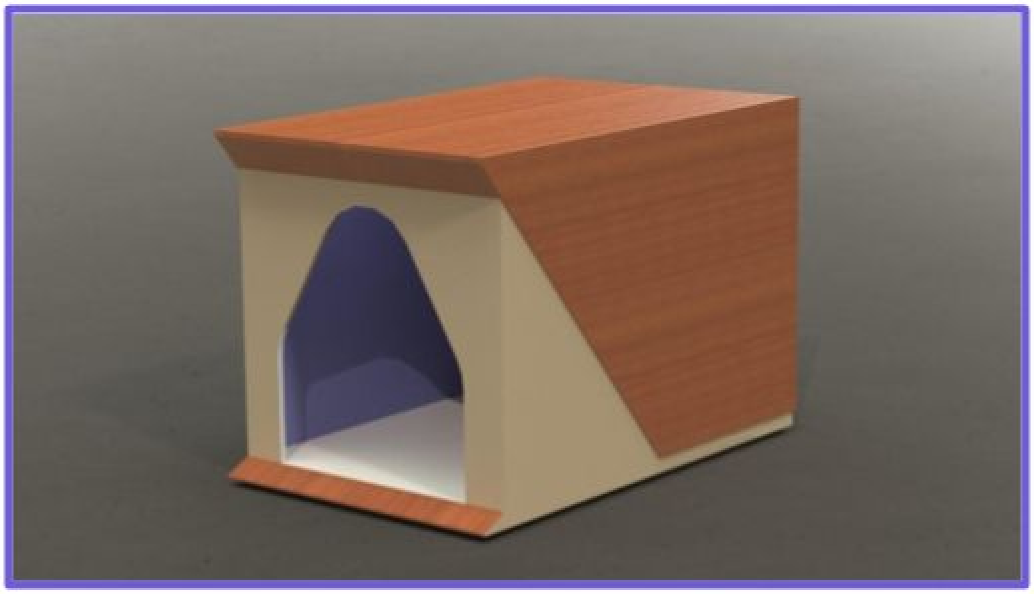
SafeCrate Technical Document

THE ENTREPRENERDS

Team 309 || *May 1, 2020*



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With Special Thanks to

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The Problem

Nearly 50% of American homes have at least one dog as a pet. Of those nearly 77 million dogs, it is estimated that half suffer from some form of noise-induced anxiety. For dogs, this is a major health issue, as frequent anxiety events can have long-term effects on well-being. For owners, this is a significant pain point and detractor from their lifestyle. Many dog owners report making major changes to plans and living scenarios based solely around their dog's nervousness. For these owners, holidays and public events mean staying home to comfort their pet. Current solutions include medication, which many owners try to avoid or cannot afford, and some products with low success rates. For millions of Americans, their dog's anxiety limits their lifestyle and has lasting effects on health.

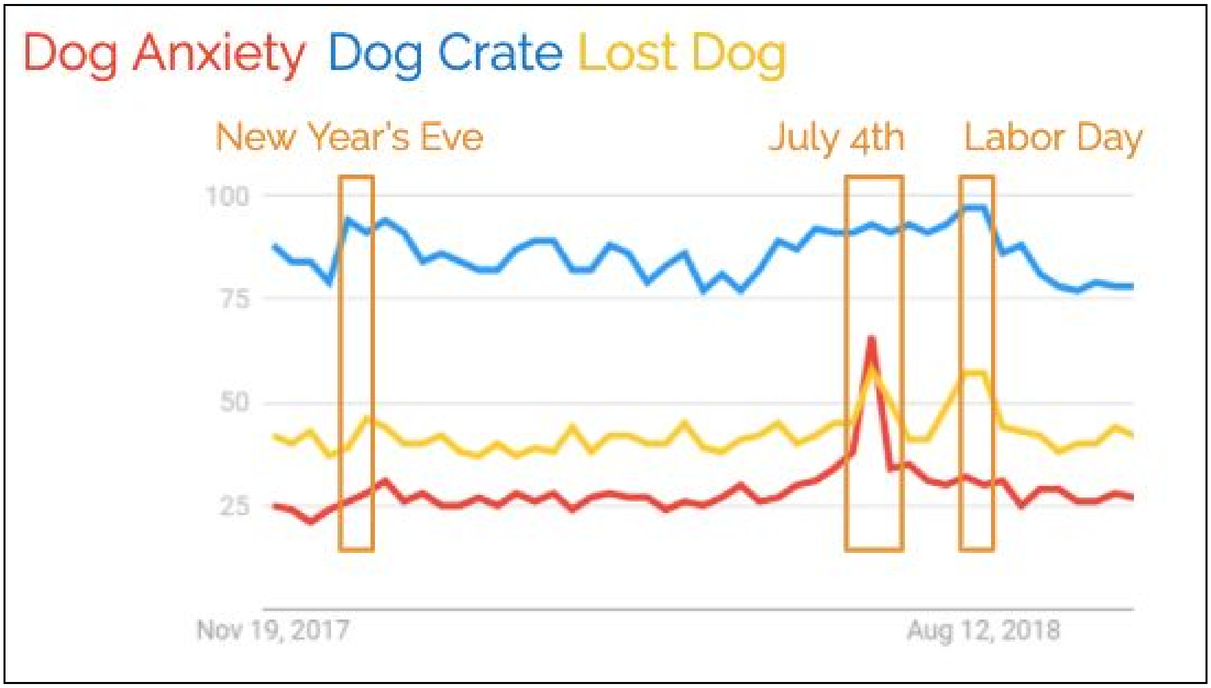

Figure 1: Google Trends 2017-2018. Terms searched are 'Dog Anxiety' in red, 'Dog Crate' in blue, and 'Lost Dog' in yellow, each ranked relative to the popularity of the others. Three peaks occurred each year, and a one year cycle is captured in this figure.

Our Solution

Our team has worked to develop a crate that provides a quieter and more acoustically-stable environment for pets which creates more relief than current products by effectively addressing the root causes of noise anxiety. Our product, SafeCrate, focuses on pet health and wellbeing - yielding a novel product that will undoubtedly attract pet owners. SafeCrate is an enclosure that utilizes Passive Noise Cancellation (PNC) and noise masking technology to limit the effect of distressing ambient sounds on pets.

Initially, our team intended to primarily rely on Active Noise Cancellation (ANC) technology not unlike what is commonly being implemented in state-of-the-art headphones and the cabins of several new lines of vehicles. This type of system works exceedingly well for low frequency sounds such as fireworks and thunder which are the most notorious distressing sounds for many pets. Figures 2 & 3 show the team's first concept of SafeCrate utilizing active noise cancellation. However, a digital ANC system would be exceedingly complicated and could realistically double production costs for the crate. Our team investigated and eventually constructed an analog ANC system which consists of a signal-inverting circuit, but found it to be ineffective at canceling sound uniformly in an open volume. This, along with research indicating that noise masking could provide adequate relief to animals, led the team to cease development of an ANC system in favor of the less complicated and more effective noise masking solution.

Figure 2: First Design Concept for SafeCrate

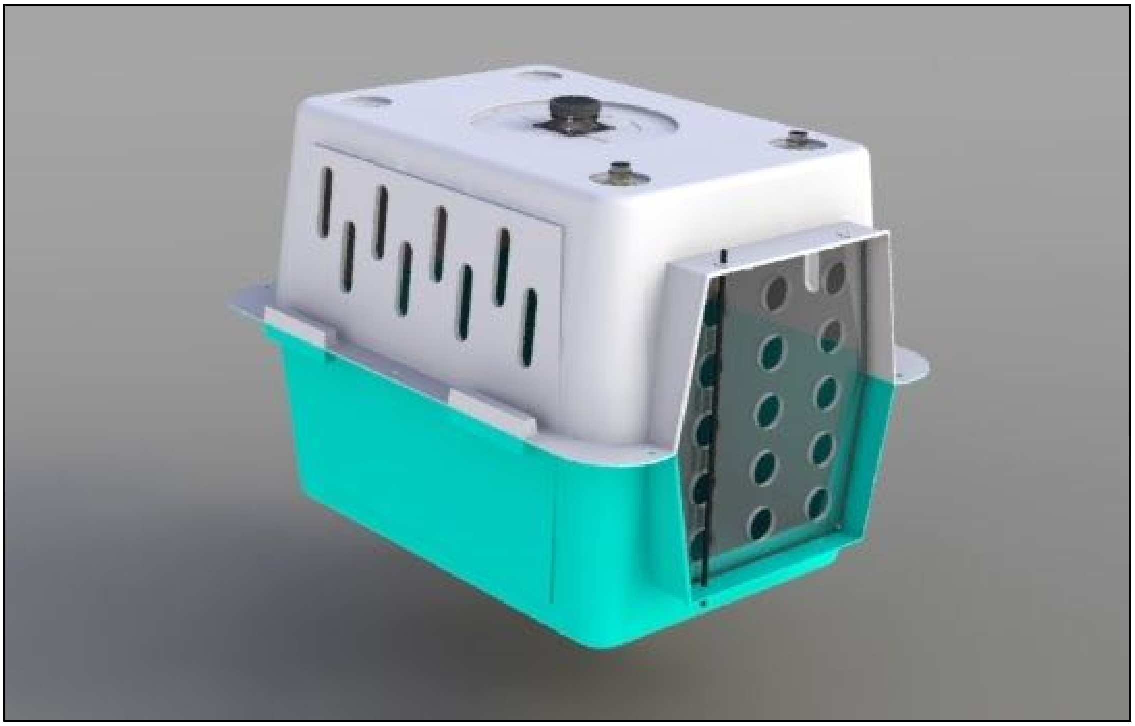

FIgure 3: Early SafeCrate Prototype Model

From numerous interviews, market research, and published studies, several key product attributes emerged which would need to be included in the MVP. Accordingly, our second prototype incorporates the following features:

Passive Noise Cancellation (PNC)
PNC technology utilizes specific material properties and acoustic design principles to dampen primarily high-frequency sound. This method ensures the best possible noise reduction from the outside to the inside of the crate and makes SafeCrate the most comforting space for distressed animals in a home. Our prototype uses a layer of high-density butyl - a material like rubber commonly used in automotive sound dampening - placed between the interior and exterior wood panels of the crate body to mitigate sound propagation through the crate walls.

Noise Masking Technology
A study conducted at Colorado State University suggests that constant and uniform audible stimulation can be soothing to animals in distressing kennel environments. Accordingly, noise masking technology can be applied to create a more acoustically-stable environment for dogs. SafeCrate features an analog white noise generator circuit to provide a constant calming sound to a pet while it occupies the crate.

Durable and Easy-Clean Interior
Anxious animals behave unpredictably. In many cases, even typically well-behaved dogs can become destructive. Some of the pet owners we surveyed reported their pet's anxiety leading to the destruction of furniture throughout the home. Additionally, a nervous animal is more

prone to accidents. Both occurrences necessitate a crate structure and interior that is not only robust enough to withstand biting and clawing, but also waterproof and easily washable. Therefore, SafeCrate features a durable hardwood body completely internally sealed by a layer of heavy-duty waterproof canvas and a floor lined with impermeable ceramic tile.

Sleek and Attractive Design
Unlike most traditional wire and plastic dog crate solutions on the market that are purely functional, SafeCrate has been designed to fit seamlessly into the modern home. Its minimalist contemporary design with crisp lines and a simple color palette makes it an aesthetically pleasing choice that will work alongside, not against, the pet owner's vision for their home.

Multiple Sizes
SafeCrate will eventually be available in Small, Medium, and Large sizes to accommodate all breeds.

Our Prototype

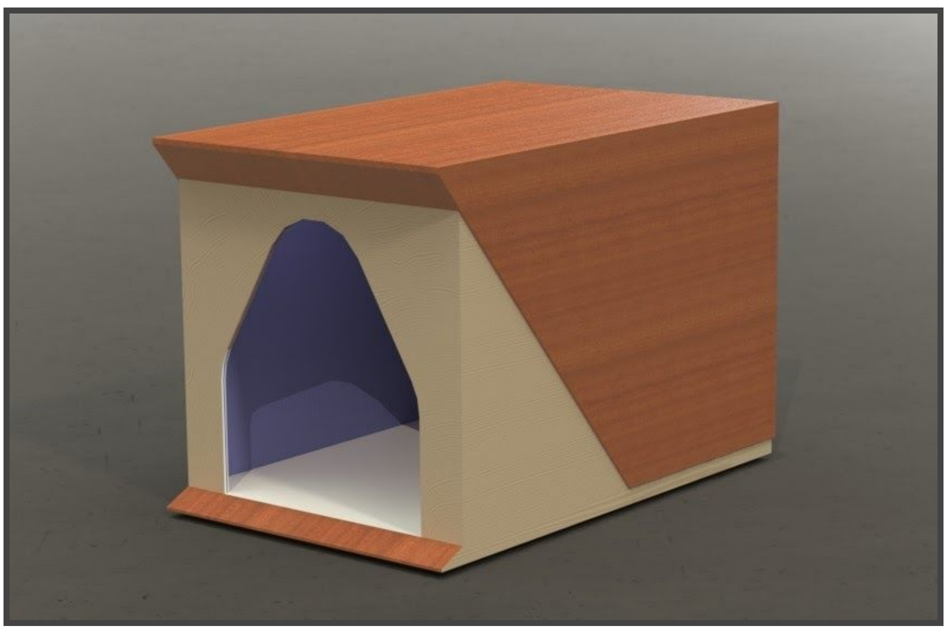

Figure 5: Final SafeCrate Design Render

Structure

Our original prototype used a pre-existing large plastic dog crate as a testing platform for the PNC body structure. The crate interior was modified to accommodate a thick layer of automotive butyl and wood paneling designed to replicate the ultimate three-layer sound dampening solution employed in the final prototype. Figure 6 depicts the first prototype. The metallic material is the protective lining for the high-density butyl.

Figure 6: PNC Testing Platform - Prototype I

Our final prototype incorporates a layer of high-density butyl between the interior and exterior wood panels in each wall and the roof of the crate. The exterior wood panel is ¼" thick, the butyl is ⅛", and the inner wood panel is ⅛". Thus, the crate walls remain relatively light and low-profile while providing excellent noise reduction. Figure 7 depicts the crate wall layering, including the protective interior waterproof canvas material.

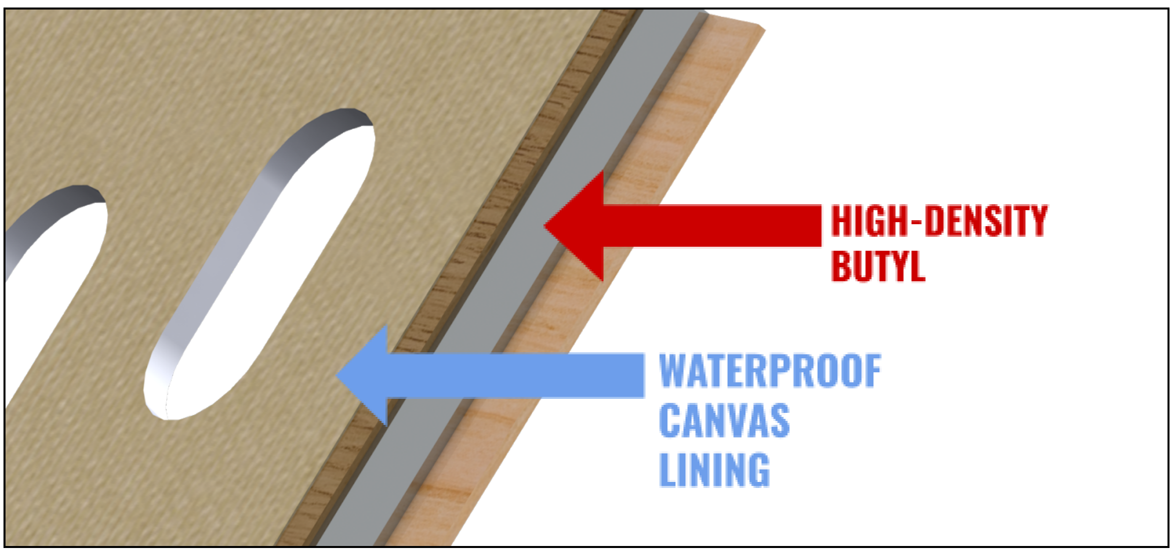

Figure 7: SafeCrate Panel Layering

Noise-Masking

For our noise-masking system, it is more cost-effective to use an off-the-shelf system for our prototype. In addition, we used an off-the-shelf breadboard power supply shown in the image below to control the amount of power going into our system. The full system can be seen in figure 8 and the circuit diagram for the white noise circuit is shown in figure 9. This system uses a reverse-biased transistor to create the white noise and while Zener diodes are typically used, transistors are known to be "noisier." The next transistor, Q2, forms a common emitter amplifier shown by how the output is leaving the emitter. The emitter follower is next and can be identified again by its output exiting the emitter. The variable resistor is used to control the volume that is inputted into what we believe is the audio driver at Q4.

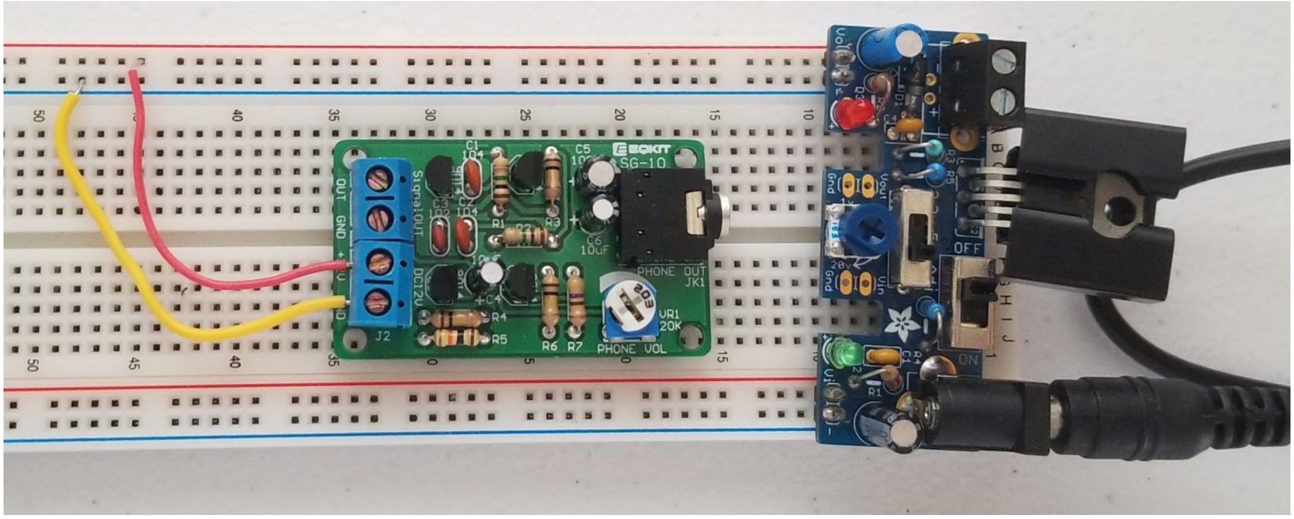

Figure 8: Off-the-shelf white noise generator and breadboard power supply

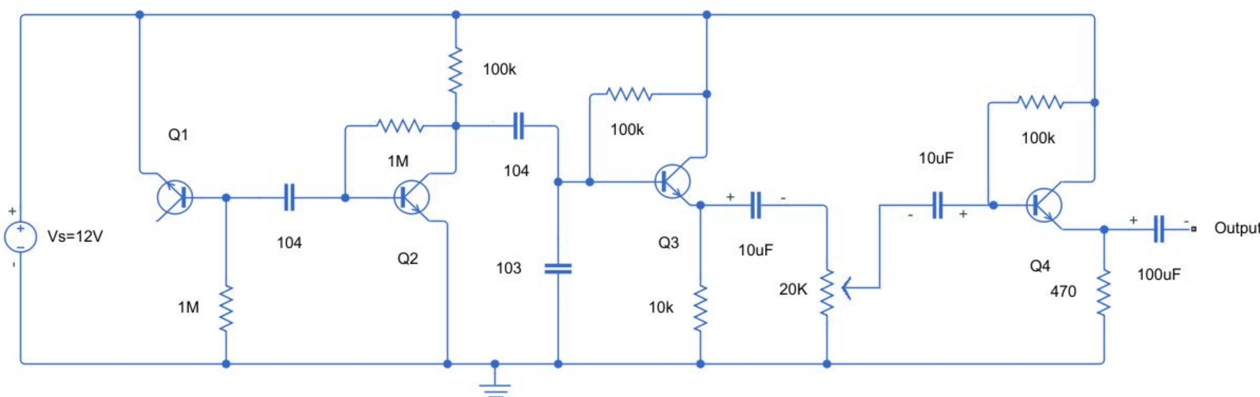

Figure 9: Circuit diagram of the white noise generator.

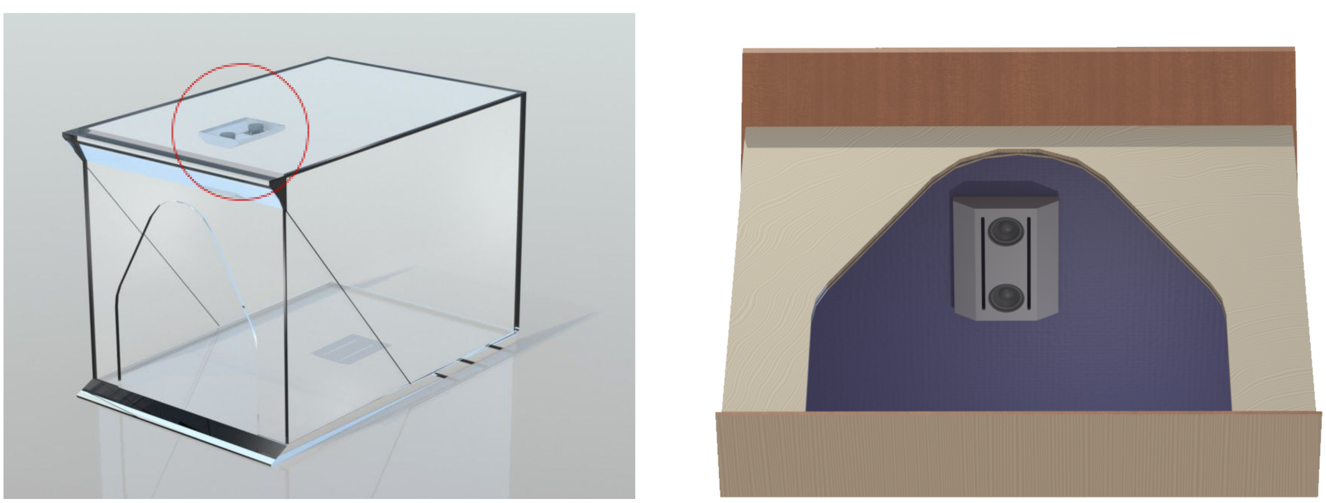

Figure 10: Housing of circuity modeled with crate. Transparent walls with electronics housing circled (left) and looking-in upward view (right)

Standards and Testing

Passive Noise Cancelation

The PNC system was tested by playing a range of frequencies and recording the decrease in sound pressure in dBa using a decibel meter. The decibel meter was placed one meter away from a speaker emitting the sound, and three sets of measurements were taken: an ambient measurement with no crate, a measurement using an unmodified crate, and a measurement with PNC material installed. The results of these tests are shown in Figure 12.

The test platform from Figure 6 was designed for and used in these tests. Had the team been able to complete the final physical prototype, this procedure would have been replicated using the completed crate. Note that the expected attenuation for the final prototype is expected to be significantly higher than the test platform, as it has more uniform and thick PNC layering.

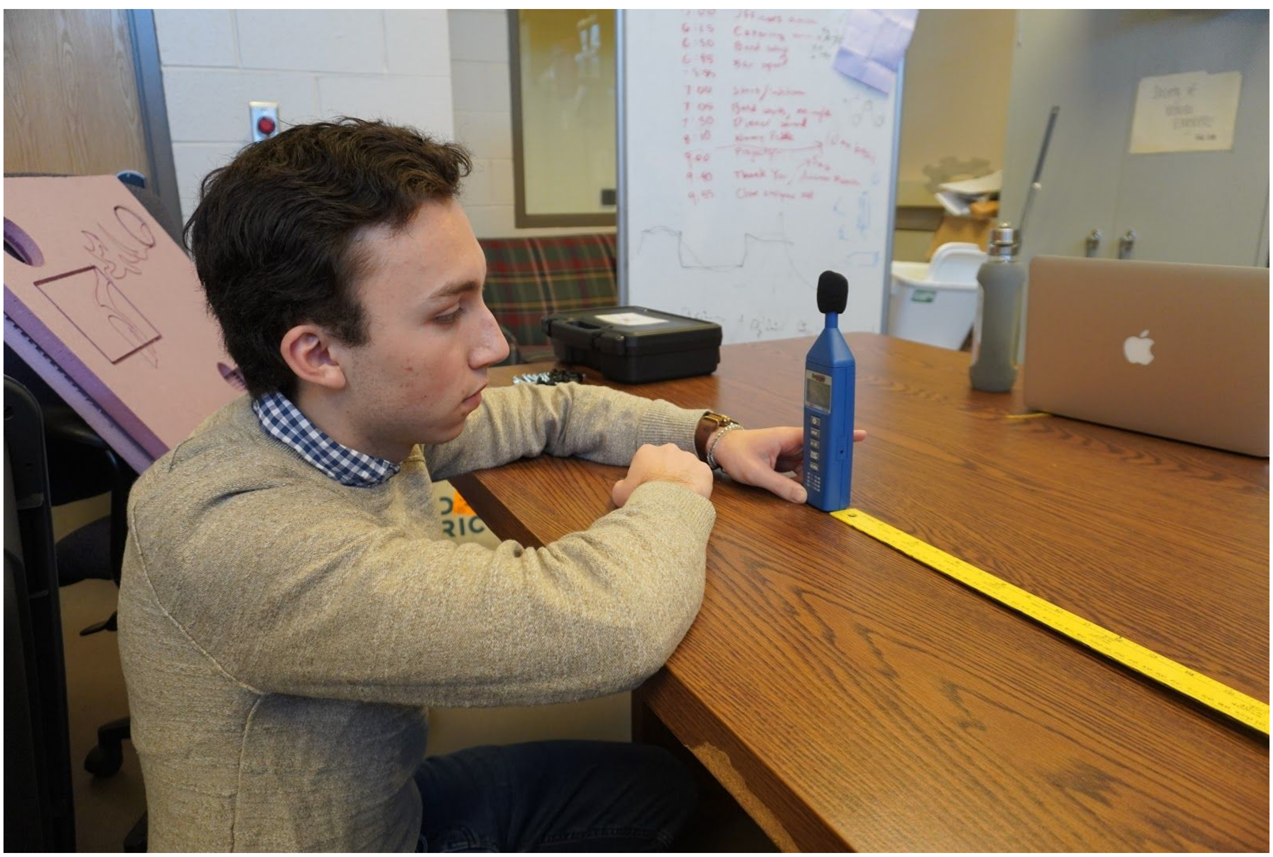

Figure 11: Phase one of PNC attenuation testing, capturing ambient data without the crate

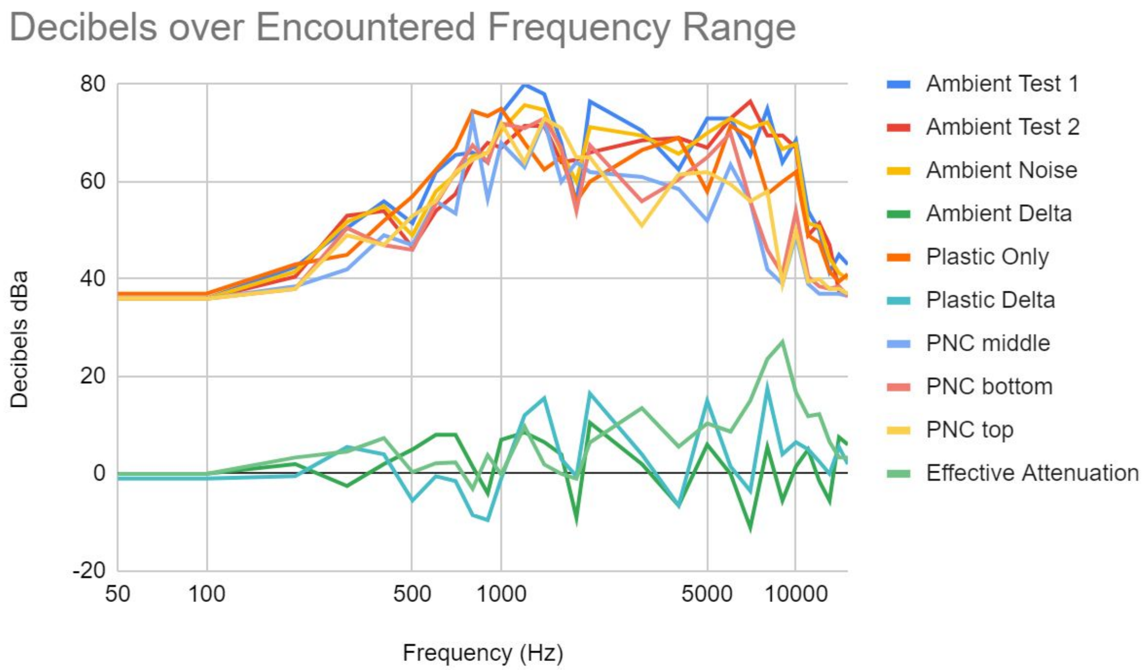

Figure 12: Over 360 manual measurements were taken manually, done in three locations throughout the crate for an averaged value. These tests were conducted three times in the same acoustic environment.

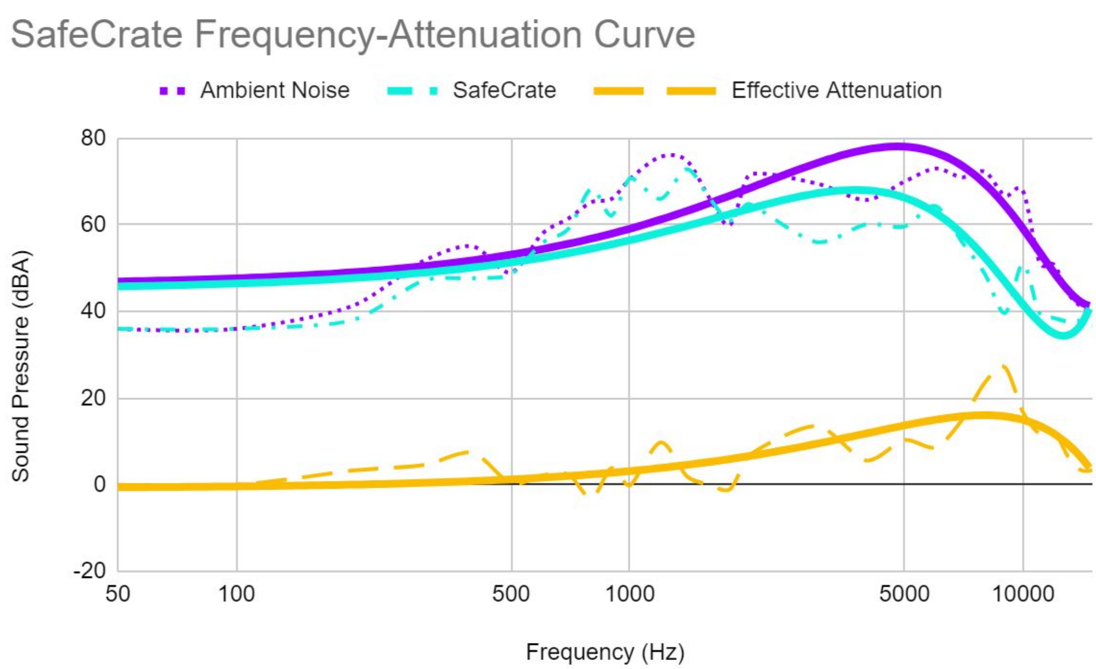

Figure 13: The PNC material resulted in a significant attenuation decibels at higher frequencies. Our PNC system reduced psycho-acoustic sensed loudness by 30.1%, and would have an EPA Noise Reduction Rating (NRR) of 29, which is on par with protective headphones found at gun ranges and in professional settings.

Our team also used acoustics software to evaluate and analyze our crate. One of these softwares is i-Simpa, a research software used to model acoustic dynamics and intensity for architectures. This software allows for the creation of geometries, sources/emitters, and the designation of point and surface receivers to record and analyze sound intensity levels. To test our crate, a model of a crate inside a room was created, and two source emitters were created to emulate speakers and the input of other noise into the room and house and the decibel levels were recorded using surface receivers on the walls and the surface of the crate. This information is helpful, as it can direct our efforts to attenuate certain frequencies and understand sonically vulnerable sections of the crate.

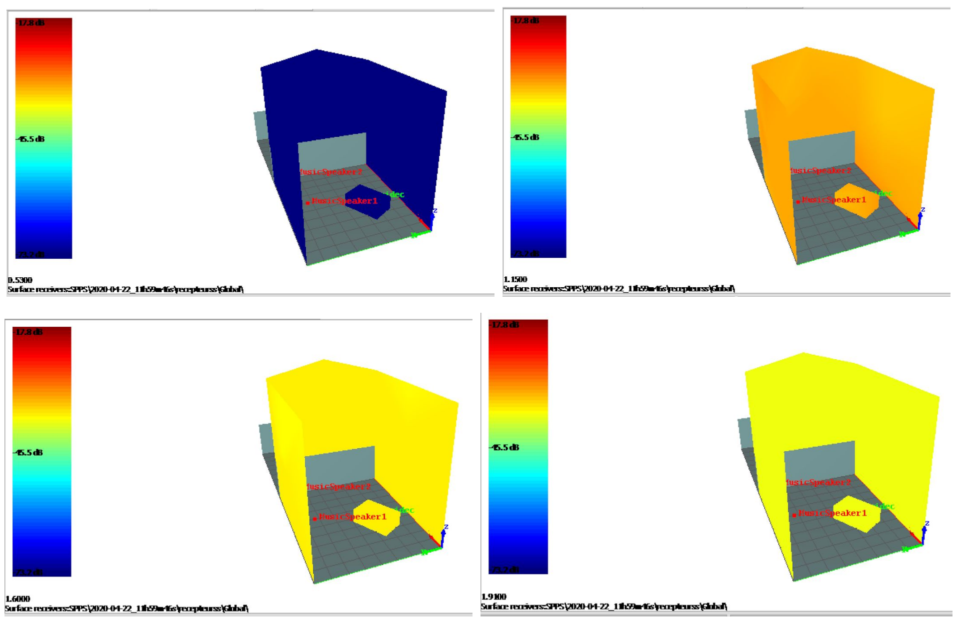

Figure 14: i-Simpa model of crate in room with active speakers over a 2s time interval, with snapshots at .53s. 1.15s, 1.6s, and 1.91s. A short burst of multi-frequency sound was emitted from the speakers with the change in decibel level visually represented using color.

Active Noise System

Before we pivoted to noise masking using a white noise generator we were attempting to create an active noise cancelation (ANC) circuit, however, we found from testing that this system was not up to par with our team's standards. Figure 15 shows the circuit diagram of this ANC system and in prototype 1 we did meet our goal of inverting the soundwave, however, we were not able to find any noticeable attenuation.

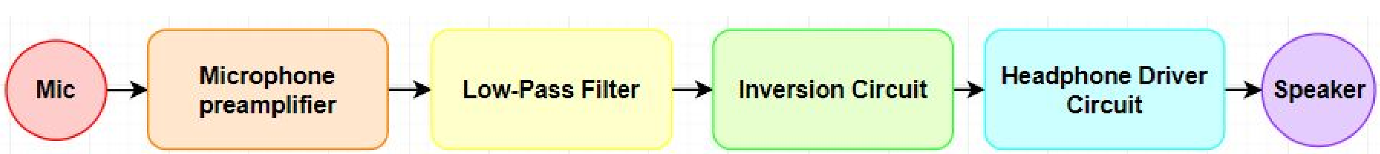

Figure 15: Block diagram of ANC system

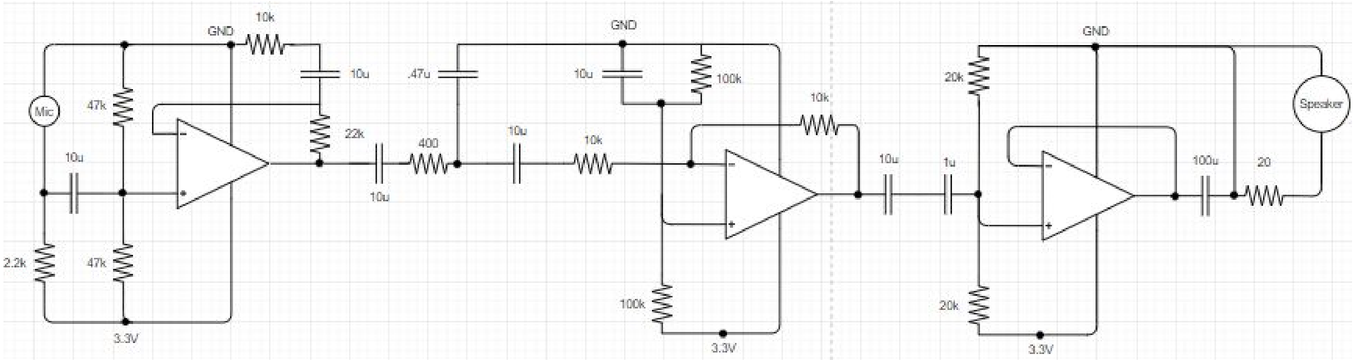

Figure 16: Circuit diagram of ANC system

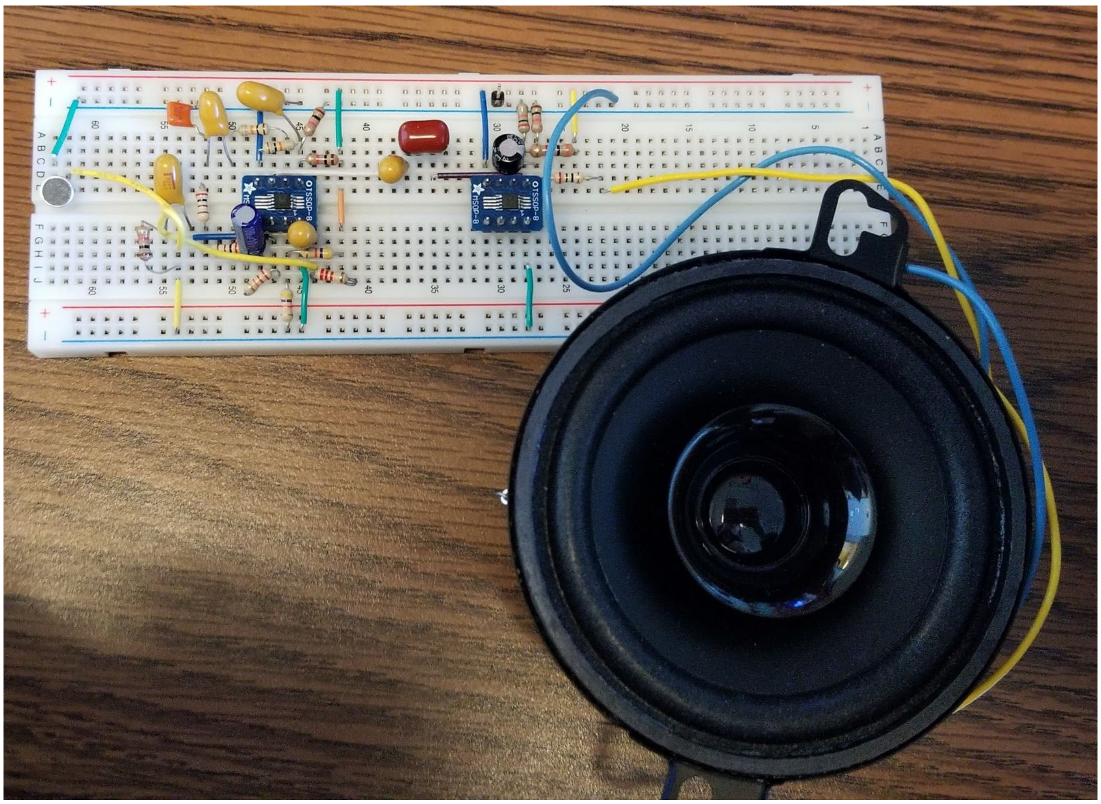

Figure 17: ANC system breadboarded with 3" cone speaker. Note: breadboard power supply was not included in this image

To test whether or not our inversion circuit was inverting the soundwave, we isolated the circuit and used an Analog Discovery 2 to feed in a sine wave as the input (blue) and compared it to the output (orange). The result of this test is shown in the figure below. As seen there is a .087 ms delay because of the time it took to invert the signal. Additionally, you can see a slight drop in altitude caused by the resistance in the circuit. These two faults can cause the system to be less effective but, in theory, it should still flatten the wave so we continued with testing the full system.

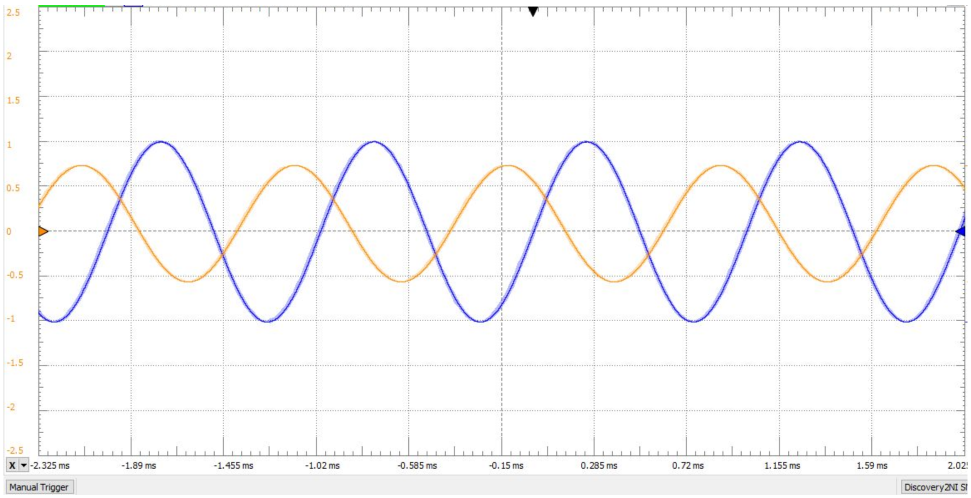

Figure 18: Inversion circuit of a sine wave shown with an Analog Discovery 2

We continued with testing the full system shown in figure 16, by playing certain frequencies into the microphone and looking for noticeable attenuation. One issue we had is that the sound output from the speaker was very quiet and increasing the gain caused a lot of audible feedback. One solution was increasing the voltage applied to the load (speaker), however, the operational amplifiers (op-amps) became a lot more unstable when were using the maximum voltage. Additionally, the input wave had a DC offset because we were viewing the output of the microphone directly and so it was shifted to so we could compare the waves better. However, this also demonstrated that the DC offset also increased at a higher voltage meaning it was also having other negative effects of the circuit.

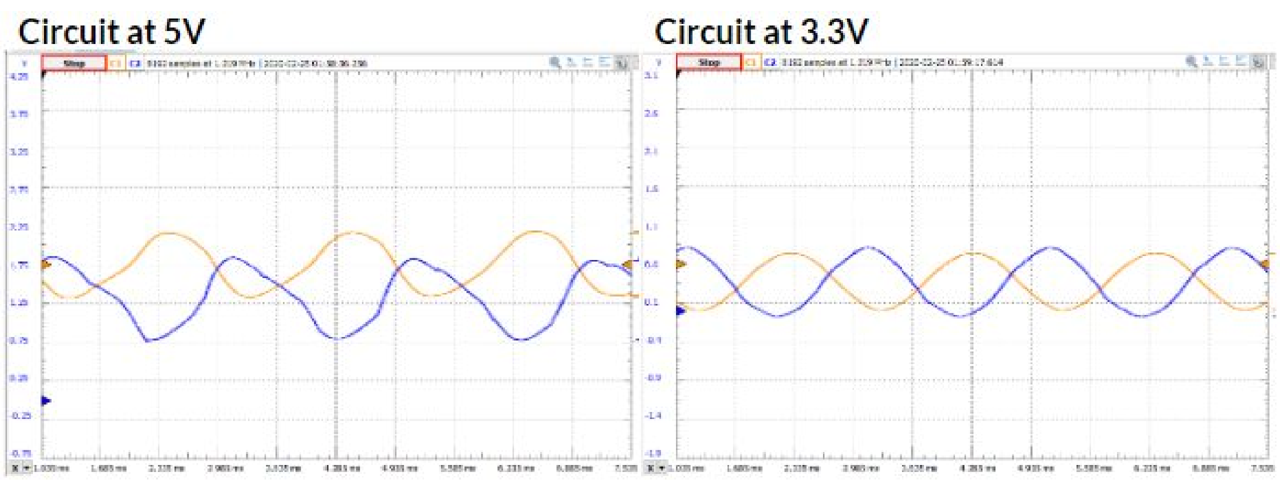

Figure 19: Input versus Output of ANC system at 5 volts compared to 3.3V. The results showed that using the op-amps at their max voltage causes a lot of distortion. Note: There was a DC offset on the input because we were using the AD2 to directly view the output of the microphone, the waves were moved to see a clearer comparison.

This could be fixed by adding in circuits to step down the voltage going into the op-amps, however, while doing more research we found a better solution to our problem and that was noise masking. More about why this is a good solution for dogs can be found in the "Solution" section. While we haven't tested our system within the crate or have been able to conduct any customer tests yet, we are still confident in our solution. The system was run from a consecutive 4 hours, without any degradation of the signal.

Customer Feedback

Concerns

- Dog adapting to the crate
- Sensory deprivation (response before pivot to active noise canceling)
- Weight of product

Requested Features

- Lighting
- Fans
- Viewing window for the dog
- Divider panel to adjust the size of crate

Our Team and Our Product

Our Team

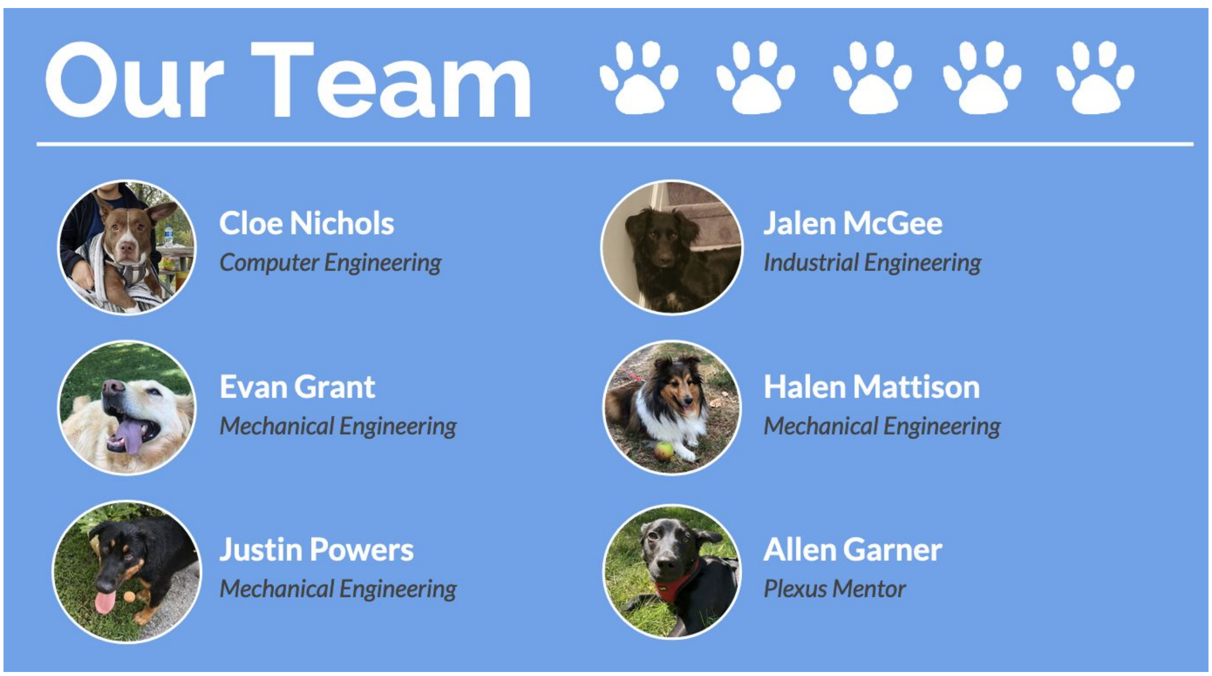

Figure 20: Our team came from a variety of engineering disciplines, but most importantly, we're all dog-owners

Final Product

Figure 21: Final render of SafeCrate in combination with casing and white noise generator

Journal Entries

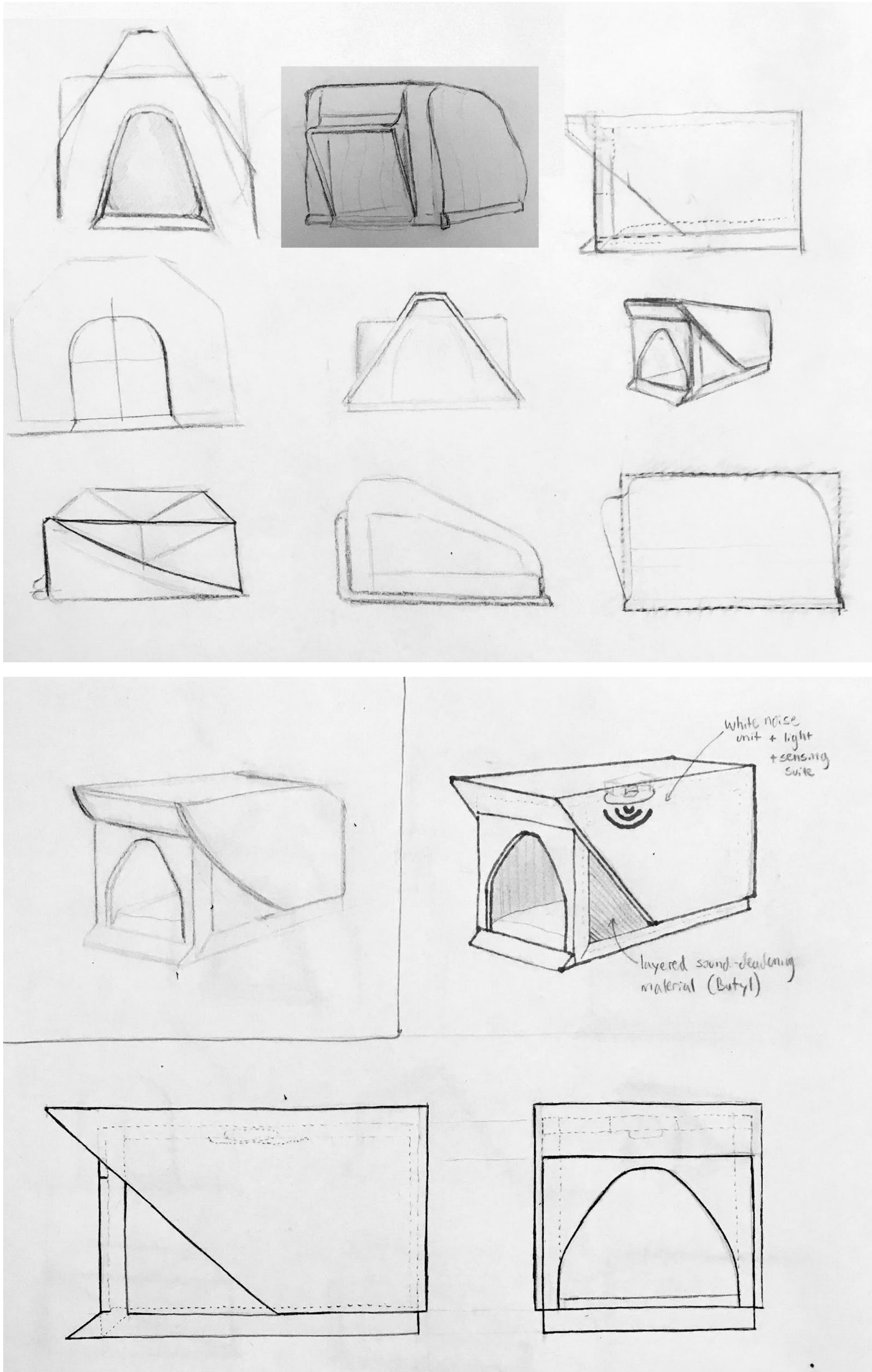

Figure 22: Journal entries of early sketches to the final sketch of SafeCrate's structure

Progression

Figure 23: Creating preliminary prototype used in the Kickstarter video

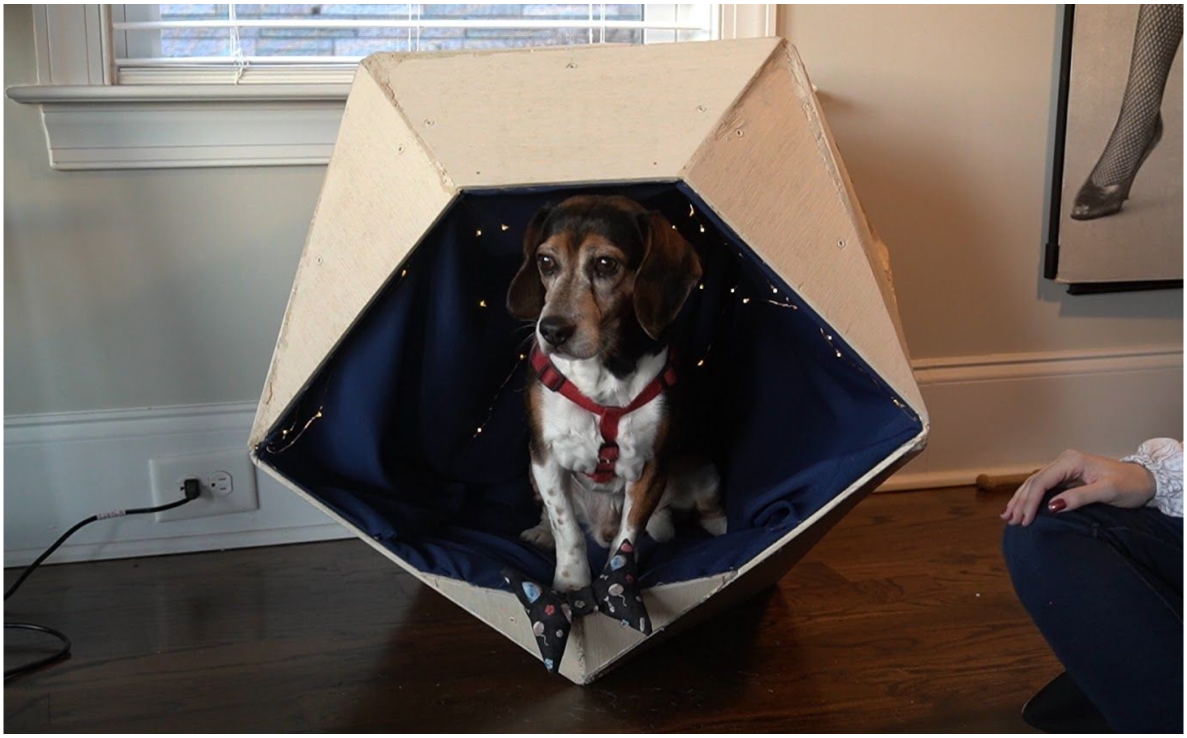

Figure 24: Informal pet testing of preliminary prototype during Kickstarter video filming

Complications

Active Noise Cancelation

Our team had an issue with completing our original goal of creating an active noise cancelation system. Our testing showed that it was not effective and it would be difficult to fix. We solved this issue by pivoting to noise masking with white noise, which has already been shown to help dogs with anxiety. This solution was more effective and was achievable for our team.

Creating a Physical Final Prototype

After on-campus labs were closed it became less achievable to create a physical product. As detailed in our continuity plan we decided to transition to completing this project in a virtual manner. This would allow our team to complete our parts separately with our available resources.