• Simplistic design • Financially affordable due to a lack of complicated hardware components	• Small range of input voltages • Large and bulky, also quite heavy

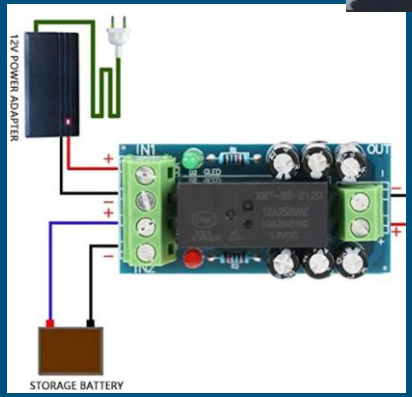
Significant PCB Design Cont'd

- System power requirements
  - Two voltage rails: 12 VDC and 5 VDC
- AC/DC converter posed more interesting of a PCB
- DC/DC converter module therefore bought instead
- All current values are maximum ratings



Battery Bank and Switching Module

- Battery bank in case of power outage
  - Rechargeable 12V 3000mAh Lithium ion Battery Pack
  - 12V/3A barrel jack output
  - 5V/2A USB output
- Switching module for battery bank and wall adapter
  - Outputs input 1 by default, unless input 1 drops below a certain voltage, then switches to input 2



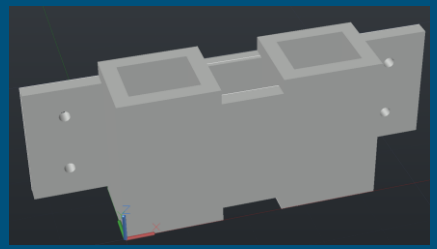
Doggy Door Materials and Construction

- The doggy door is constructed using wooden planks 8” wide and ¾” thick
- Space on each side of the door to house the locking mechanism and solenoids
- Flap is made of a polycarbonate sheet to increase durability

Doggy Door Locking Mechanism

- 3 pieces locking mechanism consisting of the locking pins, knobs, and shaft
- The design of the pins allows for the flap to work unidirectionally at any given time.
- Solenoids will be used to push the pins up to allow for the door to be opened.

(Knob)



(Shaft)

(Pin)

Doggy Door Locking Mechanism Comparisons

Locking Mechanism	Operating Voltage	Current Draw	Force	Operating Speed	Price	Size
Solenoids	12V DC	1A	20N	Instant	$11.59	2.2"x1"
Linear Actuator	12V DC	2.3 A	40N	4.5mm/s	$59.95	Extended Length: 44.3"
3D Printed Pin	None	None	N/A	N/A	$21.00	0.75"x0.5"x2"
3D Printed Shaft	None	None	N/A	N/A	Free	1.3"x3.375"x0.8125"
3D Printed Knob	None	None	N/A	N/A	Free	0.75"x0.5"x1.5"
Electromagnet	12V DC	80mA	6N	Instant	$29.24	0.75"x0.75"x0.62"

Table 11: Comparisons of the Different Locking Mechanisms

System Controller

	Microcontroller	Microprocessor
Clock speeds	Usually well below 1 GHz, especially for the small scale board we are looking for	1 GHz for the Raspberry Pi Zero W
Memory (RAM)	Usually in the KB range	512 MB for the Pi Zero
GPIO pins	Usually less than 20 for smaller sized boards	40 for the Pi Zero
Operating system	None	Linux-based Raspbian software
Programming Languages supported	Usually lower level languages	All sorts of languages up to high level languages like Python

	Raspberry Pi Zero W	Raspberry Pi Pico	Raspberry Pi 4 B
Description	The iconic, cheap, small Pi Zero with wifi and bluetooth	Raspberry Pi microcontroller	Fourth edition of the mainline Raspberry Pi devices
Price	$10	$4	$35
Dimensions (HxWxD) in inches	1.18 x 2.55 x 0.197	0.83 x 2 x 0.154	2.22 x 3.37 x 0.433
Weight in grams	9	3	46
Number of cores	1	2	4
Clock speed	1 GHz	133 MHz	1.5 GHz
RAM	512 MB	264 KB	1, 2, 4, or 8 GB
Ethernet	No	No	Yes
GPIO pins	40	26	40
Storage/Operating System	Yes, microSD/Raspbian	No	Yes, microSD/Raspbian
Wi-Fi	802.11n (only 2.4GHz)	No	802.11 b/g/n/ac (2.4 and 5 GHz)
Bluetooth	4.1 BLE	No	5.0

Databases

- Foundation for IoT integration
- Accessible by the mobile application anywhere, at any time
- Decision to go with Firebase

Name	Couchbase	Firebase	MongoDB
Short Description	JSON-based database derived from CouchDB	Cloud-hosted realtime database. All clients share one realtime instance and auto receive updates	Database that works both as a cloud service or a deployed self-managed infrastructure
Cloud-based only?	No	Yes	No
Offline mode?	No	Yes	No
Performance	Exceptional	Good	Great
Server Operating System	Linux, OS X, Windows	Hosted	Linux, OS X, Solaris, Windows
Overall Security	Good	Great	Exceptional
APIs and other access methods	CRUD, Query, Search, Analytics API	Android, iOS, Javascript API, RESTful HTTP API	Proprietary protocol using JSON
Triggers	Not immediate	Immediate	Not immediate
MapReduce	Yes	No	Yes
Server-side scripts	Javascript	Potentially limiting Google ‘rules’	Javascript

Passive Infrared Sensor

- Used to detect any living presence at the door using infrared technology
- Works in conjunction with camera and reader
- Second sensor on inside
- Decision to go with HC-SR501

	HC-SR501	LEDENET	LPIR-8A
Price	Varies, usually around $4 per sensor	$10	$8
Size (mm)	32 x 24	86 x 51	89 x 60
Field of View	<120 degrees	60 degrees	
Range (ft)	21	16-26	15

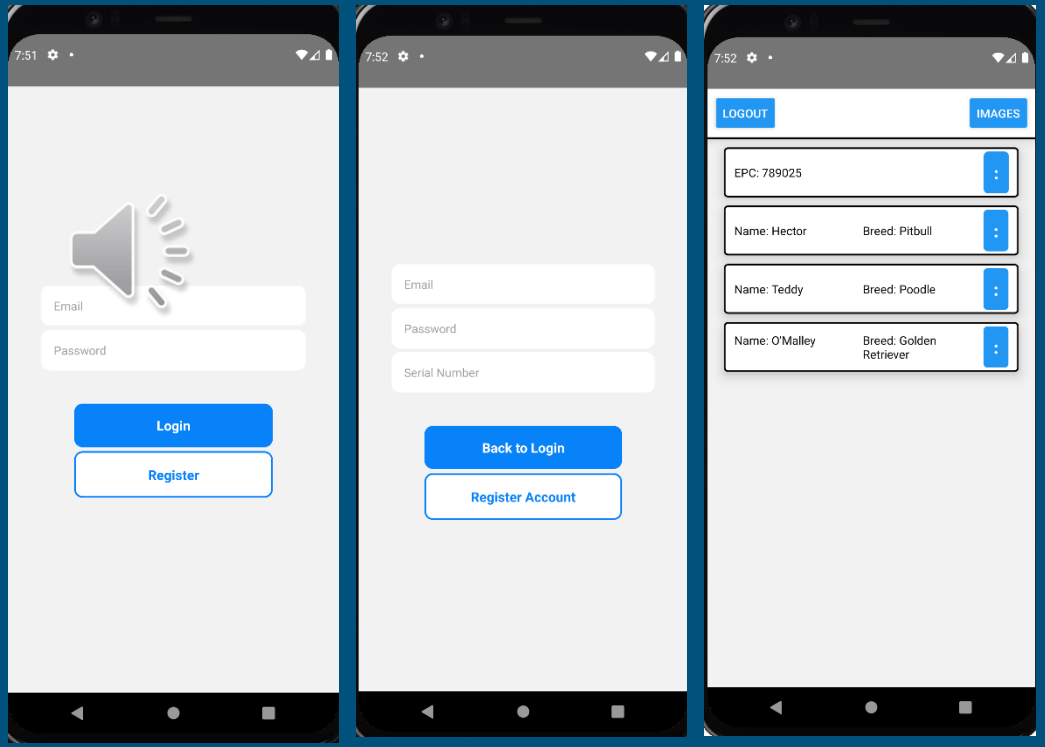
Camera

- Used for capturing images of anything that might be in front of the door
- Decision to go with the Arducam

	Arducam OV5647	Raspberry Pi Camera Mod 1	Raspberry Pi Camera Mod 2
Price	$14	$25	$25
Size	25 x 24 mm	25 x 24 x 9 mm	
Weight		3g	3g
Still Resolution	5 MP	5 MP	8 MP
Video Modes	1080p30, 720p60, 480p60/90	1080p30, 720p60, 480p60/90	1080p30, 720p60, 480p60/90
Sensor Resolution	2592 x 1944 Pixels	2592 x 1944 Pixels	3280 x 2464 Pixels
Optical Size	¼”	¼”	¼”
Full-frame SLR lens equivalent	35 mm	35 mm	
Angle of view	64 x 48 °	53.5 x 41.4 °	62.2 x 48.8 °

Mobile Application

- Software
  - React Native CLI
  - Android Studio
- Functionality
  - Registration
  - Edit and delete animals
  - Change animal permissions
  - View photos taken by camera



RFID Tags and Frequencies

Frequency ranges:

- LF: 125 - 134 kHz, 1 - 10 cm
  - Low susceptibility to EM disturbance, but slow data processing speeds
- HF: Typically 13.56 MHz (NFC), 1 - 100 cm
  - Faster transmission and relatively low EM disturbances, but too short of a read range
- UHF: 865 - 960 MHz, reaching over 30 m
  - Higher read range, but higher interference from certain materials

Active versus passive tags:

- Active tags
  - Initiator: requires battery, introducing a lifetime
  - More expensive
  - Longer read distances
- Passive tags:
  - Waits for incoming signals: no internal source of power (no battery)
  - Relatively cheap in comparison
  - Shorter read distances

RFID Tag Classes

Tag classes: ISO 18000-6C protocol standard

- Class 0: A read-only, passive UHF protocol
  - Need to write at least once
- Class 1: A write-once, read-many UHF or HF protocol
  - Perfect for our application
- Class 2: Indefinite read-write operational passive RFID tag
  - Unnecessary writing times
- Class 3: Provides read-write operations for various sensors (temperature, pressure, acceleration, etc)
  - Unnecessary sensor implementations
- Class 4: An integrated transmitter allowing for active tags to communicate with other tags and readers
  - Unnecessary and not applicable to our design
- Class 5: Active tags capable of delivering power to other tags as well as communicating to devices other than readers
  - Unnecessary and not applicable to our design

RFID Reader and Antenna

Desired parameters

- Polarization:
  - Circular
- Beamwidth:
  - Around 120 degrees
- Read distance:
  - Over 1 meter (antenna can be operated at less power to lower the read distance)
- Cost:
  - As low as possible…
- Operation frequency:
  - UHF (865 - 960 MHz)

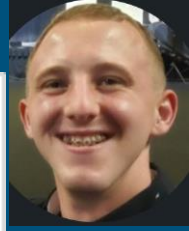
	Times-7 SlimLine Antenna	Laird Bistatic PRL90209 Antenna	Laird S9025PL Outdoor RFID Antenna	Vulcan UHF Antenna
Polarization	Circular	Circular	Circular	Circular
Gain	5.5 dBic	9 dBic	5.5 dBic	3.4 dBi
Beamwidth	115	70	100	100
Read distance	4.3 meters	unspecified	unspecified	3 meters
Dimensions	5.9 x 5.9 x 0.55 inches	10.1 x 22.6 x 1.3 inches	5.2 x 5.2 x 0.71 inches	5.4 x 5.4 x 0.13 inches
Cost	$119.00	$214.00	$134.00	$64.00
Input Power	6 Watts	10 Watts	10 Watts	unspecified
Operation Frequency	902 - 928 MHz	902 - 928 MHz	902 - 928 MHz	902 - 928 MHz

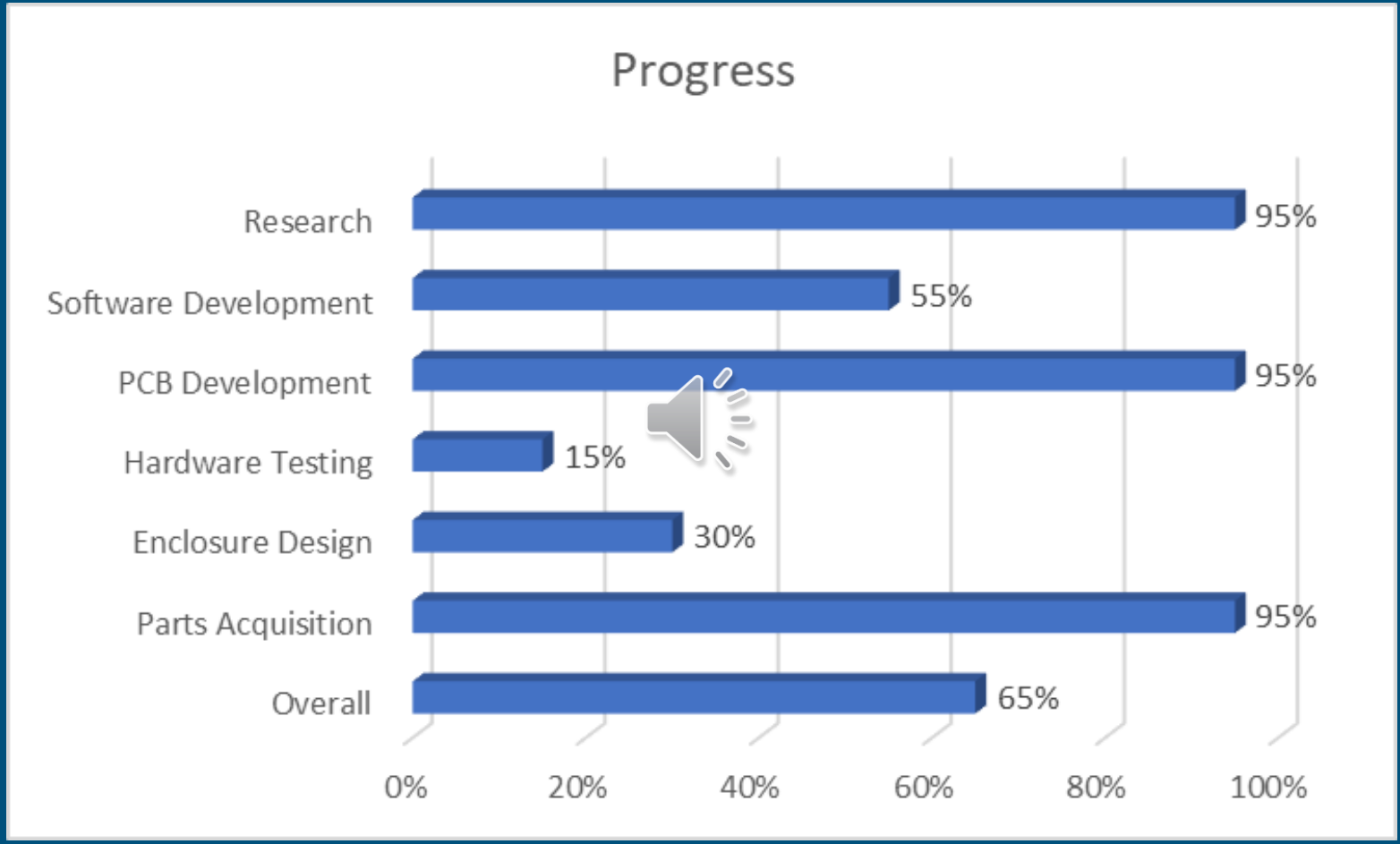
Budget (Proposed/Current)

Item	Quantity	Price
RFID reader	1	$235
RFID external antenna	1	$119
Raspberry Pi Zero W	1	$10
microSD Card	1	$8
UHF Tags	3	$2
Camera	1	$14
Buzzer	1-2	$1.50
Motion Sensor	1	$8
Solenoids	4	$30
Power Source	1	$10 - $15
PCB	1	$20 - $30
Antenna Connectors	3	$12
Door Materials	-	$70
3D Printer Filament	1	$20
External Battery	1	$20 - 40
TOTAL	N/A	~$579 - $614

Division of Work

- Logan:
  - Project manager
  - Camera research
  - Storage
  - Mobile application
  - Embedded software
- Alexis:
  - Wifi
  - Buzzer
  - Motion sensor
  - Database
  - Embedded software
- Jordan:
  - Door research/design
  - Enclosure/door construction
  - Locking mechanism
- Hunter:
  - RFID (reader, antenna, tag) research/design
  - PSU (PCB and battery bank) design
  - PCB research and construction




Progress
Research
Software Development
PCB Development
Hardware Testing
Enclosure Design
Parts Acquisition
Overall
95%
55%
95%
15%
30%
95%
65%
0%
20%
40%
60%
80%
100%

Next Steps

Tasks	2/18	2/25	3/4	3/11	3/18	3/25	4/1	4/8	4/15
Place Hardware on Door									
Test PCB/switching circuit									
RPi reading from database									
RPi integrated with camera and RFID reader									
Finish mobile application									
RPi communicating with mobile application through database									
Integration and testing									
Finishing touches and preparing for demo									