26.11.2021

MIDDLE EAST TECHNICAL UNIVERSITY

Electrical & Electronics Engineering Department

EE493 - Engineering Design I

"Cisss!"

Proposal Report

Company Name: λambda

Starting Date of the Project : 26.11.2021
Completion Date of the Project : 10.06.2022
The Project Duration : ~ 7 Months

Members of Company :

1. Berk Erhan Yüksel
2. Necdet Can Sönmez
3. Mustafa Barış Emektar
4. Alper Saraç
5. Furkan İtkü

Design Coordinator :

- Associate Professor Dr. Elif Vural

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1. Executive Summary

In today's modern, ever-developing world, people want permanent and practical solutions to their problems while also being sensitive to the environment and the ecosystem. Thanks to developing technology, innovations, and creative ideas; the primary requirement is to make people's lives easier and minimize the problems they encounter. In this way, the company, “λambda”, was established to try and create efficient and technological solutions that are oriented towards improving people’s daily lives.

Today, people have difficulty managing and taking care of their pets at home. Although loving and affectionate, pets may be pretty mischievous at times, being in unwanted locations in the house at the wrong times. For example, you have prepared a lovely table for dinner, your guests have arrived in a short time, and unfortunately, your dog has eaten the freshly baked chicken on the table. Or you have just had a new baby, and your dog is eager to play with it. You may not want it to go into the baby's crib or room.

In order to present a solution to this problem, λambda is proposing to implement a project named “Cısss!”. The project aims to produce a device that will alert the pet whenever it enters “forbidden areas'' within the home, which are to be determined by the user. The project will consist of two parts; an intelligent, wearable, low-power master unit wearable by the pet, informed of the animal's location through tags to be placed within the home and alerting the pet whenever it intrudes into forbidden areas. The other part consists of tags to be placed inside the house. These tags are intended to be small and cooperate with the master unit to allow the device to work as intended.

According to our basic requirements, this system should work with at least one restricted area and a doorway not less than 90cm. Keeping these in mind, the team foresees such requirements for the project: an RFID-based system for the communication of the Master Unit and Tags, a frequency range that is workable and unaffected by environmental factors, compact ICs, processors that can provide low power consumption, and running algorithms that provide high reaction speed and precision. If the marketability

and industrial views are examined, this project should be highly durable, aesthetic, and safe. A test jig for the evaluator shall also be presented along with the end-product.

Considering the team members' competencies in engineering fields such as signal processing and embedded firmware development, the team hopes to complete the project design and testing process in approximately eight months. Testing of modules, preparation of the conceptual design, and project presentations are also counted within the project duration and presented with a Gantt Chart which can be found in the Appendix. The team foresees a maximum of 200 $ will be needed to meet the requirements described and to develop and materialize the end-product. To avoid overspending, the project will be simulated beforehand and designed accordingly. As such, in-depth research will be done before any component purchases; if necessary, it will be simulated in software environments, and the purchase process will occur according to these simulation results.

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2. Introduction

In today's world, many people live with their pets in their homes. Many people consider their pets to be their children and do not separate them from their families. However, at times these pets may be as naughty as they are sweet. They may peek out the door and wander out of the house away from safety, or they may want to climb the kitchen countertop to eat something they shouldn't. To protect pets from harming themselves or the house, pet parents need a tool to prevent their pets from misbehaving. That is where λambda takes the stage.

λambda is proposing a new innovative device that will protect pets from potentially damaging behaviors, which is lacking in today's market. The offered product is intended to be attached to the pet's collar, although users may choose to make their pets wear it however they like, as the device is to be compact. The primary device, which is referred to as the "master unit", is to be as small and light as possible so as not to cause any discomfort to the wearer. The product does not consist simply of the master unit, however. The product will come with tags, which the user will place in the house, wherever they would

like to tag as “forbidden areas”. Whenever the pet enters these forbidden areas, the master unit will alert the pet without harming it. The planned method of alerting is to be acoustic and vibrational. Considering thousands of owners have the mentioned problems every day, it is evident that a device to inhibit animals’ dangerous behavior without hurting them could have tremendous potential on the market.

In this report, you will find λambda’s proposal to develop this project. The report includes the members of λambda as well as their competencies, the defined outline of the project and the goals and objectives the team would like to reach, the proposed solution method to the presented problem, and finally what is to be expected as the end-product.

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3. Team Organization

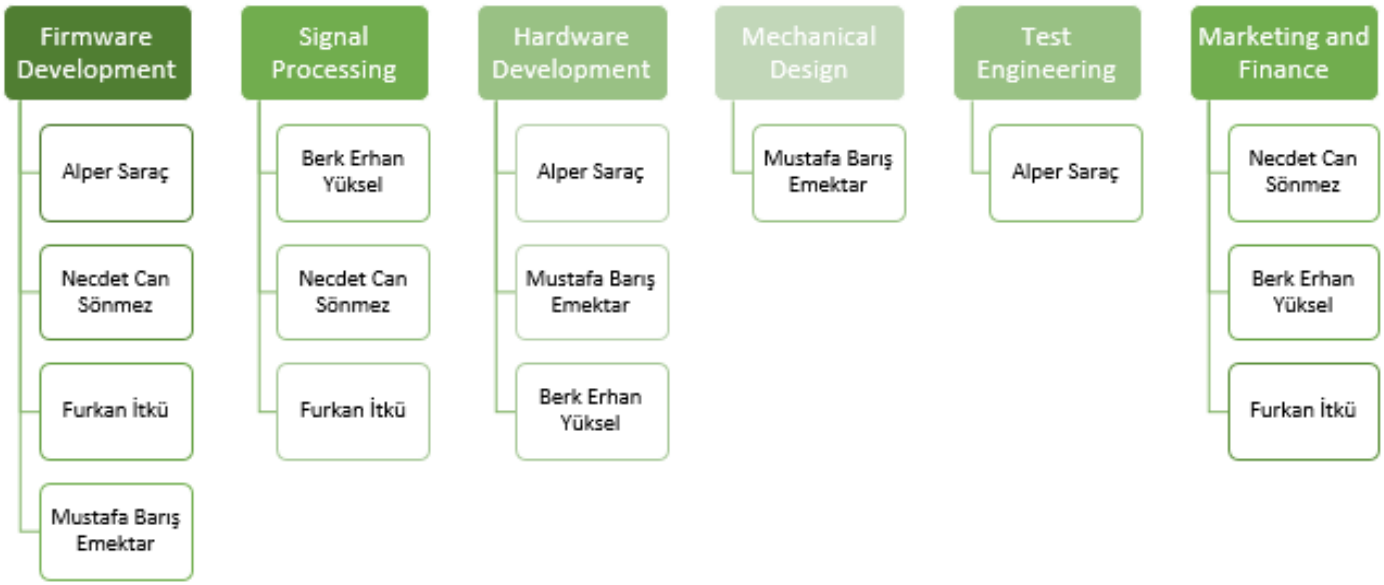

Figure 1.1 *Company Organization Chart*

As the project requires work from different areas of engineering, the team members are also competent in different areas themselves. λambda consists of 5 prospective engineers who have experience in various fields. The members have a high sense of

responsibility and teamwork and understand the importance of cooperation to achieve success. The academic background of the employees, their areas of expertise, their experiences, as well as their roles and responsibilities within the project are given below:

I. Berk Erhan Yüksel

- A senior student at Middle East Technical University, Electrical and Electronics Engineering Department. As a result of his internships, he gained experience in signal processing, telecommunication, and radar systems.
- ***Specialization Area:*** Signal Processing and Control Theory of Discrete-Time Systems
- ***Projects:*** Accuracy Improvement in FSK Radars, Designing a GPS Tracking Systems
- **Responsibilities and Tasks:** - Signal Processing
  - System Design and Control

II. Necdet Can Sönmez

- A senior student at Middle East Technical University Electrical and Electronics Engineering Department. He has experience in signal processing applications due to his internship. He is currently developing his embedded software skills as a result of his specialization field.
- ***Specialization Area:*** Computer
- ***Projects:*** Anomaly Detection in Industrial machines using vibrational data
- **Responsibilities and Tasks:** - Embedded firmware development
  - Signal Processing

III. Mustafa Barış Emektar

- He is a senior Electrical and Electronic Engineering student at METU. During his internships, he gained knowledge of embedded systems and high-level programming languages. He's also skilled in soldering, wiring, and designing-printing 3D models.
- ***Specialization Area:*** Computers
- ***Projects:*** Comparison of Two Passive Geolocation Methods, A Simple Object Tracking, Image Blurring with MATLAB
- **Responsibilities and Tasks:** - Simulation
  - Physical Implementation & Tests

IV. Alper Saraç

- A senior student of METU Electrical Electronics Engineering Department. Has had experience in the R&D process and embedded firmware development.
- ***Specialization Area:*** Computers
- ***Projects:*** Developing smart biomedical devices for monitoring patients' drug usage
- **Responsibilities and Tasks:** - Embedded firmware development
  - Algorithm development

V. Furkan İtkü

- A senior student at Middle East Technical University Electrical and Electronics Engineering Department. He has worked on embedded systems and signal processing.
- ***Specialization Area:*** Computers
- ***Projects:*** Designing mobile GNSS receiver deception algorithm with MATLAB
- **Responsibilities and Tasks:** - Embedded firmware development
  - Signal Processing

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4. Project Goals, Objectives and Requirement Analysis

4.1. Project Requirements and Constraints

As described before, the device is to alert the wearer whenever it gets in proximity to tags. The function of the device to alert the wearer in such a situation may be examined in two scenarios:

- The wearer is attempting to pass through a forbidden door; passage scenario
- The wearer intrudes into a forbidden zone; area scenario

Since there is to be only one "type" of tag, tags to be used in these two scenarios will be completely identical (i.e the user may use the same tag for whichever scenario they desire). However, it is important that we consider both scenarios separately to ensure that the device works as intended in both cases.

In the passage scenario, the user has placed the tag on the side of the door passage, tagging that passage as forbidden. The width of the passage is assumed to be no less than 90cm. The device must be able to detect that the wearer has approached the passage before it passes through, and alert it. In case the wearer passes through the door anyways, the alert could be made stronger (for example by increasing the volume of the alert sound or strengthening the vibration). To do so, the master unit must be able to deduce how far away it is from the tag with a small enough error margin, to tell if the wearer is passing through the door or has just approached it. Furthermore, the reaction speed of the device must be high enough, so that the wearer cannot deceive the device by just running through the passage.

In the area scenario, the device must be able to tell if the wearer has stepped within the range of the tag. If so, the device must start alerting the wearer. In case the wearer starts walking closer to the tag, similar to the passage scenario, the alert could be made stronger.

In addition to these, the device must operate with low power consumption; which is critical to customer convenience as well as the ecological footprint of the device. Considering the device is intended to be powered by a button battery, it would be tedious for the user to have to change the battery every day; furthermore, since batteries are harmful to the earth, it would be against the company's founding values. As such, the team aims for the master unit to have at least a month of battery lifetime.

Furthermore, safety and durability are also important concerns. Pets may bite or hit the device trying to take it off or spill water on it while playing with water. The device must not only be able to withstand these, but also it must not pose any physical danger to the wearer. External actions such as these must not cause the device to be shorted and/or electrocute the wearer. Furthermore, since the device is to work with electromagnetic waves, it is important that these waves do not cause any harm to the wearer or anyone around the wearer. The waves must also not interfere with any other waveforms that could be present in the environment, nor should they be affected by them. The components within the device must not malfunction in a short time, and the customer must be able to use the device for a long time after the purchase.

4.2. Objectives

The team members have decided on several objectives to be fulfilled for the project, which were then compared to find the overall weight of each in a democratic fashion. The comparison chart can be found in the "Appendix 9.2 - Criteria Weighted Voting" section of the report. In this section, each set objective of the project will be explained in detail.

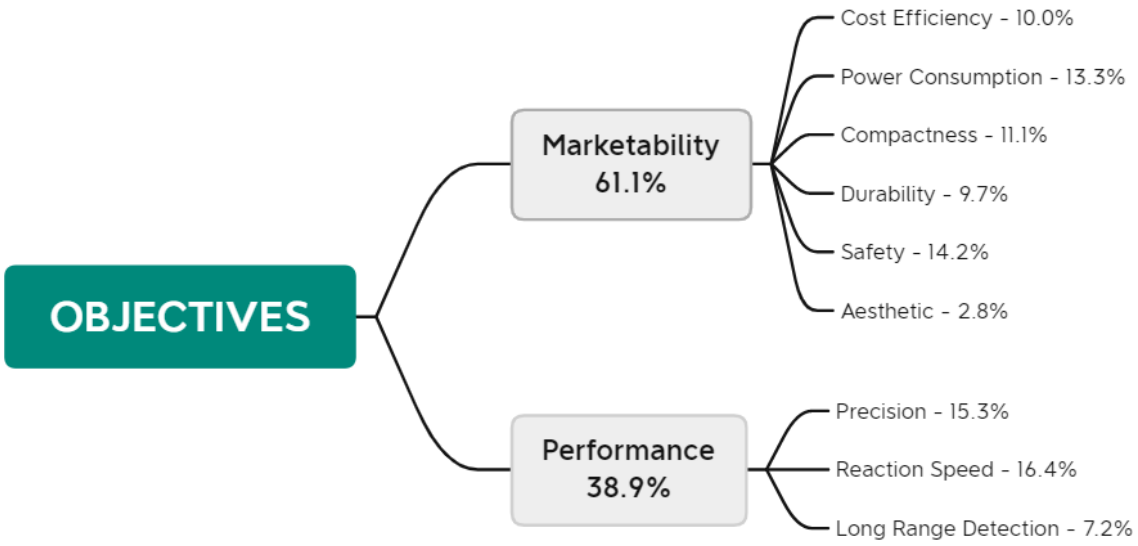

Figure 1.2 *Objective Weight Tree*

- **Cost Efficiency**

This refers to the overall cost of the end product, including hardware, R&D, and workforce costs. It is desirable that the product be as cheap as possible so that the customer will be inclined to buy it.

- **Power Consumption**

As the project is intended to be powered by a battery, it would be inconvenient for the customer to have to change the battery frequently. Furthermore, having lower power consumption would make the product eco-friendlier.

- **Compactness**

As the product is intended to be wearable, it is critical that the product, specifically the master unit, be as small and as light as possible not to be uncomfortable to wear.

- **Durability**

As pets are unlikely to be cautious, the device must be durable to physical stress and any other damage such as water. Furthermore, the lifetime of the device must be as long as possible.

- **Safety**

It is critical that the device does not hurt anyone. The device must be checked thoroughly to ensure this so that any external agents, such as water, do not short the device and shock the wearer. Furthermore, since the product will be using electromagnetic waves to operate, it is important that these waves are not harmful to health.

- **Aesthetic**

It is important for any product to be marketed to be nice to the eye so that the customers will be more likely to purchase it.

- **Precision**

The device must be able to detect whenever the wearer enters the range. Furthermore, the team would like the product to detect how far the master unit is away from the tags to improve the user experience.

- **Reaction Speed**

Since pets may move at very high speeds, the device should detect the motion even if the pet runs through the tag (or tags) at high speed. For this purpose, the product must be able to quickly pick up the signal and process it to alarm the wearer.

- **Long Range Detection**

This refers to how long of a range the device is going to have. While a range of at least 90cm is to be implemented indeed, the device should support higher ranges.

5. Solution Procedure

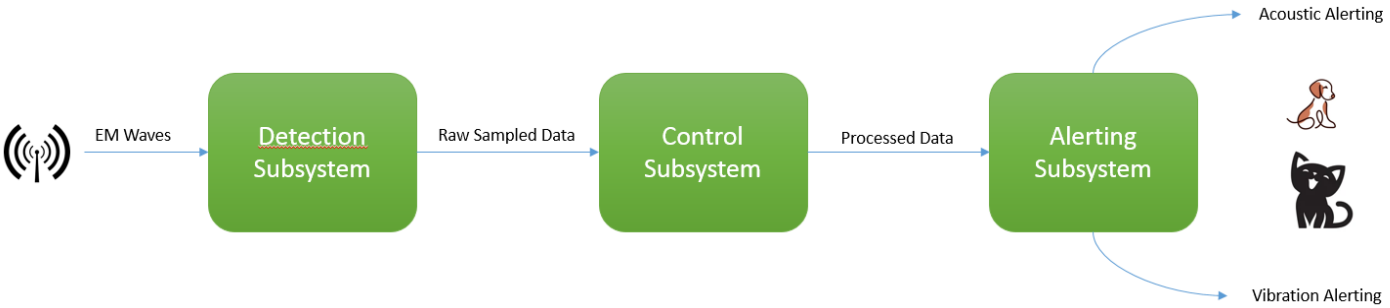

Figure 1.3 *Subsystem Block Diagram*

5.1. Detection Subsystem

The detection of the tags from a distance is one of the most critical parts of this project. Whether the tags are in the vicinity of the master unit will be determined by this subsystem. The subsystem may be seen as a distance measurement tool for the product. However, the distance measurement may or may not be necessary for the implementation and this factor will be decided in the research and development of this unit since some reduction in the power consumption may be seen as beneficial for the product. The unit may be designed to show whether the tags are closer to the master unit than the desired detection range and not measure the distance explicitly. The latter kind of design philosophy may be a more efficient solution to the problem. Thus, the operating principle of the detection subsystem and its details will have an intrinsic influence on various characteristics of the system. Thus, the design of the detection subsystem will affect the tasks that need to be done on the control subsystem and the precision of the whole project.

Possibly, this subsystem will utilize some sort of an electromagnetic radiation transmitter and receiver unit that will have some interference due to the tags and the magnitude that may be used to accomplish its aim. The details of the design are not a concern at this point of the project. However, with the funding we need, various designs will be tested to observe their reaction speed, power consumption, and cost-efficiency.

Finding an optimal design solution is crucial in order to achieve a balance between the functionality and complexity of the subsystem.

The tags are a part of the detection subsystem. The master unit will contain a detection unit that will detect the tags from a distance. The tags may be active or passive, depending on the design choices. Choosing passive tags over active tags will be more beneficial in terms of power consumption and practicality. The consumer would not have to think about if the tag's battery ran out. Choosing an active tag-based design, on the other hand, would increase the detection range and reliability of the system [1]. The design choice will be dependent on how much of a positive effect we would observe.

5.2. Control Subsystem

The control subsystem provides the device with a decision-making unit. The detection subsystem's output feeds to this unit as an input to supply the system with a measure of the distance to the tag/s.

Simply put, the main task of the control subsystem is to process the raw data taken from the detection subsystem to determine the signal that would be sent to the alerting subsystem. The contents would include a microcontroller, which would be the main component in the subsystem. The input, i.e. the signal sent from the detection subsystem, would be run through algorithms that determine possible aspects of the signal. The aspects, as a result, will be used to determine whether the tags and the master unit are close enough to each other to send a signal to the alerting subsystem.

A crucial factor in the operation of the system is the speed of the control subsystem as the precision and reliability of the whole device depends on the reaction time. A fast unit is required; however, increasing the speed beyond our constraints implies that our power consumption would increase beyond the limit set by the team. The battery life of the master unit would decrease as a result. Hence, an optimized system speed should be determined in order to have a balance between precision and power consumption.

5.3. Alerting Subsystem

The alerting subsystem is tasked with alarming the wearer whenever the forbidden areas are violated. While discussing, some methods discussed were :

- Acoustic alerting, by giving out a sound effect [2]
- Vibrational alerting, by vibrating the device
- Mechanical alerting, by warning the wearer physically, such as tightening the collar
- Electrical alerting, by giving a small shock

After considering all, acoustic and vibrational alerting methods were decided to be the most suitable. The reasons being that mechanical and electrical alerting methods were found to be unethical.

The acoustic alerting should alert the wearer by giving out a sound effect. While some ideas were discussed on how this could be implemented, more research on animal behavior needs to be done in order to decide on how this sound is to be. Considering some of the sounds heard by dogs and cats are unable to be heard by humans, using sound in this range could be a good idea, but research needs to be done if this is feasible. More research should also be done on what sounds are disturbing to pets and may deter them from undesired behavior.

The vibrational alerting is rather straightforward; the master unit, which is intended to be attached to the collar, will vibrate, which will alert the pet that they are doing something they should not.

It is also considered, that if possible within other constraints, that the processing unit infers not only that the wearer has entered a forbidden area but also how much they have entered into the range; so that the alert can get stronger as they move closer to the tags. That is, as the pet gets closer to the tag, the sound gets louder and the vibration gets stronger.

5.4. Project Timeline

The research phase of the project is to prepare the team for the design phase. The theoretical research results will be utilized in the initial physical tests that will be done to test whether the theoretical assumptions were correct. The project will require the team to start the work sequentially during the design process, starting from the detection subsystem, continuing with the control subsystem, and ending with the alerting one. The design phase of consecutive parts will overlap with one another to test the functionality of the previously designed unit and check the subsystems' compatibility. Once a working system has been achieved, all subsystems will be optimized in terms of power consumption and accuracy to obtain a polished result.

The Gantt chart detailing the timeline can be seen in the appendix, under "Appendix 9.1 - Gantt Chart".

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6. Expected Deliverables

At the end of the project, the team shall present a product ready to be marketed. The product will include the master unit and several tags, along with the user's manual. The master unit shall be small enough to fit on a pet's collar and give no discomfort, and be able to alert the wearer through acoustics or vibration whenever the wearer is within the range of the tags, which are to be placed in designated locations by the user. The aforementioned range of the tags shall be no less than 90cm. The whole product is to be completely safe, in that it will carry no risk of electrocution of harmful radiation. The product will be durable, have a long lifespan, and be resistant to water and physical hits. The device will have efficient power consumption, and the user will not need to change the battery frequently. More detailed information about the specifications of the device can be found in the preceding pages. The user's manual will present some of the product's technical specifications that the user may want to know, such as battery life and frequency range. The user manual will also include the intended usage of the device.

7. Conclusion

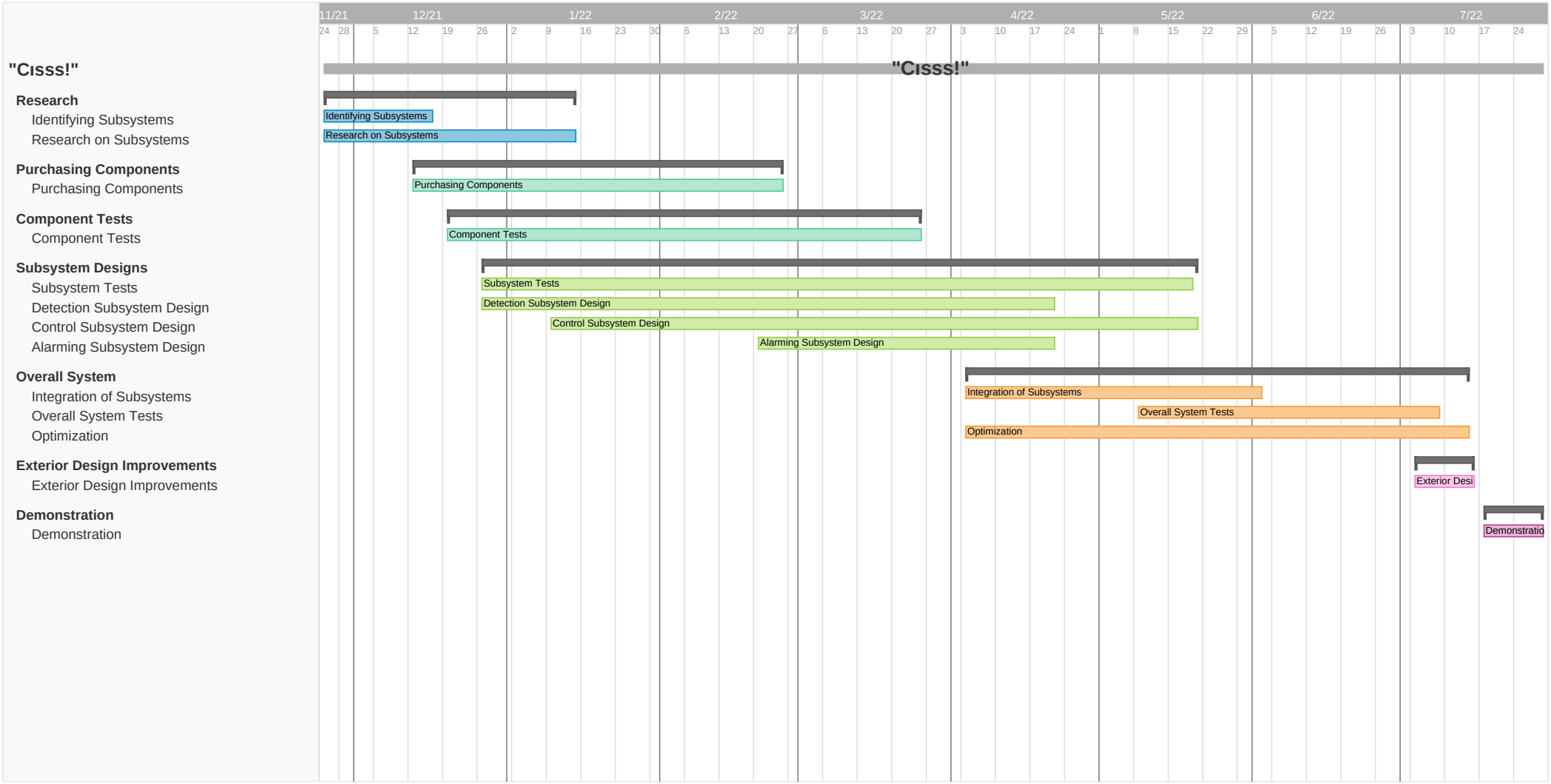
The product that is expected to be delivered as a result of this project will be beneficial to many pet owners who may want to keep their pets safe. The steps described by the "Project Timeline" part and the Gantt Chart will be followed during the project to increase the team's design efficiency. Each team member has an interest in different parts of the project. Hence, the workload is expected to be properly distributed as a natural result. The final product will be a polished and user-friendly device to increase its practicality and marketability. The safety aspect of the device is crucial due to the application being done on pets, as not being careful might get them hurt. The team believes in the project's potential as a device with a large market. Pet ownership has been increasing over the last couple of years. As a result, the market for pet safety is expected to grow, and the company's aim is to capitalize on this trend.

8. References

[1].https://www.realtimenetworks.com/blog/active-vs-passive-rfid-how-to-choose-the-right-tracking-tech-for-your-organization
[2].https://www.animalwised.com/how-to-stop-a-cat-climbing-curtains-walls-and-more-3734.html#anchor_6

9. Appendix

9.1. Gantt Chart



9.2. Criteria Weighted Voting

OBJECTIVES	CE	PC	PR	CMP	RS	LDR	DRB	SFT	AES	Total	Normalized
CE	-	4	1	1.5	1.5	2	2	1.5	4.5	**18**	**0.10**
PC	1	-	3	3	2.5	4.5	2.5	2.5	5	**24**	**0.13**
PR	4	2	-	4	2	4.5	4	2.5	4.5	**27.5**	**0.15**
CMP	3.5	2	1	-	1.5	4	2.5	1.5	4	**20**	**0.11**
RS	3.5	2.5	3	3.5	-	4.5	4.5	3	5	**29.5**	**0.16**
LDR	3	0.5	0.5	1	0.5	-	2	2	3.5	**13**	**0.07**
DRB	3	2.5	1	2.5	0.5	3	-	1	4	**17.5**	**0.10**
SFT	3.5	2.5	2.5	3.5	2	3	4	-	4.5	**25.5**	**0.14**
AES	0.5	0	0.5	1	0	1.5	1	0.5	-	**5**	**0.03**
										+	
										180	

OBJECTIVES
CE=Cost Efficiency
PC=Power Consumption
PR=Precision
CMP=Compactness
RS=Reaction Speed
LDR=Long Detection Range
DRB=Durability
SFT=Safety
AES=Aesthetic