FLORIDA STATE UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

EML 4551 Senior Design I

Team 520PC Evidence Book

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Abstract

The most significant inspiration for this project spawned from the faults of a standard dog door which allows pets to roam in and out of a house without restraint. This causes issues for home owners when pets track dirt, mud, or water into the residence. Subsequent problems can arise from these circumstances such as interior property damage. Another significant fault of conventional dog doors is the lack of security they provide. Small children could potentially fit through the door, and other risks are posed. These conditions motivated the team to envision a feasible way for homeowners' dogs to have limited or controlled access the homeowner's home interior and yard. The product would allow homeowners to remotely set locking constraints on the door based on conditions such as weather, time of day, and other relevant factors.

This is a two phase project. Phase 1 consists primarily of concept selection and design while Phase 2 consists of prototyping and building the product.

Acknowledgements

We, Team 520 PC, extend sincere thanks to the parties that have furthered the efforts of our academic research. We thank Mr. James Dafoe (Veterans Advancement Council, FSU) and Mrs. Sandra Dafoe for their financial support in our academic endeavors. We thank Dr. Yvonne Traynham, P.E., Ph. D (course instructor, FSU) for her guidance in our research. We thank Dr. Mauricio Chagas, Ph.D (technical advisor, FSU) for his guidance and involvement in our work. We thank any outside parties who have been present in our design reviews and followed our ongoing research.

Contents

1 Scope of Work

1.1 Project Description and Inspiration

The chosen project is an automated dog door that can be controlled remotely to limit access to a home's interior or exterior based on constraints such as time of day or inclement weather predictions. The inspiration for this project arises from the desire to limit and control pet access through a home's interior and exterior.

1.2 Phase 1 - Concept Selection and Design

Phase 1 consists primarily of research and design for the project with an expected completion date of April 26, 2023. The main goals for this phase are:

- Establish customer needs and wants
- Research similar products currently on the market
- Define concepts that closely align with the customer's needs
- Review and select one concept
- Refine selected design and define specifics of concept
- Present and purchase bill of materials (BOM) items

1.3 Phase 2 - Prototyping and Build

Phase 2 consists of prototyping and product build. This phase may require design revisions or adjusted configurations dependent the outcome of prototyping. An estimated completion date of July 17, 2023 is proposed. The main goals for this phase are:

- Receive and verify the ordered BOM parts
- Prototype and test assemblies
  - Test and debug electrical assemblies
  - Test mechanical assemblies
- Finalize prototype build and test total system

1.4 Objectives

- Design dog door that will automatically open and close on command
- Design door to sense when dog is approaching and open or close if door is unlocked or stay closed if door is locked
- Sense if obstruction is blocking door from opening or closing

1.5 Goals

- Allow consumer to remotely enable or disable the door's locking mechanism
- Implement rain sensor and control unit to provide an autonomous locking function
- Control locking mechanism based on meteorological data, time, and distance
- Allow proximity and sensitivity adjustment for sensors on the interior and exterior of the door
- Track number of pets in interior and exterior of residence
- Display error code in case of obstructions in the locking mechanism and notify the owner
- Directly wire into any standard U.S. home's electrical infrastructure
- Operate on battery power

2 Customer Needs and Wants

To develop a successful product, it is crucial to understand and prioritize the customer's needs and wants. The customer needs outline the essential requirements and desirable features for the automated dog door to meet the customer's expectations and provide a satisfactory user experience. The customer needs for the automated dog door include

- Securing a door-locking mechanism
- Implementing sensors for rain detection
- Collar communication and detection
- Dog door actuation
- Accommodation for large dogs
- Remote functionality via website or smartphone application

These needs form the foundation of the product's functionality, ensuring that it provides a safe and convenient way for dogs to enter and exit the house independently. In addition to the essential requirements, the customer has expressed some desirable features or wants for the product. These wants include

- Affordable cost
- Door seals for insulation and improved HVAC efficiency
- Diverse color options for discreet integration into a home

These criterion are not necessary for the successful functionality of the system. However, these considerations add value to the design and improve overall user experience.

3 Functional Decomposition

The functional decomposition for the system aims to identify and define the essential functions and components required to develop the product. By defining the system with respect to its key functions, the project team can better understand the system's operation and allocate resources effectively. The functional decomposition also allows the team to identify potential challenges and dependencies, ensuring that the product's essential functions are effectively defined, assigned, and implemented.

The necessary functions of the system can be categorized into four groups: alert, control, prevent, and sense. These are the overarching functions that the system must accomplish. All other subfunctions are contained within one of these four definitions. The figure below displays a hierarchical flow chart of the system functions.

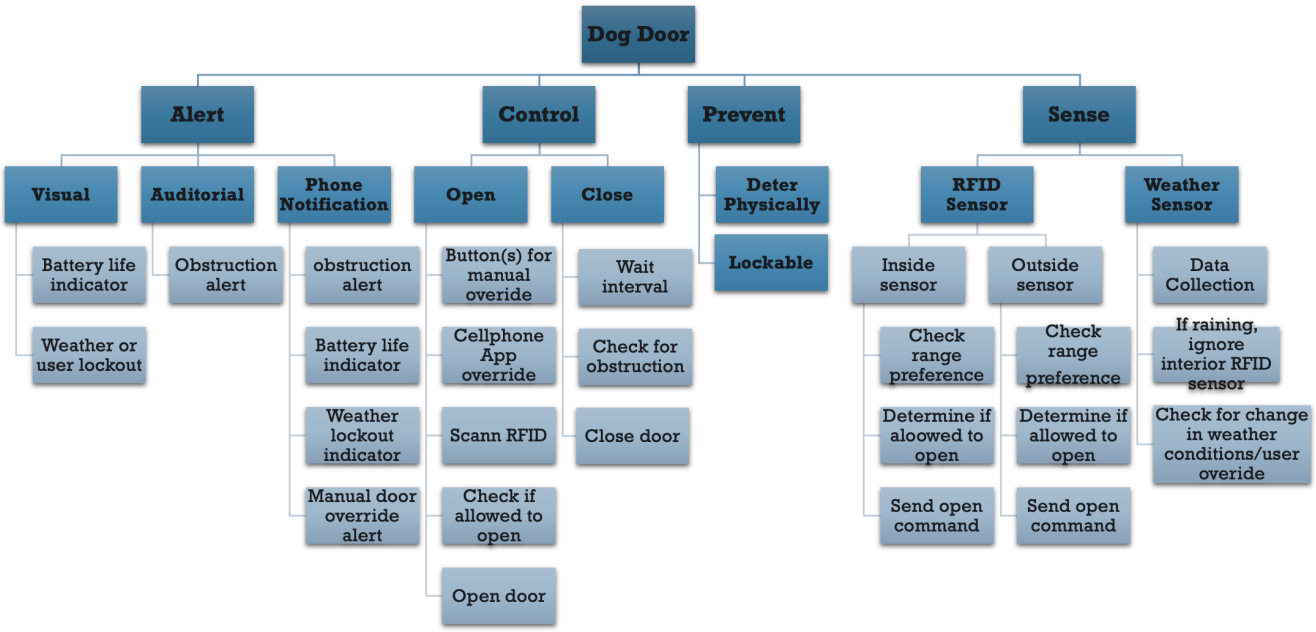

Figure 1: Functional Decomposition of System

4 Target Summary

Project targets were identified based on the objectives and goals defined previously. Functions were defined based on the functional decomposition performed. Metrics provide a means to measure or quantify the success or failure of a desired target. The target itself provides a feasible, definite goal to accomplish. Note that the defined targets cannot be tested for completion or failure of completion until a physical prototype has been constructed in Phase 2 of the project. Targets were defined based on the most necessary constraints or design requirements. These constraints include price, size, and safety, as well as other necessary functions such as remote application to achieve the objectives of the project.

Function	Metric	Target
Cost	Price of Materials and Production	< $2,000
Size	Area of Door Opening	19" x 11"
Response to Data Input	Unlock Speed	< 1 second
Response to Data Input	Door Open Speed	< 3 seconds
Safety	Sense Door Obstruction	✅ / ❌
Remote Capability	Website/App Operable	✅ / ❌
Limited Accessibility	Accept/Decline Signal	✅ / ❌

Figure 2: Targets and Metrics

5 Concept Generation

Concepts were generated based on the requirements and functional decomposition of the system. Preliminary drawings of the original generated concepts are shown below. Three initial concepts were identified: horizontal sliding door, horizontal folding door, and vertical sliding door. Each concept possesses unique means of actuating the dog door. The vertical sliding door concept was initially preferred due to its design simplicity and greater stability.

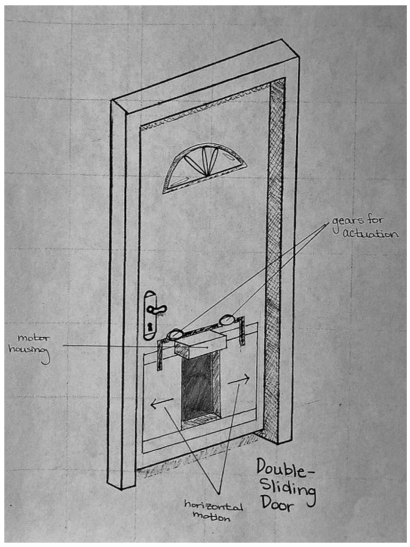

Figure 3:
Horizontal Sliding Dog Door

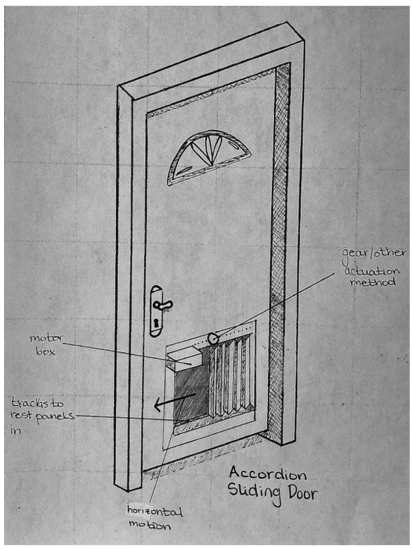

Figure 4:
Horizontal Folding Dog Door

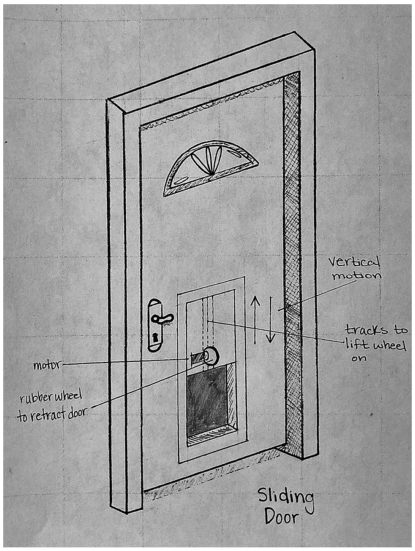

Figure 5:
Vertical Sliding Dog Door

6 Concept Selection: Decision Matrix

A weighted decision matrix was constructed to rank concepts based on the most relevant and important design factors. Cost, reliability, and functionality were determined to be the three most important components of the design. These components were divided into more specific criteria that was used to rate each design. Each concept was rated on a scale of 0 to 10, with "0" representing a totally useless solution and "10" representing the ideal solution. This point scale is based on Table 7.6 from Engineering Design, 5th Edition [1]. As seen in the figure below, the vertical sliding door concept received the highest rating on the weighted decision matrix, with a score of 4.51 as opposed to 4.36 and 4.29.

Weighted Decision Matrix for Automatic Dog Door

			Concept 1 (Vertical Sliding door)			Concept 2 (French sliding doors)			Concept 3 (Accordion Sliding door)		
Design Criterion	**Weight Factor**	**Units**	**Magnitude**	**Score[1]**	**Rating**	**Magnitude**	**Score[1]**	**Rating**	**Magnitude**	**Score[1]**	**Rating**
Material Cost	0.20	USD/lb	500	5	1.00	600	4	0.80	700	4	0.80
Electrical Comp.	0.20	USD	1200	5	1.00	1,500	4	0.80	1600.00	4	0.80
Door Battery	0.30	hr	96	4	1.20	120	5	1.50	120	5	1.50
Security	0.08	N/A	Excellent	9	0.68	Good	7	0.53	Good	6	0.45
Safety	0.11	N/A	Good	6	0.63	Good	7	0.74	Good	7	0.74
Complexity	0.12	N/A	Excellent	9	1.08	Good	7	0.84	Satisfactory	3	0.36
Totals	***1.00***				***4.51***			***4.36***			***4.29***

Figure 6: Weighted Decision Matrix

	Design Criteria	***Weight Factor***
1	Automatic Dog Door	1.00
1.1	**Cost**	**0.40**
1.1.2	Material	0.50
1.1.3	Electrical components	0.50
2.1	**Reliability**	**0.30**
2.1	Door Battery	1.00
3.1	**Functionality**	**0.30**
3.1	Security	0.25
3.2	Safety	0.35
3.3	Complexity	0.40

Figure 7: Decision Matrix Design Criteria Weighting

TABLE 7.6
Evaluation Scheme for Design Alternatives or Objectives

11-point Scale	Description	5-point Scale	Description
0	Totally useless solution	0	Inadequate
1	Very inadequate solution		
2	Weak solution	1	Weak
3	Poor solution		
4	Tolerable solution	2	Satisfactory
5	Satisfactory solution		
6	Good solution with a few drawbacks	3	Good
7	Good solution		
8	Very good solution		
9	Excellent (exceeds the requirement)	4	Excellent
10	Ideal solution		

Figure 8: Decision Matrix Point Scoring [1]

7 State Diagram

The state diagram seen below represents the system logic that will be programmed in Phase 2 of the project. The state diagram divides functions into respective paths of action based on input from the sensors in the system. The sensors, in turn, rely on input from the user(s). The users represent the homeowner, who controls locking functions, and the pet, which triggers motion sensors based on their access status set by the owner.

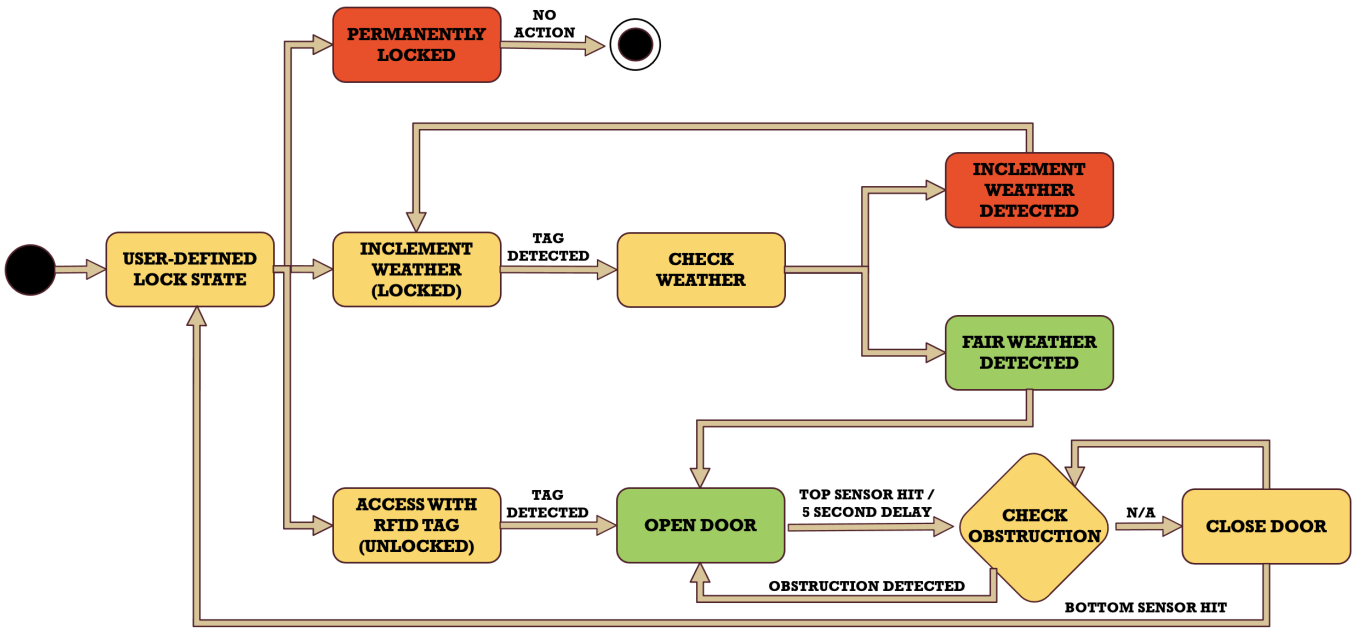

Figure 9: System State Diagram

8 3-D Models and Drawings

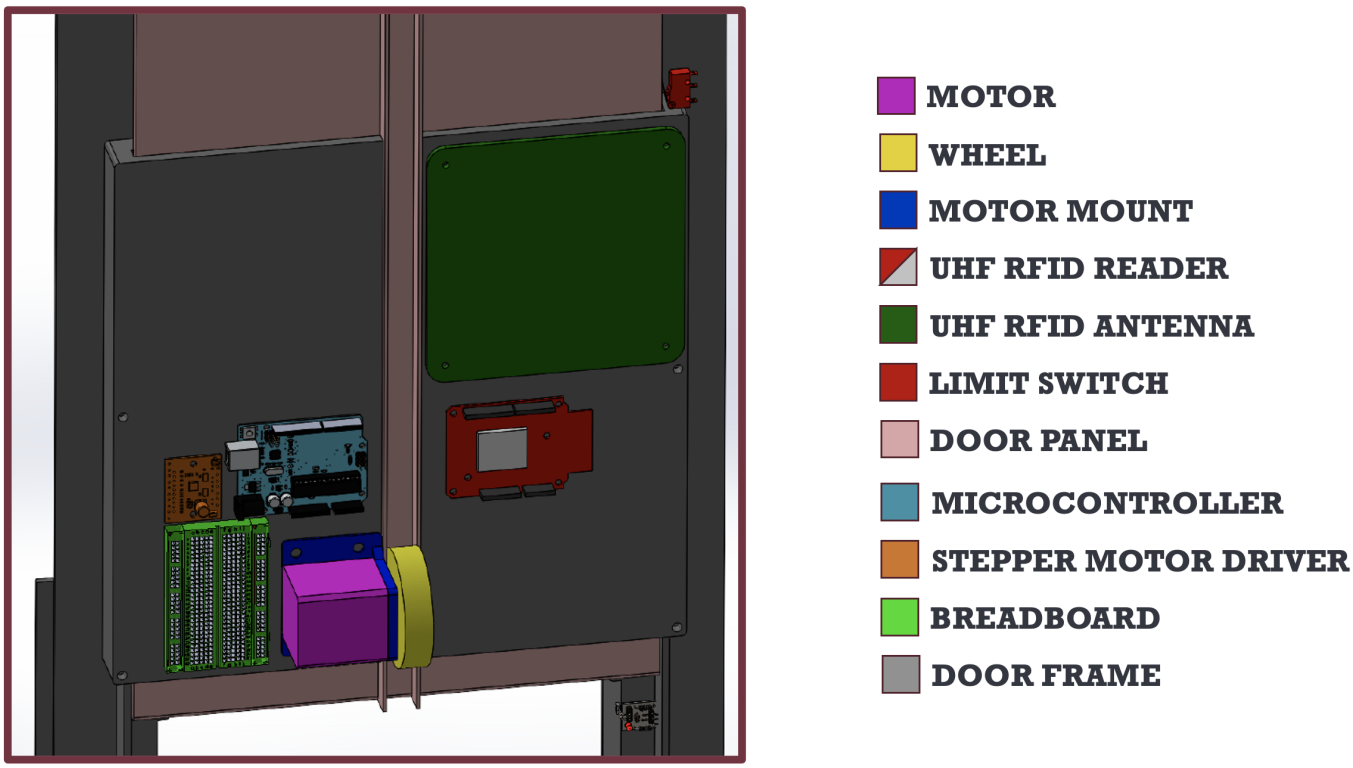

Figure 10: (a) Colored Part Model (b) Color Legend

Figure 11: Model with Cover

Figure 12: Model without Cover

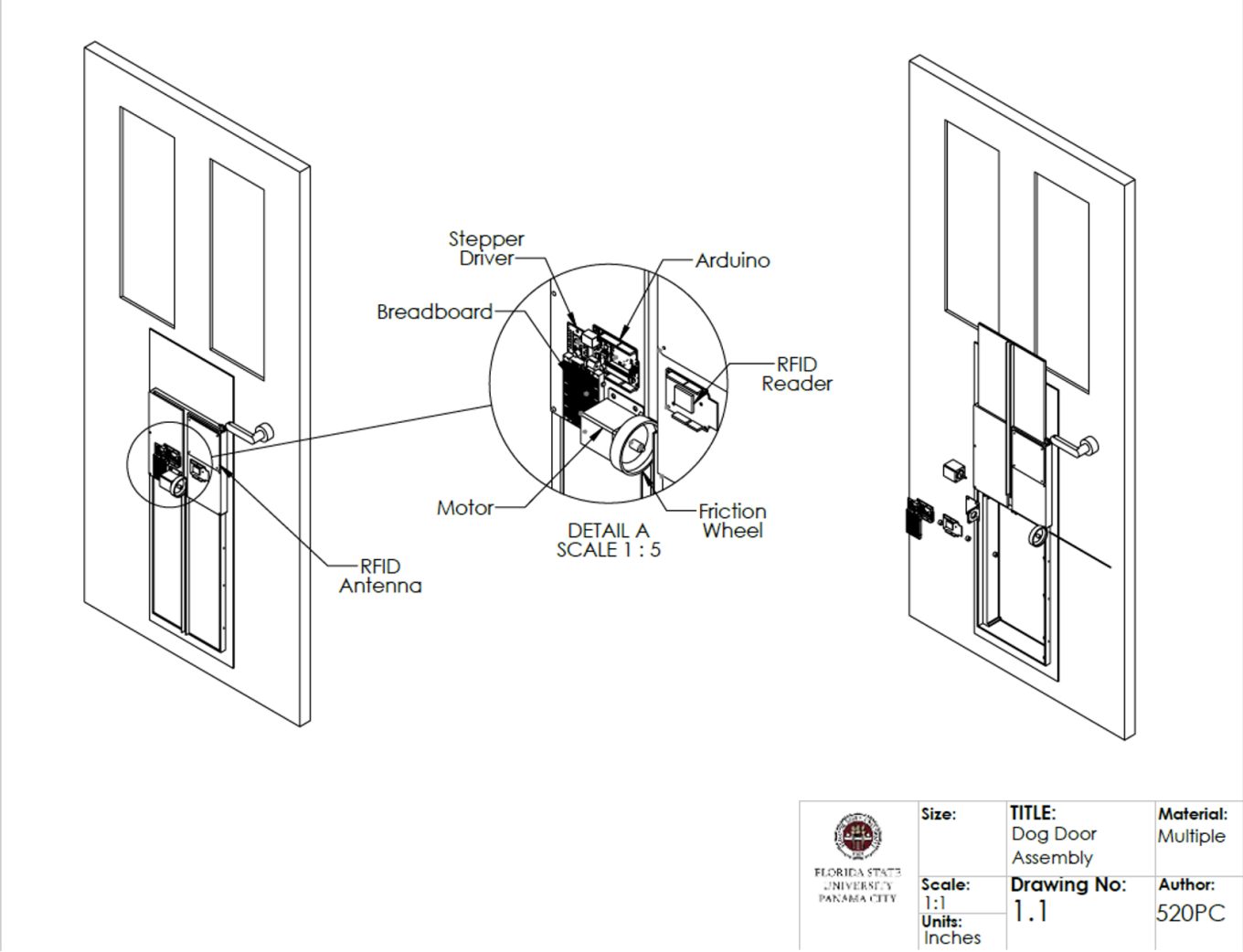

Figure 13: Component Assembly Drawing File

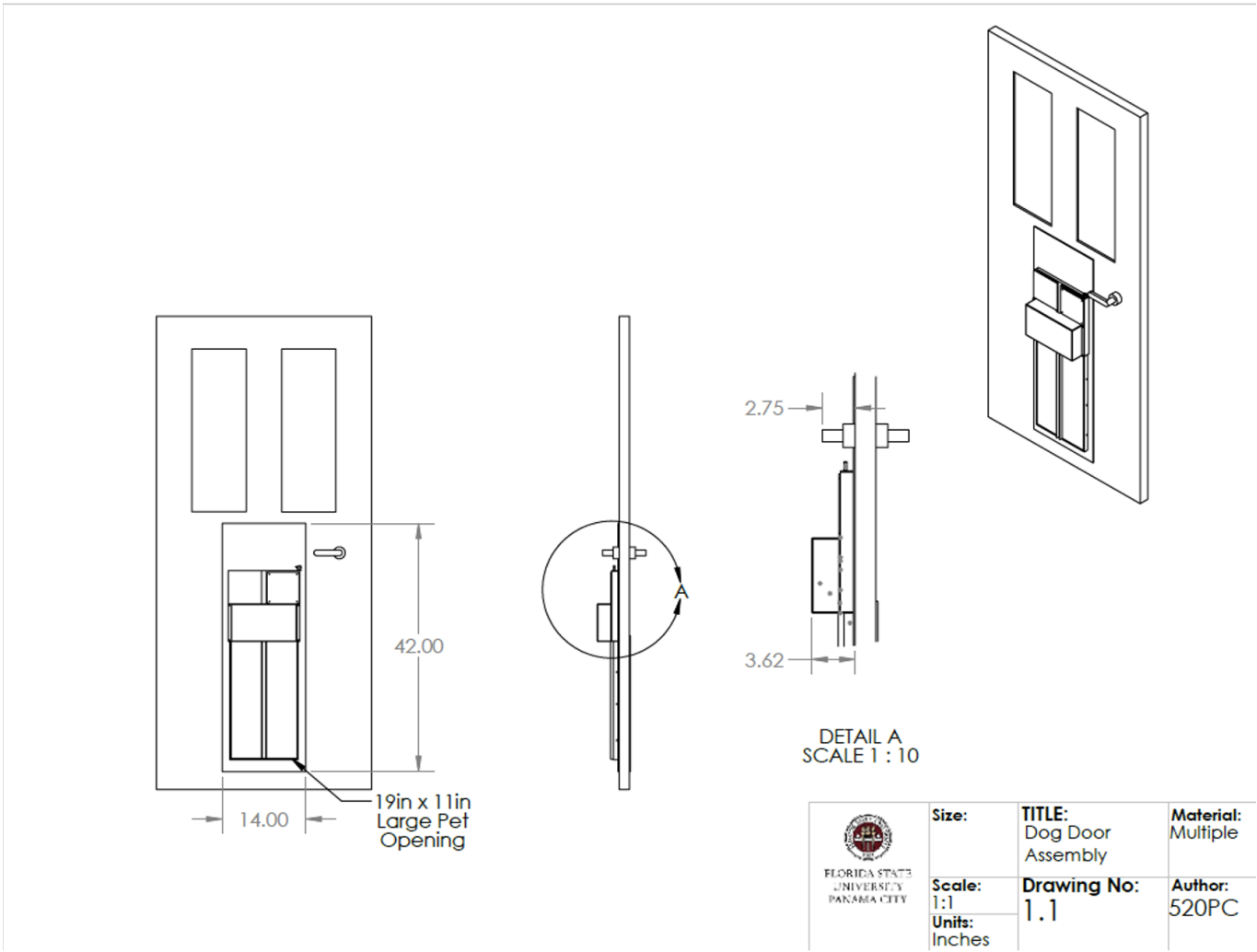

Figure 14: Dimensioned Frame Drawing File

The figures shown above display the automatic dog door system and all mechanical and electrical components. The colored part model and legend displays all relevant components and their associated designations. The assembly is shown with and without an electrical component cover. The assembly diagrams shown above display an exploded component view, as well as a detailed section view and dimensioned door frame figure.

9 Component Selection

The first section of components will include all electronics that will be used in the automated dog door. Locations and operational functions will be described for each part as well. First, an Arduino will be programmed to read sensors and send power to the motor as depicted in the state diagram. In order to create a seamless open and close process, microswitches will be placed at the top-most and bottom-most positions of the door. These sensors will send information to the Arduino as to when to stop the opening and closing procedure. This allows for accurate door placement over time, and it avoids any slip conditions that would leave the door slightly open. When the door undergoes the

close condition, three laser optic sensors will be placed horizontally along the opening of the door. If an obstruction interrupts the laser, the command to reopen the door will be sent in order to protect anything traversing through the door open area as well as the door itself.

An RFID antenna will be placed on the inside and outside frame of the door. This will connect to an RFID reader chip that will send information about local RFID tags in the area to the Arduino. If an RFID tag is approved, the Arduino will send power to the door to open it. The antenna and reader can work together in order to determine intensity, which then can be corrected to proximity of the tag. This will allow for fine-tuning of the distance the tag is from the door before actuation of the door occurs.

10 Bill of Materials

A comprehensive list of parts and materials was compiled to design and assemble the project prototype. The associated mechanical and electrical components can be referenced in the figure below.

Team 520PC Automated Dog Door Order List								Date: 4/24/23
Item #	Name	Model/Part #	Qty	$/Unit	Cost	Seller	Link	Add. Notes
1	Arduino UNO WiFi REV2 [ABX00021]	ABX00021	1	$ 54.96	$ 54.96	Amazon	https://w	N/a
2	TUOFENG 22 awg Wire Solid Core Hookup Wires-6 Different Colored Jumper Wire 30ft or 9m Each, 22 Gauge Tinned Copper Wire PVC (OD: 1.55mm) Hook up Wire Kit	B07TX6BX47	1	$ 14.99	$ 14.99	Amazon	https://w	Select "6 colors each 30ft"
3	WOWOONE 25pcs 12x12x7.3 mm Tact Tactile Push Button Switch, 4 Pin Momentary SMD PCB Micro Switch with Cap for Arduino, AE1027 5 Colors Round Cap Assortment Kit DIY Project	B08JLWTQ3C	1	$ 6.99	$ 6.99	Amazon	https://w	N/a
4	DEYUE breadboard Set Prototype Board - 6 PCS 400 Pin Solderless Board Kit for Raspberry pi and Arduino Project	B07LFD4LT6	1	$ 7.99	$ 7.99	Amazon	https://w	N/a
5	SparkFun Power Supply Sample Kit	KIT-19194 ROHS	1	$ 19.95	$ 19.95	SparkFun	https://w	N/a
6	EDGELEC 100pcs 10K ohm Resistor 1/2w (0.5Watt) ±1% Tolerance Metal Film Fixed Resistor, Multiple Values of Resistance Optional	B07QJB31M7	1	$ 5.99	$ 5.99	Amazon	https://w	Size [E5P011] 10K ohm
7	Shell	B0BCPVNDCD	1	$ 24.99	$ 24.99	Amazon	https://w	B-360(deg) -90R
8	Confidex Asset Tracking Sample Pack	Confidex-Asset-Pack	1	$ 54.00	$ 54.00	atlasRFIDstore	https://w	N/a
9	SparkFun Simultaneous RFID Reader - M6E Nano	SEN-14066	1	$ 235.95	$ 235.95	SparkFun	https://w	N/a
10	Holland Single Port Coax Tap - 5 to 1000 MHz - 9dB	DCG-9SB	1	$ 2.99	$ 2.99	Show Me Cables	https://w	N/a
11	Interface Cable RP-SMA to U.FL	WRL-00662 ROHS	1	$ 4.95	$ 4.95	SparkFun	https://w	N/a
12	UHF RFID Antenna (RP-TNC)	WRL-14131 ROHS	2	$ 42.95	$ 85.90	SparkFun	https://w	N/a
13	RuiLing 4-Pack SPDT Micro Limit Switch for Arduino,Mini Limit Switches with Straight Long Hinge Lever V-153-1C25	MLS-V-153-1C25-4	1	$ 6.99	$ 6.99	Amazon	https://w	N/a
14	SparkFun EasyDriver Stepper Motor Driver	SX09402	2	$ 20.61	$ 41.22	Amazon	https://w	N/a
15	Gikfun Digital 38khz Ir Receiver Ir Transmitter Sensor Module Kit for Arduino (Pack of 3 Sets) EK8477	gdagre-802	2	$ 7.99	$ 15.98	Amazon	https://w	Unavailble for order currently
16	Gikfun 10mm LED Emitting Diodes Light Lamp Diffused F10 Round Led for Arduino (Pack of 20pcs) AE1258	B07DC5VFZ7	1	$ 7.98	$ 7.98	Amazon	https://w	N/a
17	CATTONGUE GRIPS Non-Abrasive Grip Tape Heavy Duty Waterproof Anti Slip Tape for Indoor & Outdoor Use - Thousands of Grippy Uses: Home Goods, Hardware, Accessible Home and More! (Black Tape)	UC18-00162	1	$ 19.95	$ 19.95	Amazon	https://w	Select "1 pack"
18	Polycarbonate Lexan Sheet Clear 0.250” - 1/4" (6 mm) 24" x 48" - Thermoforming	B07KCYC7K7	2	$ 64.90	$ 129.80	Amazon	https://w	N/a
19	Duco ABS Plastic Sheet 1/8 Inch Thick 24" x 48" - Two-Sided Rigid ABS Sheet (Textured Plastic Front & Smooth Back) - DIY Home Decor and Robotics Competitions Use - Black Plastic Sheet (Pack of 1)	B0B78J9CR6	2	$ 44.75	$ 89.50	Amazon	https://w	Select 24"x48"
20	48mm Body 4-Lead W/ 1m Cable and Connector Compatible with 3D Printer/CNC	17HS19-2004S1	1	$ 13.99	$ 13.99	Amazon	https://w	N/a
21	ml	50133	3	$ 6.98	$ 20.94	Amazon	https://w	N/a
22	Soldering Iron Kit Electronics, 60W Soldering Welding Iron Tools with ON-Off Switch, 5pcs Soldering Iron Tips, Solder Sucker, Soldering Iron Stand, Tweezers, Solder Wire, Wire Cutter, PU Carry Bag	9160	1	$ 15.99	$ 15.99	Amazon	https://w	Select 60w 12 in 1
23	HGMZZQ 60/40 Tin Lead Solder Wire with Rosin core for Electrical Soldering 0.031 inch(0.8mm-50g)	6040-08-50	1	$ 7.39	$ 7.39	Amazon	https://w	Select 0.8mm-50g
				Total	$889.38			

Figure 15: Bill of Materials

References

[1] Dieter, George E., and Schmidt, Linda C. Engineering Design, 5th Edition. McGraw Hill, 2013.