MODERN DAY ADVANCED MANUFACTURING OF ANTIQUE TOY WALKERS

by

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ABSTRACT

MODERN DAY ADVANCED MANUFACTURING OF ANTIQUE TOY WALKERS

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The purpose of this thesis is to display the findings of: patent research, develop a passive dynamic toy walker design, prototype using a 3D printer, and explore the possibility of beginning a tech startup. The patents explored are from around the world and date back to the late 1800s. Using the patents as inspiration, a new passive dynamic toy walker was designed. The design process included sketching, CAD work, and various geometric file conversions for the capability of 3D printing. Prototyping of the toy was done by use of a 3D printer. While prototyping, hypotheses are expressed in the paper and motion analysis was performed for each of the printed designs. Upon testing conclusions were drawn throughout the iterative process, allowing for product improvement. Eventually a successful prototype was printed and used as a model for the basis of a future tech startup company.

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CHAPTER 1: INTRODUCTION

Manufacturing itself has evolved in the past few decades from labor-intensive mechanical processes to information-technology based processes or advanced manufacturing.

What is Advanced Manufacturing exactly? Advanced manufacturing has been given many definitions, however most are based on the idea that it is the use of innovative technology to improve products or processes [1]. The term has also been referred to as dynamic in the sense that with the progress of time comes new advances, therefore an ever evolving definition.

In particular and for the purpose of this thesis, I have chosen to use the advanced manufacturing method of Three-Dimensional printing or 3D printing as you may have heard more commonly. Now you may be wondering, why 3D printing versus any of the other existing advanced manufacturing methods? There were a couple of pretty good reasons that came to my mind when selecting a manufacturing process. The first being that the lab supporting the research, known as The Robotics and Motion Laboratory at The University of Texas at San Antonio has a desktop 3D printer which I was granted unlimited access to (availability of process to me). The second main reason was that I decided to close the paper with what I believe to be the formula needed to become a successful tech startup founder. Further elaborating on the latter reason, I wanted to convey the message to readers interested in the business of developing and selling their own products, which is now more possible than ever due to the increased availability of at-home 3D printers.

CHAPTER 2: THESIS STATEMENT

The purpose of this thesis is to display the findings of: patent research, develop a passive dynamic toy walker design, prototype using a 3D printer, and explore the possibility of beginning a tech startup.

CHAPTER 3: METHODS AND APPROACH

3.1-Choosing a Product of Interest

Growing up as a child on the Texas-Mexico border, I was introduced at a very young age to Mexican folklore toys. Mexican folklore toys are defined as, "…(toys) made by artisans rather than manufactured in factories…dating as far back as the Mesoamerican era, but many dating to the colonial period." [2]**.** These toys capture the eyes of many due to their bright and elaborately painted exteriors. In high school, I was introduced to 3D modeling software and quickly became consumed in redesigning some of my most beloved childhood toys.

During the second half of my college career as a student in the Department of Mechanical Engineering at The University of Texas at San Antonio, I was introduced to all sorts of emerging technologies, including 3D printing. I also chose to enroll in a Robotics course. It too quickly became one of my newest areas of interest. I wanted to find a way to combine the two for a project.

What do you believe a robot is defined to be? Well, surprisingly there is no strict definition to date. While many have attempted to write the rules as to what is and what isn't a robot- none have truly succeeded. The reason is that robots have been and will always be evolving; growing ever smarter as technology rapidly develops. Many people today imagine robots to be the complex androids that we see in action films or sci-fi thrillers. The truth is however, that a robot can be incredibly simple and designed to perform a very particular task or function. In fact, the following images are some of the world's first patents of "robots".

3.2-Patent Research of Existing Products of Similarity

George T. Fallis of St. Joseph Missouri was the first to invent and patent the passive dynamic walking toy [Figure 1]. A passive dynamic toy does not include any electrical components and purely uses gravity to propel itself. He created the design, "to simulate either the human frame or that of any or most of the lower order of animals or brute creation…" [3].

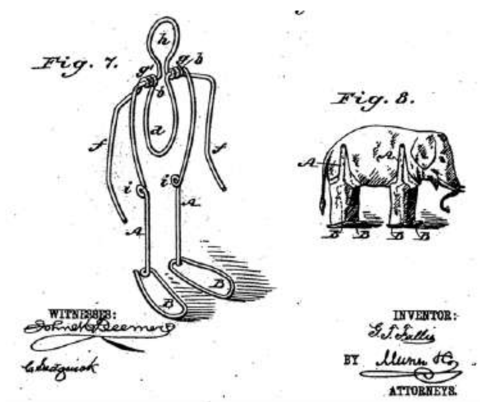

Figure 1: Image from Fallis Patent Concept

A European take of the design was by Balduin B. Bechstein and Paul O. Uhlig of Germany with their patent of a passive dynamic toy walker without curved sole feet [4]. Instead, the designers were the first to propose angled cuts on the bottom of the soles [Figure 2]. The angled cuts are assigned in the patent and the projected walking path so as to show a profound rigid rocking effect versus a gradual and oscillatory rocking effect.

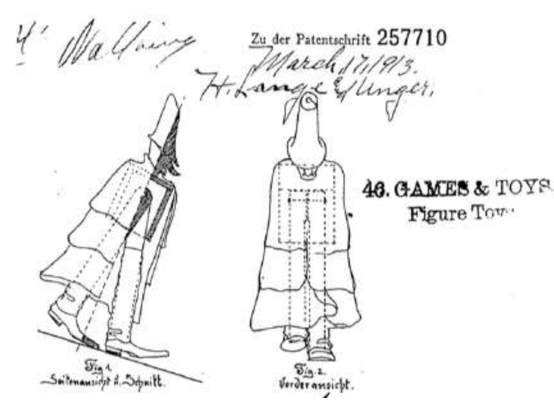

Figure 2: Image from Bechstein and Uhlig Patent Concept

James J. Mahan of Jersey City, New Jersey patented the first toy walker with aid of balance [5]. The toy consisted of the same two-leg pendulum rotational about a pivot point, bottom soles cut to angle very similar to the previously observed German design, and now the first application of aided balance in the form of balancing rods attached to protruding arms. The balancing rods have inside of them induced weights at their bottoms so as to lower the position of the toys center of gravity. The balancing rods may be seen here in Figure 3.

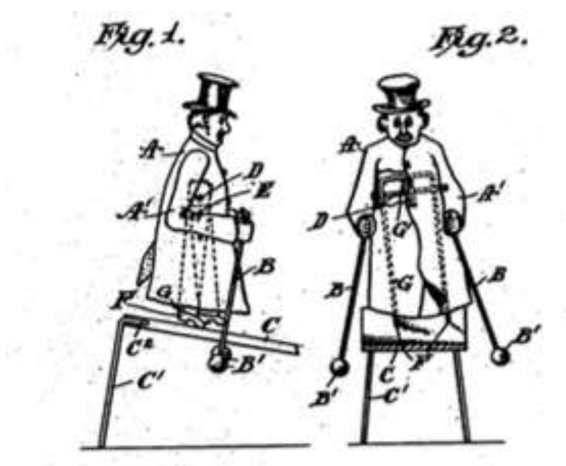

Figure 3: Image from Mahan Patent Concept

Allison's design is the most peculiar looking of the bunch. When further examining the set of figures attached to the patent, it becomes obvious that the design really isn't that complex but more so extremely clever [6]. The toy itself is a self walking (as all the others) and relies only on the help of gravity to propel its movement. What makes it so unique however is that it is able to balance its self-propelled movement while walking atop a downwards inclined tight rope [Figure 4]. The bottoms of the feet are curved in all directions and contain a v groove that engages with the tight rope. Also, because the toy is required to have clearance between its legs, each leg has a peculiar bearing piece that attaches to the pivot shaft. Outward extending arms that hold staffs aid in balancing the toy on the rope. Heavy weights at the bottom ends of the shafts actually shift the body’s center of gravity downward causing a dramatic improvement in its overall balance.

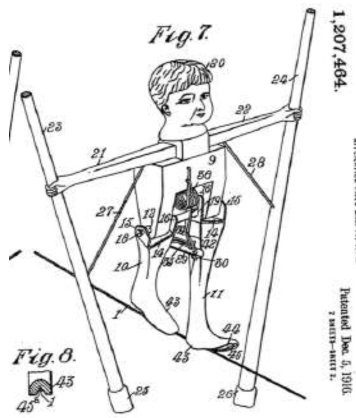

Figure 4: Image from Allison Patent Concept

The “Wilson Walker” is a walking toy having the form of a penguin. The patent for the walker specifically states a geometrical relationship that differs from the rest that were researched for comparison [7]. The two feet of the walker have a curvature from front to rear that is “accurately the curvature of a circle ‘C’, whose center is at an imaginary point.”

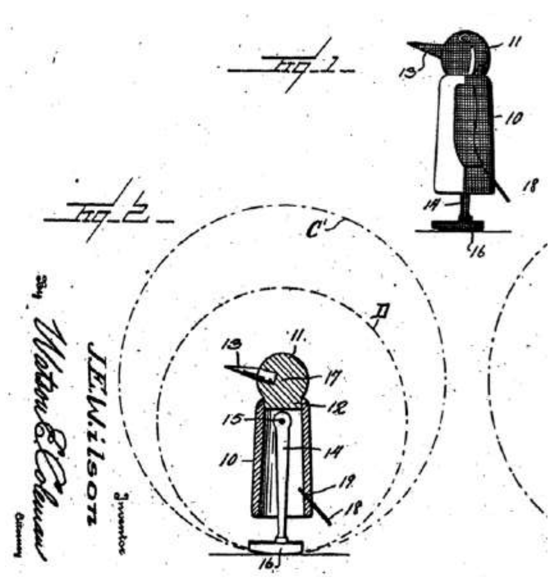

Figure 5: Image from Wilson Patent Concept

In simpler terms, the radius of curvature of the bottom of the feet are the exact curvature of an imaginary sphere [Figure 5]. Also, the point at which is known as the "pivot point" or point where the legs rotate about is the dead center of another, smaller imaginary projected circle. Radial relationships are clearly established by the inventor, John E. Wilson, and although his calculations for the basis of these relationships are not referenced, it can be assumed that they were of good thought due to the popularity and successful replication of the walker.

The following patent is what I consider to have the simplest design in appearance of a half-body passive dynamic toy walker [Figure 6]. In reality it is basis of what we know today as "passive dynamic robots" [8]. Although it is the most recent of the six researched patents, it clearly defines the evolution of the six-toy walkers mechanical design. I believe the inventor drew inspiration for his patent based on previous toy patents which date back to just over 100 years, and have spanned across Europe and North America.

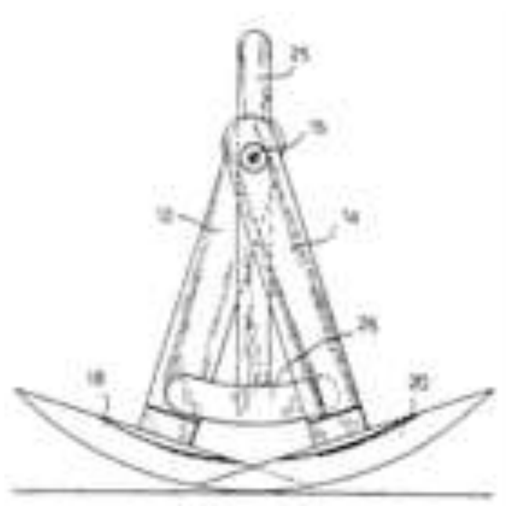

Figure 6: Image from Maestri Patent Concept

The final researched patent was filed by inventor, William I. Ravert in the year 1932. An American patent, the toy walker is shown [Figure 7] with an assisting ramp design that allows for a very straight path as the toy makes its way down the ramp [9]. The duck design has both legs rotating about the same axis. In order to achieve the “wobbling” motion, the axis must also act as the center of mass for the entire toy. The overall shape of the duck seems to resemble an oval or egg, I hypothesized that the particular geometry aided in achieving the wobbling effect. The feet of the duck also contain a certain radius of curvature.

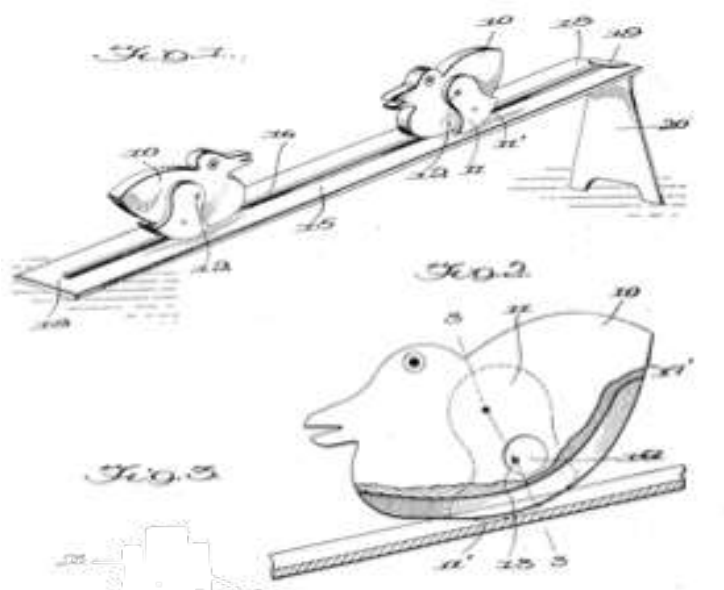

Figure 7: Image from Ravert Patent Concept

Once I completed gathering background patent research of the world’s first “robots”, I then created what is known as a decision matrix via the Pugh method [Table 1] Pugh Concept Selection is defined as, “a quantitative technique used to rank the multidimensional options of an option set…frequently used in engineering for making design decisions…” [10]. I developed the matrix to aid in selecting a single patent that would serve as my design inspiration. By choosing a design already proven to work, I was able to innovate a toy by bringing it up to speed with a modern day manufacturing method.

Table 1: Patent Design Selection Matrix using Pugh Methodology

Inventor	Dimensional Analysis	Manufacturability	Production Costs	Marketability	Final Score
Fallis	0	-1	-1	-1	-3
Bechstein and Uhlig	0	-1	-1	+1	-1
Mahan	0	-1	-1	+1	-1
Allison	-1	-1	-1	+1	-2
Wilson	+1	+1	0	+1	+3
Maestri	+1	+1	0	-1	+1
Ravert	+1	+1	+1	+1	+4

The dimensional analysis category is based on the level of projected ease to calculate scalable set dimensions for the prototype using the original patent. The Wilson, Maestri, and Ravert patents all were given the highest scores for the category based on their additional annotations and reference figures as provided by the inventors.

The manufacturability category is based on the ease of manufacturing. Considered complexity factors include the number of pieces included within the assembly, various abstract surfaces, and expected hours to create the computer aided design. Once more, the Wilson, Maestri, and Ravert designs received the highest category scores based on their limited number of parts, materials, and lack of geometrical complexity.

The production costs category is inclusive of the expected 3D printing model that will be used to perform the printing (cost of operation based solely on electric energy), estimated "cost per part", and raw material costs of a PLA (polylactic acid) spool of material.

The final preliminary selection category is marketability and is based on a few factors. The first factor is the general appearance of the toy and its appeal to consumers. Next is the expected functionality of the walker and the very important connection between its appearance as well as its predicted movement. Finally considered is the toys overall estimated cost.

Points were awarded ranging from -1 to +1. A negative score was given if the design was hypothesized to produce a negative outcome, a score of 0 if the outcome of the design was neutral or difficult to predict, or a positive score if the design was thought to produce a positive outcome. All scores were based individually within respective categories.

3.3-Developing an Original Design

Sketches are important, as they show the true style of the artist, designer, or engineer. Included are sample sketches that I developed for the Rowdy Walker.

I personally find it helpful begin a sketch with a rough geometrical assignment. Using simple shapes such as circles, squares, rectangles, and triangles, helps me to create the figure and discover its proportions. You can clearly see the simple shapes I used when assigning proportions to the Rowdy Walker Concept in Figure 8.

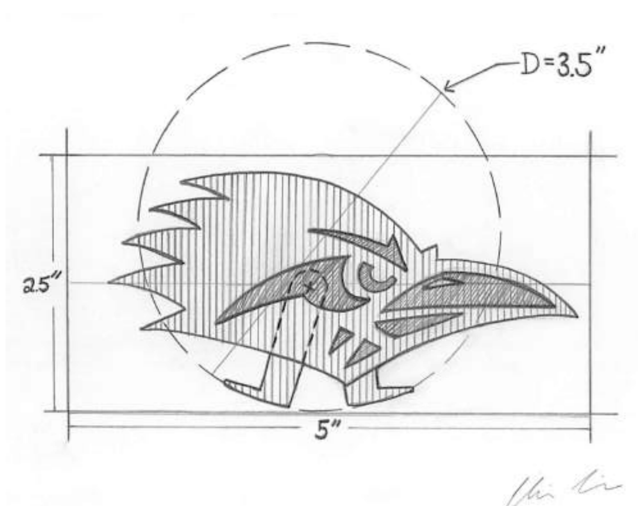

Figure 8: Hand Sketch of Rowdy-Walker Concept

As sketches develop, it is recommended to associate rough dimensions with the figure. This helps immensely when designers/engineers assign dimensions to 2D and 3D drawings in SolidWorks or other similar CAD programs.

3.4-CAD Modeling of Designs using SolidWorks

SolidWorks is a 2 dimensional (2D) and 3 dimensional (3D) Computer Aided Drawing (CAD) software used for making precise technical drawings that could later be used for prototyping. I used the 2014 SolidWorks Standard 3D CAD Package in creating all of the RowdyWalker 2D dimensioned sketch drawings as seen in Appendix A, 3D annotated drawings, and 3D final renderings that can be found in Appendix B.

The process of developing a CAD drawing using SolidWorks for the toy involved two steps. First I created a 2D sketch using various lines, arcs, and circles. Next, I used the "Extrude" feature to transform the drawing from 2D to 3D. The final five designs can be seen in 2D form in Figures A-1 to A-6.

Manufacturing predictability is the main advantage of using such technical software. SolidWorks has amazing simulation features such as calculation of overall mass, material properties, and even stress analysis! The most helpful calculative process tool I discovered and used was for finding the Center of Mass (COM). The COM is defined to be, "The point in a body or system of bodies at which the whole mass may be considered as concentrated." [11]. This proved critical when assigning the axis of rotation for the free to move leg of the walker.

The following table [Table 2] displays some of the simple physical properties that a user can either define in SolidWorks or receive aid in calculating. The overall heights and overall widths that can be seen are based on a 1:1 scale of the toy. Therefore, the calculated weight is also based on a 1:1 scale unlike the 3:4 scale that was actually used for the printing of the toy.

Table 2: Physical Characteristics of Rowdy Walker Designs #1-5 as Modeled in SolidWorks

	Overall Height (in.)	Overall Width (in.)	Overall Weight (lb.) Scale 1:1
Design #1	2.96	2.00	0.46
Design #2	3.05	2.00	0.45
Design #3	3.05	2.00	0.39
Design #4	3.05	2.00	0.41
Design #5	3.19	2.00	0.46
Design #6	3.19	2.00	0.48

As mentioned, SolidWorks may be used to perform stress analysis. Due to the lack of need for me to conduct stress analysis on the toy I simply created a Free Body Diagram (FBD) [Figure 9] as a way to clearly where the main forces were acting upon the toy.

Notations for the FBD are defined as follows: CM= Center of Mass, L_{leg}=Length of Leg (in.). F_R= Resultant Force, F_B: Force of the Bearing Load on the Shaft, F_N: Force Normal to the Contact Surface, R_{Foot}: Radius of Curvature for Foot, θ_{Ramp}: Angle of the Ramp (degrees). It was very important that I designed the toy so that the Center of Mass went straight through the shaft of the toy. This can be seen in detail (red) on the figure.

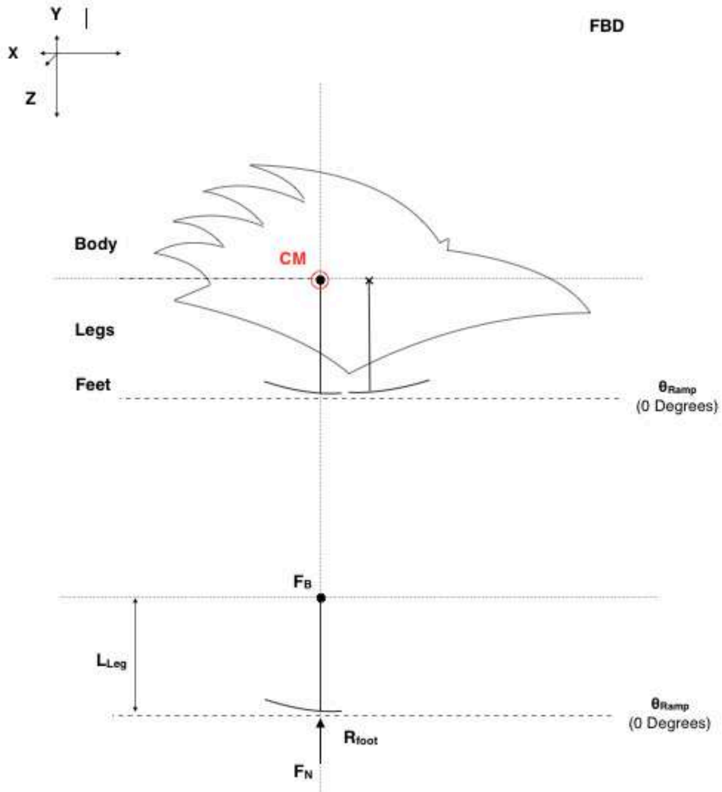

Figure 9: Rowdy-Walker Free Body Diagram (FBD)

3.5- Background and Processes of 3D Printing

When researching the evolution and background of 3D printing, I realized just how far the process and machines have come since what was considered to be the very first 3D printer. These are the various notable 3D printing methods that I found also commonly referred to "additive processes".

3D printing is simply an additive process, where a three-dimensional object is made of a particular material from a digital model [12]. The additive process is where successive layers of thin material are added until the desired product is completed. Chuck Hull created the first additive printer in the early 1980s working at his founded company, 3D Systems Corporation [13].

Stereolithography (SLA) was the choice method of Chuck Hull when he created his printer. The technology uses a beam of ultraviolet light (UV), which focuses on the surface of a vat filled with liquid photocurable resin.

Also from the 1980s came the method of Selective Laser Sintering (SLS) by Carl Deckard and his colleagues [14]. The process of SLS is very similar to SLA through the use of lasers, yet instead of resin there is powdered metal. The lasers actually sinter the powdered metal in order to bind together the desired product.

The PolyJet Photopolymer method is where a photopolymer liquid is very precisely jetted out and then hardened with a UV light into successive layers [15]. The syringe ultimately extrudes the melted material in precise layers that bond together until the final product is completed.

Another method of an additive process is Fused Deposition Modeling (FDM), which was invented by Scott Crump also in the late 1980s [15]. FDM technology is where an object is produced by an extrusion of melted material that forms a product layer by fused layer. Of all the additive processes, it is one of the least expensive 3D methods. This was the method that I ultimately used to 3D print the product that I designed, developed, and prototyped.

There are eight general identified steps in the 3D printing process for any of the above printing methods chosen [16]. The first step of the process is to create the initial design for your product using a computer aided design (CAD) software. This is by opinion the most important step in the process for the reason that this it serves as the most accurate representation of what will ultimately be printed. The software itself can even model the products structural integrity, stress analysis based on the desired materials chosen, and even display an endless array of aesthetic combination possibilities.

The next identified step is to convert the CAD file into a programming language file of which the particular printing machine can read. The most widely used language file format is the standard tessellation language or "STL" for short. Most 3D printers accept the STL file format, however there are also many other languages offered such as ZPR by Z Corporation or ObjDF by Objet Geometries. The need for the file conversion from a CAD model to an STL file is to achieve surface faceting using triangulated representation. This allows the complex surfaces to be broken down into simple triangles that are manageable to be traced by the nozzle of the printer.

A user next must transfer the language file to the computer that controls the 3D printer. This is where the size and orientation of the product is chosen, similar to selecting preferences while using a standard inkjet printer at home.

Depending on the make and model of the printer that was chosen, certain requirements must be met for the machine setup. This step can include set up requirements such as refilling the polymers or ceramics and adding a tray as a base support.

The actual building process is next, which is almost entirely controlled by the machine. Depending on the thickness of the layers, the chosen machine and the materials used, this process could take anywhere from minutes to days. The machine is even checked on periodically to ensure that no errors have taken place.

The following step would be to remove the product or products from the machine bed. Safety precautions must be taken at this point such as wearing gloves, goggles and even a lab coat to protect oneself from harsh chemicals if required.

Post processing of the printed product is usually required to a certain degree depending on the accuracy of the functioning machine. This could include brushing the product free of loose powder or residue or bathing the product free of water-soluble supports. The user must be extremely careful while handling during this phase due to the extreme weakness of the product based on its material make.

The final and most exciting step to the process is its application! The product has been designed, created, and is now ready for its intended purpose and application.

3.6- Prototyping with a Desktop 3D printer

With access to an Ultimaker 2 by Ultimaker desktop printer, I was able to prototype easily and at my own convenience. However, the largest drawback in using a desktop printer was the amount of time it took for the printer to complete its job. Originally, I had planned on printing the walker at full scale according to the dimensions that I had assigned to the drawings in SolidWorks. However, once I realized that the printer would take over 24 hours to complete a single prototype at full scale, I quickly chose to print at 3:4 scale and reduced the printing time by about 10 hours.

Upon completion of the 3D CAD in Solidworks, a file conversion from .SLDPRT to .STL, the file may be uploaded to a program named, Cura. The program is known to be a free and open source 3D slicing software. A slicing software simple cuts the product into hundreds (sometimes thousands) of slices so that a printer can recognize a finite amount of layers that must be printed for the completion of the entire deposition process. Below is an example [Figure 10] of one of the Rowdy Walker conceptual designs when modeled in Cura. Images for the entire suite of the Rowdy-Walker layered profiles may be found in Appendix B.

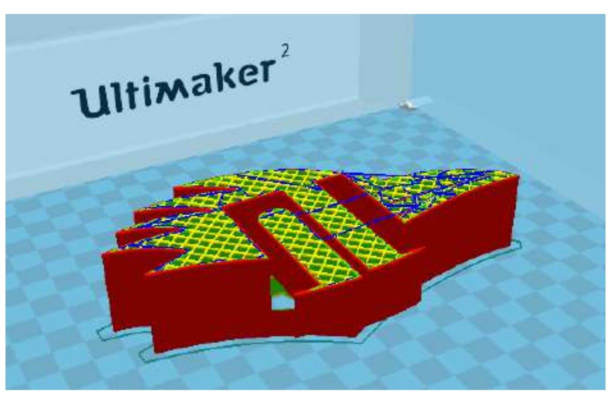

Figure 10: Cura layered profile for Concept Design #1

Following is a table [Table 3] of only the shared printing properties for all of the Rowdy-Walker designs as selected in Cura including the layer height of the PLA filament, thickness of the walls (also known as shell thickness), the thickness of in between the individual layers or fill, the printing speed, the support.

Table 3: Shared Printing Properties of Rowdy Walker Designs #1-5 as Modeled in Cura

	Quality	Fill	Speed & Temperature	Support
Layer Height (mm)	0.1	-	-	-
Shell Thickness (mm)	0.8	-	-	-
Enable Retraction	Yes	-	-	-
Bottom/Top Thickness (mm)	-	0.6	-	-
Print Speed (mm/s)	-	-	50	-
Structure Type	-	-	-	Lines
Overhang Angle for Support (deg)	-	-	-	60
Fill Amount (%)	-	-	-	10

As the prototyping process quickly developed, I learned which settings worked best for my particular material, product, and machine, so that I could achieve the best Rowdy-Walker possible. The next table [Table 4] displays the various contrasting printing properties of the designs that I selected in Cura while manufacturing.

Table 4: Contrasting Printing Properties of Rowdy Walker Designs #1-5 as Modeled in Cura

	Fill Density (%)	Support Type	Platform Adhesion Type	Estimated Time to Print (hrs)	Print Scale (%)
Design #1	80	Everywhere	Raft	13.4	75
Design #2	80	None	Raft	14.5	75
Design #3	100	None	Raft	15.6	75
Design #4	60	Everywhere	Brim	29.5	100
Design #5	80	Everywhere	Brim	15.0	75
Design #6	80	Everywhere	Brim	15.0	75

CHAPTER 4: ANALYSIS OF RESULTS AND IMPROVEMENTS

4.1-Ramp Trials

To determine the required slope for each of the prototypes to achieve a number of steps, I used a rigid piece of wood and various sized boxes to obtain a number of slopes as seen in the table below. I used a protractor to measure the many slopes in degrees by taking the average of five runs down the ramp. The sensitivity based on slope can be seen in the following results in Table 5. The various prototypes of the toy proved to be highly sensitive. Also sensitive, was the way in which I launched to toys. I found that I was able to launch the toy two ways: one by pushing the back of the head down onto the ramp and then quickly releasing, and the second was by pushing the beak down on the ramp and quickly releasing. Too quick or too slow of a release also affected the launch negatively.

Table 5: Results of Ramp Trial Testing

Slope of Ramp	5 Degrees	10 Degrees	15 Degrees	20 Degrees	25 Degrees
Design #1	No	No	No	No	No
Design #2	No	No	No	No	No
Design #3	N/A	N/A	N/A	N/A	N/A
Design #4	Yes (1)	Yes (2)	Yes (1)	Yes (1)	No
Design #5	N/A	N/A	N/A	N/A	N/A
Design #6	Yes (1)	Yes (6)	Yes (4)	Yes (1)	No

I identified a number of problems as I developed the various prototypes. Design #1 [Figure 11] failed for every single angle of slope. The reason was very obvious- the curvatures of the feet were far too substantial. This was the very first design change and the main difference between Design #1 and #2.

Figure 11: Photo of 3D Printed Prototype #1

Once the second design [Figure 12] was ready for testing, it also was nonfunctional. Due to its nature of displacement, I drew the hypothesis that both Design #2 and Design #1 required additional weight along the feathers of Rowdy to gain enough momentum to wobble and achieve a step. I tested this hypothesis by taping 3 driving bit amounting to a weight of 19.03 grams.

Figure 12: Photo of 3D Printed Prototype #2

By discretely enlarging the feathers of the Rowdy logo in SolidWorks, I successfully added 19.0 grams where needed. Aiding in the redistribution of the toys weight in order to offset the center of mass, I also hollowed out the beak. With these changes, the third walker [Figure 13] was printed. Soon after removing the supporting material, the dynamic leg broke from the toy. When relooking at the CAD file I drew the hypothesis that the tolerance between the leg and the shaft was far too small.

Figure 13: Photo of 3D Printed Prototype #3

Fixing the tolerances between the shaft and dynamic leg was the first change for Design #4 [Figure 14]. I experimented with the scaling and chose to print a 1:1 scale for this design. Unfortunately, during testing I realized that without redistributing the weight for the new scale I would continue to print unworkable walkers.

Figure 14: Photo of 3D Printed Prototype #4

I switched back to 3:4 scaling for Design #5 [Figure 15]. Having changed the tolerances once more between the leg and the shaft, I stopped the printing process about halfway. As with the print of Design #3, the tolerance was far too minimal.

Figure 15: Photo of 3D Printed Prototype #5

By combining all of the previous design strengths and ridding of the flaws, Rowdy-Walker #6 [Figure 16] was the final prototype that I produced and found to be very successful at a ramp slope of about 12 degrees. The final prototype can be seen in the dynamic stills below [Figure 17].

Figure 16: Photo of 3D Printed Prototype #6

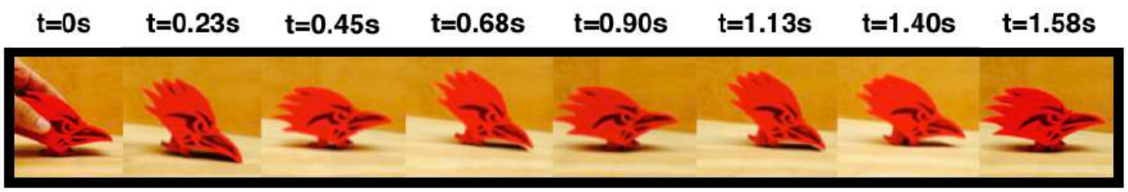

Figure 17: Dynamic stills of Rowdy-Walker Design #6

CHAPTER 5: APPLICATION OF RESEARCH

5.1-Characterization of beginning a Tech Startup

Discussed in an online article, a tech startup is a company quick in beginnings that involve using technology, engineering, and the sciences to create something new [17]. More entrepreneurs are emerging due to the availability and reasonable affordability of tools such as 3D printers. My dream is to one day successfully start my own tech company from home. This design process that I chose to pursue with the Rowdy-Walker toy evolved from this dream.

5.2-Creating Company Product Names, Logos, and Patenting

One of the most exciting steps in creating a company is choosing a name. For me, it was a little easier to first choose a name for the product, aka Rowdy-Walker. Inspirational credit may be given however to the long existing, Passive Dynamic Toy Walkers. Knowing that I wanted to develop a product that would capture UTSA school spirit, I began with the word, “Rowdy”. Rowdy is the name of the UTSA roadrunner mascot. The word itself is a bit fun due to its synonymous nature with “Unruly”, “Uncontrollable”, and “Wild. Together, the words “Rowdy” and “Walker” gave way to my new product name. Choosing university colors and various fonts, I was able to design the “Rowdy-Walker” logo as seen below in Figure 18. To use any of the UT System’s logos or colors for the selling of a product, I had to receive permission from UTSA as well as the UT System. UTSA has already granted me permission after seeing the toy, and I have yet to approach the entire system. Also, the colors I used had to match the red, green, and blue values or RGB for UTSA exactly.

Rowdy-Walker

Rowdy-Walker

Figure 18: Product Name and Logo

Next, I thought about the future of the brand and what it could possibly entail. In my mind, I envisioned an unlimited amount of UTSA colored, mascot inspired, and “Rowdy” memorabilia for fans, Alumni, and students such as myself. Pairing the word “Rowdy” once more now with the second half of “Memorabilia”, I came up with a company name and logo for “Rowdybilia”. My selected fonts and colors can be seen below in Figure 19 and are the exact UTSA colors as accepted for use by UTSA.

rowdybilia!

rowdybilia!

Figure 19: Company Name and Logo

When talking with various professionals, most urged me to pursue a patent as soon as possible if choosing to mass-produce and sell the toys. UTSA also has an office that assists students throughout this process.

5.3-Package Design of a Product

When approaching any sort of investors, whether they are offering money, advice, or even their time, it is best to put your best foot forward as a new entrepreneur. I learned that you not only need a product, you also need somewhat of a business plan, marketing scheme, and even packaging! Having the prototype working and looking its best will make a huge difference when you are asking others for any sort of investment.

My packaging concept is still in the early conceptual stages. I plan to create a box that can be unfolded into a ramp for the toy walker.

5.4-Mass Scale Production

Due to the extremely long 3D printing process, I also am looking into the benefits of mass production with an external manufacturing company. A very important problematic issue has arisen however, the company's that create the molds to produce the plastic toys do not take into account the distribution of mass (something I continually have to tweak with all designs depending upon any sort of small modifications.) The cost for their engineers to review and achieve the perfect rotation about the center of mass is outrageous for a startup such as myself. For this reason, I am now looking into scaling down the model into a 1:2 scale, which is estimated to print in 7 hours. Also, if possible I am open to the idea of buying a duplicate printer and printing on both machines simultaneously.

5.5-Target Marketing a Product using Social Media

Millennials have taken a strong hold of social media as their eye to the world and all it has to offer. Social media has now become the new advertising choice of companies major to the everyday entrepreneur working from their home. The biggest attraction for small startups?- it's free!

5.6- From Research and Development to Product Designer

This thesis has served as a great growing experience; in helping me realize the beginning steps required to research, design, and prototype a product in efforts to staring a tech startup. Using the resources available to me throughout the university, I was able to gain the exceptional mentorship needed to pursue such a great task.

After successfully completing the challenging manufacturing process I had at hand of 3D printing an assembly of parts in a single sweep, I now consider myself to be a true Product Designer. I am excited for the continuation of this assignment and am very much looking forward to final business outcome of the product!

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APPENDIX A: 2D CAD DRAWINGS

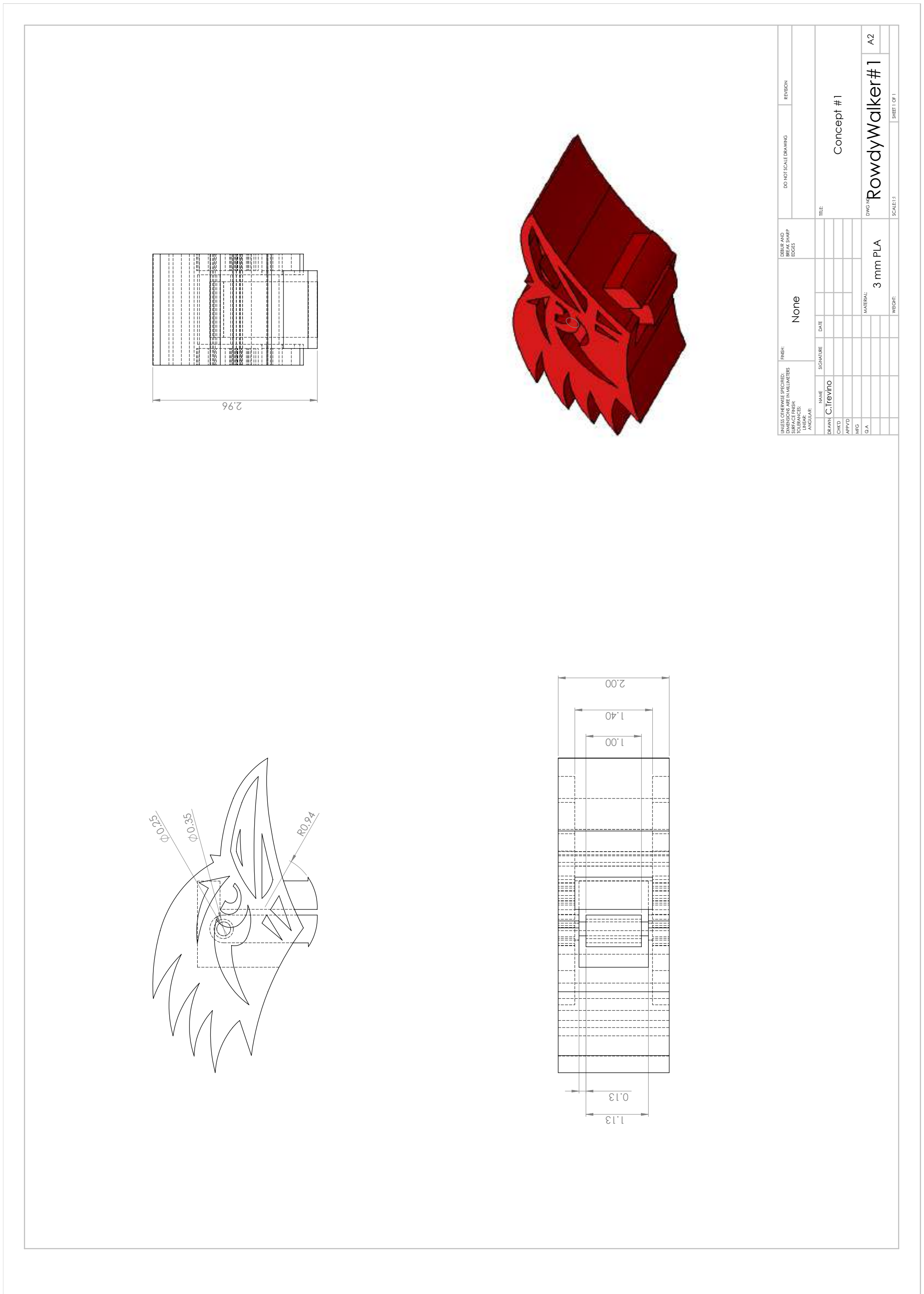

Figure A-1: 2D CAD Drawing for Conceptual Design #1

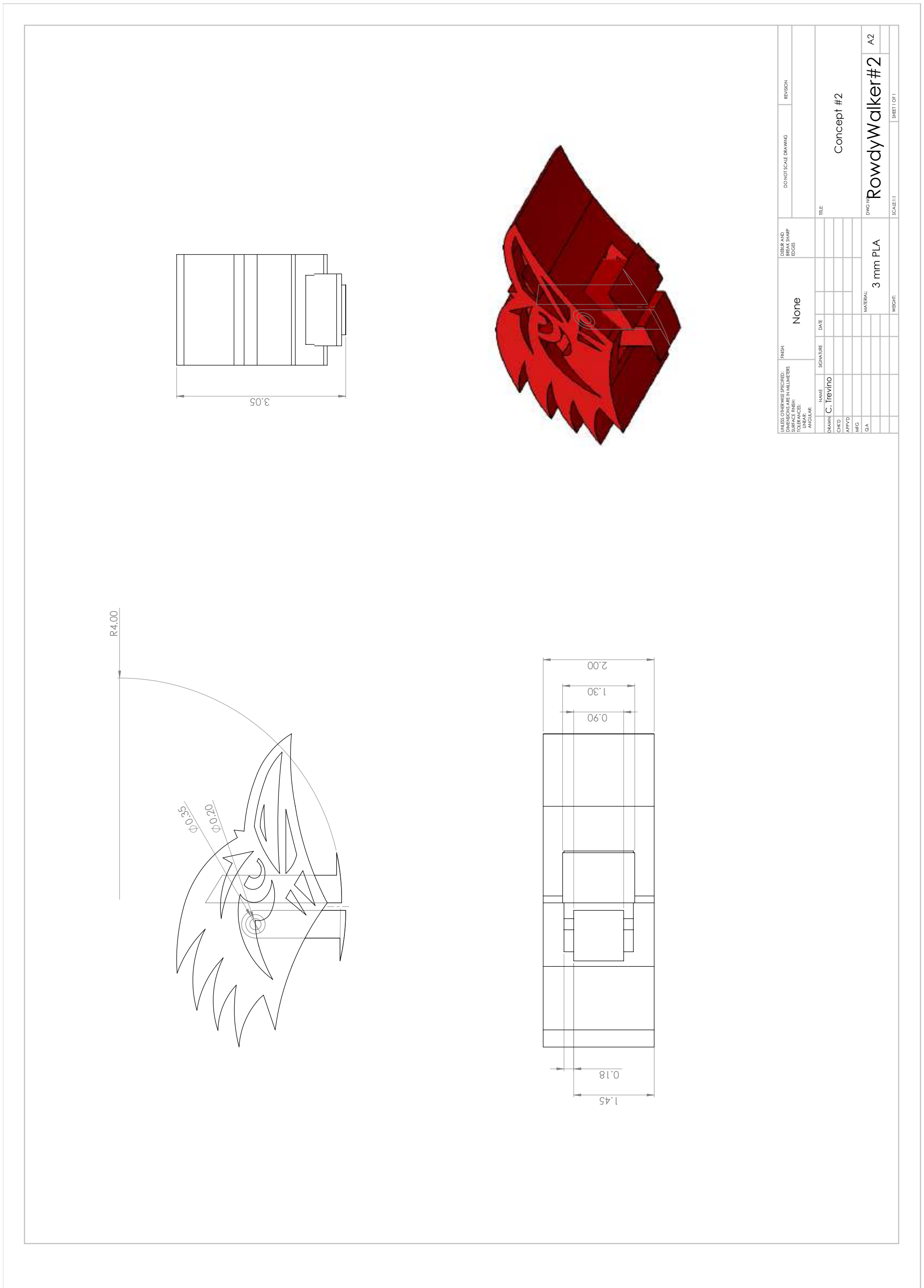

Figure A-2: 2D CAD Drawing for Conceptual Design #2

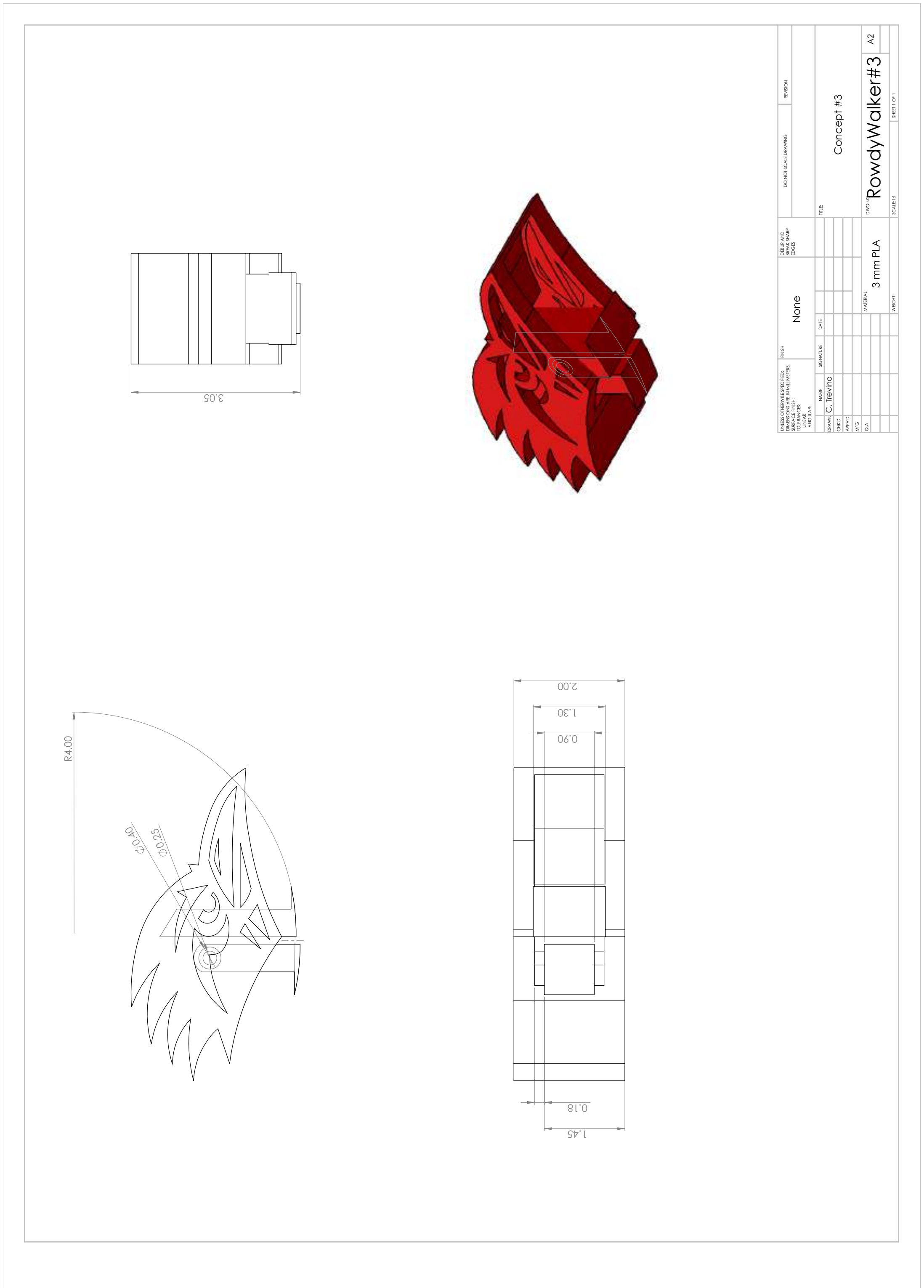

Figure A-3: 2D CAD Drawing for Conceptual Design #3

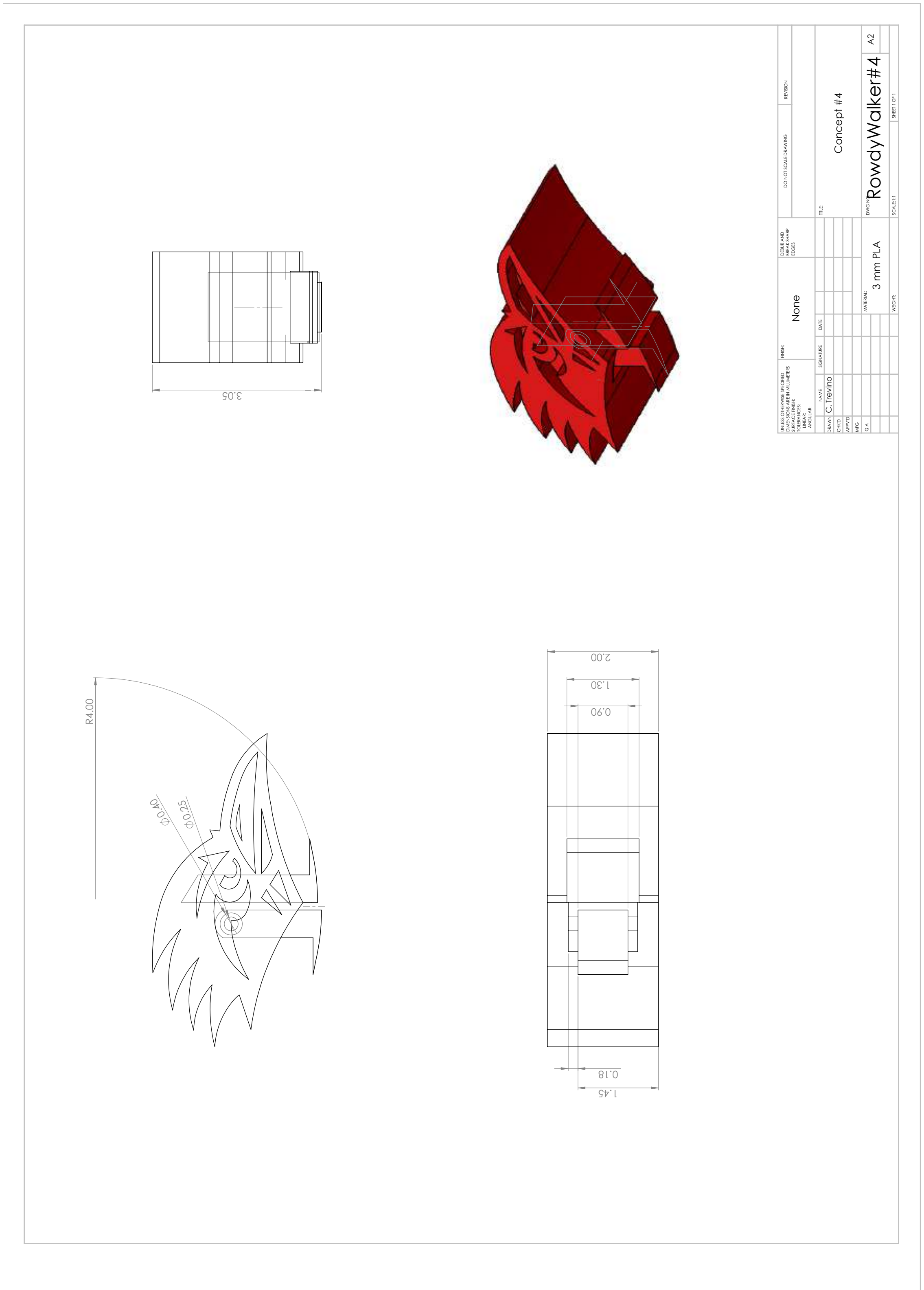

Figure A-4: 2D CAD Drawing for Conceptual Design #4

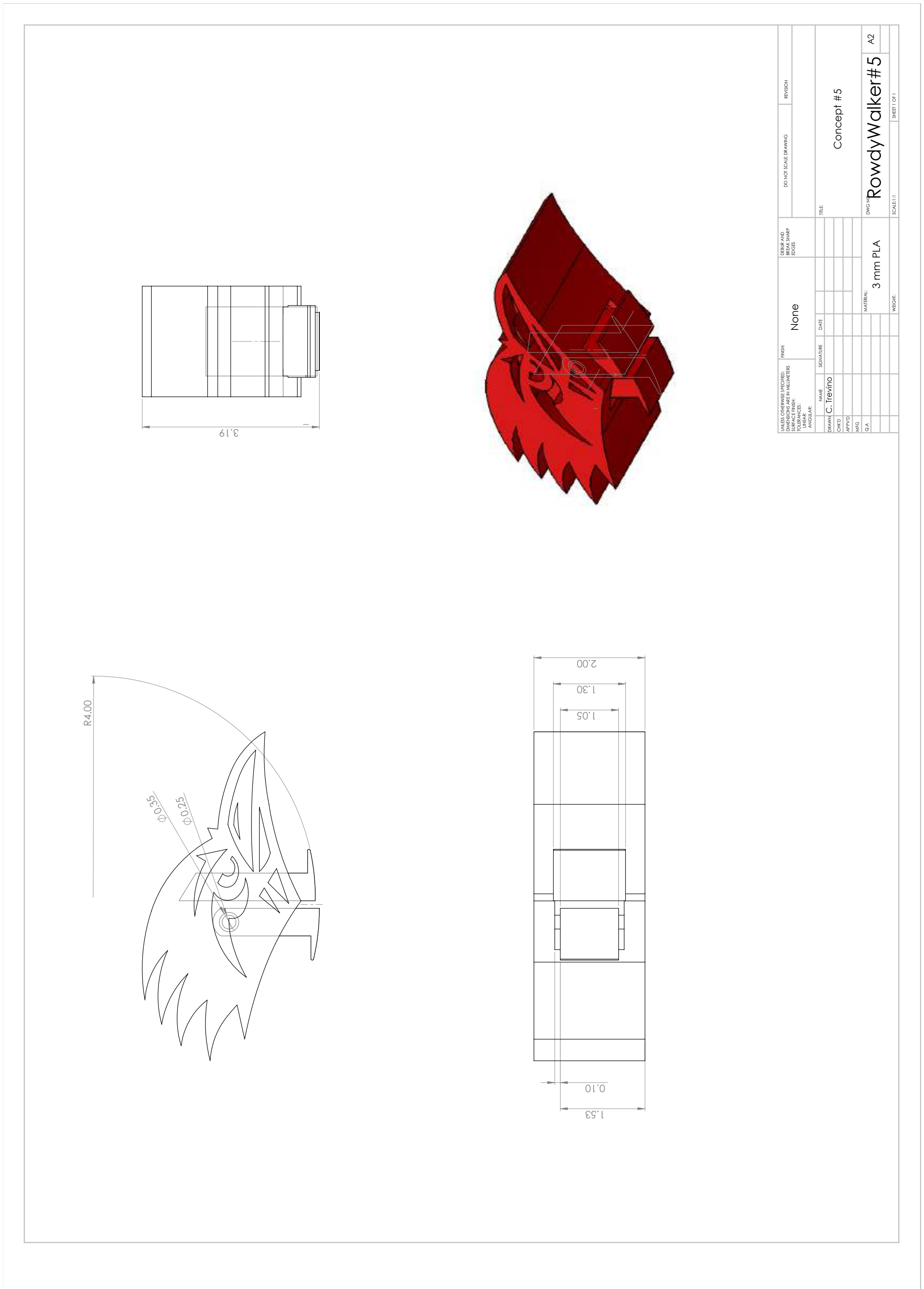

Figure A-5: 2D CAD Drawing for Conceptual Design #5

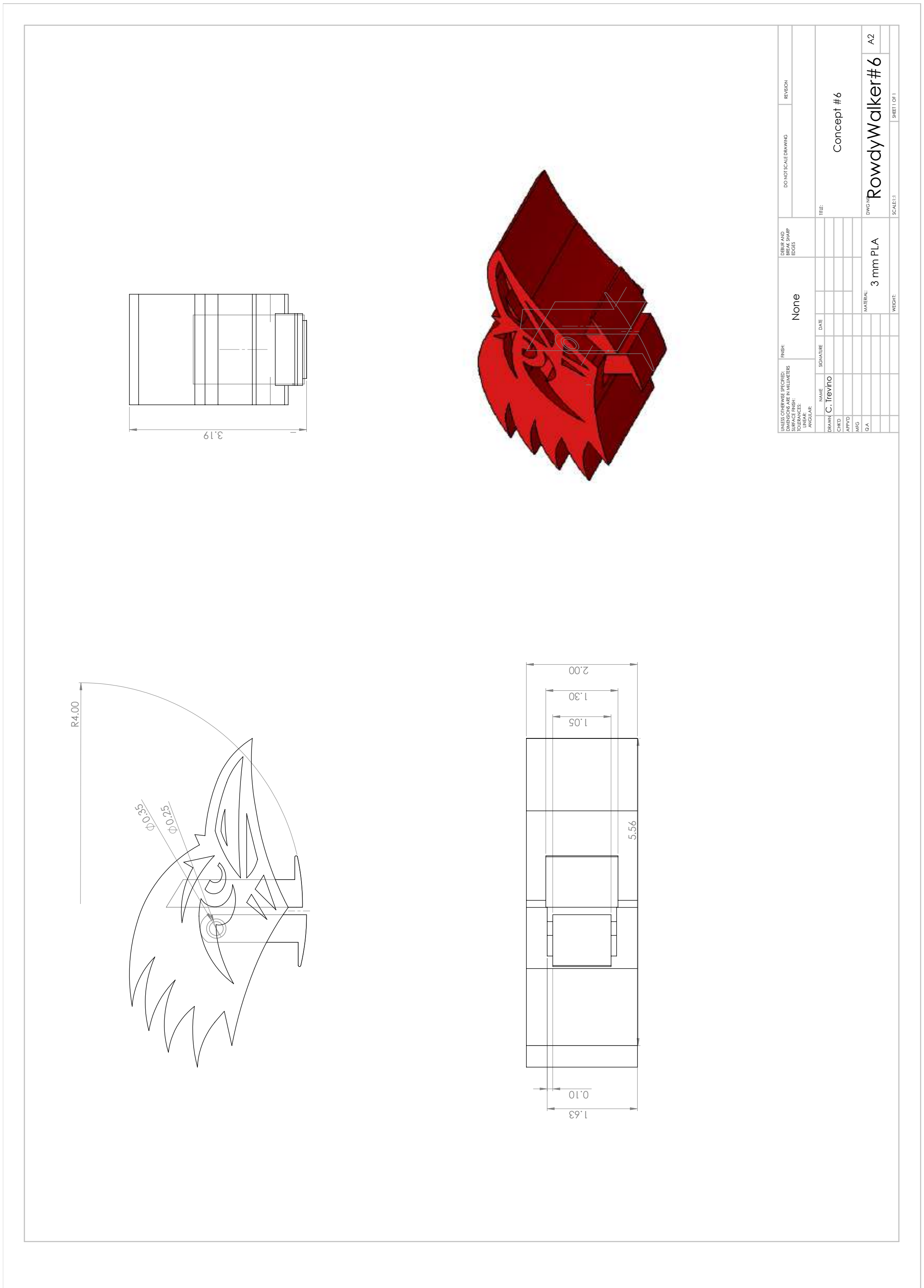

Figure A-6: 2D CAD Drawing for Conceptual Design #6

APPENDIX B: 3D CAD RENDERINGS

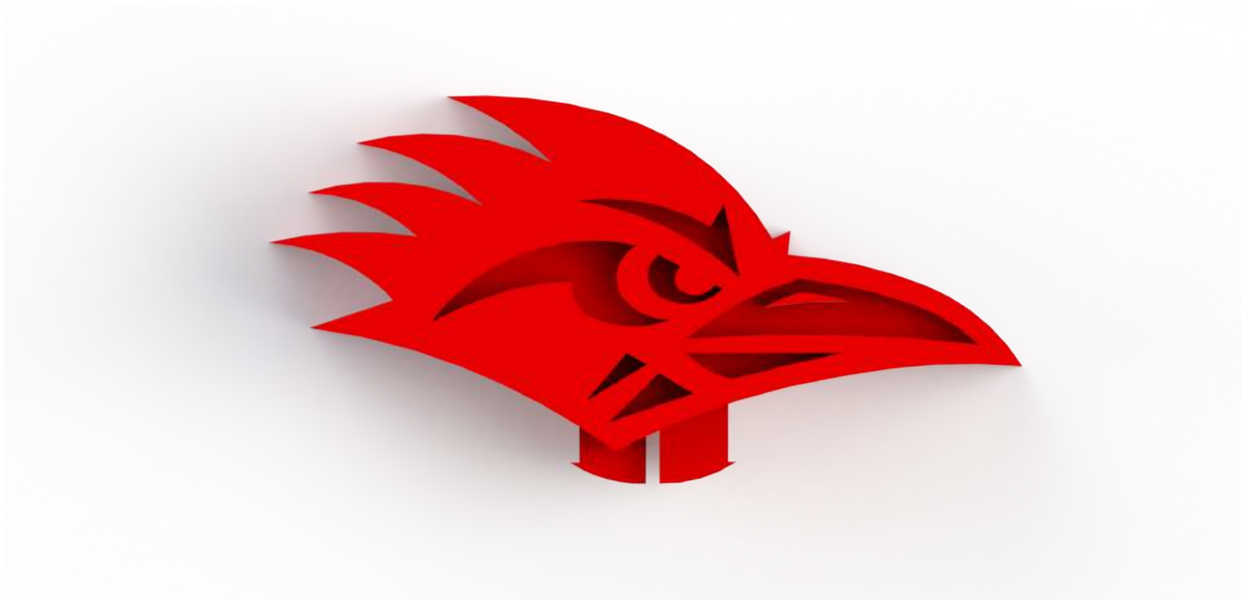

Figure B-1: SolidWorks Rendering of Conceptual Design #1

Figure B-2: SolidWorks Rendering of Conceptual Design #2

Figure B-3: SolidWorks Rendering of Conceptual Design #3

Figure B-4: SolidWorks Rendering of Conceptual Design #4

Figure B-5: SolidWorks Rendering of Conceptual Design #5

Figure B-6: SolidWorks Rendering of Conceptual Design #6

APPENDIX C: 3D CURA LAYERED PROFILES

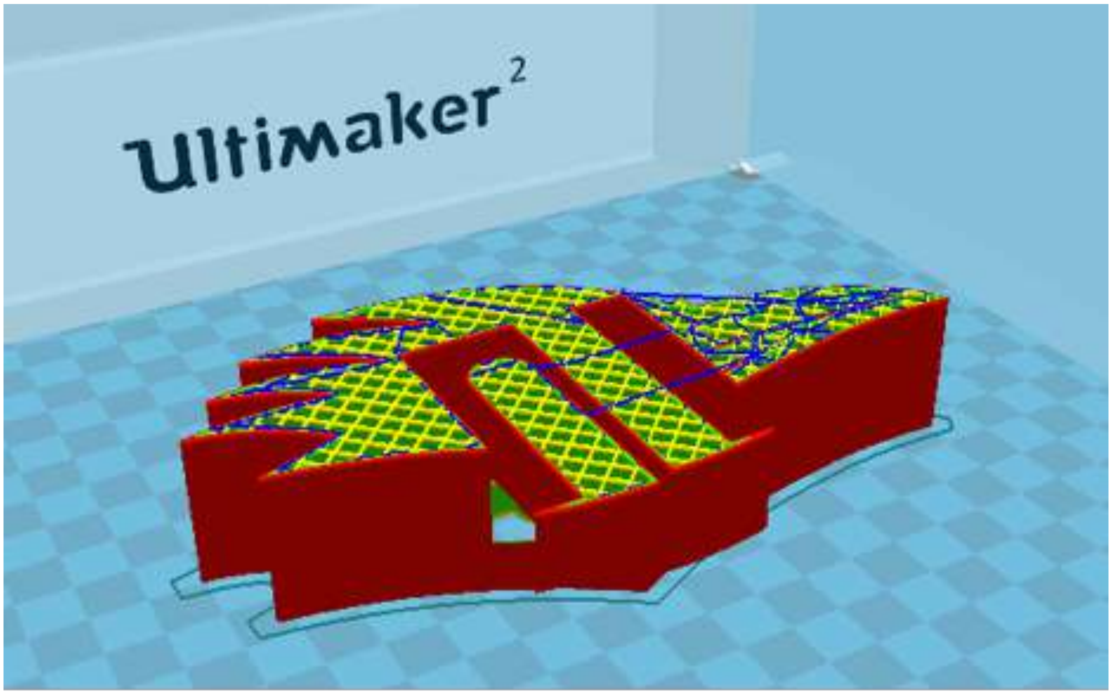

Figure C-1: Cura Layered Profile for Conceptual Design #1

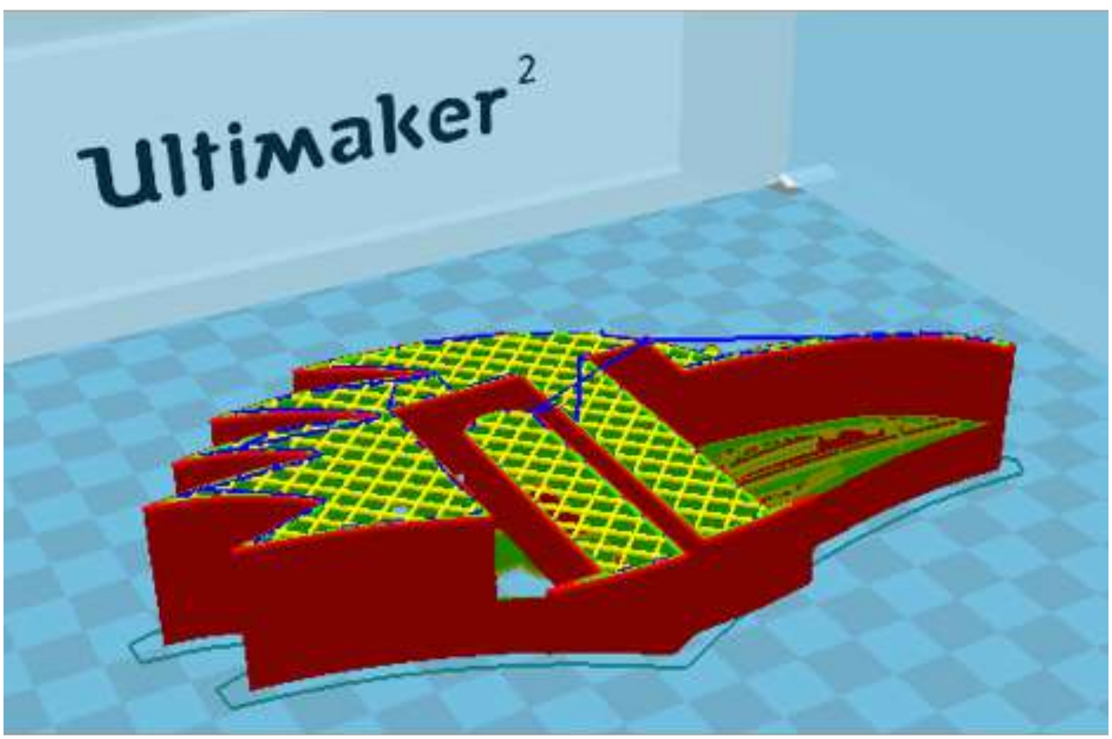

Figure C-2: Cura Layered Profile for Conceptual Design #2

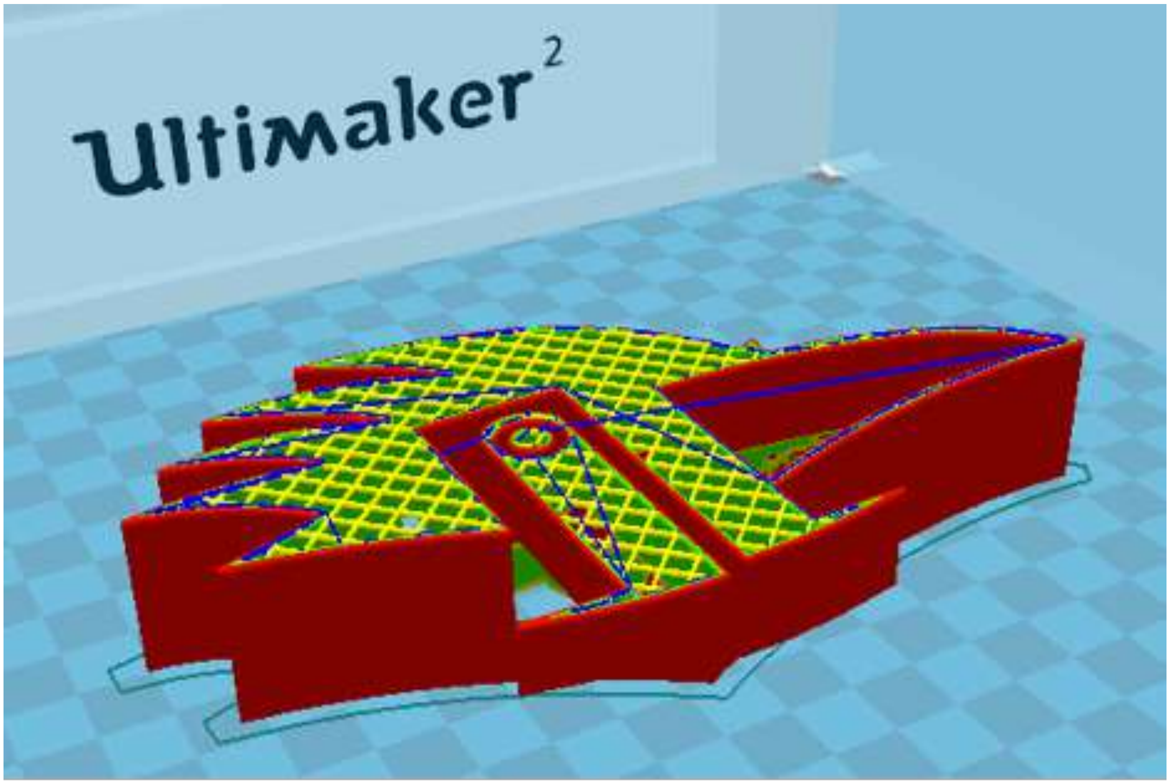

Figure C-3: Cura Layered Profile for Conceptual Design #3

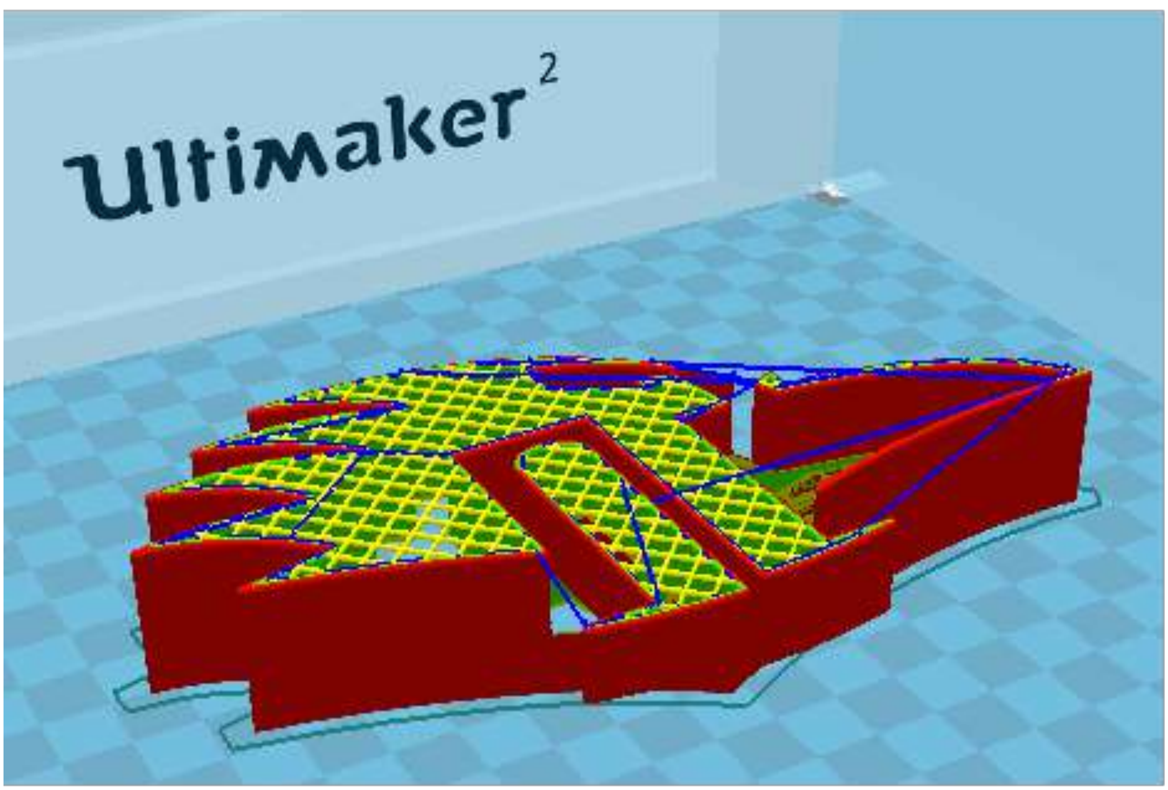

Figure C-4: Cura Layered Profile for Conceptual Design #4

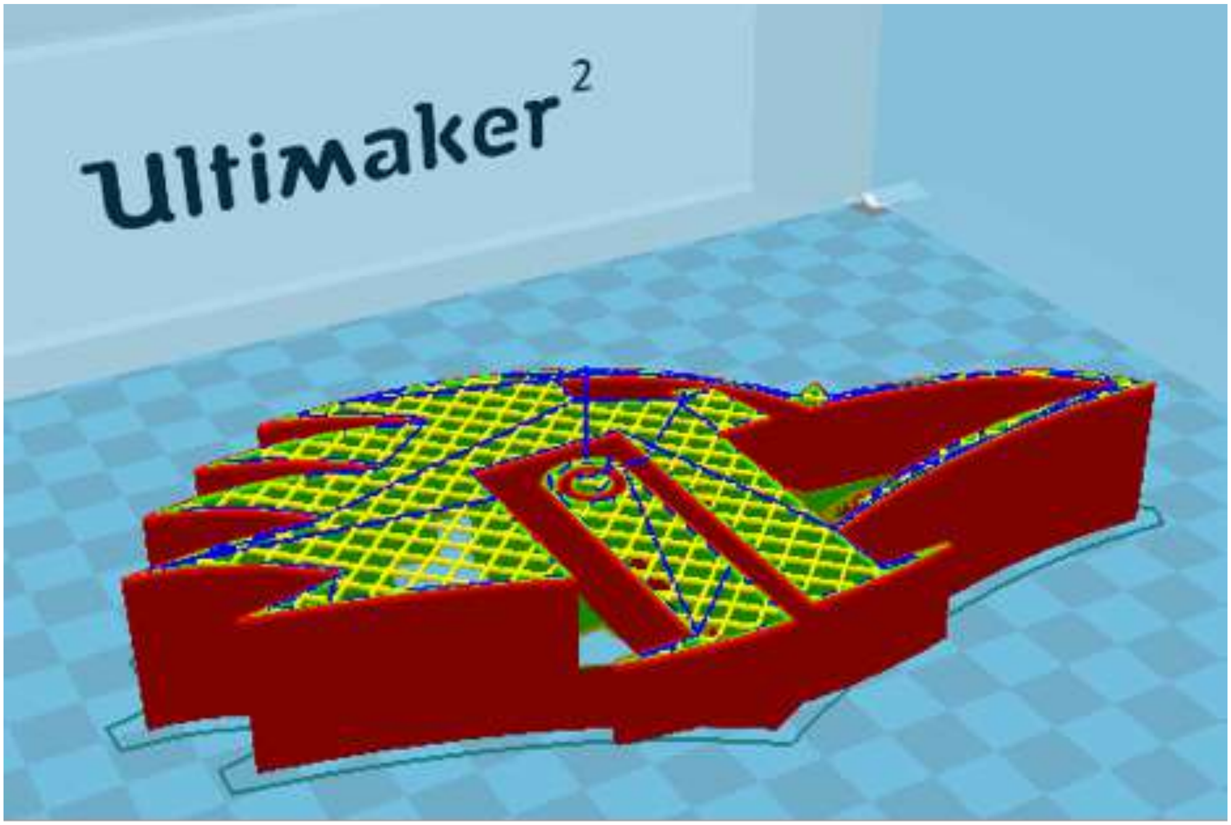

Figure C-5: Cura Layered Profile for Conceptual Design #5

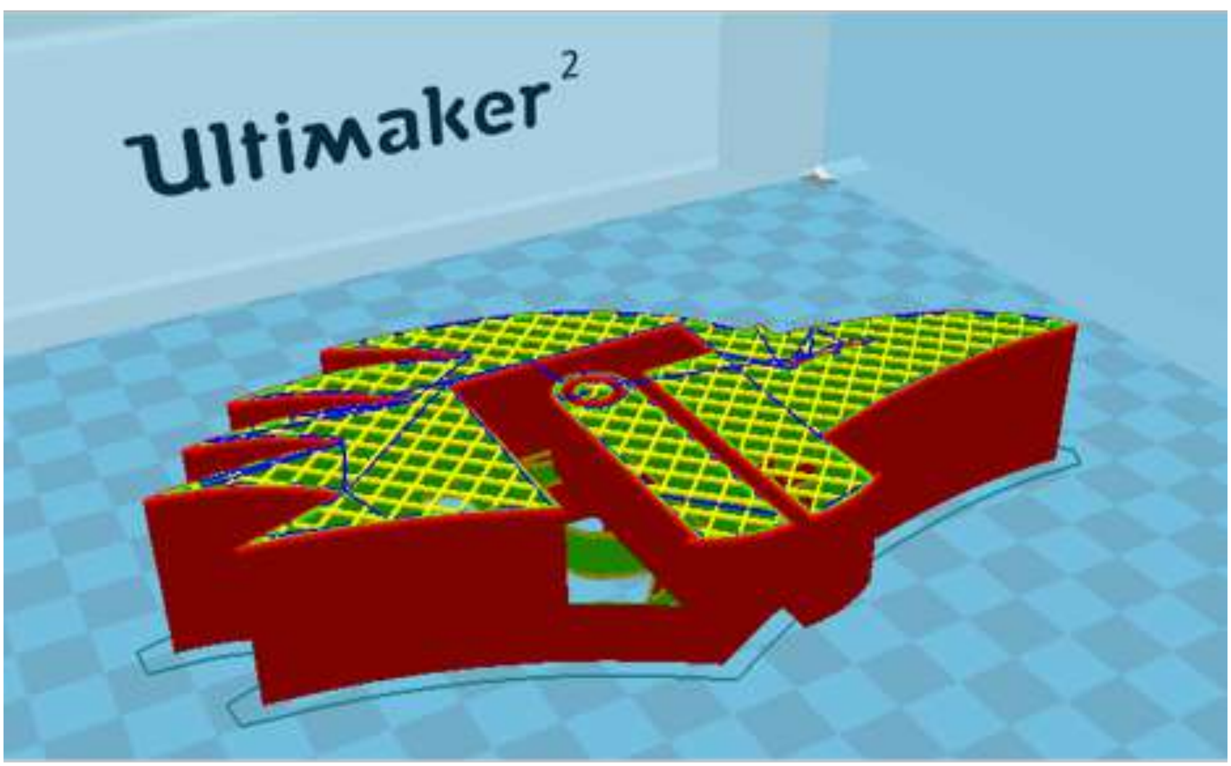

Figure C-6: Cura Layered Profile for Conceptual Design #6