Fall Final Report

Team 6

Design of a Less-Deafening Hair Dryer

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ABSTRACT

There is a fundamental problem with the current design of many hair dryers, which is the fact that they produce an unappealing amount of sound during use. This present endeavor will seek to design a hair dryer that is quieter than what is currently in the market and just as effective, while also maintaining low cost of manufacturability. Optimal results to this project will include a working prototype, as well as a business plan for marketing and commercializing the product. In order to reduce the sound produced, Team 6 will target and aim to improve the loudest noise sources that are currently in hair dryers. The significant noise sources are found to be a combination of the fan and its intake, the fan flow over internal components and the motor operation. Many of the project constraints were chosen in order to maintain consistency with the current market for hair dryers. Some design concepts are presented along with a Gantt chart that contains future tasks for the project.

1. Introduction

Hair dryers are an easily found appliance in countless homes across the country. Currently the average hairdryer produces a sound level that is bothersome, invasive and harmful. Some examples include salons where hair dryers are constantly in use producing excessive noise pollution, or the case where someone is sleeping in close proximity of someone needing to dry their hair. The average hair dryer also produces a sound level that can be threatening to one's long term hearing with prolonged use. Being that there is this inherent problem associated with the current hair dryer, it offers a niche in the market for this project to fit a need. A solution that would be deemed fit is to be able to offer the same amount of power output, while reducing the noise that it produces compared to current hair dryers in the market. This project also asks the group to analyze the entrepreneurship aspect and to generate a product that is suitable for the current market by creating a device that meets safety regulations, provides equivalent drying quality, and also is quieter. With this in mind, all design aspects must be made to ensure the product can easily be transferred to the market and be mass-produced inexpensively.

This assessment will begin with some background on the current state of hair dryers, where the current noise sources come from and information on components critical to the design. The needs of the project and design goals will be clearly stated to give an idea of what we would like to accomplish in this project. Major considerations for which the designs will be based off is presented in the form of a house of quality; this shows what is important to the customer as well as what the important engineering characteristics are. Methodology of the design will look to incorporate methods to reduce noise output. Major components of a hair dryer are analyzed, along with technical specifications and a functional analysis. This will transition into the presentation of some concept designs. A Gantt chart is created in order to set the plan for the project moving forward and keeping with the schedule.

2. Project Scope

2.1 Background Research

Hair dryers are one of the most widely used hair-related instruments, seen in both personal and commercial environments with the purpose to style and dry hair quicker. Their primary use is to speed up the time that it takes to dry hair. In order to make hair dryers perform efficiently, their heating elements and air flow rate must be extremely effective. However, this causes one big problem: the level of sound created by the hair dryer. It has been observed that people are unhappy with the noise that is associated with using a hair dryer. The typical hair dryer produces anywhere between 80 - 90 decibels [1]. This not only creates an unpleasant experience for the user of the hair dryer, but also can produce undesired noise to the surroundings of both business and personal settings. Many sources cite that noise-induced hearing-losses begin at the sound level of 85 decibels [2], thus making the average hair dryer detrimental to ones hearing over time. The range of noise levels generated with different hair dryer designs vary greatly based on the design. The causes of the sound come from a plethora of sources. Some of these include the fan intake, vibrations from the motor, and turbulent flow over internals components. The measure that is used to quantify the acoustic power of the sound produced is the decibel (dB).

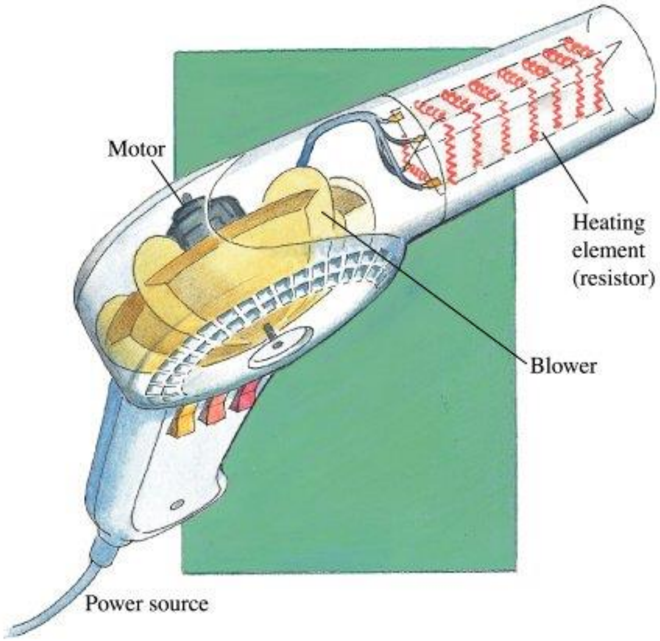


Figure 1: Breakdown of a Simple Hairdryer

A hair dryer is a simple electromechanical device; some basic parts are shown on the left (Figure 1). It begins with a power source that reaches a motor to power a fan device that forces air over hot wiring, thus producing a hot stream of air. The heat is generated by passing a current through the wires where the resistance is high, then subsequently pulled away by the air forced over it. This means of heat transfer is called *forced convection*. The progression of the handheld hair dryer design has been happening since the 1920's when the first of its kind was invented. Over the years, its design has changed to a lighter, safer, and more powerful device. Most of the safety measures include mechanisms that are connected to the circuitry that kill power if something that isn't supposed to happen. These protect against water immersion as well as a sudden fan stoppage; both cases will cut the power to the device.

The main mechanical component of hair dryers are the motors and device that moves the air. Most models use either a DC or an AC motor to rotate the fan component. It is observed that more expensive and quieter designs use an AC motor even though a DC motor weighs less. Typical hair dryers run on 6-24 volts and operate around 6000 rpm. The DC-type motors have two varieties: brushed and brushless. Brushed DC motors typically provide more torque than the brushless counterpart, while both have a higher torque output compared to AC motors. The AC motors have a much longer lifespan compared to DC, making them more desirable to be applied to a consumer product. As for the device that the motor powers which moves the air thru the hair dryer, some common ones seen are axial fans and impellers shown below (Figure 2). All of these designs are protected by an inlet cover to prevent objects from reaching the moving parts. The axial fans are the most common types in hairdryer designs and it works by pulling air thru, parallel to the shaft. The radial impeller on the other hand takes air in, then ejects it in a manner that is perpendicular to the inlet [3][4].

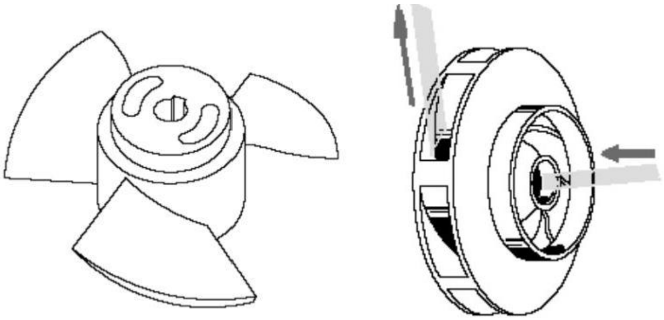


Figure 2: Axial Fan and Radial Impeller

Performing a review of literature of cases where tests were performed to target and improve the noise output of hair drying devices showed helpful in better understanding the problem. Akehmetov et al. [5] examined the noise source ranking of a hair dryer. They focused on using microphone array measurements in a semi-anechoic chamber to record the sound pressure level at distances comparable to those encountered during use. They tested two hair dryers: one normal and one marketed as "quiet". Tests were performed measuring the SPL during operation. They quantified various noise sources by isolating various sound sources by removing components, then measuring again. This included the intake and outlet grill, an air filter and the heating element. Results showed a decreases in SPL for removal of components. An observation they made was for the quieter hair dryer; there was acoustic treatment applied to the interior. Shen et al [6] sought to enhance the performance and the noise of the hair dryer though improved designs to the inlet cover, fan rotor, and stators. They were able to achieve a 9 dBA level of noise reduction while maintaining the same volume flow rate.

This problem of noisy hair dryers has been taken by multiple companies (one of these being Revlon) to produce a “quiet” hair dryer. The “Revlon RVDR5045 Quiet Pro Ionic Dryer” was claimed to be 50% more quiet than the leading brands [7]. Another device is the “Centrix Q-Zone” hair dryer, and it is said to produce roughly 10 less decibels than its competitors [8]. The other is the “Envy + Onyx” made by Velecta-Paramount, which is said to produce only 64 decibels, but with its higher price tag of $300 and its production in Paris, it is not as popular as other models. [9] Both companies suggest that their products utilize advanced noise-cancelling technology. Unfortunately, these companies do not give much more insight into their design improvements as to protect their trade secrets.

2.2 Needs Statement

Existing hair dryers are too loud. Currently, the average hair dryer on the market operates between 80 and 90 decibels. This type of noise can be damaging to one’s long-term hearing and also cause unwanted disturbances to the user’s environment. Currently, the top-performing and quiet hair dryers on the market are upwards of $200. This creates a need for a hair drying device that is both quiet and effective, while also remaining at an inexpensive price point.

2.3 Goal Statement

The goal of this project is to design and build a working prototype of a hand-held hair drying device that significantly reduces the noise output compared to that is currently available; it must also be roughly equal in its effectiveness of drying hair. Along with designing a quieter device, a business model of the manufacturability and marketability of the current design will be done. Ultimately, the final package submitted will include both a working prototype, as well as this in-depth market study.

2.4 Constraints

Team 6 was set with only two restraints: the device needed to be quieter than current hair-dryers, and that the budget for this project is $1500. The product is also being designed for the market, therefore there will be additional constraints, such as being manufacture-friendly and affordable. Some aspects of a hair-dryer design have become a "norm" in most user's experiences. Although, in this case, the user expects a safe and effective heat output, a light-weight product, and an inclusion of all standard safety measure. These, along with other constraints and needs that Team 6 deems necessary, will be listed below to give an overview of where the design is bounded.

- Budget of $1500, yet can be extended with special permission
- Noise generated less than 70 dBA
- Must weigh less than 1.5 lbs.
- Heat of exposed parts may not exceed 115^{o} F
- Have maximum size dimensions less than 10 x 10 x 4 inches (length x height x width)
- Insulation and casing needs to be melt-resistant at any usable temperatures
- Safety components, must include ground fault circuit interrupter for immersion protection

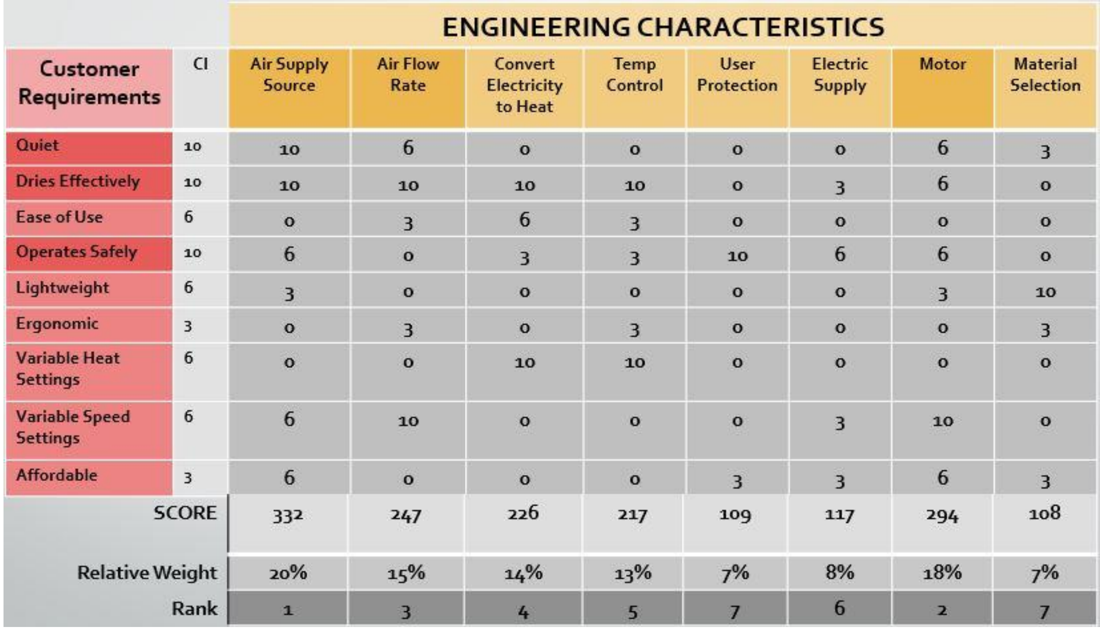
Elaboration on some key constraints will be given below.

- Budget – This budget will be used for the prototyping and testing of the device.
- Noise Output – The team evaluates a "quieter" hair-dryer constitutes a sound output of less than 70 dB.
- Weight – The device should not cause struggle or be uncomfortable to hold during use.
- Temperature Output – The device must be limited on the heat that it can produce to ensure safe use and no burns occur.
- Size – The size of the design should be similar to current products on the market due to a "norm" associated with current hair dryers.
- Safety – Certain safety measures are required to be incorporated in hair dryers based on regulations from the Consumer Product Safety Commission. This includes a means to prevent electrocution from immersion in water [7].

3. Methodology

Team 6 will aim to produce a device that is effective at drying hair and is not unpleasant nor damaging to ones hearing during use. Starting any project from scratch requires a lot of foundation-work and background research in order to determine the best possible method of moving forward. The team will need to determine the type of technology that is used in current hair-dryers, as well as other plausible technologies that could be integrated. The reverse engineering of hair-dryers will also aid in understanding the intricacies of these devices. Other topics of interest to study that will help in design include air flow using fans, acoustics and circuitry. The main focus in reducing sound from the device is to target the highest source of noise; this will be the most effective means at reducing the overall sound produced.

Team 6 constructed a House of Quality diagram (Figure 3) in order to determine the most important customer requirements for the product, as well as the engineering design characteristics, that are most significant. This is important for the team to effectively design around the things that make for a better product. Research that has been done was incorporated into its conception [10]. The top customer requirements were that it must be quiet, dries effectively, and operates safely. The highest ranking engineering characteristics were the air supply source, the type of motor and the speed of the output flow.



		ENGINEERING CHARACTERISTICS							
Customer Requirements	CI	Air Supply Source	Air Flow Rate	Convert Electricity to Heat	Temp Control	User Protection	Electric Supply	Motor	Material Selection
Quiet	10	10	6	0	0	0	0	6	3
Dries Effectively	10	10	10	10	10	0	3	6	0
Ease of Use	6	0	3	6	3	0	0	0	0
Operates Safely	10	6	0	3	3	10	6	6	0
Lightweight	6	3	0	0	0	0	0	3	10
Ergonomic	3	0	3	0	3	0	0	0	3
Variable Heat Settings	6	0	0	10	10	0	0	0	0
Variable Speed Settings	6	6	10	0	0	0	3	10	0
Affordable	3	6	0	0	0	3	3	6	3
SCORE		332	247	226	217	109	117	294	108
Relative Weight		20%	15%	14%	13%	7%	8%	18%	7%
Rank		1	3	4	5	7	6	2	7

Figure 3: House of Quality

Once sufficient background research is done, the team will progress to testing of the components and creating conceptual designs where multiple ideas will be implemented. A hairdryer that is currently on the market and advertised as a quiet hair dryer was purchased and reverse engineered. The team will look to use parts from the purchased hair-dryers in order to reduce prototyping costs; other needed parts will be ordered once designs are finalized. The main components that will be recycled from the purchased hair dryer are the electrical components. The reason for this is that they are very universal in many hair drying devices and do not contribute to the noise produced.

3.1 Schedule

The group's work breakdown structure can easily be viewed in the created Gantt chart listed in the appendix of this report. It contains the tasks that are upcoming in the project plans and the where the team is in the current design process.

3.2 Resource Allocation

There are multiple current resources utilized by the group. The first of which is the internet; the group has used this resource in order to obtain and cite publications that are oriented toward the disassembly/assembly and component-comprehension of the hair dryer. The group's secondary resource is their appointed advisor. This individual provides technical supervision and motivational support for the group; his job is not only to provide assistance with possible issues, but also to point the group in a reasonable direction. A ternary resource would be the use of the anechoic lab in the AME building. This testing location will allow the group to perform necessary sound-quality tests of the hair-dryer in a quiet environment. The final resource (the most viable resource) are the actual group members. Mark Johnson is not only the team leader of the group, but also is the individual who delegates tasks to other members, maintains the quality of the group's overall activity and progress, controls the schedule of events, edits final reports, and provides technical engineering support toward the production of the group's project. Peter Van Brussel is the person in charge of financial expenditures, provision of detailed measurement tools, webpage design leader and assistance in technical fluid-dynamics knowledge. Kiet Ho is responsible for providing expertise as one of the two lead mechanical engineers in computer aided drafts and designs for the hair dryer; he also is responsible for including the mathematical support which correlates to the information created and tested via CAD, Matlab, Mathcad, or any other useful software programs. Shawn Eckert is the other leader in engineering designs, but is not limited to just this task; he is also responsible for maintaining communications between the group and the sponsors/advisors/instructors. Nevertheless, each individual in the group is not limited to their specified tasks; all students will provide assistance to each other as needed.

4. Design and Analysis

4.1 Functional Analysis

Within a hair dryer, there are numerous components; some of which are mechanical, while others are electrically-based. Eventually, these components will be integrated into a single electromechanical device. Each of these parts are listed below.

- Impeller
- AC or DC Motor
- Motor-to-Fan Transmission Shaft
- Motor Vibration Housing
- Fan Speed Switches
- Device On/Off Switches
- Sound Dampening Material
- Heating Element
- Inlet/Exit Grill Covers
- Air Filter
- L-Shaped Housing Unit

The majority of the previously listed components are dependent on the overall final prototype design, however some components may be altered, replaced, or removed in order to achieve the goal of producing a less-deafening hair dryer.

With respect to the most important factor in decreasing overall sound pressure level, the impeller at the inlet must be observed. Generally, typical hair dryers contain an inlet grill with an air filter; both of which are utilized for safety purposes. Based on research regarding the determination of noise-source ranking in a hair dryer, the inclusion of an inlet grill and an air filter produce an overall sound pressure level of approximately 99 decibels. By further removing the grill, would reduce the previous tonal noise level by 4 decibels. Furthermore, by also removing the air filter would decrease the sound pressure level by an additional 7 decibels. These results indicate that the addition of grills, air filters, etc., in the path of the flow increase the noise considerably and innovative means to reduce their noise or alternate quiet means to provide their functions need to be implemented [11].

With respect to that actual impeller, the component needs to be designed to not only provide a fully-developed flow through the exit of the hair dryer's nozzle, but provide air to the motor. A proper impeller-housing unit that mutually functions in such a fashion has yet to be fully determined by the group.

When observing noise near the exit of the nozzle, it exhibits broadband behavior; this is where the sound pressure fluctuations are non-periodic in nature with relatively random phase and amplitude [12]. If one were to imagine an axis running through the center of the exit of the nozzle, and angularly deviate from said axis between 20˚ - 90˚, one would find that the overall sound pressure level of such noise is predominant the less one deviates from the axis; an image describing this can be found below (Figure 4) and its results can be located ahead as well (Figure 5). Therefore, the shape of the nozzle, along with the components which cover or surround the exit of the nozzle must be arranged and oriented in a fashion as to reduce such effects.

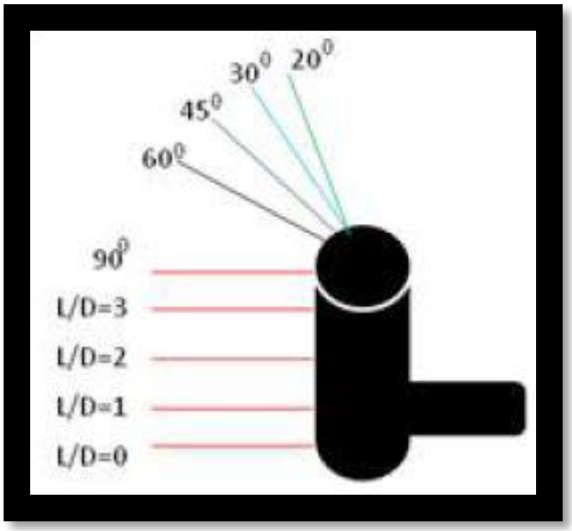


Figure 4: Image of positional angular and non-dimensional measurement locations of hair dryer

When considering the OASPL of the use of grill covers for both the inlet and exit of the hair dryer, one should notice that its application (Figure 5) actually has an increase in sound pressure versus not utilizing a set of grill covers. However, the use of grill covers is necessary for the protection of the user; a user should not have easy-access into the main housing of the device.

One possible solution to reducing sound pressure levels of said grill covers would be to design the grill covers with a wedge-shaped wiring structure, i.e. the wiring spokes would be triangular in shape with the pointed-end facing the inside of the hair-dryer, while its flat base faces the outside of the hair dryer. If the angle of the triangular-shaped spokes is oriented at 45˚, extra unwanted noise can be potentially deflected away from the user's ear; prior research has shown that at a 45˚ angle from the center axis reduces the overall sound pressure level by approximately 5 decibels with respect to the results displayed from a 20˚ angle.

With regards to the housing unit of the hair dryer, the overall design has a major impact on sound pressure level output. For example, by designing a hair dryer whose length from the inlet to the exit, divided by the diameter of the nozzle is equal to a non-dimensional value of 3, would decrease the impact the overall sound pressure level. Based on research regarding non-dimensional results from lengths divided by diameters, ranging from 0 to 3, the overall sound pressure level decreases as the length over the diameter is increased; this can be found below (Figure 5).

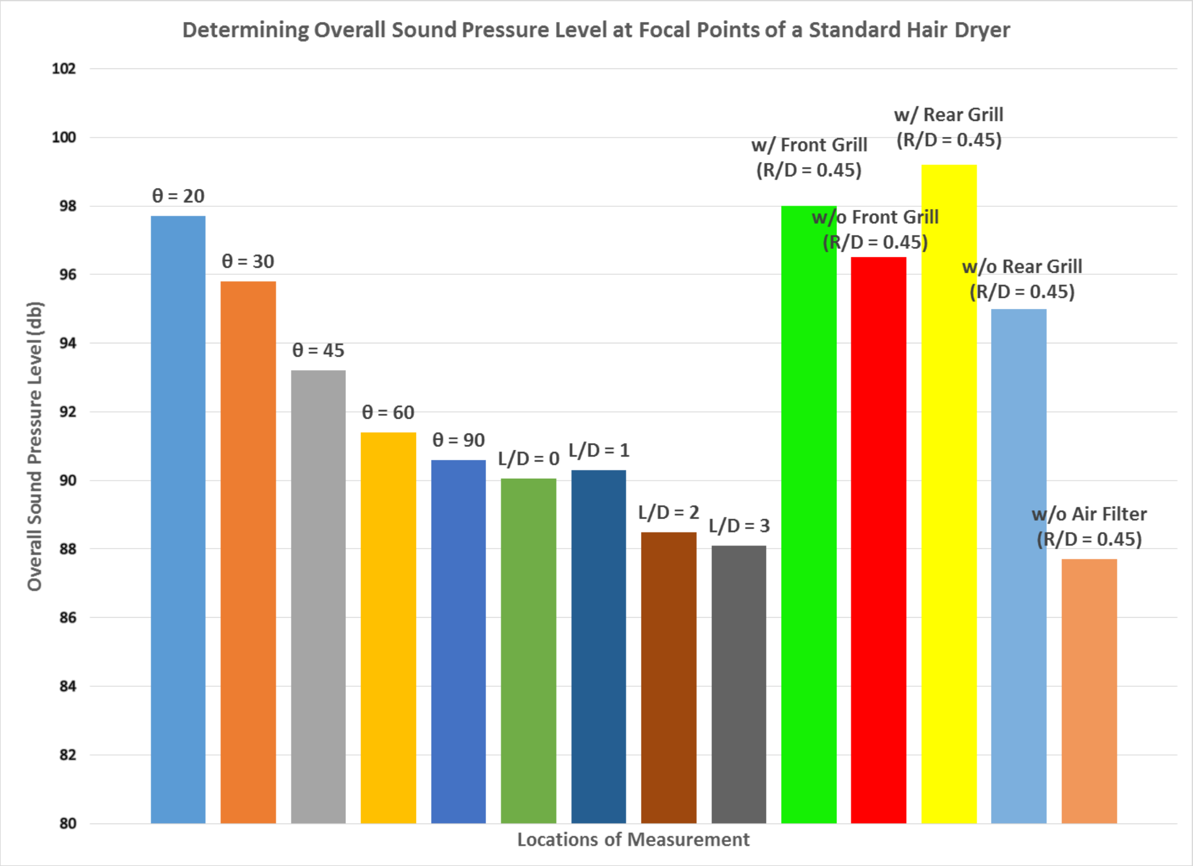


Figure 5: Bar graph for determining OASPL of different locations of hairdryer

Another aspect of the hair dryer's housing unit that affects pressure output is its overall shape. One may notice that the majority of hair dryers have a typical "teardrop" shape, with the wider end originating from the inlet, then decreasing in width toward the nozzle. This shape resembles that of a Helmholtz resonator. According to previous research, the resonant frequencies are inversely proportional to the volume of the Helmholtz resonator, and the increase of the volume results in a decrease of the resonant frequency [13]. Therefore, theoretically speaking, increasing the volume of hair dryer housing unit where the fan resides (in the cavity), has an overall decreasing output of resonant frequency; this ultimately reduces the pitch produced from the hair dryer, and provides added comfort to the user. Unfortunately, the blade passing frequency tuned-in from the resonator is directly proportional to the speed of the fan, which is directly coupled to the speed of the motor to which the fan is mounted [14]. Also, the speed output of the motor has to be tuned properly because the Helmholtz resonator is only effective at a small bandwidth; this may be determined via future testing.

Another important addition to the internal region of the housing unit is the implementation heat-resistant acoustic liners; these should either be placed near both the inlet and outlet, or throughout the entire interior of the housing unit.

With regards to the design/selection of motor implementation, the primary source of noise for DC motors generally results from vibration. According to a study of DC motor noise sources, shaft bearings can cause vibration and noise due to misalignment, improper lubrication, loose bearings, and high friction sintered bearing material [15]. Therefore, the group needs to design a more effective structure of the motor casing, and to also effectively ensure that the shaft which connects the motor to the fan is properly secured and adjusted to reduce vibrations.

4.2 Part Selection

4.2.1 Motor

The possible motor choices for the quiet hair dryer are a brushed dc motor, brushless dc motor, and an AC induction motor. Out of the three, only one motor will be chosen for the final design. To start the process, a great deal of background research was conducted to determine the basics of each motor, and from there an engineering-characteristics table was created (Table 1), as seen ahead.

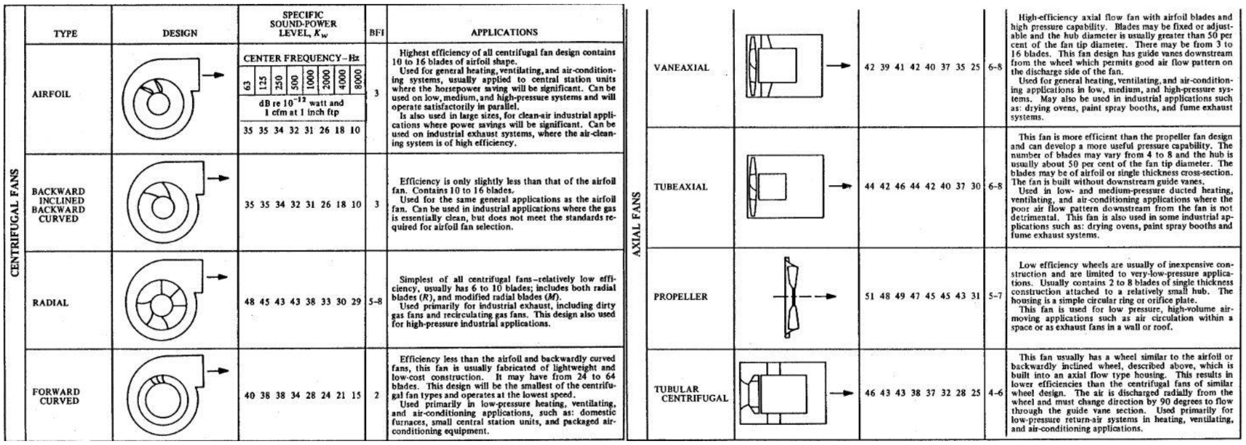
Table 1: Engineering Characteristics of Motors

Engineering Criteria	Motors		
	Brushed DC	**Brushless DC**	**AC Induction**
Price Range($)	8-10	69-120	69-124
Voltage(V)	12	12	110 - 120
Life Length (Hours)	2,000 - 5,000	20,000	40,000
Weight (lbs)	0.18-0.2	0.25	1.65-2.31
Rpm	5,000 - 6,000	3,000-4,000	1,500 – 1,800

From the choices above the most cost-effective motor would be a brushed DC motor because Team 6 has in its possession 5 different brushed dc motors that could be taken from the purchased hair dryers. However, the most silent of the motors would be the AC induction motor, but the downside to this motor selection would be its high weight, and also it would need extra controls to convert DC power to AC, therefore creating an extra task that Team 6 is not capable in handling. The same can be said about the brushless DC motor; it may be lighter than the AC induction motor, but it would also need some circuitry work done to change the DC power to AC power. Once again, Team 6 is lacking in detailed circuitry knowledge, such that this task may prove to be more difficult to apply when trying to make the final product "safe". Though both brushless DC and AC motors are better in performance, the debate between motors is still in progress. However, regardless of the motor choice, a sound detuning-casing will be created for the choice motor to stabilize, as well as vibration control the motor will produce.

4.2.2 Fan Housing

With regards to the particular impeller and fan housing selected for the future prototype, multiple options are available for application. There are several styles of impellers, such as the airfoil, backward-inclined-backward-curved, radial, forward curved, vane-axial, tube-axial, and propeller. Selecting one alone for maximum efficiency, with regards to creating the lowest sound pressure level, would prove to be difficult due to the fact that there are so many varied-versions of each style available in the world today. Therefore, research had to be completed in order to determine the most suitable choice to sound-pressure-level reduction. According to research based on fan-noise prediction, the appropriate choice would be to select the airfoil-style impeller. Justification for such a choice can be seen ahead (Figure 6).

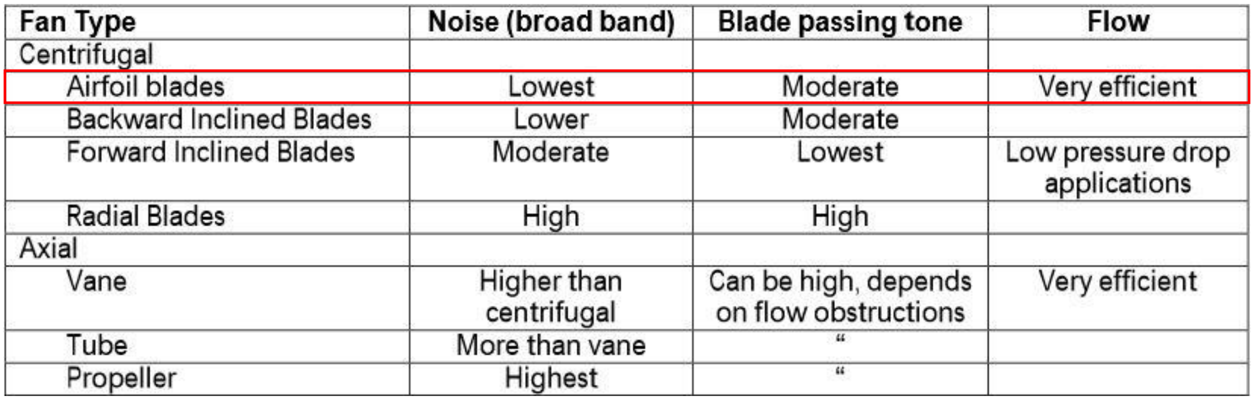


	TYPE	DESIGN	SPECIFIC SOUND-POWER LEVEL, K_w — CENTER FREQUENCY–Hz 63	125	250	500	1000	2000	4000	8000	BFI	APPLICATIONS
			dB re 10^{-12} watt and 1 cfm at 1 inch ftp									
CENTRIFUGAL FANS	AIRFOIL		35	35	34	32	31	26	18	10	3	Highest efficiency of all centrifugal fan design contains 10 to 16 blades of airfoil shape. Used for general heating, ventilating, and air-conditioning systems, usually applied to central station units where the horsepower saving will be significant. Can be used on low, medium, and high-pressure systems and will operate satisfactorily in parallel. Is also used in large sizes, for clean-air industrial applications where power savings will be significant. Can be used on industrial exhaust systems, where the air-cleaning system is of high efficiency.
	BACKWARD INCLINED BACKWARD CURVED		35	35	34	32	31	26	18	10	3	Efficiency is only slightly less than that of the airfoil fan. Contains 10 to 16 blades. Used for the same general applications as the airfoil fan. Can be used in industrial applications where the gas is essentially clean, but does not meet the standards required for airfoil fan selection.
	RADIAL		48	45	43	43	38	33	30	29	5–8	Simplest of all centrifugal fans–relatively low efficiency, usually has 6 to 10 blades; includes both radial blades (*R*), and modified radial blades (*M*). Used primarily for industrial exhaust, including dirty gas fans and recirculating gas fans. This design also used for high-pressure industrial applications.
	FORWARD CURVED		40	38	38	34	28	24	21	15	2	Efficiency less than the airfoil and backwardly curved fans, this fan is usually fabricated of lightweight and low-cost construction. It may have from 24 to 64 blades. This design will be the smallest of the centrifugal fan types and operates at the lowest speed. Used primarily in low-pressure heating, ventilating, and air-conditioning applications, such as: domestic furnaces, small central station units, and packaged air-conditioning equipment.
AXIAL FANS	VANEAXIAL		42	39	41	42	40	37	35	25	6–8	High-efficiency axial flow fan with airfoil blades and high pressure capability. Blades may be fixed or adjustable and the hub diameter is usually greater than 50 per cent of the fan tip diameter. There may be from 3 to 16 blades. This fan design has guide vanes downstream from the wheel which permits good air flow pattern on the discharge side of the fan. Used for general heating, ventilating, and air-conditioning applications in low, medium, and high-pressure systems. May also be used in industrial applications such as: drying ovens, paint spray booths, and fume exhaust systems.
	TUBEAXIAL		44	42	46	44	42	40	37	30	6–8	This fan is more efficient than the propeller fan design and can develop a more useful pressure capability. The number of blades may vary from 4 to 8 and the hub is usually about 50 per cent of the fan tip diameter. The blades may be of airfoil or single thickness cross-section. The fan is built without downstream guide vanes. Used in low- and medium-pressure ducted heating, ventilating, and air-conditioning applications where the poor air flow pattern downstream from the fan is not detrimental. This fan is also used in some industrial applications such as: drying ovens, paint spray booths and fume exhaust systems.
	PROPELLER		51	48	49	47	45	45	43	31	5–7	Low efficiency wheels are usually of inexpensive construction and are limited to very-low-pressure applications. Usually contains 2 to 8 blades of single thickness construction attached to a relatively small hub. The housing is a simple circular ring or orifice plate. This fan is used for low pressure, high-volume air-moving applications such as air circulation within a space or as exhaust fans in a wall or roof.
	TUBULAR CENTRIFUGAL		46	43	43	38	37	32	28	25	4–6	This fan usually has a wheel similar to the airfoil or backwardly inclined wheel, described above, which is built into an axial flow type housing. This results in lower efficiencies than the centrifugal fans of similar wheel design. The air is discharged radially from the wheel and must change direction by 90 degrees to flow through the guide vane section. Used primarily for low-pressure return-air systems in heating, ventilating, and air-conditioning applications.

Figure 6: Acoustic properties of various fan types [16]

Furthermore, the use of a centrifugal housing would be the proper choice for containing not only the airfoil-fan, but also to move air in the most efficient way (with respect to the ratio of pressure output versus pressure input); this can also be seen ahead (Table 2).

Table 2: Comparison of noise from various fan types



Fan Type	Noise (broad band)	Blade passing tone	Flow
Centrifugal			
Airfoil blades	Lowest	Moderate	Very efficient
Backward Inclined Blades	Lower	Moderate	
Forward Inclined Blades	Moderate	Lowest	Low pressure drop applications
Radial Blades	High	High	
Axial			
Vane	Higher than centrifugal	Can be high, depends on flow obstructions	Very efficient
Tube	More than vane	"	
Propeller	Highest	"	

The impeller designs will be created by a 3D printer from HPMI, the COE machine shop, or an outside source, and will be smoothed out with acetone to ensure less friction from air flow; thus, creating less vibration. Each blade design will be connected to the DC motor of choice and tested for sound production, force of air flow, and vibration effects. The force of air flow for each blade design will be calibrated by adjusting the brushless DC motor's angular velocity to ensure the desired amount of airflow is achieved. Keeping in mind that slower rotation speeds mostly contribute to less sound production, the design that produces the most amount of air flow at the lowest motor speed, in addition of the least amount of vibration, will be chosen as the blade for the final design.

4.3 Design Concept

In the concept generated below (although similar to the purchased hair dryer “Centrix Quiet Q”), will implement much better sound detuning technology and a much different casing more suited for vibration control, as well as a larger fan housing for a greater flow volume generated. Both the schematic of the proposed prototype (Figure 7) and the exploded view can be seen ahead (Figure 8); this concept design will follow the dimension constraints.

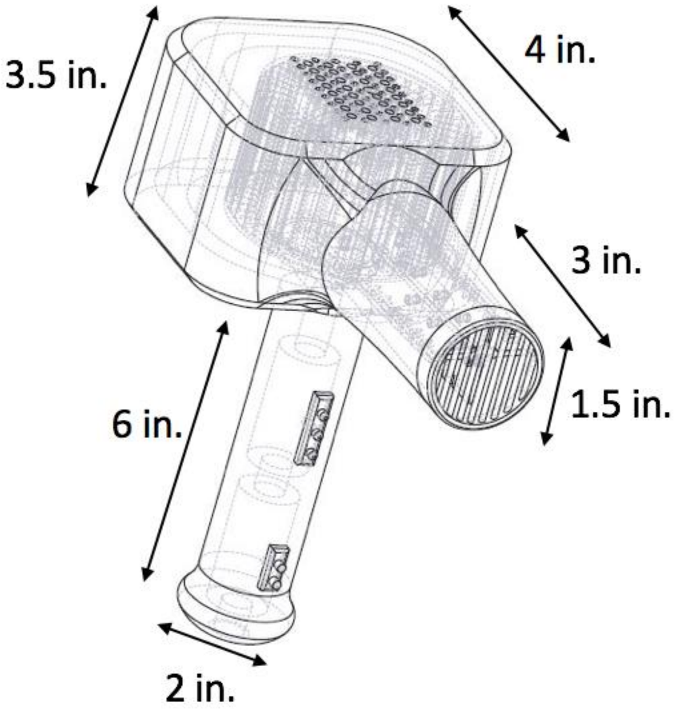


Figure 7: Current Concept Design

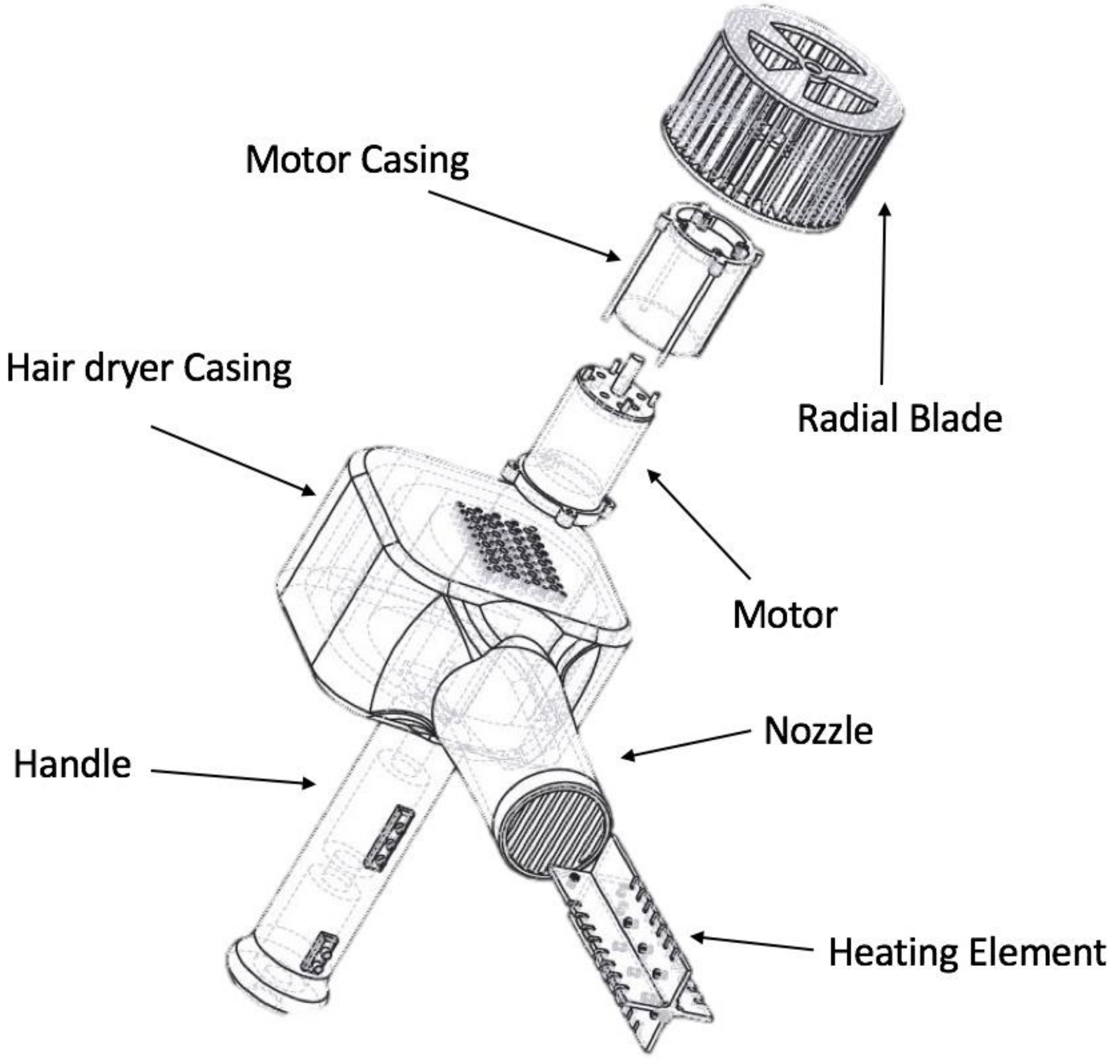


Figure 8: Exploded view of concept design

The exploded view above shows the entire make-up of the concept design, minus the electric components. Starting from the top, the concept design will be a radial-style blade that was mentioned about in the impeller-choice section. Below that, is the motor casing that will control the vibration the motor produces, thus controlling some of the sound produced by the motor. Right below that is the motor, and as discussed in the motor-selection section, this motor has yet to be chosen and is still waiting for further testing. Not seen in the schematic is the turbo style housing that will enclose the motor, motor casing, and radial blade. A better representation of the turbo style housing can be seen ahead (Figure 9).

Figure 9: Turbo Style housing

Enclosing the turbo-style housing will be the entire casing of the hair dryer; this looks like a typical hair dryer for the reason of creating a more user-friendly hair dryer. The differences between this design compared to typical hairdryers, is that the air intake is on the top of the hairdryer compared to the rear intake of most hair dryers. This was primarily done to angle the sound production away from the user at a 90-degree angle. The casing is where most of the sound-reducing materials (from rubber vibration dampeners to sound-reducing paint) will be implemented. The casing also houses all the electronics and controls for the hair dryer, and most of this will be located in the handle of the hair dryer. The nozzle of the design will enclose the heating element that will produce the heated air.

4.4 Concept Design Re-evaluation

The current concept only satisfies very general aspects of what the group wants to apply to their actual prototype, and is very limited in its practical function to achieve a less-deafening hair dryer. Each component and part will be modified in the future in order to achieve a low overall sound pressure level output. The motor will most likely be a DC brushless motor, however the proper operating voltage output, angular velocity capabilities, and size will still need to be selected; further calculations and testing will need to be provided in the future as justifiable reasons for selection.

With regards to the current impeller and fan housing in the concept, several modifications will need to be implemented to the correct specifications. The selection of the impeller will change from a radial-style fan to an airfoil-style blade system, due to its capability of achieving higher efficiency values. After sizing each individual blade, the dimensions of the centrifugal housing can be determined. Furthermore, multiple tests and mathematical calculations will be used to refine several factors which relate to sound power and sound pressure levels of the device.

With respect to the electrical components, those items will initially be utilized and re-purposed from already-purchased hair dryers. Afterwards, the group can make further decisions regarding whether or not they should purchase their own electrical components which relate more closely to their modified concept involving their motor, airfoil blade system, and dimensionalized centrifugal housing system.

4.5 Conducting Future Sound Measurements

In order to be more confident in the sources of noise that are emitted from hair dryers, Team 6 plans on conducting tests that will provide information to better their design. Research on cases where hair dryer noise has been tested is very scarce. The few sources Team 6 have, do not provide specific enough locations and data of their measurements to be considered a reliable source to base their designs. In the research paper, “The Noise Source Ranking of a Hair Dryer”, some key things Team 6 gained from it was their method of isolating certain hair dryer components in order to evaluate their contribution to the overall sound pressure level. Another paper looked at improving fan performance and resistance to the flow, giving insight into possible measurements the group can perform. The measurements that each group performed were sound pressure-level measurements using microphones where the registered values depend on the both the direction angle and the distance to the source. They also require the use of an anechoic or semi-anechoic chamber as the results vary based on the sound field the measurements are taken in; this makes the results different for different settings.

Measurements conducted by the team can be tailored to better suit our design goals and provide more insightful results. The measures which they plan to conduct include sound intensity, sound power and sound pressure. Sound intensity is useful for directing the measured-value back to a source and localizing the noise. Sound power is the total acoustic energy radiating from a source, which is a good measure of the sound being outputted to its surroundings. Sound pressure measurement will be useful in determining sound at specific locations around the hair dryer, similar to what one would experience when operating the device. Another main aspect would be to acquire the frequency-spectra of the device during operation. This gives insight into which tones are being produced and can be related to the moving components and geometry where noise is generated. Also, human hearing is more sensitive to certain frequencies (roughly 2 kHz - 5 kHz), which correspond to resonance in the ear canal; bringing dominant frequencies below this mark will allow for a quieter perceived device.

5. Conclusion

In conclusion, the overall problem statement has been properly addressed; hair dryers are simply too loud. There are numerous factors which revolve around the source of noise, however either both the intake and exit of the air through the hair dryer have proven to be the most critical points of observation. Numerous studies have supported the previous statement; therefore, it has caught the group’s full attention. These studies have also shown other factors involved, and will not be remised, including a risk assessment; this can be found in Appendix B. Overlooking risks not only equals potential for a bad product, but also increased probability of injury upon either the users or creators.

By applying certain methods, such as the House of Quality table, has also narrowed down the priorities of engineering characteristics versus customer requirements regarding hairdryer selection, along with critical focal points. Also, with the application of a Gantt Chart, the group is able to stay motivated, prepared, and properly scheduled towards upcoming tasks.

With respect to the design and analysis of existing hair dryers, specific research has brought insight toward a future, less-deafening hair dryer. On that note, several concepts were digitally-devised by the utilization of complex design software in the past, and a current concept has been implemented; this current design will be further modified toward the final outlook of a prototype. A satisfactory amount of research has been completed, along with some minimal testing, but future insight and progress will not end there; future testing in sound mapping should provide better information toward the evolving concept. Eventually, a final, remastered concept will be selected for prototypical production.

References

[1] http://www.asha.org/public/hearing/Noise/

[2] http://www.nidcd.nih.gov/health/hearing/pages/noise.aspx

[3] http://visual-makeover.com/hair-dryers/

[4] http://hobbyking.com/hobbyking/store/__223__59__Electric_Motors-TURNIGY.html

[5] Akehmetov, B, and Gupta, S, and Ahuja, K; "Noise Source Ranking of a Hair Dryer.", AIAA

[6] Shen, M, and Lin, S, and Chen, W, and Leong, J; "The Study of Improving the performance and the noise of a hair dryer." ; 16th international symposium on transport phenomena.

[7] http://www.amazon.com/Revlon-RVDR5045-Quiet-Ionic-Dryer/dp/B007PAIGYA

[8] http://besthairdryerreviews.net/centrix-q-zone-quiet-dryer/

[9] http://www.velecta-paramount.com/blowdryers/envy-onyx.html

[10] "*Engineering Design Process(2)*". Retrieved January 23, 2015. Microsoft Office PowerPoint PResentation. [Slide # 33 / 111]. Dr. Ruturaj Soman, soman@cap.fsu.edu

[11] Akhmetov, Bakytzhan, Siddhartha Gupta, and K. K. Ahuja. *Noise Source Ranking of a Hairdryer*. Rep. Atlanta: AIAA Aviation, 2014. Print

[12] http://www.brd-nonoise.com/RequestDetails.aspx

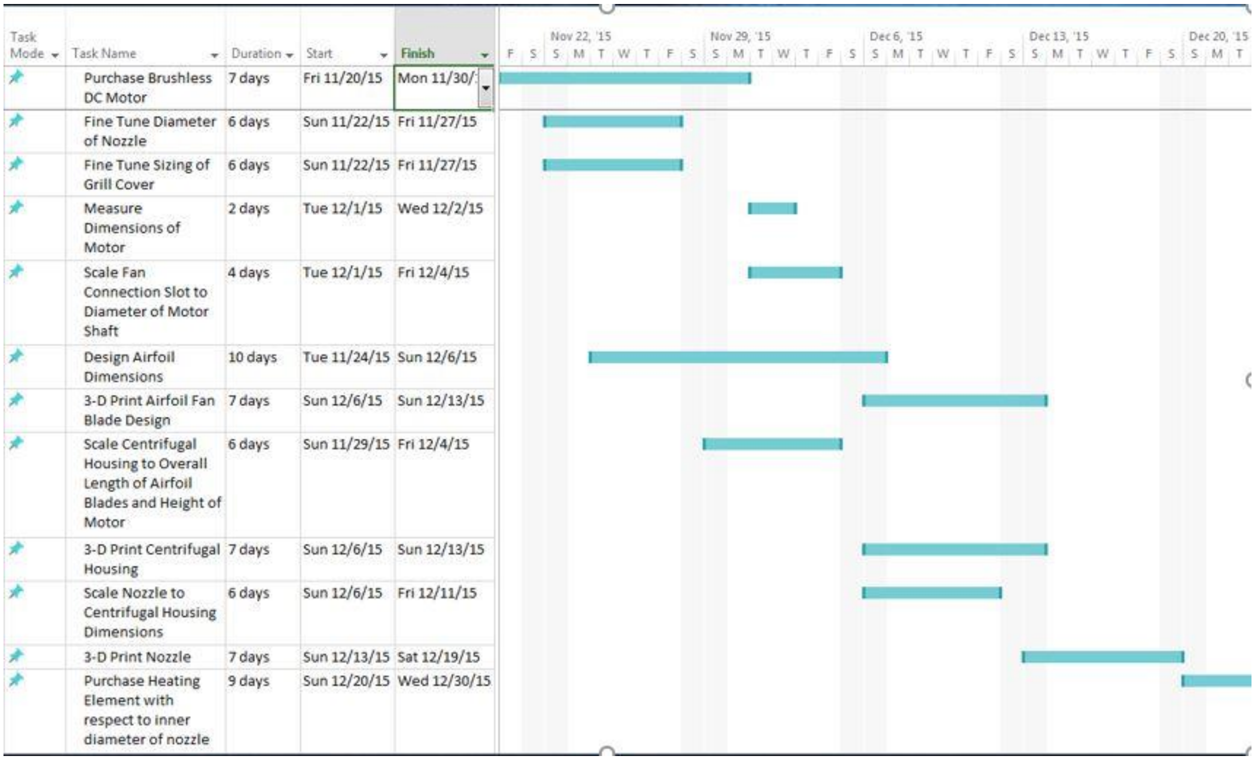
[13] http://preserve.lehigh.edu/cgi/viewcontent.cgi?article=2015&context=etd

[14] http://www.google.com/patents/EP2327327A1?cl=en

[15] http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1177&context=ecetr

[16] http://www.mne.psu.edu/lamancusa/me458/11_fan.pdf

Appendix A – Schedule



Task Mode	Task Name	Duration	Start	Finish
📌	Purchase Brushless DC Motor	7 days	Fri 11/20/15	Mon 11/30/
📌	Fine Tune Diameter of Nozzle	6 days	Sun 11/22/15	Fri 11/27/15
📌	Fine Tune Sizing of Grill Cover	6 days	Sun 11/22/15	Fri 11/27/15
📌	Measure Dimensions of Motor	2 days	Tue 12/1/15	Wed 12/2/15
📌	Scale Fan Connection Slot to Diameter of Motor Shaft	4 days	Tue 12/1/15	Fri 12/4/15
📌	Design Airfoil Dimensions	10 days	Tue 11/24/15	Sun 12/6/15
📌	3-D Print Airfoil Fan Blade Design	7 days	Sun 12/6/15	Sun 12/13/15
📌	Scale Centrifugal Housing to Overall Length of Airfoil Blades and Height of Motor	6 days	Sun 11/29/15	Fri 12/4/15
📌	3-D Print Centrifugal Housing	7 days	Sun 12/6/15	Sun 12/13/15
📌	Scale Nozzle to Centrifugal Housing Dimensions	6 days	Sun 12/6/15	Fri 12/11/15
📌	3-D Print Nozzle	7 days	Sun 12/13/15	Sat 12/19/15
📌	Purchase Heating Element with respect to inner diameter of nozzle	9 days	Sun 12/20/15	Wed 12/30/15

Appendix B – Risk Assessment

• Project information:

Design of a Less-Deafening Hair Dryer	October 30, 2015
Name of Project	Date of submission

Team Member	Phone Number	e-mail
Mark Johnson	850-524-2321	maj12b@my.fsu.edu
Shawn Eckert	850-826-2414	sme13b@my.fsu.edu
Peter Van Brussel	850-712-7869	pav11b@my.fsu.edu
Kiet Ho	850-322-4972	kth13c@my.fsu.edu

Faculty mentor	Phone Number	e-mail
Dr. Nikhil Gupta	850-410-6201	ng10@my.fsu.edu
Dr. Chiang Shih	850-410-6331	shih@eng.fsu.edu

• I. Project description:

Develop a quieter hair dryer than what is currently in the market. Also to understand the entrepreneurial aspect of it.

• II. Describe the steps for your project:

Know your group members. Gain research and literature based on hair dryer. Perform tests. Develop concepts. Select a concept. Purchase and assemble parts. Test some more. Refine device. Test again. Finalize prototype. Understand market aspect.

• III. Given that many accidents result from an unexpected reaction or event, go back through the steps of the project and imagine what could go wrong to make what seems to be a safe and well-regulated process turn into one that could result in an accident. (See examples)

Performing tests – Injuries could occur due to tool misusage, electric shock, loss of hearing, etc.

*These mishaps may also occur during the actual development of the device

• IV. Perform online research to identify any accidents that have occurred using your materials, equipment or process. State how you could avoid having this hazardous situation arise in your project.

-People have endured electrical shocking from improperly handling the electrical components of the hair dryers

-There have been incidents which involve cutting or scraping of body parts

V. For each identified hazard or “what if” situation noted above, describe one or more measures that will be taken to mitigate the hazard. (See examples of engineering controls, administrative controls, special work practices and PPE).

-Don’t be complacent
-Remain cognizant
-Don’t operate something that you’re not aware of
-Use protection

VI. Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don’t just state “be careful”).

-During test performance, utilize all the proper safety gear to protect yourself
-Don’t operate machinery without proper knowledge or without an advisor
-Don’t be in a hurry when attempting to either take apart or assemble a device

VII. Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

-Contact 911
-Inform faculty members
-Remain calm

VIII. List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone Number	Faculty or other COE emergency contact	Phone Number
Dr. Nikhil Gupta	850-410-6201		
Dr. Chiang Shih	850-410-6331		

IX. Safety review signatures

- Faculty Review update (required for project changes and as specified by faculty mentor)
- Updated safety reviews should occur for the following reasons:
  1. Faculty requires second review by this date:
  2. Faculty requires discussion and possibly a new safety review BEFORE proceeding with step(s)
  3. An accident or unexpected event has occurred (these must be reported to the faculty, who will decide if a new safety review should be performed.
  4. Changes have been made to the project.

Team Member	Date	Faculty mentor	Date
DIGITALLY SIGNED			
MARK JOHNSON	October 30, 2015		
SHAWN ECKERT	October 30, 2015		
PETER VAN BRUSSEL	October 30, 2015		
KIET HO	October 30, 2015		

Appendix C – Current Concept Components

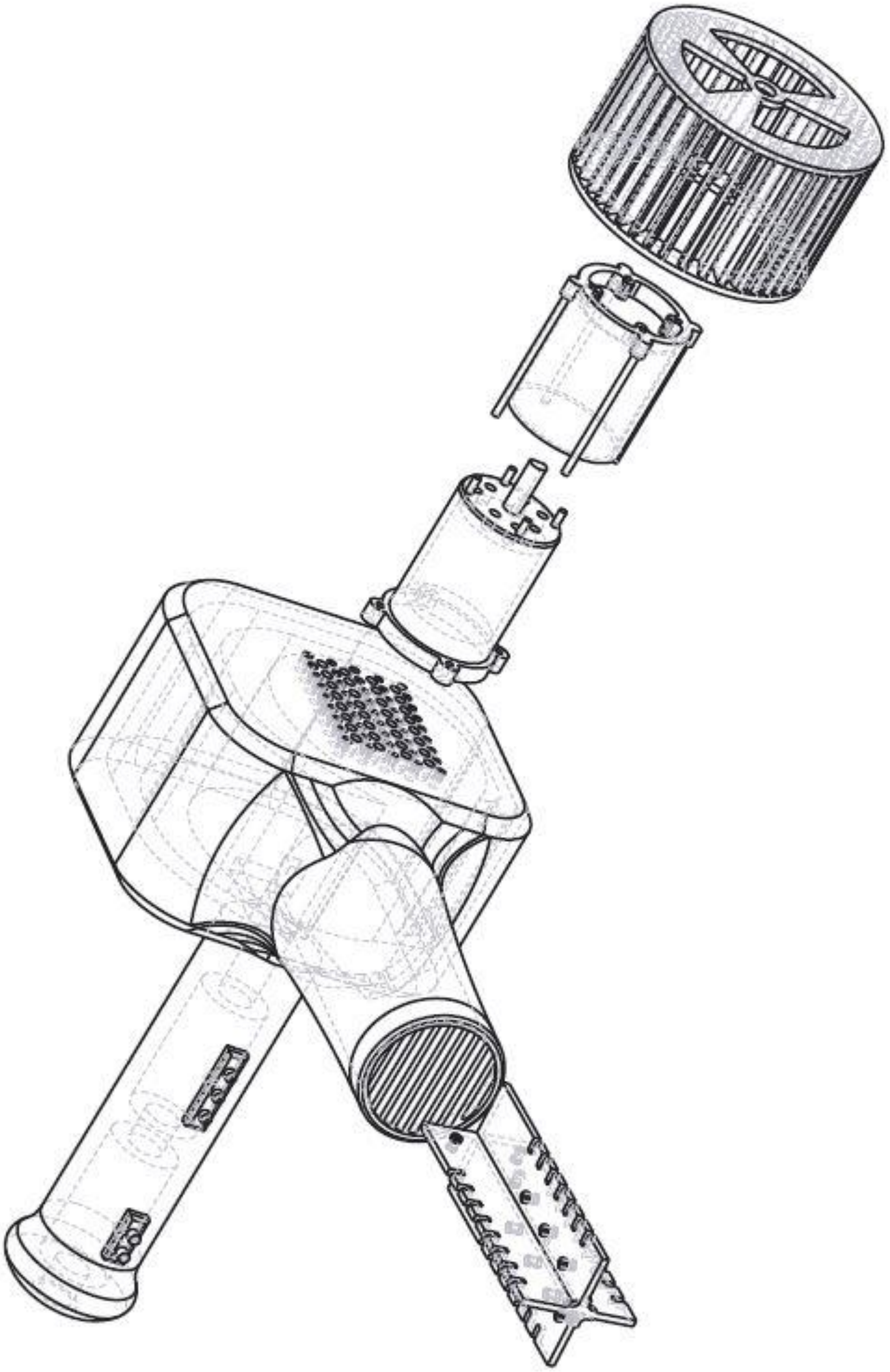


Figure 10: Exploded view of current hairdryer concept

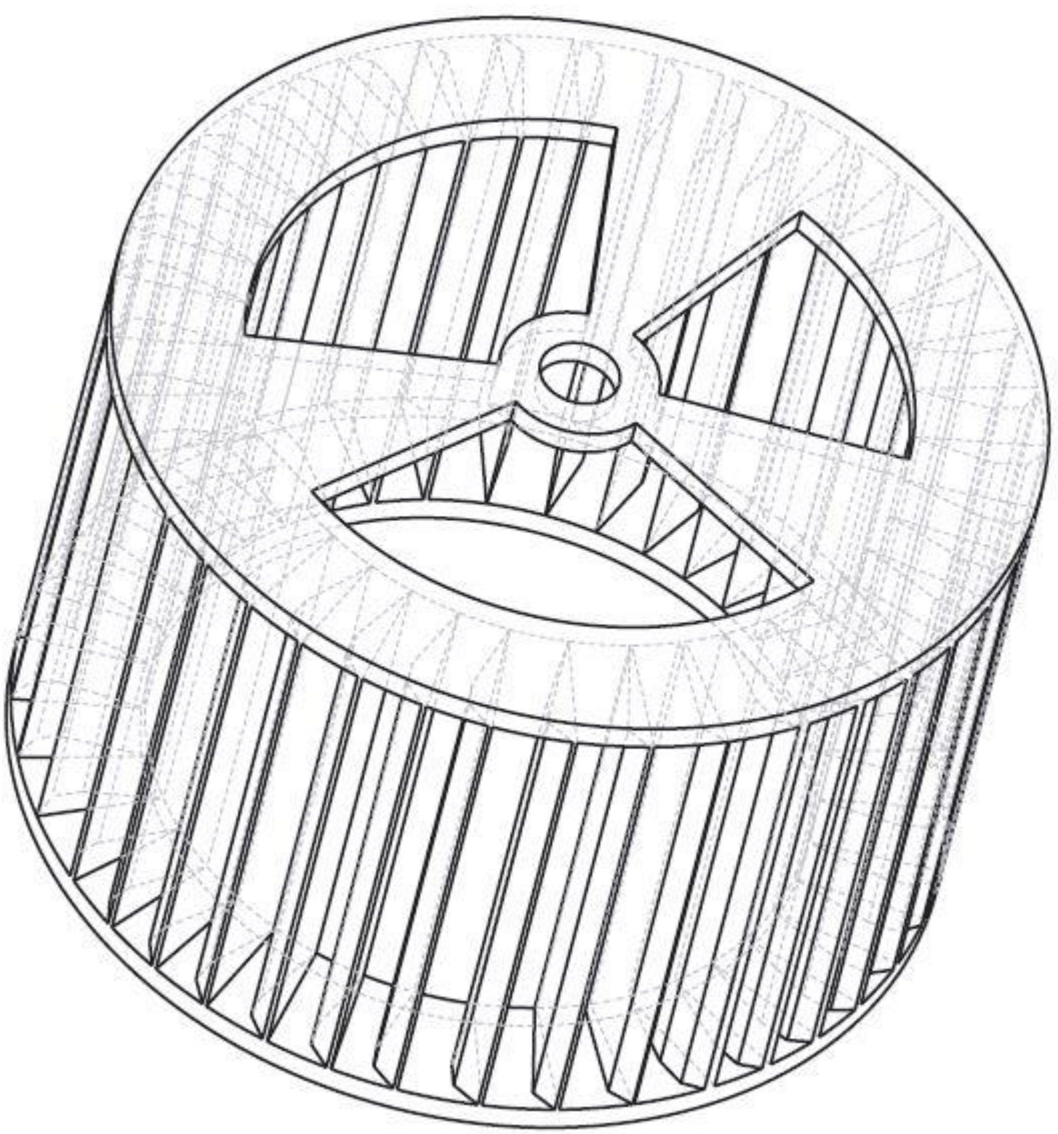


Figure 11: Current radial-fan concept

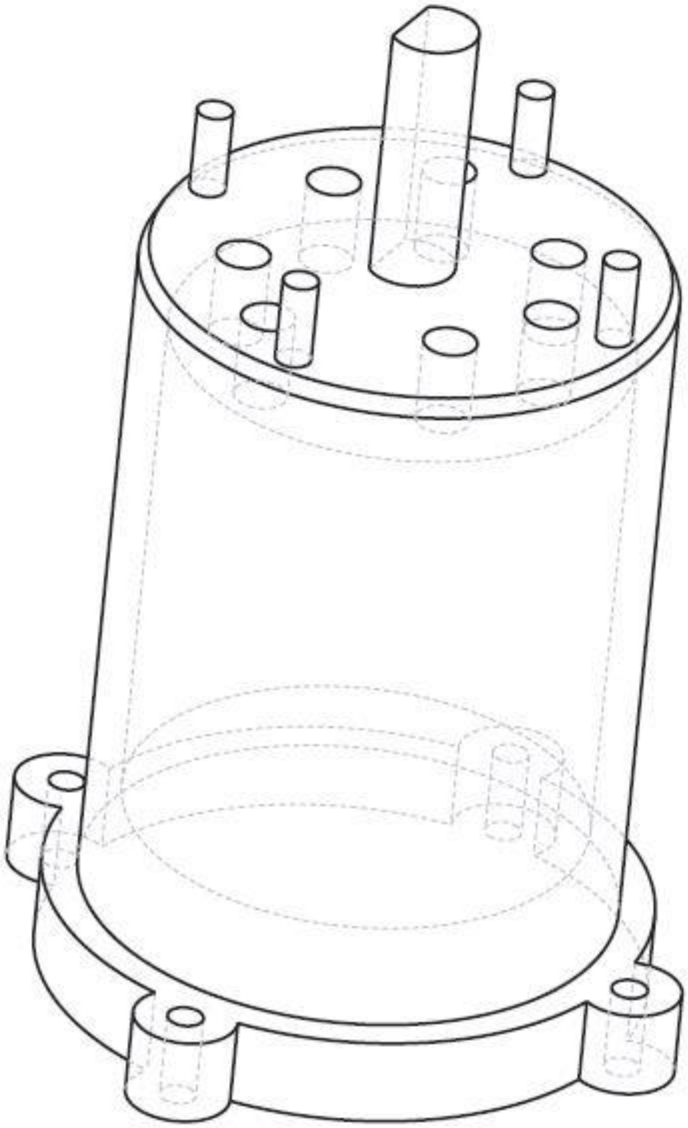


Figure 12: Current DC motor concept design

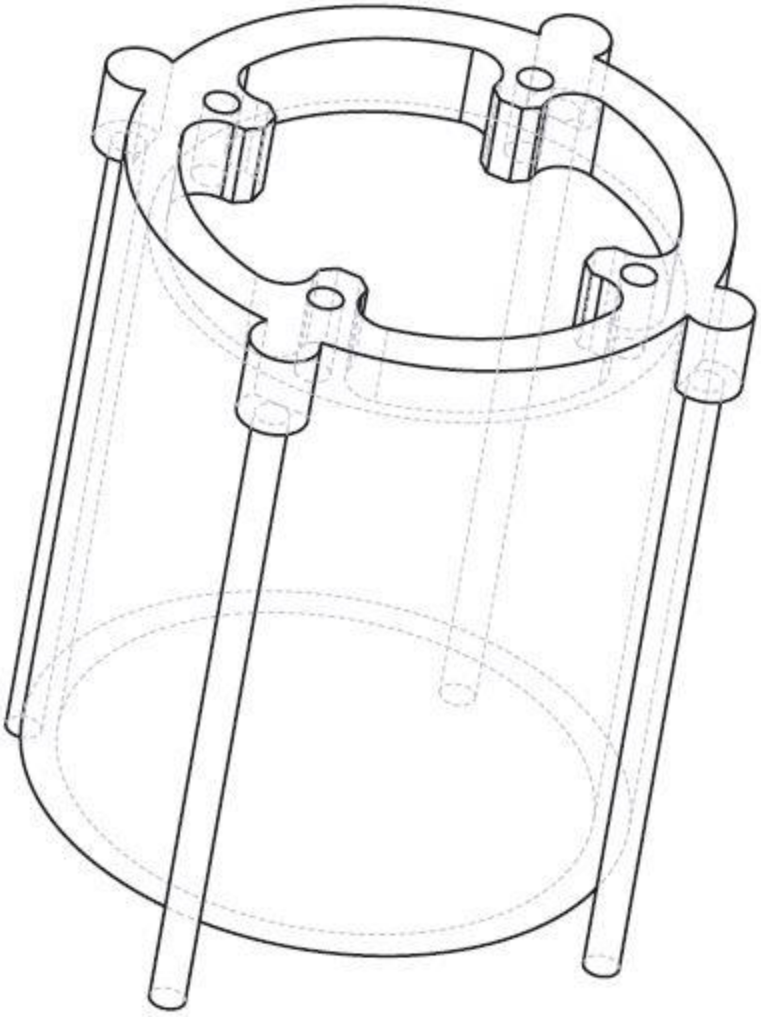


Figure 13: Current motor housing unit concept design

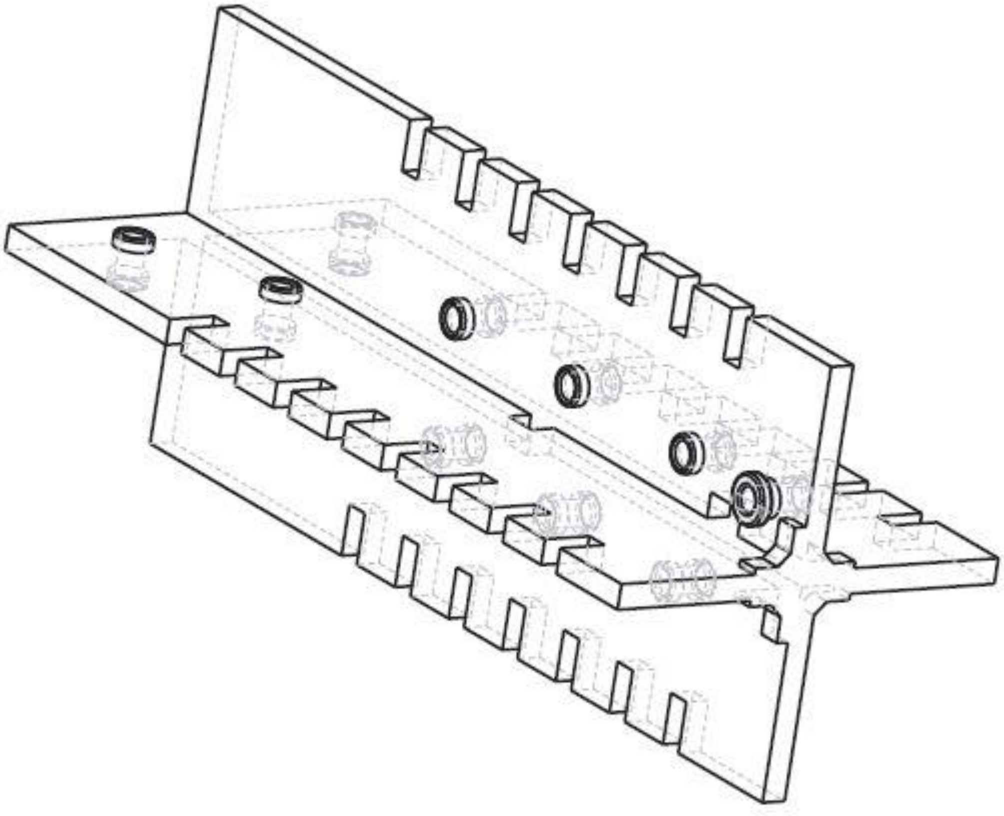


Figure 14: Current heating element concept

Biography

Mark is a Senior Mechanical Engineering student from Fort Walton Beach. He served in the US Airforce for 6 years as C-17 Airdrop Instructor Loadmaster and wants to apply the tools learned the military to a future career in Mechanical Engineering. His area of interests include dynamics and wants to start a business in designing and creating new and improved versions of old mechanical designs for entertainment.

Peter is a Senior Mechanical Engineering student from Pensacola, FL. He has interests in the topics of fluid dynamics and renewable energy. He is part of the Florida State University's BS-MS program and also a member of the university's nationally ranked ultimate Frisbee team.

Shawn is a senior in Mechanical Engineering completing his final year. He is from a small town known as Crestview and transferred to FSU in the fall of 2013. He specializes in mechanical work and analysis/simulation. Shawn is a brother of the Phi Delta chapter of Theta Tau. He would like to pursue a career in National Security for a defense contractor. He is also interested in pursuing an MBA after gaining experience in the workforce.

Kiet is from Florida and a senior in Mechanical Engineering. He is interested in the materials field in engineering and also going into research and development for new methods to enhance productivity. He was a FGLSAMP robotic technician under Dr. Collins Adetu in 2013 and worked on constructing robots with various sensors.