Final Report

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DISCLAIMER

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Executive Summary

This report illustrates the building process of a kinetic sculpture and progress throughout two semesters. The kinetic device was created based on customer requirements provided by the client. The device should utilize several mechanical engineering principles that connect together creating a mechanical system which consist of more than two subsystems transferring energy from one part of the design to another with minimal effort eventually creating a display that combines art with engineering. Therefore, the team chose to build a device that consist of two main parts, each part represents a branch of study. The artistic branch is represented by the bird shaped sculpture and the engineering branch is represented by the mechanical subsystems. Furthermore, the team's client Dr. Sarah Oman requires a device that is lightweight where two people can carry it, fits through a standard size door and contains at least three mechanical principles thus the team cultivated the device based on these requirements. The team created three initial designs thus accumulating ideas and mechanical principles to create a final design shown in figure 1. The design overall cost was around $900 and exceeds the number of mechanical principles required by the client. The subsystems created are; crankshaft, camshaft, bearings, bevel gears, and a pulley system with a v-belt. Some parts of the sculpture were manufactured in a machine shop and the rest were manufactured by the team utilizing power and basic hand tools. Testing for each subsystem was performed and are mentioned in detail in the report. For future reproduction, some of the part's material can be replaced with materials such as aluminum and wood.

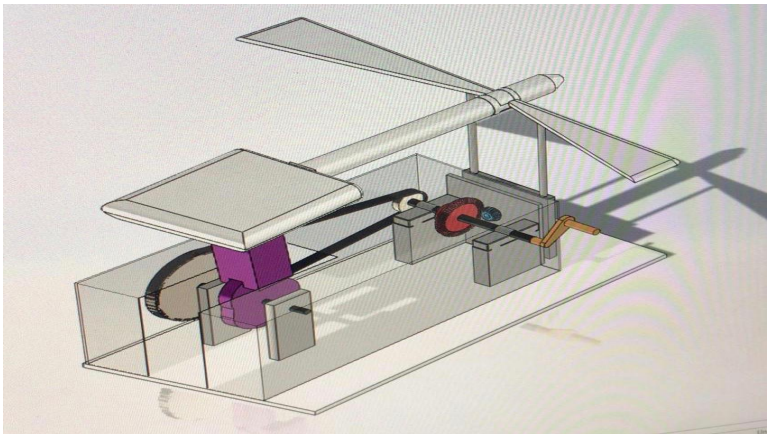

Figure 1: CAD Model

1 Background

1.1 Introduction:

The aim of this project is to create a kinetic sculpture that illustrates several principles of mechanical engineering combined with an artistic method. Kinetic sculptures are forms of art used to exhibit motion that would improve attractiveness of the object. This artistic object utilizes engineering concepts such as energy and transferring it to express fascination. The blending of engineering and art has been displayed in various kinetic sculptures. In this assessment, the major interest is on a kinetic sculpture made of different types of materials. In addition, the project is developed to provide a deeper understanding of the physical nature of engineering. The kinetic sculpture is made to comprehend the working of the designing principles and material science behind the development of specific items [2]. The motivation behind the task is to make a moving model that contains several mechanical engineering principles that shows moving parts connecting together. The device comprises of two primary segments, one is the flying bird that incorporates moving wings and a tail. The second segment is a case that contains the subsystems. The customer requirements were assigned to begin the building process by a mechanical engineering professor as a client. The client will supervise the device's development throughout the time span of two semesters. The device should illustrate a product that combines two branches of studies which are engineering and art thus the design consists of two main components. The first component is the bird that represent the artistic branch and the second part is the mechanical subsystems that shows the engineering part of the project. The imaginative and focal point of this project will be outlined through the feathered bird development of wings and tail. The working mechanical components such as gears, shafts and rods will illustrate the engineering principles and knowledge learned at NAU.
So as to most viable pass on what NAU brings to the table to imminent understudies, we expected to survey what school destined understudies find vital while choosing a college to visit. In particular, we were keen on recognizing factors that may separate one school from another. Our plan and idea were defined to help NAU pull in potential understudies. Regardless of whether the model is set in the Campus Center, Labs, or, when completed, the remodeled Alumni focus, it must be effectively open to visit gatherings and show how run of the mill address learning can be taken and connected to both energizing and viable structures. As of now, NAU infrequently shows SCP extends in the engineering building. Notwithstanding, these activities are not explicitly intended to educate and interesting visit gatherings. This is the thing that makes our venture better than showing another undertaking that was made to satisfy some other need. Our model gives a physical outline of some of what the college brings to the table while encapsulating the basic undertaking knowledge that is so underscored by NAU. Furthermore, this device was made with limited resources. Parts in this device can be replaced with better and much durable materials. For future production, the wooden shafts can be replaced with aluminum shafts, the 3D printed gears can be made with metal materials, The Styrofoam can be replaced with wood and the plastic rods can be replaced with steel rods.

1.2 Project Background:

Kinetic Sculptures could be separated into two classifications. The main classification introduces to the forming with genuine movement. The other one classification is that the molding is

stationary yet would frame figment marvel in movement observation towards the sight. The Kinetic Sculpture before the twentieth century essentially expected to make an increasingly helpful and effective way of life. After the twentieth century, the results of current modern innovation (i.e., new hardware, instruments, and materials) continued being created, and the once amusement arranged kinetic sculpture structuring moved towards the field of sculpture.
Innovation Exists in Creative Thinking The incorporation of Kinetic Sculpture and science will move Kinetic Sculpture portrayal to a phenomenal condition of success. Not just light, power, and different science and innovation can turn into the materials for Kinetic Sculpture portrayal, distinctive types of intensity source can likewise be utilized as the methods for Kinetic Sculpture portrayal, to build up the Kinetic Sculpture portrayal with new sort of condition of development. Given where Kinetic Sculpture is at today, the impact of Kinetic Sculpture can be said is amazingly extensive. The mechanic-specialized Sculpture of the later piece of the twentieth century, on account of the foundation of related details that are delicate/equipment and logical hypothesis, has empowered Kinetic Sculpture inventive embellishments creation to accomplish an extraordinary advancement. It empowers designers to help control both the Kinetic Sculpture's structure and substance, and this likewise empowers the show of inventiveness and thoughts. In the meantime, mechanical innovation has its accentuations on organizing artistic methods to help illustrate mechanical components, designing standards, and input. These are altogether epitomized by Kinetic Sculpture inventive trim, which uncovers the way that Kinetic Sculpture embellishments co-usable connection with innovation has could really compare to ever previously. Then again, Interactive Sculpture empowers Kinetic Sculpture trim to change once more, permitting Kinetic Sculpture embellishment to produce intelligent manifestations, changing the piece's substance, structure and the manner in which it is being displayed through the groups of onlookers' eyes. This implies the groups of onlookers' involvement, sensation and input become some portion of the piece's importance.

The Performance of Kinetic Sculpture Will Combine Interaction. Through connection among watcher and work of Kinetic Sculpture, when such work can be openly constrained by watcher's inclination or mindfulness, it permits the new aesthetic taste and fun experience of such work to be brought out. Along these lines, in the present fast improvement of 3D innovation and promotion, while making intelligent Kinetic Sculpture works, the maker must consider keeping intuitiveness in thought, and after that through fun factor to upgrade the whole Kinetic Sculpture idea.

1.3 Project Description:
For the project description team targeted several statements enlisted from the client to create the design from an assortment of inspirations to offer one of its own for a complex Kinetic sculpture. To satisfy the descriptions, each group member must work out the accompanying multifaceted undertakings:

- Build a strategy that shapes the plan and improvement of the group's Kinetic model and burden into an attractive structure design.
- Team decided on documentations and blue prints in order to contribute the brainstorming process for the project.

- Configuration, fabricate, and present a remarkable, mechanical-driven component depending on the two branches team strategize and then test the mechanical segments.
- Members should create mechanical principles that is protected, dependable and successful.

2 Requirements:

This part will convey various needs and objectives given from the client in detail.

2.1 Customer Requirement:

Customer requirements are illustrated in Table 1

Table 1 Customer Requirements

Customer Requirements	**Weight (T=250)**	**Description**
Mathematical link to the Kinetic Principal	49.5	This ensures that the sculpture made has gone through a mathematical test and linked with the entire project.
Energy Production	36.25	It shows that with the movement of mechanical components under various conditions determine the production of energy within the system.
Mechanical Components Modeling	31.25	It shows the mechanical components such as bearing, belt, and gears are safe to use and integrated with each other.
Uncertainty in the Modeling	27.5	How often the mechanical components need maintenance? Determine the life cycle of each component
Installation of System	26.5	Ease of installation of the mechanical parts and lubrication of the system and estimated reduction in cost for the initial installation process
Kinetic Sculpture Operation and Maintenance		Ease of Sculpture maintenance and a further reduction in the operational cost of the system making it more reliable.

2.2 Engineering Requirements:

Engineering requirements are stated in Table 2;

Table 2 Engineering Requirements

Engineering Requirements	**Measurements**
Weight of Device	45 lb.
Volume	4 x 2 x 2.3 ft
Wingspan	4 ft
Crankshaft	18 in

A House of Quality (HoQ) is utilized to organize building necessities dependent on the client needs. Each need is weighted by the related significance of the client requirements. In this way, designing classifications can be clearer. The team's table demonstrates the course of action of each building process in the best possible request of significance, where one has the most significant need. Each designing necessity has a resistance in which esteems can fail and still meet the required needs. In order to proceed with designing, the team discussed several attributes as enlisted and requested from the client, but in order to approach the problem these requirements need to be switched to engineering requirements to apply it when designing and creating the principles. Firstly, the target needed to be set is using technical analysis into transforming the situations and problem statements given towards the analytical term. Secondly, is having the device to fall due to the weight, as if it does many systems will stop working and redesigning should be considered. Third in process, is the appraised crankshaft speed, which is the planned shaft speed for the revolution of the mechanism. Evaluation made, shows that overpowering or exceeding in power would decrease the lifespan. Next, are friction impacts, which are the increase in pressure disturbing the movement of an active model or even might cause a slip. In cases the more the friction the higher the chance of slipping would occur, having to decrease the lifespan of several parts.
The use of solidworks contributed into fulfilling the engineering requirement in terms of aesthetics and creating durable parts. This process contributed into introducing team members to a new work environment to hone their skills through teamwork and creativity as well as time management to help build preparations for a career path.

2.3 House of Quality:

The place of value has been utilized effectively by mechanical engineering professors, that has skills referring to motors, machines, systems, pulleys, shafts, and etc. Professors in the department of Northern Arizona University (NAU) use it for administrations to recognize the qualities of the design of various aspects. Multiple sorts of arrangements and scheduling applies into submitting a design with high quality value. First a plan is necessary to help target designing reducing failures. The frame of the work being delivered based on the house of quality in figure 2 reflects the message being tasked by the client/sponsor. The place of creative skills is somewhat guidance that gives the way to interventional arranging and interchanges.

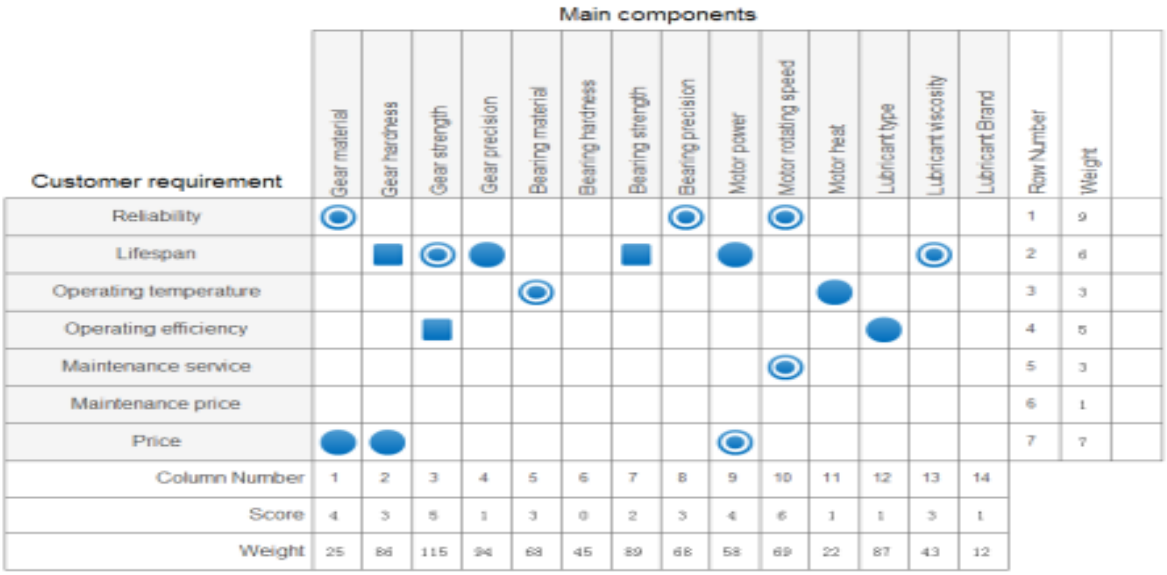

Figure 2: House of Quality

2.5 Design Link (DL):

To guarantee that building necessities were met, correlation of the outcomes with the designing prerequisites was performed. Note that the DL underneath was numbered dependent on the client without including several aspects.

- **2.5.1 Sculpture Weight**

The Sculpture weight was met at 45lb by investigating the heaviness of every segment and weighing the whole device. The parts were particularly picked to meet the requirement based on materials

- **2.5.2 Door Fitting:**

Whether or not the device fits the door was utilized by taking the volume resulting in a 2 ft x 4 ft x 2.33 ft making the device door fitting. The dimensions of an average size door are 6.5 ft x 3 ft.

- **2.5.3 Three principles:**

Mechanical principles used have been exceeded through the usage of a crankshaft, Bearing, bevel gears, V-Belt, and a camshaft for an overall five mechanical principles.

- **2.5.4 Aesthetics**

Design aesthetics have been met through symbolizing peace by creating a bird sculpture with realistic motion and sound effects making the device attracting. This part fulfills the artistic attributes needed in the design.

3 EXISTING DESIGNS

Several existing designs have captured the team's attention into applying the final actual design

3.1 Design Research

So as to inquire about current structures in the Kinetic sculpture industry, the group needed to limit the substantial range of business sectors that the design industry is engaged with to help influence people more than selling it. Through various researches and approaches, team started with researches, as "The various assortments of the class incorporate artistic models whose segments are moved via air flows based on other designs just to boost the level of creativity, as in the notable mobiles of Calder; by water; by attraction, the claim to fame of Takis; by mechanical gadgets; or by the investment of the observer himself. The Neo-Dada satiric nature of the Kinetic model made amid the 1960s is exemplified by crafted by Jean Tinguely [5]." His falling to pieces "Praise to New York" idealized the idea of a model being both an item and an occasion, or "occurring." The point of most Kinetic artists is to make development itself an essential piece of the plan of the figure and not just to confer development to an effectively complete static article. Calder's mobiles, for instance, depend for their tasteful impact on continually changing examples of relationship occurring through reality. Whenever parts are utilized, the shapes and measurements of the model may experience nonstop changes.

3.2 System Level

The Client chose for the team to look into including changes by getting inspired from researchers' active figures in the past from various areas. Every one of these models was picked dependent on their capacity to utilize little segments to play out the essential material science or building main and help create the team's design. So as to effectively advertise any item, there must initially be a requirement for the item. At that point, there must be some overall revenue around there for the field-tested strategy to bode well that have been received from the client.

3.2.1 Kinetic Sculpture 1:

A standout amongst the most outstanding active works of art is portable, which is a hanging model comprised of different adjusting components. They might be basic in structure, or be extremely expansive and mind-boggling, made up of a large number of individual parts. Some bigger mobiles may demonstrate little development, yet most will move and change positions consistently in the scarcest breeze.

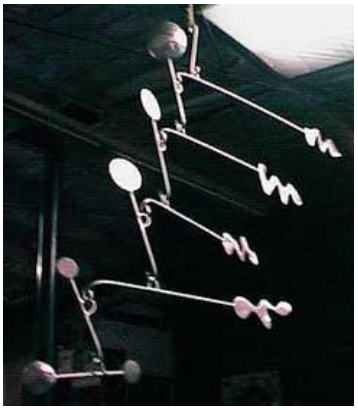

Figure 3: Kinetic Sculpture 1

3.2.2 Kinetic Sculpture 2:

Another notable type of active workmanship is the moving ball machine or "kugelbahn." This is a figure that lets loose (or balls) that pursue a track or pathways by either the power of gravity alone or with the expansion of mechanized gadgets to sustain the movement of the ball. These figures have numerous potential outcomes for tricks or exercises over the span of its way and may incorporate melodic tolls, circle the circle, switches for exchange ways, hops, lifts, spinners, loop hops, and so forth.

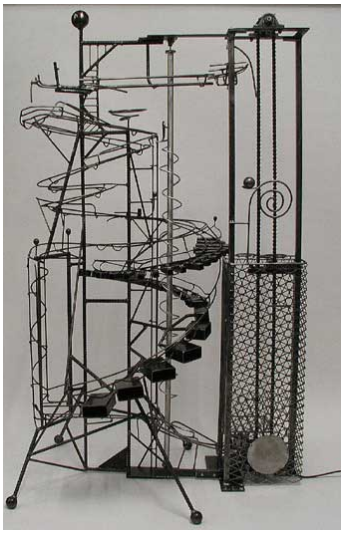

Figure 4: Kinetic Sculpture 2

3.2.3 Kinetic Sculpture 3:

Attractive workmanship is a type of motor craftsmanship with numerous varieties. Some include suspended powerful magnets, and others may welcome the watcher to take part in the fine art by changing the situating of components that are versatile on the grounds that they are just held set up by attractive power. The utilization of powerful magnets can likewise introduce a circumstance that seems unthinkable or doubtful to the watcher.

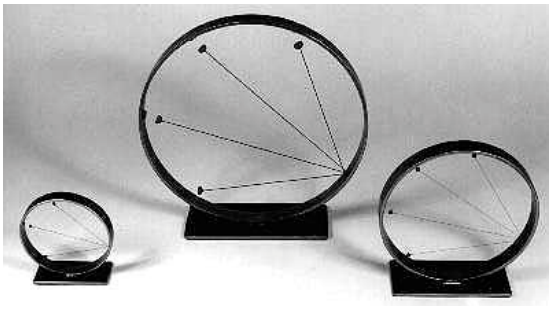

Figure 5: Kinetic Sculpture 3

3.2.4 Kinetic Sculpture 4:

Melodic workmanship is a fascinating Kinetic fine art. This is regularly communicated as a figure of useful workmanship that has a type of melodic characteristics that the watcher may cooperate with. This might be an element of a moving ball machine mold or other work of art too. Wind rings could likewise be arranged here, and are presumably the most prevalent melodic fine art.

Figure 6: Kinetic Sculpture 4

3.3 Subsystem Level

So as to best serve one, or all, of these business designs and ideas, the group dissected the key parts for the Kinetic Sculpture design to work successfully. These parts comprise of Bevel Gears, a Crankshaft, V-Belt, Rods, Pulleys, bearings, and a camshaft. Apparatuses are in charge of changing over active vitality of building through mechanical vitality, while the crankshaft exchanges the vitality to the remainder of the working systems. Finally, the functionality of the design is the main target of the creating the whole device or kinetic sculpture. Contingent upon the objective client requirements, the structure limitations for every one of the segments will change dependending on over powering, friction, and different elements.

3.3.1 Subsystem #1: Bevel Gear

Two critical ideas in equipping are pitch diameter and pitch gear ratio. The pitch diameter of both gears shown in figures 7 and 8 are the key to meshing the bevel gears. The gear ratio had to be in

a range that does not include decimals such as a 1:1 ratio to increase liability, having 16:16 teeth ratio but in the kinetic sculpture utilized by the team a ratio of 3:1 with a pitch of 10 for the bevel gears used. Bevel gears were utilized by the team to change the direction of energy 90 degrees as illustrated in figure 9 from the red gear fitted on the shaft to the blue gear thus connecting it to the eccentric pulley that eventually moves the wings with the use of two plastic rods.

Figure 7 and 8: Bevel Gears

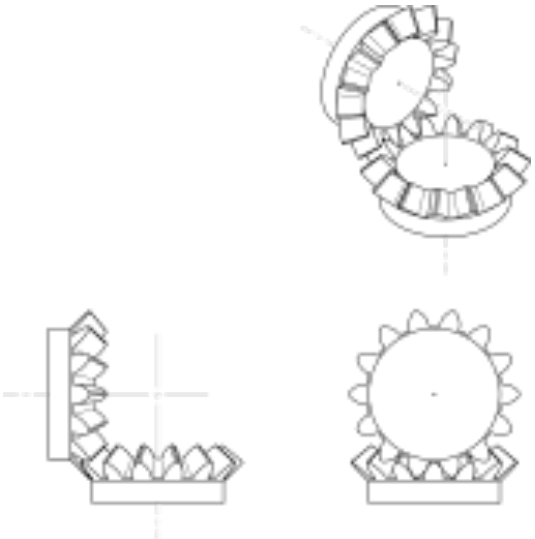

Figure 9: The 90 degrees change in direction [7]

3.3.2 Subsystem #2: Pulley and V-Belt

The team used a V-belt system and a solitary pulley basically alters the course of the draw or power connected as shown in figure 12. The types of pulleys used to transfer energy are normal pulleys and an eccentric pulley. At that point, the system additionally increases the power connected other than altering its course. A belt is a circle of adaptable material used to connect at least two pivoting shafts precisely, frequently parallel. V-belts tackled the slippage and arrangement issue. It is presently the essential belt for power transmission and transferring the shaft's energy. The team decided to incorporate v-belt as an additional subsystem. v-belts are mechanisms of transferring energy between axles as a linkage connecting at least two pulleys in the device to ensure an adequate transport of power with minimal loss. Furthermore, the pulley system simplicity makes certain that the camshaft receives sufficient amount of power and movement in the tail shall occur.

Figures 10 and 11: Small and Big Pulleys

Figure 12: v-belt

3.3.3 Subsystem #3: Crankshaft and Camshaft

These two principles are the pillars of the project. The crankshaft and camshaft are basically rods that exists in engines connecting different parts thus creating movement in several subsystems. Furthermore, Shafts can be easily manipulated in order to transfer energy from one point to another by connecting them to belts, chains and gears. In engines, the camshaft is utilized in opening and closing valves in a four-stroke engine. The team used the energy generated by the crankshaft to move two subsystems; the bevel gears and the pulley system. The camshaft utilizes the energy transferred through the v-belt to move the tail. The crankshaft and camshaft were manufactured from wood with adding an additional styrofoam piece attached to the camshaft. The two shafts are connected to two bearings at both ends for stability and smooth rotational movement thus reducing friction and ensuring an adequate transfer of energy.

Figures 13 and 14: Crankshaft and Camshaft

3.3.4 Subsystem #4: Bearings

A bearing is an essential mechanical engineering principle that improve relative motion and help reduce friction in rotational movement thus transferring energy between subsystems in an efficient process. Bearing is a principle that helps run mechanical system in a smoother way by reducing the amount of friction. Using two types of bearings, the double roller bearing and a pillow block ball bearing. The double roller bearing works as a hole within any sorts of designs such as a board or wood fragment. Secondly, a pillow block bearing was used through the process of mounting rather than working as a hole changing the process could also be referred as a mounted ball bearing. The bearings are going to support both shafts the crankshaft and the camshaft.

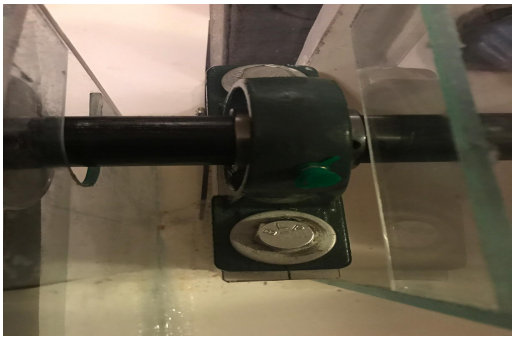

Figure 15: Bearing

4 Design Considerations:

4.1 Consideration of the Design

The device arrangement was pivotal in light of the fact that just steady, solid and sturdy plan can guarantee a working proficiency for the whole sculpture. The point amid the structure thought was to guarantee that plan is manageable. Manageable plan is the rationality of planning physical and calculated items, the constructed condition and administrations to satisfy the standards of monetary, social, and durable supportability. With reference to a review done via Autodesk Inc, the outcomes show that mechanical architects hope to see an expansion in maintainable structure work in 2010 [4]. "As indicated by review results, plans that utilization less vitality or diminish emanations remain the most essential economical innovation practice, while producing forms that utilization less vitality and normal assets were likewise a need." There are a few elements to think about while making a manageable structure. They are natural supportability, assembled condition, monetary manageability and social duty. Durable supporting abilities help managing issues with respect to the common. Feasible plans are accomplished through touchy structures, for instance, vitality effectiveness.

It is farfetched whether any standards of configuration are all inclusive in the craft of model, for the rules that administer the association of the components of figure into expressive arrangements vary from style to style. Truth be told, refinements made among the significant styles of figure are to a great extent dependent on an acknowledgment of contrasts in the standards of structure that underlie them. The standards of sculptural plan administer the methodologies of artists to such essential issues as introduction, extent, scale, explanation, and equalization. For imagining and depicting the introduction of the types of figure in connection to one another, to an observer, and to their environment, some sort of spatial plan of reference is required. This is given by an arrangement of bird like design and planes of reference. A hub is a nonexistent focus line through a symmetrical or close symmetrical volume or gathering of volumes that proposes the gravitational turn of the mass. Therefore, all the fundamental segments of the bird body have a curve shaped design of their own, while an upstanding figure has a solitary vertical pivot going through its whole length. Volumes may pivot or tilt on their curved wings.

Planes of reference are nonexistent planes to which the developments, positions, and headings of volumes, bird’s body, and surfaces might be alluded. The vital planes of reference are the frontal, the even, and the two profile planes. Corresponding relations exist among straight measurements, regions, and volumes and masses. Every one of the three sorts of extent exist together and collaborate in model, adding to its expressiveness and excellence. Frames of mind toward extent contrast significantly among artists.

Now and again it is important to adjust the extents of figure to suit its situation in connection to a symbol of peace. A figure sited high on a structure, for instance, is typically influenced bigger in its upper parts so as to balance the impacts of foreshortening. The size of model should once in a while be considered in connection to the bigger size than of the environment. When it is one component in a bigger intricate, for example, the exterior of a structure, it must be bigger in scale

than the rest. Since one will in general relate the size of model to one's own human physical measurements, the passionate effect of a bird figure to help neutralize peace.

4.2 Factors affecting design:

At the point when the creator plans the components of the machine or the total machine, they need to think about a few critical parameters. Here are a portion of the critical variables to be considered while doing machine plan:

- Cost has dependably been the central point of thought while structuring the machine components or machine and in this time of boosting creativity it has turned out to be increasingly essential. The best machine configuration is the one which gets the completed item with all the real functionalities and most elevated conceivable quality at the least conceivable expense.
- High yield and productivity: Earlier machines used to be exceptionally substantial and expend levels of intensity. Presently the pattern is of full useful machines expending low power and giving high yield as far as the quantity of the of items fabricated. Some mechanical or physical controlled machines can produce the segments exceptionally quick and are exceedingly effective.
- Strength: The machine components or the machine ought to be sufficiently able to continue every one of the powers it is intended for with the goal that it isn't harmed or for all time distorted amid its life time. Directly at the season of the structuring the machine the originator ought to consider the hand powered machine can be connected to and consider all the important variables that could influences its life.
- Stiffness or unbending nature: The machine ought to be sufficiently inflexible so that under the impact have connected powers for which it is planned there is no disfigurement of the machine or machine components past as far as possible. In the event that there is over the top twisting, there are odds of the disappointment of the machine components and the entire machine.
- Wear obstruction: Wear is the expulsion of the material from the metallic surface when two surfaces rub with one another. In the event that there is more expulsion of the material, the segment will end up flimsier and in the end break. The wear of the reaching surfaces can be diminished by the oil of the surfaces, expanding the quality or the hardness of the working surfaces. The impact of wear can likewise be decreasing by expanding the surface, so that amid the lifetime of the mating machine components they won't bomb regardless of whether there is some wearing between them.
- Lubrication: Lubrication between the two mating surfaces of the components of the machine help diminishing rubbing among them and wearing of the two surfaces, which results in the expansion in life of the segments of the machine.

4.3 Design Modification:

The iterative structure procedure might be connected all through the new item advancement process. Notwithstanding, changes are most straightforward and more affordable to actualize in

the soonest phases of improvement. The initial phase in the iterative structure process is to build up a model [3]. The model ought to be assessed by a center gathering or a gathering not related with the item so as to convey non-one-sided conclusions. Data from the center gathering ought to be combined and joined into the following emphasis of the structure. The procedure ought to be adjusted to the client specifications to a worthy dimension. The real change done in the underlying plan is recorded underneath:

- Bevel Gear created with 3D Printer
- V-Belt used for efficient transfer of energy
- Dense Styrofoam Bird was made instead of wooden bird
- PEX Plastic rods instead of Metal rods
- Melamine Board used as a Base.

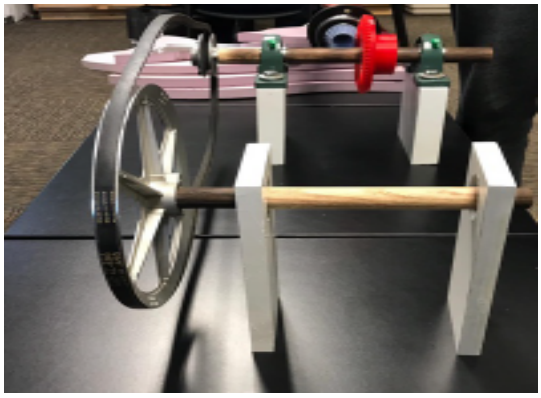

Figure 16: Modification procedure

Product Safety and Liability:

The essential thought for safety in structure configuration is to guarantee that the utilization of the moving parts is not dangerous or risky. Wellbeing and item risk issues can cause human damage. Engineers should likewise consider the issues of safety in structure due to risk emerging from the utilization of a moving item. Engineers must make accurate calculations to insure the safety of the client and end-user.

4.4 Mechanical/Strength Analysis:

Building examination of a starter configuration regularly incorporate the investigation of its mechanical highlights. Numerous ideas create friction, so you have to decide whether the plan can disperse the majority of the force friction being produced. Friction investigation is a critical situation of mechanical gear. Numerous bits of mechanical hardware flop rashly because of insufficient energy caused by friction. A performance quality estimation is required will almost certainly bolster the predefined mechanical burdens. As a mechanical design is exposed to connected burdens, it will misshape or divert so the team worked on utilizing the issue by printing gears and technically analyzing to avoid friction. Numerous items contain a few subsystems and, regularly, the assessment is done on every one of the subsystems instead of the total item itself.

5 Design Selected:

Design was selected based on research and sketches that contributed into picking the final product.

Figures 17 and 18: Final Design

5.1 Rationale for Design Selection

The team created a Pugh chart (Appendix A) to help in selecting the final design along with the use of a decision matrix (Appendix B). From the initial designs shown in the report, the team collected several aspects and ideas to create the selected model. These aspects were chosen after comparison to the essential requirements which are shown in Tables 1 and 2. The requirements mentioned assisted the team in the elimination process eventually easing the selection method and approach. The designs and sketches that helped in the design selection are shown in figures listed below.

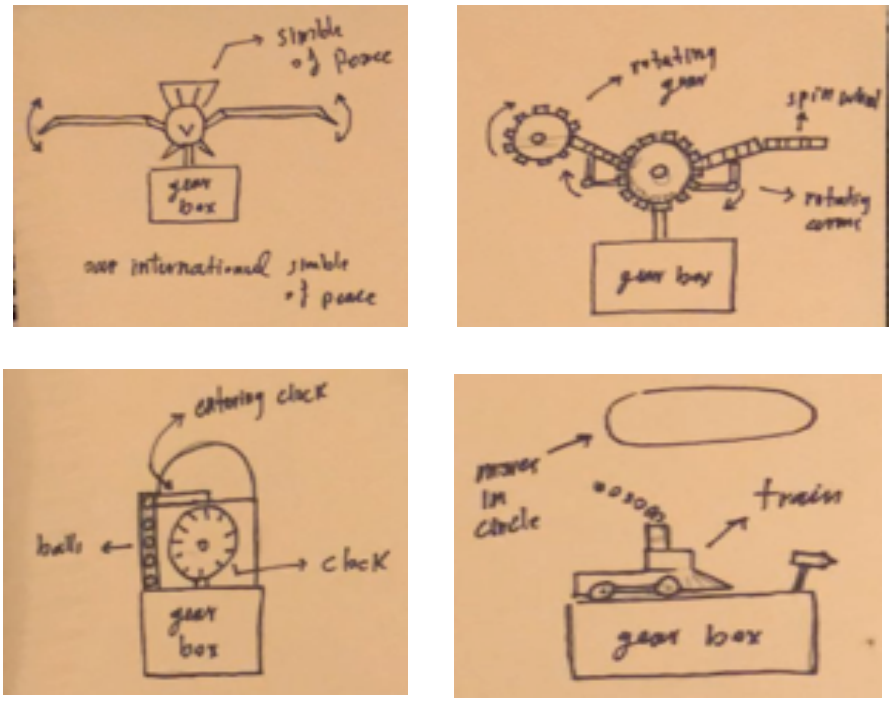

Figure 19,20,21, and 22: Hand Sketches towards selecting design

5.2 Design Description

The client required several design prototypes to be created illustrating the mechanical engineering principles after an initial design is selected. The selected design based on customer requirements ensures that all aspects were met. Figure 23 and 24 shows that the team have fulfilled both branches combining art with engineering creating a device that is entertaining and interactive at the same time. The device allows the visitors of the Engineering Building to interact with the device and examine the mechanical principles working together creating and transferring energy. The viewer will witness subsystems connecting together creating a unit that represents many skills that can be obtained through the study of mechanical engineering.

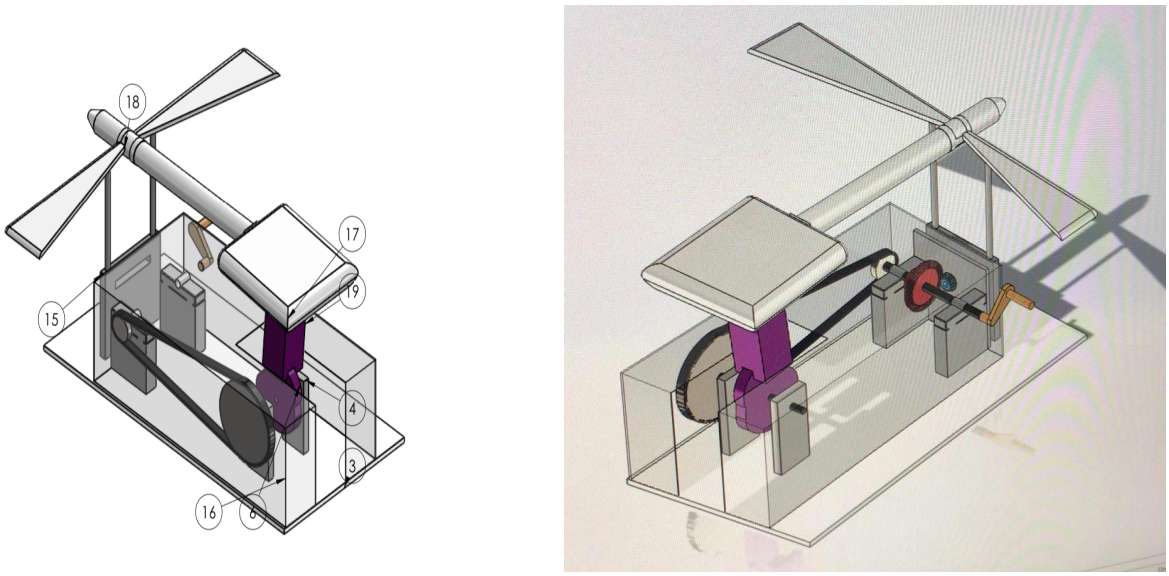

Figure 23&24: Final CAD model with balloon numberings

6 Proposed Designs:

The team had several proposed designs into picking the correct design. Three stages of design were made into finalizing the last model or kinetic sculpture.

6.1 Initial Design

The initial design was based on one principle that is the crankshaft. Within this principle, inspirations started to build more ideas and mechanism. At first, two initial designs were created. Starting with a design based on 3-D printing and cardboard box. For the second initial design it was based on a shaft and two rods connected to the wooden wings of the bird.

6.1.1 First initial design

The first design was made from a cardboard box, strings, black tape, two foam sheets, and 3D PLA printed designs. The design was then created to help illustrate the use of 3D printed parts and to help modify the design. Listed in figure 25 the first initial design is provided

Figure 25: First initial Design

6.1.2 Second Initial Design

Second initial design was made using acrylic glass, aluminum shaft, steel rods and balsa wood for the bird. The device's goal was to help illustrate our main source of energy and interaction which is the crankshaft

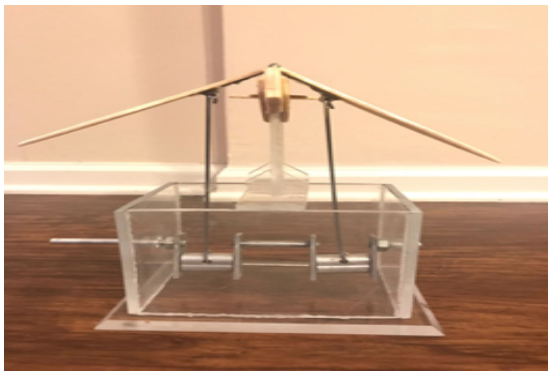

Figure 26: Second initial Design

6.1.3 Third Initial Design:

The last initial design helped illustrate several mechanisms inspired from past devices as well as newly developed mechanisms such as shaft, spring motor, gears, and a v-belt. The materials used are wood, plastic crown gears, aluminum sheet and rubber bands.

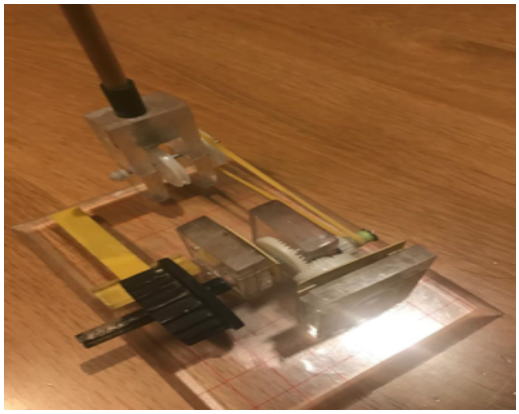

Figure 27: Third initial Design

7 Implementation

This Section will provide several changes occurred throughout the process of designing and also shows the design or prototype achieved

7.1 Manufacturing:

Many parts have been manufactured from different sites and locations in order to perfect the design and reduce cost.

7.1.1 CAD Designing and 3D printing:

Solidworks (or CAD) is to help in the creation, change, examination, or enhancement of a structure. Designing through solidworks utilizes the expansion through increasing profit and attract, as well as improve the nature of configuration, it interchanges through documentation, and to make a design base of parts for assembly [1]. Solidwork designing makes an electronic document to help print or other assembling tasks. Solidworks design programs mechanical structures that utilizes stress-based illustrations to portray the objects points of weakness and help redesign it to reduce the stress and force illustrations. As in the manual drafting of specialized and designing illustrations, the yield of Solidworks must pass on information, for example, materials to show strength, and resistances to show durability.

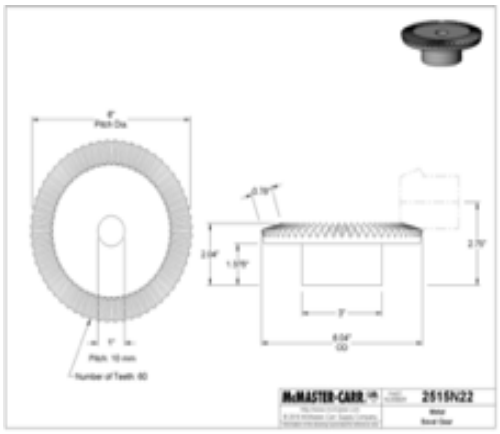

Figure 28: Big Bevel Gear [7]

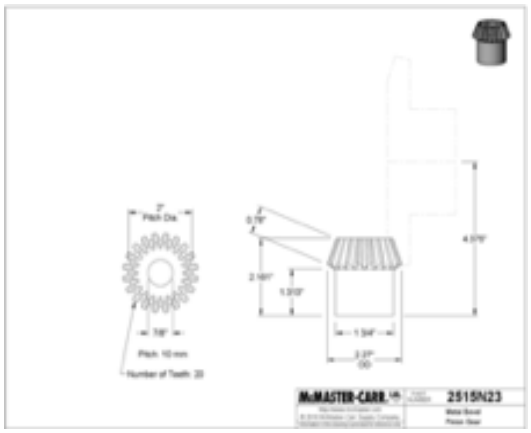

Figure 29: Big Bevel Gear [8]

7.1.2 Machining:

Machining is a term used to depict an assortment of material evacuation forms in which a cutting instrument expels material from a work piece to create the ideal shape. The work piece is ordinarily cut from a bigger bit of stock, which is accessible in an assortment of standard shapes, for example, level sheets, strong bars, empty cylinders, and formed bars. Machining can likewise be performed on a current part, for example, a throwing or producing. As a material evacuation process, machining is characteristically not the most practical decision for an essential assembling process. Material, which has been paid for, is removed and disposed of to accomplish the last part. Additionally, in spite of the low setup and tooling costs, long machining occasions might be

required and along these lines be cost restrictive for extensive amounts. Thus, machining is frequently utilized for constrained amounts as in the creation of models or custom tooling for other assembling forms. Machining is additionally in all respects ordinarily utilized as an optional procedure, where negligible material is evacuated, and the process duration is short. Because of the high resilience and surface completes that machining offers, usually used to add or refine exactness highlights to a current part or smooth a surface to a fine completion. As referenced above, machining incorporates an assortment of procedures that every expel material from an underlying work piece or part. The machining of a section will ordinarily require an assortment of activities that are performed in a deliberately arranged grouping to make the ideal highlights.

7.1.3 Sanding

Sanding was a major part into manufacturing as it was used for several stages into building the final design. Sanding is a power tool used to smoother and polish the design. Several tool machines used in creating the design. First method was working with sandpaper to smooth the 3D printed gears. Secondly, Using the tool machine instead of hand power to help smoothen the wooden shaft. Sanding help the process of mechanical principle used.

7.1.4 Torching

The method of torching was used for both crankshaft and camshaft. Torching helped reduce the frictional force within placing the shafts into the bearing as well as loss of energy into rotating the device. The process of torching the wood helped a lot towards our main principle reducing weight onto rotation.

8 Testing:

8.1 Crankshaft Procedures:

The crankshaft is an essential part for starting the movement to activate the mechanisms for the entire device. It will be worked by human physical power into a counterclockwise rotation by a circular force getting to move the entire shaft to get the movement going. The shaft movement would rotate with the smallest amount of energy loss and least amount of friction due to the bearings attached causing a smooth rotational movement. The testing procedures are illustrated in Table 3 below;

Figure 30: Crankshaft with crank-handle and miscellaneous

Table 3 Shaft Testing

Crankshaft	Crank Handle	Shaft
1st Test	Handle wasn't stable and it was shaking	Rotation was rigid and movement was hard
2nd Test	Handle was little edgy and sharp	Crankshaft started to move but still rigid and hard
3rd Test	Success rate reach 100% succession	Item started working 100% properly

8.2 Bevel Gears Procedure:

After getting movement from the shaft, the bevel gears start rotating on a clockwise direction transferring energy from front view to the side view of the device due to 90-degree positioning. As the Big gear starts to drive the smaller gear, rotation starts in an instant. The opposite end of the smaller gear has an eccentric pulley connected to it. Therefore, energy is transferred to a PEX plastic pipes that are attached to a pulley thus starting a vertical movement to make the wings execute an adequate motion. Bevel gears testing procedures are shown in Table 4

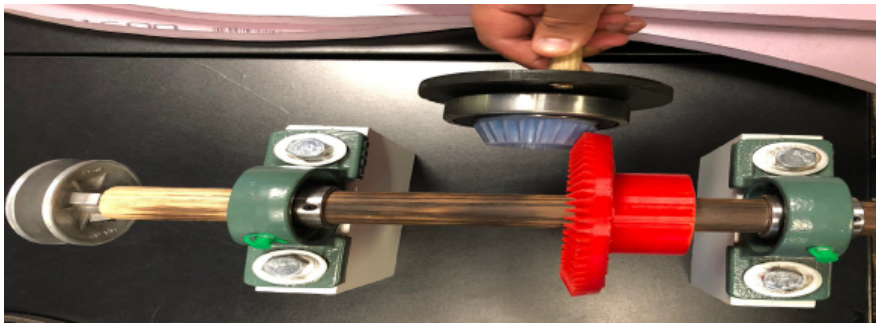

Figure 31: Bevel Gears and Pulley Tastings

Table 4 Bevel Gears Testing Procedures

Gears	Big Bevel Gear	Small Bevel Gear	Eccentric Pulleys Attached
1st Test	Gear is dense and durable worked accordingly	Gear gave excellent results and also durable	Faced issue related to the stiffness of pulley
2nd Test	Kept Giving good results	90-degree attachment sustained position	Started pulling off and worked well
3rd Test	Item sustained 100% activity and durability test	Item sustained 100% achievement and durability	Working perfectly without any issue

8.3 V-Belt Procedures:

From the same main source of energy, the shaft causes the small timing pulley to move on a clockwise rotation. Within the small timing pulley, a rubber belt is attached from the end of the shaft where the small timing pulley is located towards the other side into the big timing pulley where it has another smaller wooden shaft attached. As the shaft starts rotating the V-Belt starts making its movement and technique towards transferring the energy into the smaller wooden shaft and an eccentric wheel attached close to the center where a piece of wood starts pushing the tail to start moving in a vertical realistic movement. The testing procedure is shown in table 5

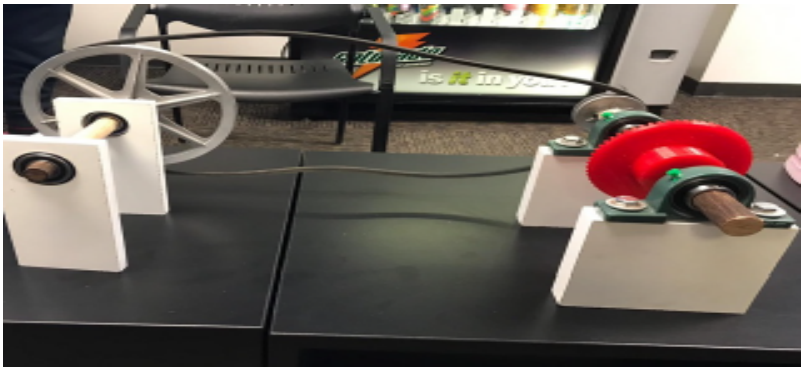

Figure 32: V-Belt testings'

Table: 5 V-Belt Testing Procedure

V-belt	Big Timing Pulley	Small Timing Pulley	Belt
1st Test	The pulley worked but there was little vibration	Small pulley had minor shake and lack of stability	Belt was little loose and refused to be attached
2nd Test	After adjusting pulley position the movement started to work better	Fixed but movement was rigid and slow	Movement started although stability needed to be fixed
3rd Test	Pulley is working well, and no issues were detected	Worked well without any issue	Belt was attached properly, and it maintained it stability

8.4 Bearing Procedures:

As the shaft starts moving the bearings has an efficient role into reducing the friction and loss of energy. The first two bearings are attached into the wooden base that are wider than it is in height which is carrying the main shaft. The amount of mechanisms located on the main shaft requires sturdy and strong bearings. The two other bearings (Bearing #3 & 4) are located on a secondary

shaft with a smaller diameter. Smaller bearings are used due to the lower energy needed to start the tail movement. Furthermore, the last two bearings dimensions proved adequate to the amount of energy transferred. Friction was at a minimal level which helped in stabilizing the overall movement. Testing procedure of the bearing is illustrated in Table 6

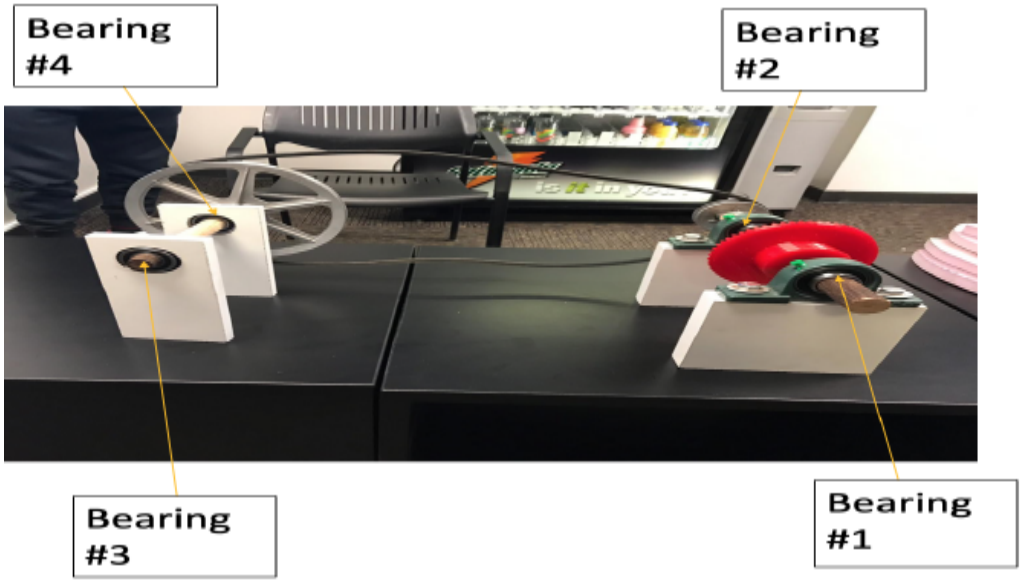

Figure 33: Bearings Testing

Table 6: Bearings Testing Procedure

Bearing	#1	#2	#3	#4
1st Test	Stiff rotation then WD 40 was added as lubrication	Same performance as #1	Movement was unstable and shaft needing sanding	The bearing had a small shake through fitting it into the wooden hole
2nd Test	Rotates well and no issues were detected	Positioning needed a bit adjustment	No issues were detected	A minor slip occurred from attaching the wood and had to burn the end tip
3rd Test	No issues	No issues	No issues	No issues

9 Conclusion:

The purpose of the project is to create a kinetic sculpture that contains several engineering concepts that illustrates moving parts. The sculpture consists of two main sections, one is the bird model that includes moving wings and a tail. The second section is a box that contains the mechanism. The project is designated to start by an interacting user. The user will start the sculpture's movement by rotating a crank handle that rotates the crankshaft which transfers the energy to the remaining mechanical parts such as; gears, rods and a pulley system. The artistic part of this project will be illustrated through the bird movement of wings and tail with the assistant of mechanical engineering concepts. The project also utilizes methods of artistic creative skills by using engineering equipment along with different materials that completes the sculpture. The testing of

the subsystems would be acquired by attaining the parts needed. We have tested each part separately. Additionally, due to limited budget, modifications and enhancements can be made for future device production. Parts in this device can be replaced with suitable materials that extend the device's life. The wooden shafts can be replaced with aluminum shafts, the 3D printed gears can be made with metal materials, the styrofoam can be replaced with wood and the plastic rods can be replaced with steel rods.

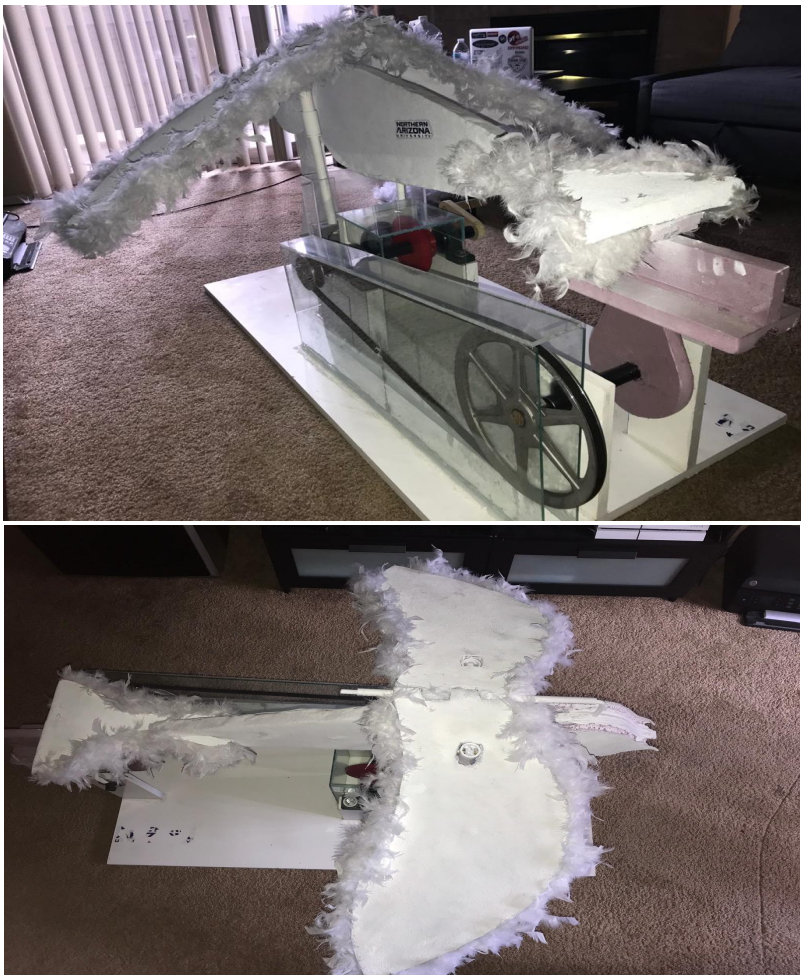

Figure 34 and 35: Design after Aesthetics

9.1 Contribution to project success

A lot of effort and work have been achieved in our design. All the requirements were met. All in all, this have been acquired through stages learned throughout the course starting from teamwork, time management, and the ability to gain new sets of skills and experience while manufacturing the device and technically analyzing the systems with the process of precision. With the help of our technical advisor, client, and the professor's assistant (TA), the ability to attain such level of expertise and designing was achieved by reducing the amount of interruption and gaining the most amount of lessons learned.

9.2 Opportunity for Improvement

With more time, improvements in aesthetics and reducing the weight of the device would've been increased making the bird kinetic sculpture move more freely and realistically. Not much drastic changes would've been occurred as the principles attached and applied were professionally rotating as well as working into the right path. From efforts added the aesthetics maintained the goal of having the device be more inspiring than having a price tag attached.

10 References

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11 Appendices:

Appendix A: Pugh Chart

Table 7: Pugh Chart

KINETIC SCULPTURE	Weight	Catapult Sculpture	Bird Sculpture (crankshaft)	KINETIC SCULPTURE DATUM	Rotating Gears	Clock Rolling	Train Message	Bird sculpture (Gear Box)	Football Sculpture	Walking Robot	Ball Rolling
Fits into the Door	7	+	+	D	+	-	-	-	+	+	-
Two can lift	6		+	D	-	+		+	+	+	+
Durable	5	-	+	D	+	-	-		+	+	-
Entertaining	4	+	+	D	+	-		-	-	+	
Robust	3	+	+	D	S	-	+	-	+	+	
Interactive	2	+	+	D	-	+	-	+	-		+
Portable	1	-	+	D	+	-	-	-	+	-	-
Pluses		4	7	-	4	2	1	2	5	5	2
Minus		2	0	-	2	5	4	4	2	1	3
Total		2	7	-	2	-3	-3	-2	3	4	-1

Appendix B: Decision Matrix

Table 8: Decision Matrix

Decision Matrix	Fits into the door	Two can Lift	Durable	Entertaining	Robust	Interactive	Portable	Total
Weight	7	6	5	4	3	2	1	
Bird Sculpture	6x7=42	6x6=36	4x5=20	6x4=24	6x3=18	4x2=12	5x1=5	157
Rolling Ball Clock	4x7=28	3x6=18	2x5=10	4x4=16	3x3=9	2x2=4	2x1=2	87
Train Message Sculpture	2x7=14	3x6=18	3x5=15	3x4=12	2x3=6	2x2=4	3x1=3	72

Appendix C: CAD model

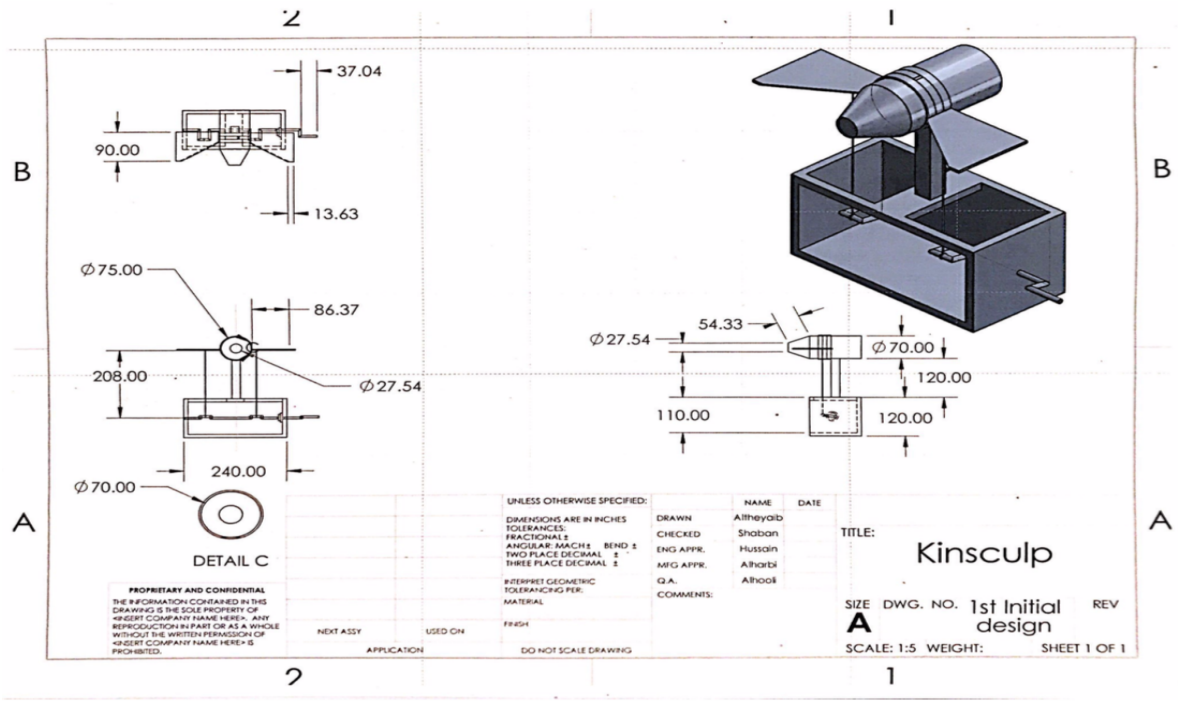

Figure 36: Second Initial design CAD Drawing

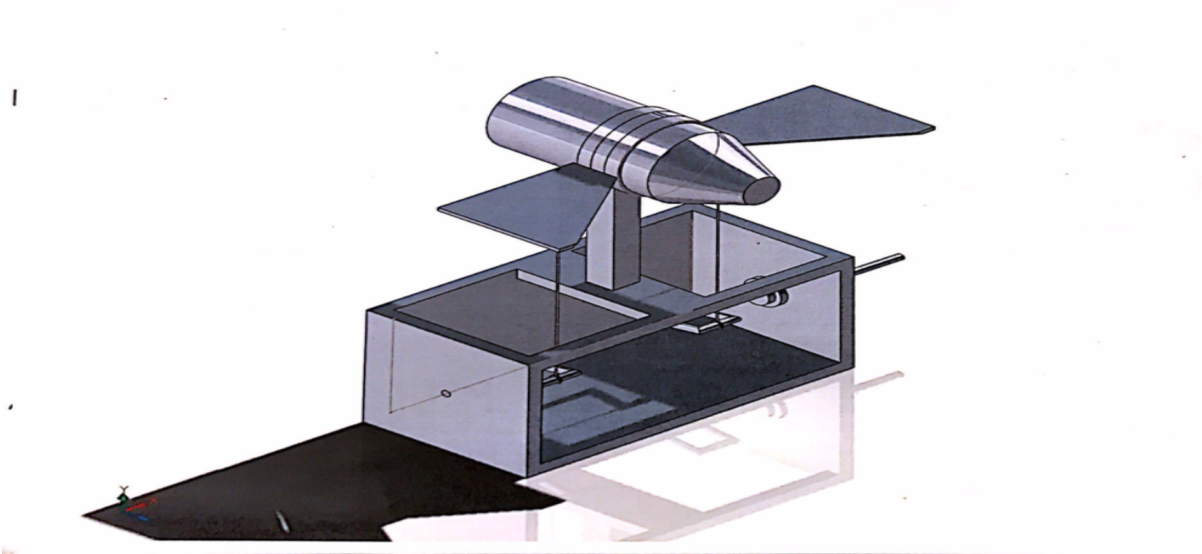

Figure 37: Second Initial design CAD Assembly

Appendix D: Sketches

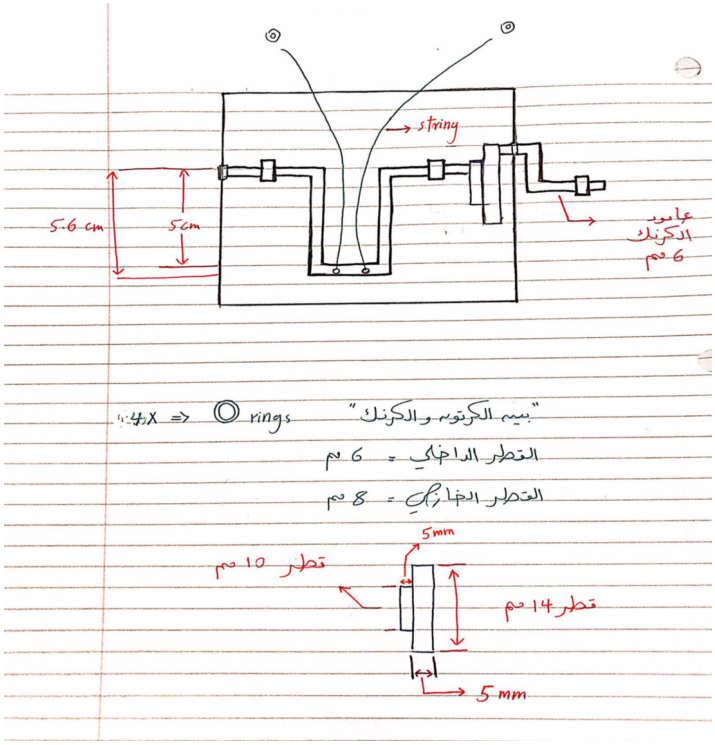

Figure 38: First Initial design Sketch Hand Drawn

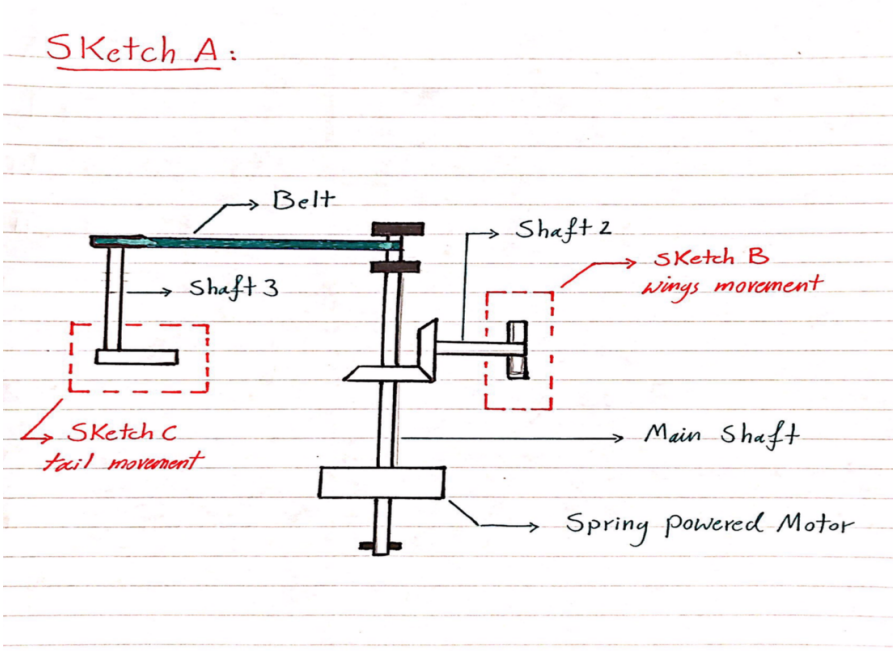

Figure 39: Final Initial design Sketch hand drawn

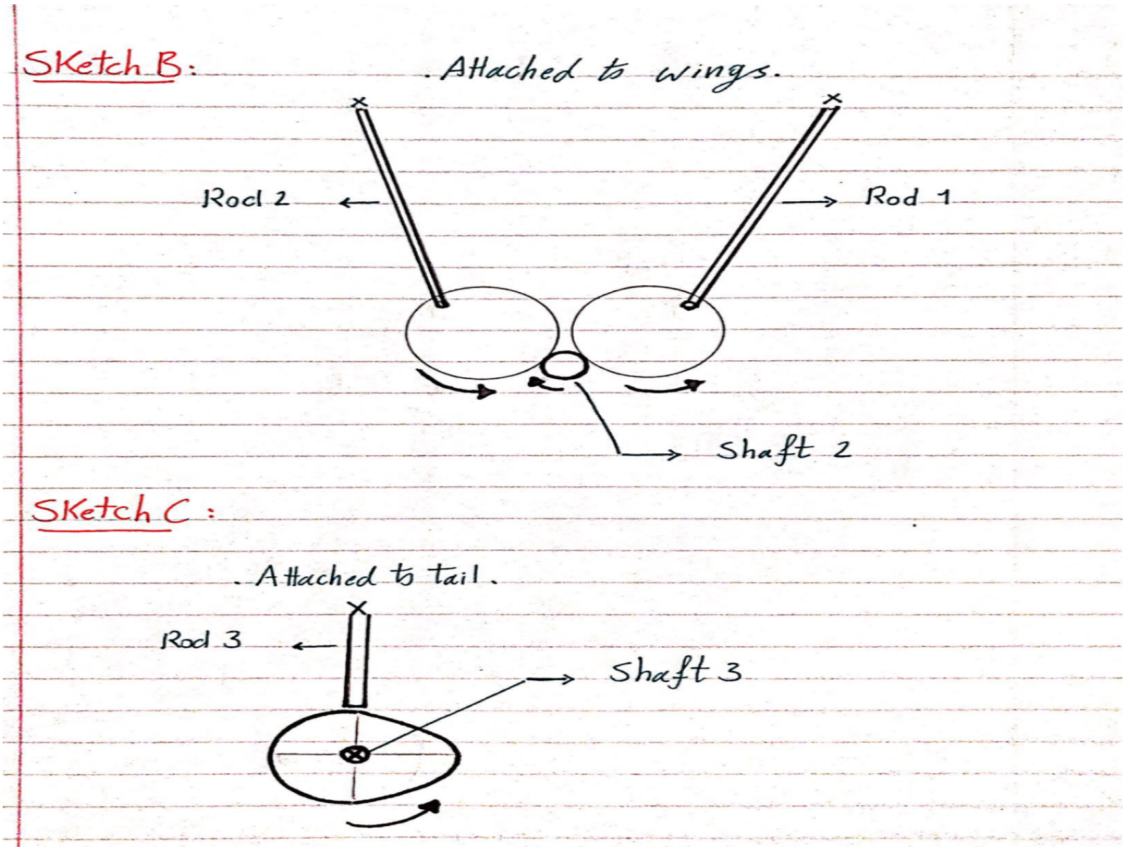

Figure 40: Movement Mechanisms of Final design sketches

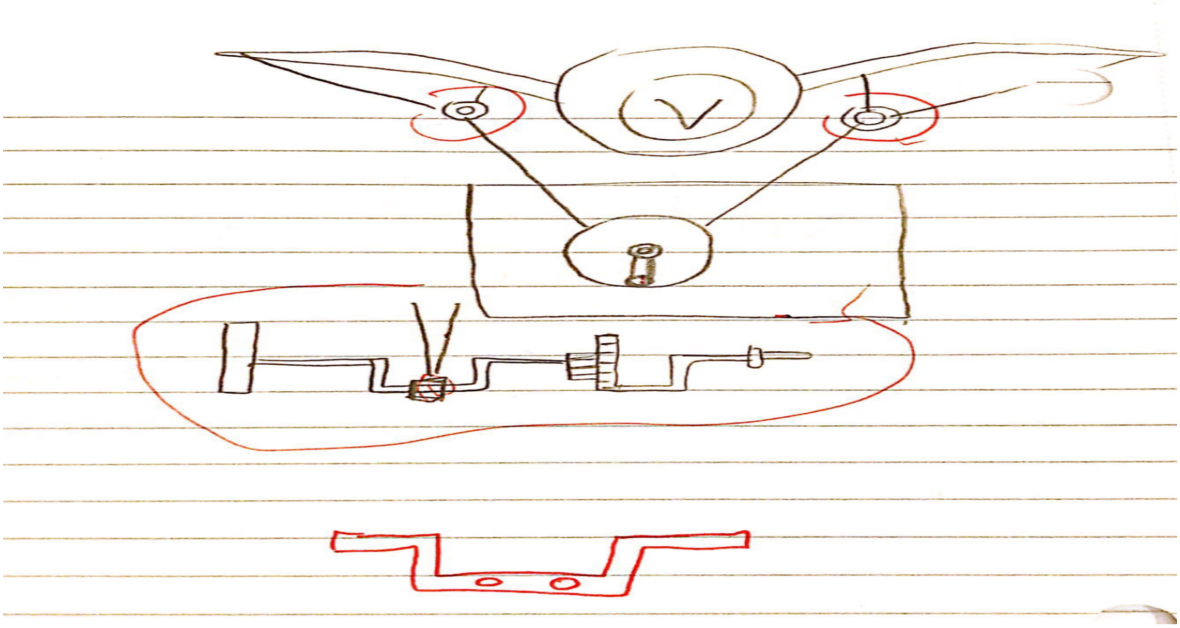

Figure 41: First initial design movements hand drawing

Appendix E: Bill of Materials (BOM)

Table 9: First set of bill of materials

Bill of Materials							
		Team					
Part #	Part Name	Qty	Description	Functions	Material	Dimensions	Cost	Link to Cost estimate
1	Liquid Super Glue	1	Use to stick the material	Create strong bonding	Chemical	-	$5.97	Homedepot
2	Poplar Board	1	For the box	To put items in the box	Wood	0.25 x 3.5 x 48 i	$5.98	Homedepot
3	Black PVC Project Board	1	PVC board is strong to bend	For making the upper part	PVC	0.118 x 24 x 36 i	$4.04	Homedepot
4	Stop Set	1	to stop the running part	Put to stop the rotation	Aluminum	1/4 in	$1.92	Homedepot
5	Stop Set	1	to stop the running part	Stop the motion	Aluminum	1/16 in	$1.24	Homedepot
6	Strap Hinge	1	Provide open close option	To put on the door	Steel	2 in x 4 in	$2.97	Homedepot
7	Brazing Rods	1	For making connection	Hold the top system with the rod	Aluminum	36 x 4 x 4	$4.21	Homedepot
8	Flat Plate	1	A straight sheet to make anything	Make the fins	Aluminum	36 x 4 x 8	$4.28	Homedepot
9	Hinge	1	Hold for open close	To put the door with it	Steel	2 x 5 in	$1.97	Homedepot
10	Round Rod	1	A rod to attach things	Make the Central standing part	Steel	36 x 2 x 2	$5.77	Homedepot
11	Dowel	1	Cylinderical rod	Put in the system	Wood	1/4 x 48 in	$4.98	Homedepot
12	Dowel	1	Cylinderical rod	Put in the system	Wood	1/2 x 48 in	$1.75	Homedepot
13	Dowel	1	Cylinderical rod	Put in the system	Wood	1/8 x 48 in	$4.48	Homedepot
14	Round Rod	1	A rod to attach things	Make the Central standing part	Zinc	36 x 3 x 1/16 in	$2.97	Homedepot
15	Wood Glue	1	Sticky action	Create strong bonding	Chemical	-	$3.97	Homedepot
16	Shaft	1	An aluminum pipe	welded to be a shaft	Aluminum	D=1" , L=48"	$27.49	Amazon
17	Shaft	1	An aluminum pipe	welded to be a shaft	Aluminum	D=0.5", L=48"	$19.99	Amazon
18	Blower pulley	1	A pulley made from steel	Pulley to help turn the V-belt	Steel	10 x 1 "	$13.78	Homedepot
19	Motor Pulley	1	A pulley made from steel	Pulley to help turn the V-belt	Steel	3-1/4 x 1/2	$9.88	Homedepot
20	V-Belt	1	Made from rubber	Help transfer the energy or mechanism	rubber	69"	$5.78	Homedepot
21	Galv roll	1	A roll of steel	In order to create the spring inside the gear	Steel	8" x 10'	$13.34	Homedepot
22	F-150	1	Will be chopped down to meet needs	To help make the base	Wood	1" x 4' x 8'	$23.00	Homedepot
23	Melamine White Pannel	2	Helps fitting through cutting	Cut it down to create the base	wood	75" x 48"	$33.84	Homedepot
24	White PEX Pipe	1	Works as rods	They are going to help move the wings	Plastic	3/4" x 5'	$3.26	Homedepot
25	PEX Pipe	1	Works as rods	To connect to timing pulleys	iron	1/2" x 5'	$1.86	Homedepot
26	Aluminum Flashing	1	A roll of Aluminum	Help make a spring compared to the steel	Aluminum	6" x 25'	$12.58	homedepot
27	Center snips	1	Tool for pipes	Cuts down the pipes to required sizing	Steel	No	$9.97	Homedepot
28	3-D Gears	2	Source of mechanism	rotates energy	PLA	D=6" , L=2.25"	$42	Makerlab
29	3-D Gears	2	Source of mechanism	rotates energy	PLA	D=3.5" , L=2"	$19.35	Makerlab
30	3-D Gears	1	Source of mechanism	Ratchet Gear needed for spring	PLA	D=7", L=3.5	$66.21	Makerlab
31	3-D Gears	2	Source of mechanism	rotates energy	PLA	D=2", L=1.5"	$9.38	Makerlab
32	3-D Gears	2	Source of mechanism	rotates energy	PLA	D=6", L=2.5"	$51.63	Makerlab
33	Mounted ball bearing	2	Bearing to with mounts	Reduces the friction of the rod	iron	1-1/4''	$16.45	Amazon
34	white melamine edging	1	use to paint tools		wood	2"x8'	$5.07	Amazon
35	Oak Dowel	1	Cylinderical rod	Put in system	wood	1/4x36	$8.98	Homedepot
36	Oak Dowel	1	Cylinderical rod	Put in system	wood	1x1x36	$5.98	Homedepot
37	Pillow Block	2	Bearing	Reduces the friction of the rod	iron	1 in	$13.96	Homedepot
38	Deep Groove Ball Bearing	1	Bearing	Reduces the friction of the rod	steel	45mm	$16.28	Amazon
39	Springs	3	a loop made spring	Initial Design as a source of principal	Steel		$138.94	Vulcan Spring Manufacturing CO.

Table 10: Second set of bill of materials

37	Pillow Block	2	Bearing	Reduces the friction of the rod	iron	1 in	$13.96	Homedepot
38	Deep Groove Ball Bearing	1	Bearing	Reduces the friction of the rod	steel	45mm	$16.28	Amazon
39	Springs	3	a loop made spring	Initial Design as a source of principal	Steel		$138.94	Vulcan Spring Manufacturing CO.
40	LAG Screw	4	use to hold things	attach it with things	metal	1/2"x3	$3.48	Homedepot
41	Washer Galve	4	use to hold the screw	attach it with screws	metal		$1.44	Homedepot
42	Painter Caulk	1	use to paint tools	Create strong bonding	chemical	10.1 OZ	$1.78	Homedepot
43	Foil Tape	1	use to tape things	to cover things	Aluminum	1.89"x50	$7.88	Homedepot
44	Spray Paint	1	use to paint tools	to paint things	chemical	1x3	$4.18	Homedepot
45	Foamular Panel	1	use to	type of insulation		2x2	$5.98	Homedepot
46	White Board	1	a board	To put items in the box	wood	24x36	$7.99	Homedepot
47	Acry Sheet	1	a cover sheet	to cover the materials	glass	7/8x23	$29.78	Homedepot
48	Clr Acrylic GRN Edge	1	use to cover mateerials	cover sheet	glass	24"x36"	$37.95	Homedepot
49	OSC BRT White	3	Used for the device	BRT		11/16x8	$11.70	Homedepot
50	Plastic & Polycarbonate silicon	1	Some what a glue	Used to stick parts of the device	silicon		$8.58	Homedepot
51	PVC Coupling SXS	4	use to hold the wings	attach it with the wings	pvc	3/4"	$1.84	Homedepot
52	PVC Bushing SPGXS	2	A circular piece of plastic	Used to attach the rods to the wings	pvc	3/4"x1/2"	$1.14	Homedepot
53	PVC Pipe	1	Works as rods	to connect the mechanism	pvc	1/2"x2'	$1.31	Homedepot
54	PVC40 PE Pipe	1	Works as rods	to connect the mechanism	pvc	3/4"x10'	$2.71	Homedepot
55	V-notch trowel	1	to cut things	hand tool	wood	3/16x5/32	$3.96	Homedepot
56	Acry Sheet	1	a cover sheet	to cover the materials	glass	7/8x47	$73.98	Homedepot
57	Felt	3	A roll of felt material	Used for aesthetics for the styrofoam	Felt	6 ft x 6 ft x 6ft	$0.69	Walmart
58	GE CLRW	3	Sticky action	Create strong bonding	chemical		$13.41	Walmart
59	Wiggly Eyes	1	use to have the eyes for the bird	accessories			$1.97	Walmart
60	Duck Carpet	1	Sticky action	Create strong bonding			$5.47	Walmart
61	Doublside Tape	1	Sticky action	Create strong bonding			$5.22	walmart
62	Minuteweld	1	Sticky action	Create strong bonding	Chemical		$5.97	Homedepot
63	Quick Connect elbow	1	to connect things	to connect the PEX pipe	metal	3/8x3/8	$4.93	Homedepot
64	Lexan	1	a cover sheet	to cover the items	glass	7/8x9	$4.98	Homedepot
65	Dowel	1	Cylinderical rod	Put in systems	wood	3/16"x48"	$0.70	Homedeport
66	PEX Pipe	1	Works as rods	To connect to timing pulleys	iron	1/4in x 5ft	$1.76	Homedepot
67	ROD Round	1	A rod to attach things	Make the Central standing part	steel	36x3/8x3/8	$5.97	Homedepot
			TOTAL VALUE			$882.25		
			TOTAL COST with Taxes		=	$	958.12	