Team 18F02 Kinetic A

Report 1 (Preliminary Report)

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DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

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1 BACKGROUND

1.1 Introduction

Engineering is one of the most important things in our world today. Without this, a vast majority of products we use every day would not exist. Our goal is to build a kinetic sculpture that will showcase many different concepts of engineering such as fluid flow, gear mechanisms, and conservation of energy. If the group accomplishes this, it could potentially lead to an increase in the interest and the enrollment of students in the engineering program at NAU.

1.2 Project Description

Following is the original project description provided by the sponsor, Dr. Sarah Oman;

“This project would involve creating a Kinetic Sculpture for the Engineering building at Northern Arizona University (NAU). The focus of this sculpture would be to provide a physical example of Mechanical Engineering principles in a fun and engaging manner. The system should be robust to moving from room to room if needed, and clearly illustrate at least three engineering principles. It should have signage that describes the principles and represents the ME department in a positive, marketable light.”

1.3 Original System

This project involved the design of a completely new kinetics sculpture. There was no original kinetics sculpture before this project began.

2 REQUIREMENTS

Contained within this section of the report are the descriptions of the requirements of the Kinetic Sculpture capstone project. Below, are sections containing the Customer Requirements, Engineering Requirements, Testing Procedures, House of Quality (QFD), and Black Box Model.

2.1 Customer Requirements (CRs)

The results of team meetings and discussion with the project sponsor brought about the customer requirements and ratings as shown below.

Table 2.1.1: Customer Requirements and Weightings

Customer Requirements	Average Weighting
Moveable (Can Fit Through Door)	3.875
Cost Effective	2.5
Durable	2.75
Represent Engineering Positively	4.25
Safe To Use	4.25
Visually Pleasing	4
Reliable	4

The customer requirements, seen in Table 2.1.1 above, were found to assist the team to meet the requirements of the project which are that it is easily moved, under $5000, and to represent engineering positively. The group made some of the requirements more specific by applying more measurable values to the requirements. While the original requirements said to make the sculpture easily movable, the group decided to limit the sculpture to be able to fit through a door and be durable enough to last a few years. Also, the group decided that in order for people to freely use and interact with the sculpture, safety and reliability would be important customer requirements so that the sculpture will always work without the fear of injury. Lastly, the group added the visually pleasing customer requirement to the list because it is a sculpture so, it should be aesthetically pleasing to the general populous. After generating and weighing the customer requirements for the project, the group was then able to create engineering requirements to be measurable representations of the customer requirements.

2.2 Engineering Requirements (ERs)

After finding and evaluating the customer requirements (above) for the project, the group was then able to extract engineering requirements out of the customer needs to ensure that every need would be met in a measurable way. The engineering requirements, rational for choosing them, and their respective units determined are listed below:

- Less than 150 lbs (pounds)
    - The kinetic sculpture is required to be able to move relatively easily throughout the engineering building for demonstrations and events and so, it must be able to be lifted and moved by two people. The group decided that 150 lbs would be the maximum weight for the project by assuming that the average person can lift around 75 lbs with relative ease.
- Less than 3x3x6 ft (ft^3)
    - The sculpture is required to be easily moveable and this includes being able to be carried through doorways and so, the group determined that a size of 3x3x6 ft would be the maximum size of the sculpture so that it may be carried through doorways and not be a

“tight fit”.

- Under $5000 ($)
    - Because the kinetic sculpture will involve many moving parts, the group decided that the sculpture will cost no more than $5000 so as to not waste money where it does not need to be wasted.
- Material Strength (kpsi)
    - Because durability is a customer requirement, the group determined that material strength is an important engineering requirement because the group does not want the sculpture to yield due to stresses put on it by itself or others interacting with it.
- Material Hardness (B)
    - To further elaborate on the durable customer requirement, the group decided that knowing the Brinell hardness of the materials used will be important so to make sure the materials used are tough enough to withstand the stresses placed on them as well as to reduce pitting corrosion.
- Corrosion Rate (mm/year)
    - By knowing the corrosion rate (CPR) of the materials when interacting with each other, the group will be able to place materials together that will not diffuse and corrode each other as fast as others. Thus, adding to the durability and reliability of the sculpture.
- Factor of Safety
    - By finding the factor of safety for the kinetic sculpture, the group will be able to increase the safety of the sculpture and plan/design around potential dangers with the sculpture to decrease the risk to those interacting with the machine.
- At Least 3 Engineering Principles
    - The requirements of this project are to display at least three engineering principles in the sculpture and so, the group determined that this would be a measurable engineering requirement.
- Operational For At Least 30 Minutes Without Power (minutes)
    - The group determined that, in order to say the system is “reliable”, they would like the system to run for at least 30 minutes without power after receiving around 30 seconds to one minute of power through human energy input.
- Least Power Required (W)
    - For the reliable customer need, the group determined that the least amount of human energy required to run the sculpture is ideal and so, a requirement of least power required was determined to be necessary.
- 9/10 People Like the Aesthetics (People)
    - For the “visually pleasing” customer need, the group determined that a measurable engineering requirement would be that 9/10 people surveyed like the sculpture and the way it looks and operates.

Once the customer and engineering requirements were all found and compiled by the group, they were then able to arrange and sort them all into a House of Quality (QFD).

2.3 House of Quality (HoQ)

After the group created and compiled the customer needs and engineering requirements, they were then able to create a House of Quality, seen in Figure 2.3.1 below. This house of quality has helped the group to create concepts and design around the requirements given and created in order to create a kinetic sculpture that meets and/or exceeds the requirements of the project. The requirements of the project given to the group were to create a kinetic sculpture that displays at least three engineering principles in a positive manor and be visually pleasing while still being of a proper size and weight to easily transport throughout the engineering building and NAU campus.

Roof Matrix

	Less than 150 lbs	Less than 3x3x6	Under $5000	Material Strength	Material Hardness	Corrosion Rate	Factor of Safety	At Least 3 Principles	Operational For 30min W/out Power	Least Power Required	9/10 People Like
Less than 150 lbs		NO INPUT IN THIS AREA									
Less than 3x3x6	**										
Under $5000		*									
Material Strength	*		-								
Material Hardness	*		-	*							
Corrosion Rate			*	*	*						
Factor of Safety			*	*	*	**					
At Least 3 Principles			*				*				
Operational For 30min W/out Power								-			
Least Power Required						-	*	-	-		
9/10 People Like											

**	Strong Pos. Correlation
*	Positive Correlation
	No Correlation
-	Negative Correlation
--	Strong Neg. Correlation

PHASE I QFD

Design Objectives	Customer Weights	Less than 150 lbs	Less than 3x3x6	Under $5000	Material Strength	Material Hardness	Corrosion Rate	Factor of Safety	At Least 3 Principles	Operational For 30min W/out Power	Least Power Required	9/10 People Like
	Preferred (up or down)											
		Specifications										
Moveable (Can Fit Through Door)	3.875	9	9					3				
Cost Effective	2.5	3	3	9					1	1		
Durable	2.75	1	1	3	9	3	3					
Represent Engineering Positively	4.25								3	1		3
Safe To Use	4.25	9	1		1		3	9				
Visually Pleasing	4								3	1		9
Reliable	4				1	1	1	3		3	3	
	ATI	83.375	49.375	30.75	33	12.25	25	61.875	27.25	22.75	12	48.75
	RTI	21%	12%	8%	8%	3%	6%	15%	7%	6%	3%	12%
	Unit of Measure	lbs	ft^3	$	kpsi	B	mm/year			min	W	People
	Techical Target											

Figure 2.3.1: QFD (House of Quality)

The House of Quality has helped the team in the design process by allowing the group members to keep watch of the requirements and details of the project while at the same time allowing them to create more creative designs due to the broad nature of the project. For example, since there are only seven major customer requirements, the group has not found much difficulty in concept generation while at the same time, meeting all customer requirements.

3 EXISTING DESIGNS

Through research, a plethora of designs for kinetic sculptures were unearthed. Most of these designs were fluid, motor, or spring powered. This is due to the ease of implementation of these power supplies. Renowned fluid sculpture artists include Anthony Howe and Theo Jansen. David Roy is the most well – known kinetic artist using springs to power his sculptures. Jean Tinguely and Anthony Calder are the most famous kinetic artists that primarily use a motor to power their sculptures. Although these are the three main power sources most kinetic artists use, there are multiple ways to power these sculptures. Other power sources could be gravity, electricity, and even computer programming. However, due to the team's background, it will be easier to analyze and calculate for motors and springs rather than Arduinos and circuit boards.

3.1 Design Research

All research of existing designs was conducted through the internet. First, the team wanted to get an idea of what a kinetic sculpture encapsulates. To do this, the team watched videos of various kinetic sculptures. The team then would search artists by name and identify how they powered their sculptures. The first sculpture identified was Anthony Howe. He is most known for his wind sculptures. His website, howeart.net, gave an insight on how to harness the wind's energy. Anthony Howe has also created sculptures powered by motors. Since these sculptures are fairly large and made of metals, the motors powering these sculptures must be powerful. Realizing there are multiple ways to power a kinetic sculpture, the team found artist, David Roy. David Roy is known for his spring/tension powered kinetic wall sculptures. Compared to Anthony Howe's art, David Roy's sculptures are easily transportable. David Roy's website, woodthatworks.com, introduced the team to constant torque springs. With these springs, the team can design a sculpture that has a long duration time. Once the constant torque springs were discovered and researched, the team dedicated concepts to that power source.

3.2 System Level

Kinetic sculptures try to achieve perpetual motion. Since energy is finite and perpetual motion can't be reached, kinetic artists have found ways to power their sculptures for long durations. Through research, the team has found this to be an important requirement. As stated earlier, constant torque springs can create enough torque to last hours. To achieve this, a hand crank will wind a constant torque spring. The spring will be connected to a gear train. As the spring unwinds, it will activate the gear train, causing our design to activate.

3.2.1 Existing Design #1: Di-Octo by Anthony Howe

This was the design that pushed the team towards pursuing a constant torque spring powered device. On David Roy's website, he showcases the design on a video. He states that with a full wind of the spring, the design can last for 48 hours [1]. This design includes a "3-wheel 2-spring arrangement" [1] that is away from the moving pieces. This can be seen in Figure 3.2.1 below.

Figure 3.2.1: Kindala - Forest by David Roy [1]

This arrangement allows for more control of the torque output. Placing the torque springs away from the moving pieces and adding wheels and ropes gives this design a long duration time.

3.2.2 Existing Design #2: Di-Octo by Anthony Howe

Di-Octo is a wind sculpture created by Anthony Howe in 2014. In 2017, Anthony Howe donated Di-Octo to Concordia University [2]. This sculpture is powered solely by the wind. Di-Octo can be seen in Figure 3.2.2 below.

Figure 3.2.2: Di-Octo by Anthony Howe [2]

Figure 3.2.2 showcases how Di-Octo harnesses the wind's energy. Attached to the 'tentacles' are metal, concave plates. These scoop the wind as the wind blows. According to the Montreal Gazette, Di-Octo is 8 meters tall, weighs 725 kilograms, and only requires 2 km/hr of wind for its moving parts to activate [3]. This design showcases the ease of utilizing wind energy.

3.2.3 Existing Design #3: Serendipity by David Roy

Serendipity is one of Roy's earlier works. This design showcases the notion of controlling the movement of the sculpture. Serendipity can be seen in Figure 3.2.3 below.

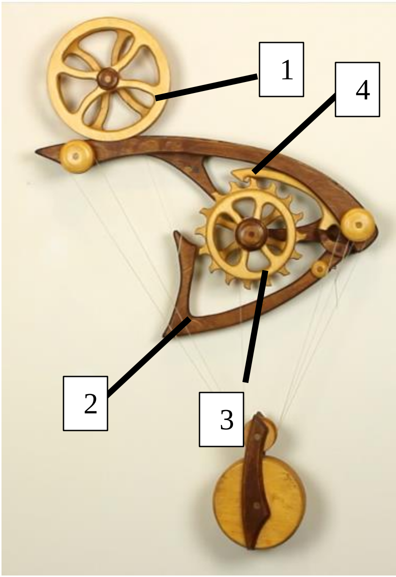

Figure 3.2.3: Serendipity by David Roy [4]

Serendipity's design is unique to his other sculptures. Strings are attached to every piece. The motion of the top disk, labeled 1 in Figure 3.2.3, activates the tension in the strings causing the other pieces to move. Once the top disk hits the bottom of the curve, it causes tension in the string causing the wooden piece, labeled 2 in Figure 3.2.3, to move up and push the gear. The gear, labeled 3 in Figure 3.2.3, is moved up, causing piece 4 to lift. While piece 4 is lifted, the gear rotates. Piece 4 then falls to stop the moving gear.

3.3 Functional Decomposition

Contained within this section is the team's functional decomposition of the Kinetic Sculpture project. Through the process of creating a Black Box Model, Work-Process Diagram, and description of each subsystem, the group was able to better comprehend their projects requirements.

3.3.1 Black Box Model

Through elaboration and clarification of the groups project, the team was able decide upon general inputs and outputs for objects, energies, and signals in order to determine and create a Black Box Model, seen in Figure 3.3.1 below.

Figure 3.3.1: Black Box Model

This model helps the group to further understand their project as well as its general functions and flows in order to create concepts and better define them in a way that better meets the projects requirements.

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

Based on the Black Box Model that the team developed, discussed above, a Work-Process Diagram was constructed to develop a more in depth look into how the overall function of our final design should work. The reason the team decided to use a Work-Process Diagram, opposed to a Functional Model or a Hierarchical Diagram, was because based on the scope of the team's project and design a detailed description on each function would be cumbersome, and so a broader look into the functions would be more appropriate. The Work-Process Diagram helped the team identify the key functions that are needed to accomplish the team's task and where those functions are required to be.

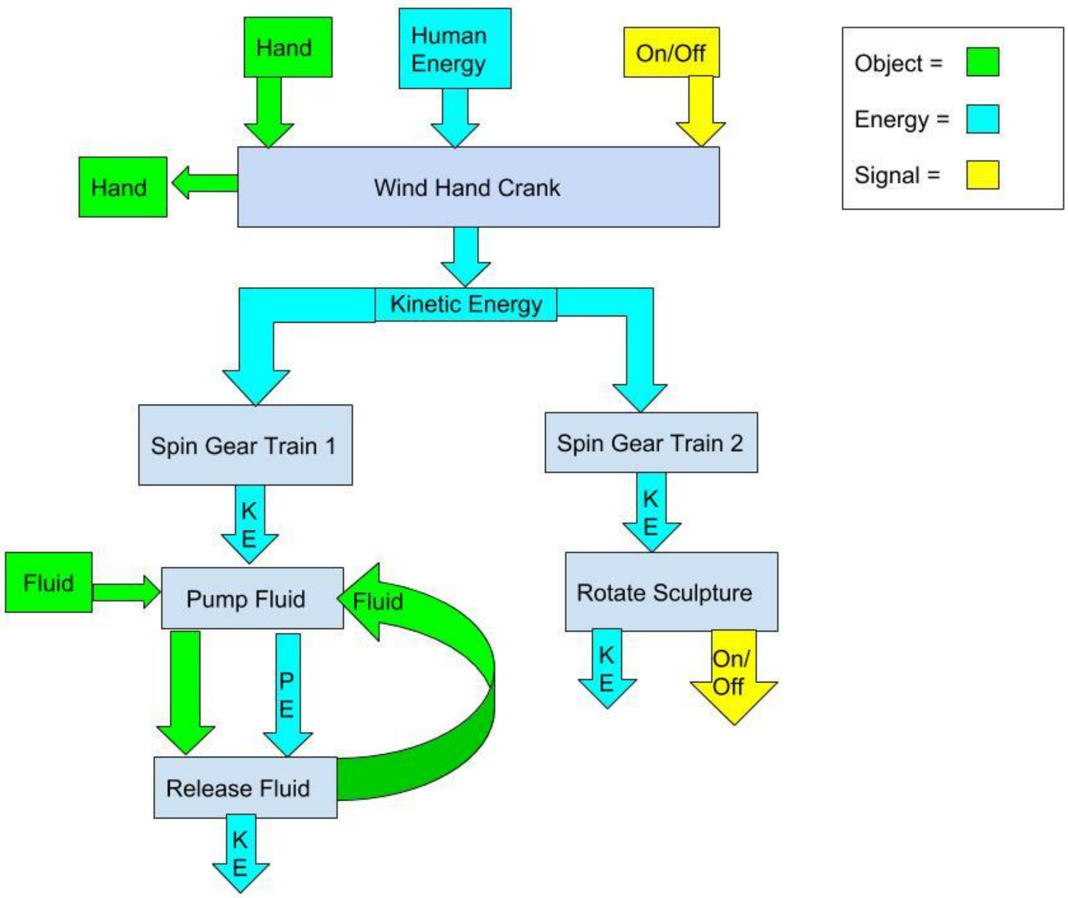

Figure 3.3.2: Work-Process Diagram

As seen in Figure 3.3.2 above, human energy begins the process of a kinetic sculpture. The team decided to start with this since most of our top designs utilized this. The user winds the hand crank, creating potential energy in a spring. When the stored energy within the spring is released, it activated a gear train using kinetic energy. The gear trains will either cause rotation of the sculpture, or it will activate the movement of the fluid.

3.4 Subsystem Level

There are many examples of kinetic sculptures created by different artists which contain the same or similar subsystems to the team's general ideas. These artists tend to use gears and constant torque springs in order to supply mechanical power to their pieces to allow them to run/operate for extended periods of time. The discussion of the important subsystems and existing designs are discussed below.

3.4.1 Subsystem #1: Wind Hand Crank/Spring

Through research, the most common kinetic sculptures were powered by wind energy or potential energy in a spring being converted to kinetic energy, winding a hand crank directly correlates with the latter. The hand crank would be connected to a spring, the team is considering a constant torque spring. The user will spin the hand crank, winding the constant torque spring. Once the user finishes using the hand crank, the spring will unwind. The team can use the rotation of the unwinding spring to make our sculpture move.

3.4.1.1 Existing Design #1: Duality by David Roy

This design utilizes the wind of a constant torque spring. In a video on David Roy's website, he showcases the sculpture. He starts by winding the spring by rotating the two main components clockwise. These two main components are labeled 1 in Figure 3.4.1.1 below.

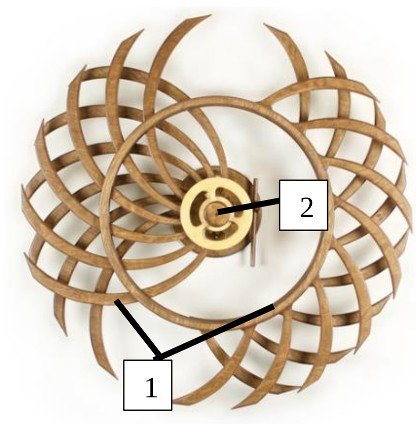

Figure 3.4.1.1: Duality by David Roy [5]

David Roy has been utilizing constant torque springs for years. He discreetly places the springs within the sculptures. For Duality, he places the springs in the center, labeled 2 in Figure 3.4.1.1 above. Roy states this design is called 'Duality' for the multiple balances needed to achieve while creating kinetic sculptures [5]. This sculpture's mechanical movements are in balance by a precise amount relative to gravity. Duality showcases the precise measurements and calculations the team needs to create a reliable, aesthetically pleasing sculpture. Also, Duality can run for approximately 8 hours off of one full wind of the spring [5]. If the team can fully understand how to efficiently implement a constant torque spring, the duration of our final design can be increased.

3.4.1.2 Existing Design #2: Zinnia by Clayton Boyer

Although very similar to Duality aesthetically, Zinnia differs in terms of how to wind the sculpture. With a constant torque spring placed directly in the middle, two opposing designs surround it. As seen in Figure 3.4.1.2 below, the two moving pieces rotate in opposite directions.

Figure 3.4.1.2: Zinnia by Clayton Boyer [6]

Unlike winding Duality, to wind Zinnia, the user must hold on to the moving piece in the background. Once the background moving piece is held, the user rotates the front piece clockwise, winding the constant torque spring. This method of winding the sculpture exemplifies the capabilities of torque springs. The team can manipulate the torque springs unwinding velocity, creating desired movements of our sculpture.

3.4.1.3 Existing Design #3: Circumvolve by Tom Boardman

This design utilizes a constant torque spring, however, the springs unwinding is manipulated by using ropes and tension. Circumvolve can be seen in figure 3.4.1.3a below.

Figure 3.4.1.3a: Circumvolve by Tom Boardman [7]

Circumvolve is wound by rotating the mechanism on the bottom, which contains a stainless steel constant force spring, about 22 times [7]. The rope allows for minimal use of the constant force springs rotations, which gives the sculpture a higher duration time on one complete wind. A closer inspection of the design, as seen in Figure 3.4.1.3b below, reveals the use of two constant force springs.

Figure 3.4.1.3b: Close-up of Circumvolve's winding mechanism [7]

The use of two constant force springs gives the sculpture a longer run duration time. This design unveils the practicality of using two constant force springs. These springs combined with tension in rope to create motion can be implemented in the team's design to add duration to our sculpture's motion.

3.4.2 Subsystem #2: Spin Gear Train

If the team pursues the use of constant torque springs, a gear train might be added to create motion within our sculpture. With manipulating gear ratios in a gear train, the team can calculate a desired output speed for a sculpture.

3.4.2.1 Existing Design #1: Colibri by Derek Hugger

Colibri is a kinetic sculpture that simulates the movement of a hummingbird flapping its wings. This is achieved by the use of a gear train. This particular gear train spans horizontally at first, then rises vertically, as seen in Figure 3.4.2a below.

Figure 3.4.2a: Colibri by Derek Hugger [8]

The various gear ratios create the separately timed movements of the wings, head, and body of the sculpture. The multitude of moving parts aids in the simulation of a flying hummingbird. This design showcases bio-mimicry and the creative liberties our team has with the movement of a kinetic sculpture.

3.4.2.2 Existing Design #2: The Promise by Andrea Davide

This design consists of a gear train that creates two moving pieces. These two pieces meet to create a visually pleasing sculpture. Once these two glass pieces touch, they stay connected for a few seconds, then they move apart from each other back to their initial places. As seen in Figure 3.4.2b below, the sculpture is powered by motors, Arduinos, and motion sensors [9].

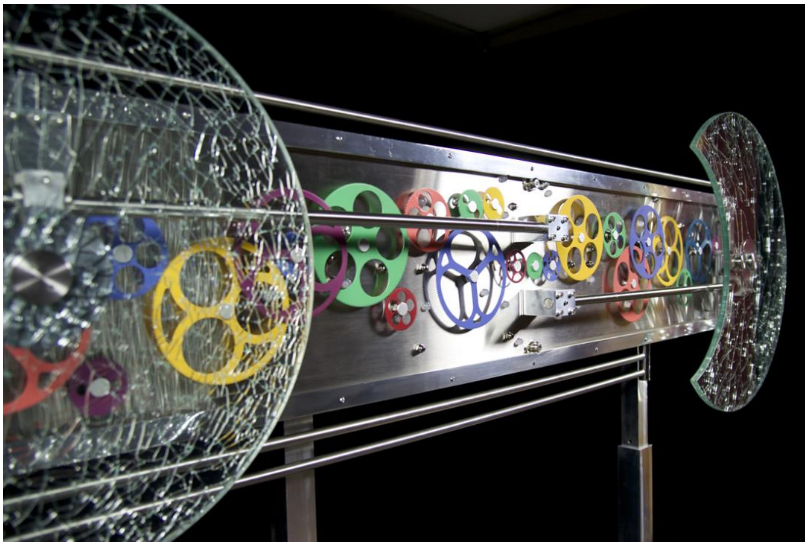

Figure 3.4.2b: The Promise by Andrea Davide [9]

The gear train that causes movement of the glass pieces is seen above. This gear train is large and consists of various gears with different diameters and rotational speeds. The Promise showcases how gear trains can be manipulated to create an ideal linear or rotation velocity. The team can utilize this design to ensure our final design moves at a desired rate.

3.4.2.3 Existing Design #3: Viper by Clayton Boyer

This interactive design is inspired by the coiling of a viper. This sculptures motion depends heavily on a knowledge of gear trains.

Figure 3.4.2c: Viper by Clayton Boyer [10]

At their initial position, the snakes are coiled vertically. As the user turns the crank, it causes the gear train to activate. The movement of the gear train uncoils the snakes, as seen in Figure 3.4.2c above. This unique design showcases the artistry behind the engineering and gives insight on train design and bio-mimicry.

3.4.3 Subsystem #3: Pump Fluid

The team's last subsystem included a movement of fluid within the design. Researching existing designs utilizing this subsystem can broaden the horizons of concept generation. The fluid can either assist in the movement of the sculpture or it can add an aesthetic.

3.4.3.1 Existing Design #1: STRANDBEEST by Theo Jansen

Theo Jansen creates a series of extremely large wind-powered sculptures called STRANDBEESTs. These wind sculptures mimic animal movements. Theo Jansen posts videos of these sculptures 'walking' on a beach on YouTube.

Figure 3.4.3a: STRANDBEEST by Theo Jansen [11]

Figure 3.4.3a showcases a STRANDBEEST sculpture created by Jansen. This sculpture requires the user to actively start the movement of the legs. Once the user creates motion, wind can carry this sculpture for a certain time period. The durability of this design is dependent on the force of the wind. This design shows the team how wind can be controlled to move large designs.

3.4.3.2 Existing Design #2: By the Bucket Full

This design includes water as its moving fluid. Made of metal, a bucket is filled with water. The velocity of the water hitting the full bucket causes it tip over, spilling the water. Then, the unbalanced weight causes the bucket to tilt back up to be filled with water again.

Figure 3.4.3b: By the Bucket Full [12]

Figure 3.4.3b showcases By the Bucket Full sculpture at its initial placement. At this stage, the bucket is filled with water that is running through the pipe. Once the bucket is filled, the weight displacement causes the bucket to tip over, spilling the water. Once the bucket is emptied, the weight at the bottom of the bucket exceeds the top weight, causing the bucket to return to its initial spot. This design shows how the team can use a fluid to create motion in a sculpture.

3.4.3.3 Existing Design #3: Synergy

This design consists of 5 metal pieces with water flowing off of them. The metal pieces represent human forms with different dimensions and water flow rates [13]. Each piece of this sculpture will take on different characteristics depending on the view angle, time of day, and amount of light reflecting off the sculpture.

Figure 3.4.3c: Synergy [13]

Figure 3.4.3c showcases the water sculpture, Synergy, viewed at night. The water cascades differently for each piece. This sculpture shows the team how a fluid can be used to add to the aesthetics of the whole sculpture.

4 DESIGNS CONSIDERED

After researching into existing designs of kinetic sculptures and using those as benchmarks, the team's next step was to begin the concept generation process. The first round of concept generation as done individually by each team member. After sharing the developed concepts with the entire team, the team began the second round by doing a 4-3-4, which is a version of the 6-3-5 method that was better suited for the team. For the third and final round of generation, the entire team came together to create and combine the existing concepts that the team thought to be the most practical. In total, the team developed twenty concepts. The top six designs are presented in descending order of how they scored on the decision matrix and Pugh chart, seen in Appendix B. The other designs generated are present in Appendix A.

4.1 Design #1: Archimedes Screw

An Archimedes Screw's purpose is to convert rotational energy into kinetic energy. It does this by using a helix pattern that has one end in a fluid and the other at the top of where the fluid is supposed to exit, cascading over a planetary gear system, as seen in Figure 4.1 below.

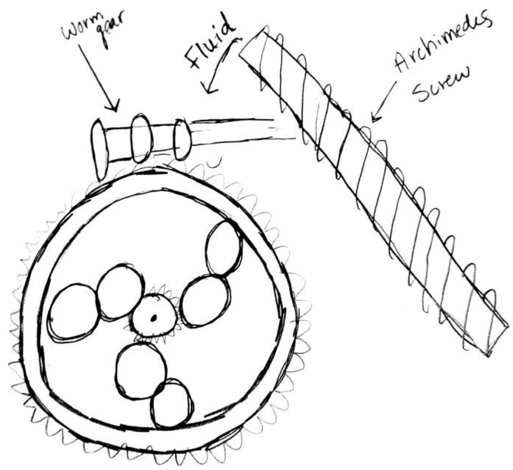

Figure 4.1: Archimedes Screw Concept

The screw should be tilted on a 30-60 degree angle to function properly. The Archimedes screw will be activated by winding a constant torque spring. The unwinding of the spring will activate a gear train. The gear train spins a worm gear, thus activating the planetary gear system. One positive aspect of this design is being able to pump a fluid with the use of only rotational energy, opposed to electric or hydraulic energy. A potential negative aspect for this design is the rate of which the fluid will be pumped for if the rate is too slow then it will not create the aesthetic look that the team is looking for.

4.2 Design #2: Solar System

A sun gear is placed in the middle. Surrounding the sun gear will be nine gears of various sizes that will spin around the sun gear, the nine gears will represent the nine planets, seen in Figure 4.2 below.

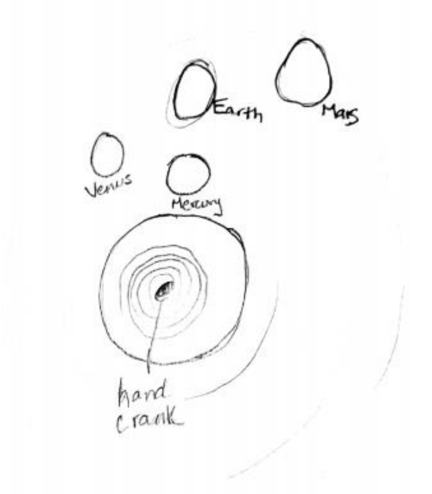

Figure 4.2: Solar System Concept

The goal will be to have them rotate around the sun gear proportionate to the planets revolution. A positive aspect of this design will be effectively using gears that are already in use to also create an aesthetically pleasing piece of art. A negative aspect of this design is the calculations behind the proportionality of the planets revolutions around the sun with the gears revolutions around the sun gear.

4.3 Design #3: 60 Seconds

The moving gear will make one revolution every 60 seconds, as seen in Figure 4.3 below.

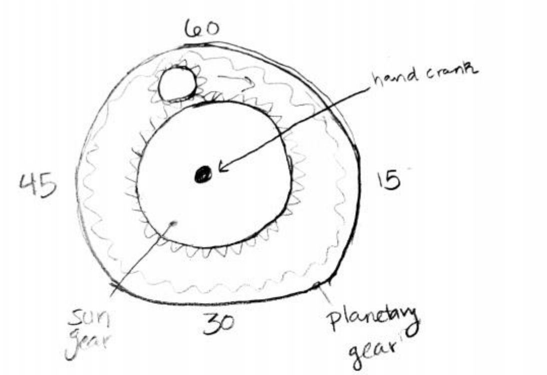

Figure 4.3: 60 Seconds Concept

Attached to this gear would be a minute hand that could then display the time by the minutes. The simplicity of this design is a positive aspect. The ease of implementation given gear sizes and input power, the team could easily make a gear that could run at one revolution per minute. However, the constant unwinding and winding of the spring will cause discrepancies in tracking time.

4.4 Design #4: Run Doggie, Run

Powered by a constant torque spring, a gear train will connect to a dog sculpture. The dog's legs are connected to two gears at the end of the gear train, as seen in Figure 4.4 below.

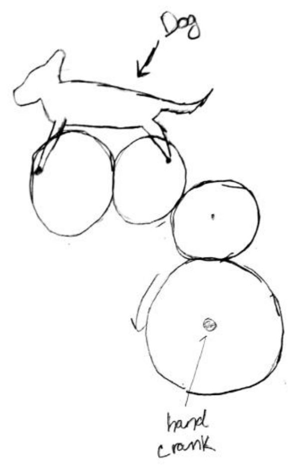

Figure 4.4: Run, Doggie, Run Concept

The rotation of the gears will simulate a dog running. This design is aesthetically pleasing and the cost would be low. However, this design has a lot of moving parts and tedious calculations, which increases the difficulty and feasibility.

4.5 Design #5: Bubble Blower

This concept involves a pipe that utilizes air as its moving fluid. This pipe will include several holes around the circumference. The velocity of the fluid and the diameters of the holes must be minimized in order to keep the durability of the design high. The pipe will be coated in a soap-like substance that will generate bubbles to be blown out of the holes on the pipes sides.

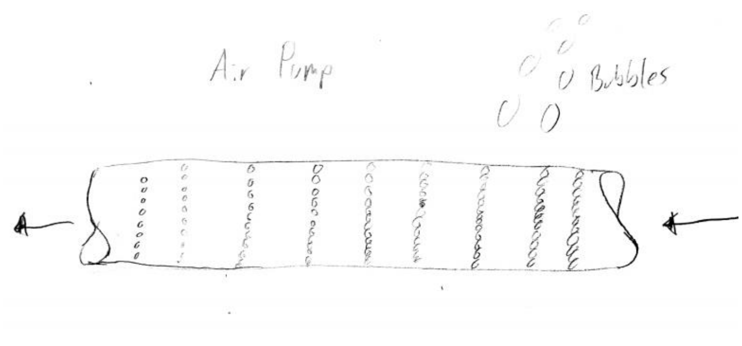

Figure 4.5: Bubble Blower Concept

Positive aspects of this design include the low price for purchasing a pipe and the ease of machining holes along the pipe. Negatively, the simplicity of a pipe with holes and flowing air decreases the aesthetic appeal. Also, constantly resupplying the soap lowers the durability of the design.

4.6 Design #6: Magnetic Pendulum

The magnetic pendulum concept uses the properties of magnets and how similar poles resist each other. By dropping the magnets from a height while having their north poles directed towards each other, they will reach a point of resistance and forcibly bounce away and their south poles will travel towards the top of the design which will be lined with south poles to "shoot" the pendulums back down. The concept is supposed to bounce back and forth indefinitely, simulating perpetual motion. This design concept can be seen below, in Figure 4.6.

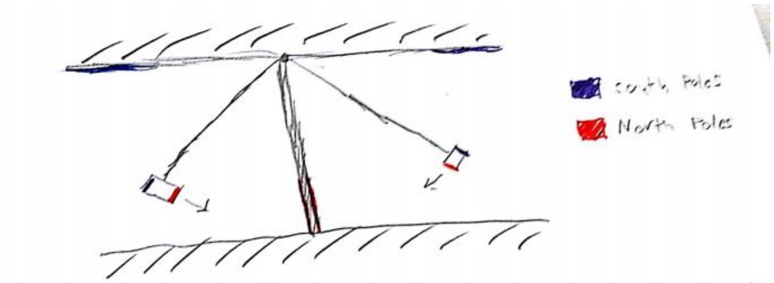

Figure 4.6: Magnetic Pendulum Concept

A positive aspect of this design is the single action by the user to drop the pendulums. This design could also be educational, teaching future NAU students about magnetism. Although the design seeks to find perpetual motion, it can never be achieved. Also, the magnets will need to be replaced fairly often as their poles unpolarize.

5 DESIGN SELECTED – First Semester

From the team's twenty designs considered they have decided to combine a few of the better designs into a single final design of their kinetic sculpture. The design selected will be a combination of the following designs; Archimedes Screw, Solar System, 60 Seconds, and Run Doggie, Run.

5.1 Rationale for Design Selection

After evaluating all twenty designs considered through a Pugh Chart, found in Appendix B, the team was able to narrow down the designs to the top seven designs. The team then evaluated these seven designs in a decision matrix, also found in Appendix B, and again narrowed down their selection to the top four designs. Those top four designs are the four designs that the team has decided to combine into a single final design. The Archimedes Screw is the perfect solution for adding more fundamental engineering principles, which is a key customer requirement for the team, for it brings together rotational motion and fluid dynamics and while there was another option to introduce fluid dynamics into the final design (i.e. the Bubble Blower), the Archimedes Screw was the easiest way to implement that principle into a kinetic sculpture. The Solar System, Run, Doggie, Run, and 60 Seconds designs will highly influence our final design. The gear systems within these designs will help the team design and calculate a gear system that produces desired outputs.

5.2 Design Description

The final design will consist of a hand crank that will begin to wind up a constant torque spring that will then lead to a constant motion of the rest of the sculpture for a long period of time. Connected to the constant torque spring system will be a gear train. At the end of the gear train will be a worm gear spinning the planetary gear system seen below in Figure 5.2.

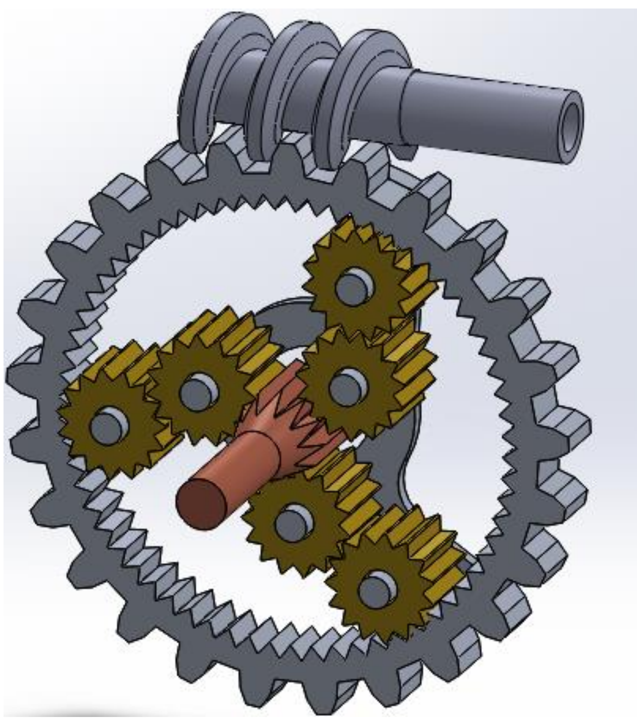

Figure 5.2: Planetary Gear System with Worm Gear

As the gear train causes the worm gear to spin, the movement of the planetary gear system will cause the movement of the Archimedes screw. The screw will be connected to the planetary gear system using a rear-end gear. The Archimedes screw will be submerged in a fluid. The rotation of the screw will carry fluid up. The fluid will cascade down over the gear systems, creating an aesthetically pleasing sculpture.

6 CONCLUSIONS

This report details the teams progress, thus far. Starting with a project description, the team was able to derive customer needs and engineering requirements, research and benchmark existing designs, generate concepts, and eventually evaluate and select a concept to further pursue. The team is currently conducting analytical tasks of the selected designs sub-systems. These analyses will determine if we can pursue the selected design, or if several iterations are needed.

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8 APPENDICES

8.1 Appendix A: Concepts not Discussed

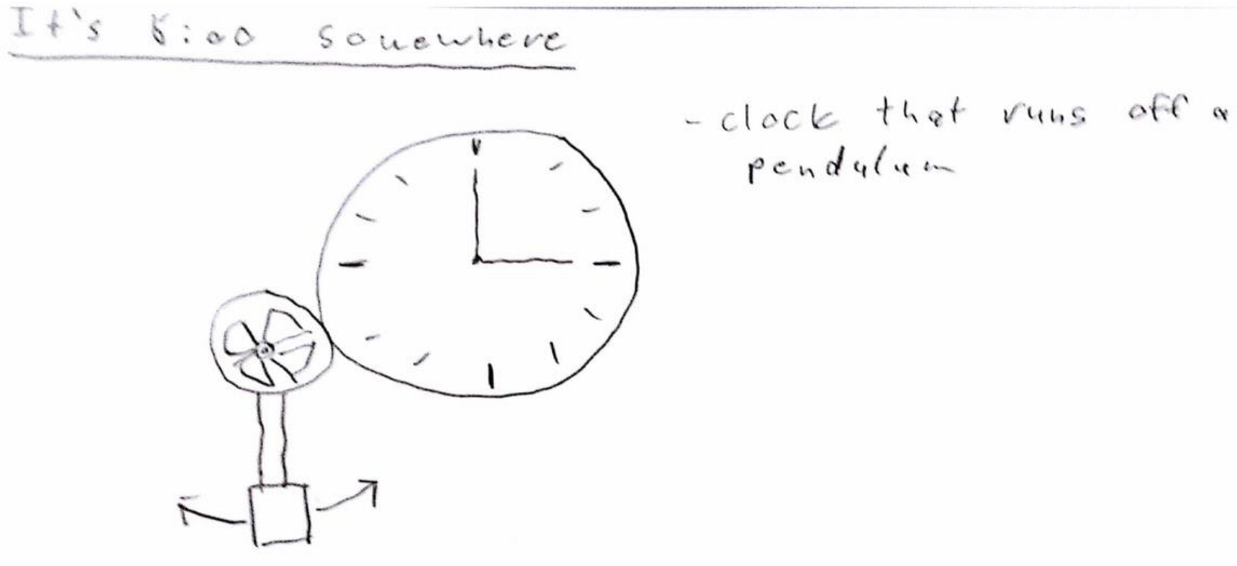

Figure 8.1.1: It's 5 o'clock Somewhere

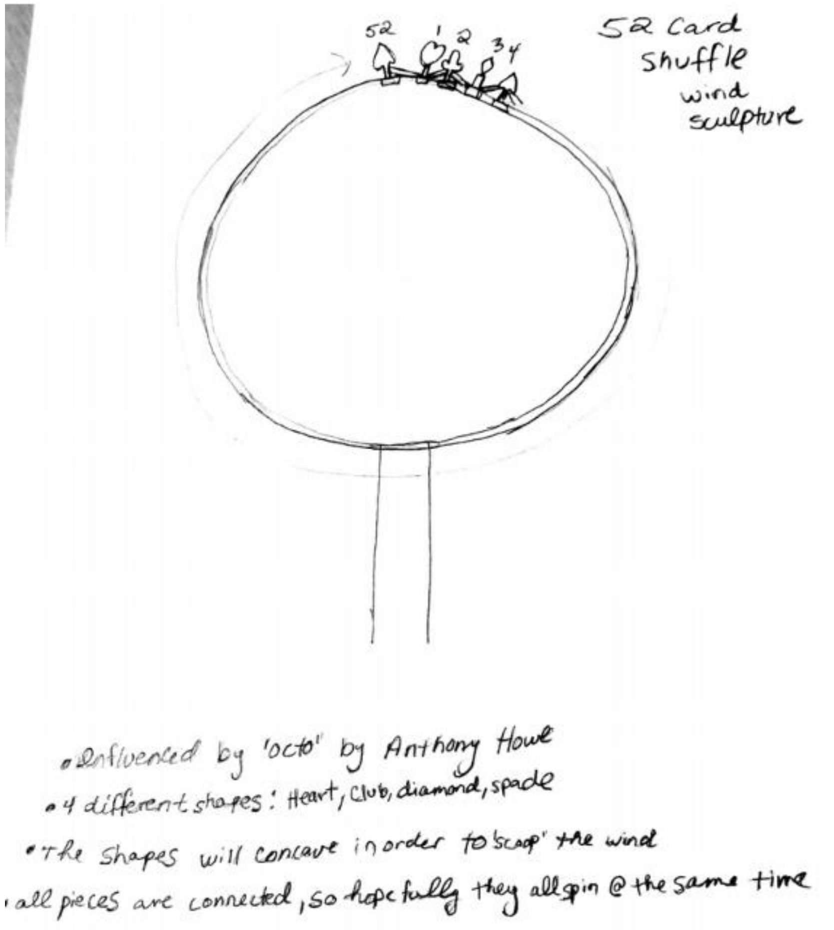

Figure 8.1.2: 52-Card Shuffle

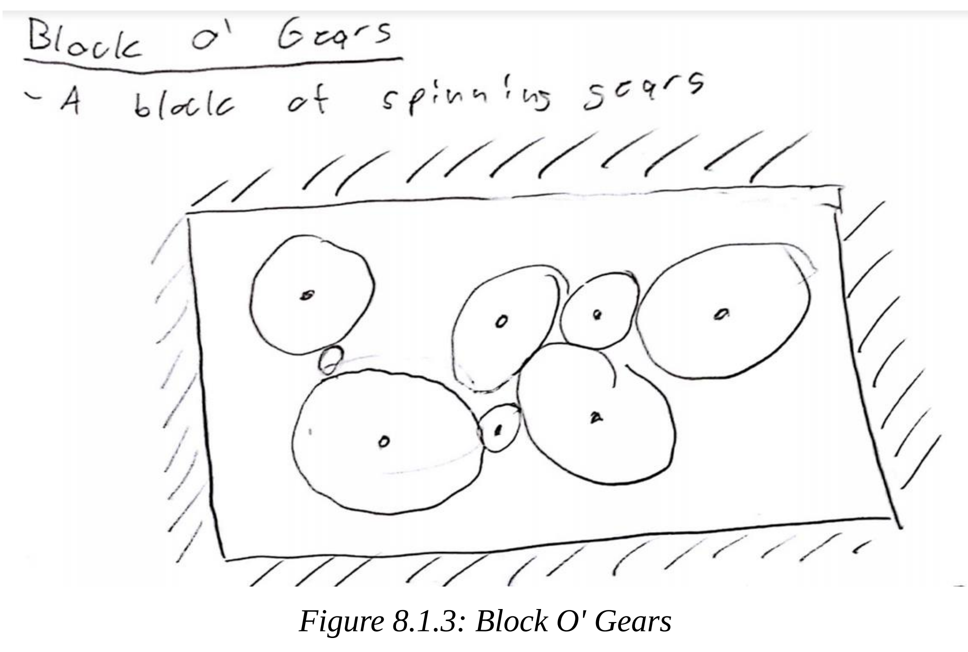

Figure 8.1.3: Block O' Gears

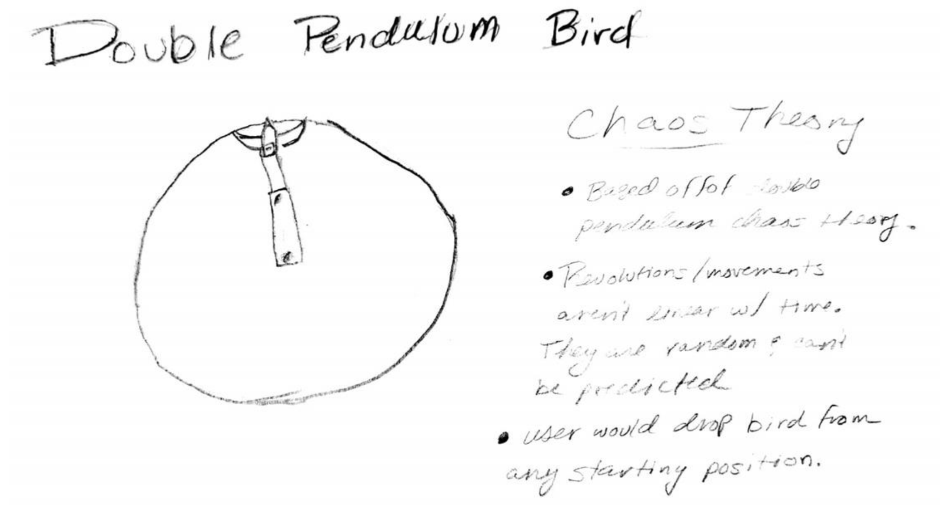

Figure 8.1.4: Chaos Theory: Double Pendulum

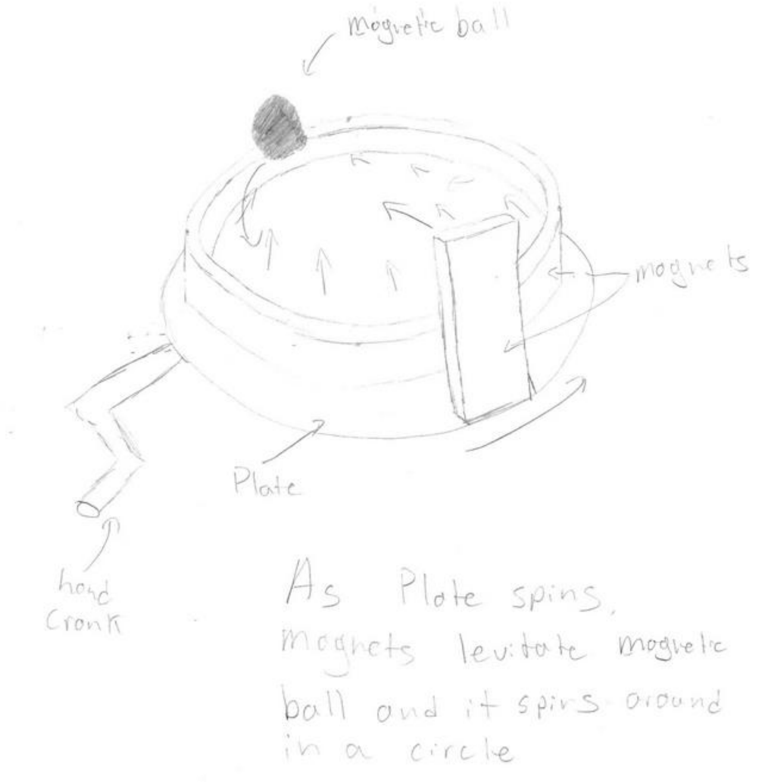

Figure 8.1.5: Magnetic Ball

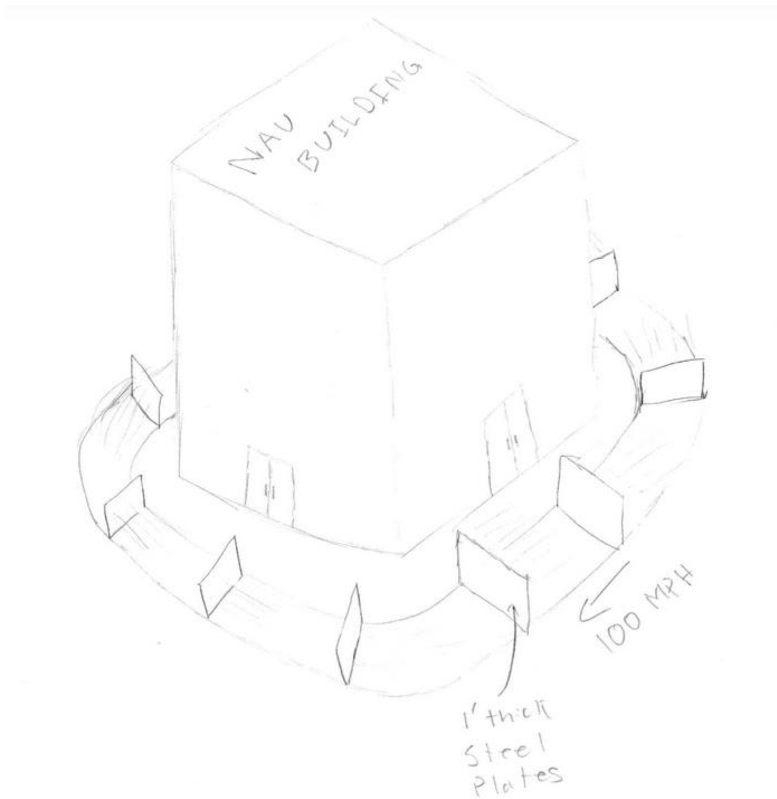

Figure 8.1.6: Tech-Tonic Plates

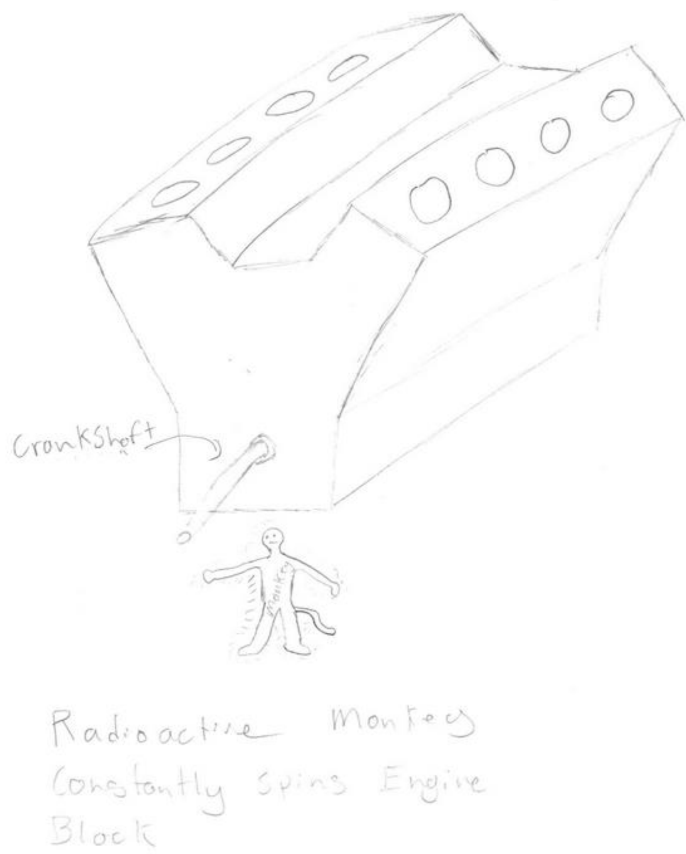

Figure 8.1.7: Radioactive Monkey

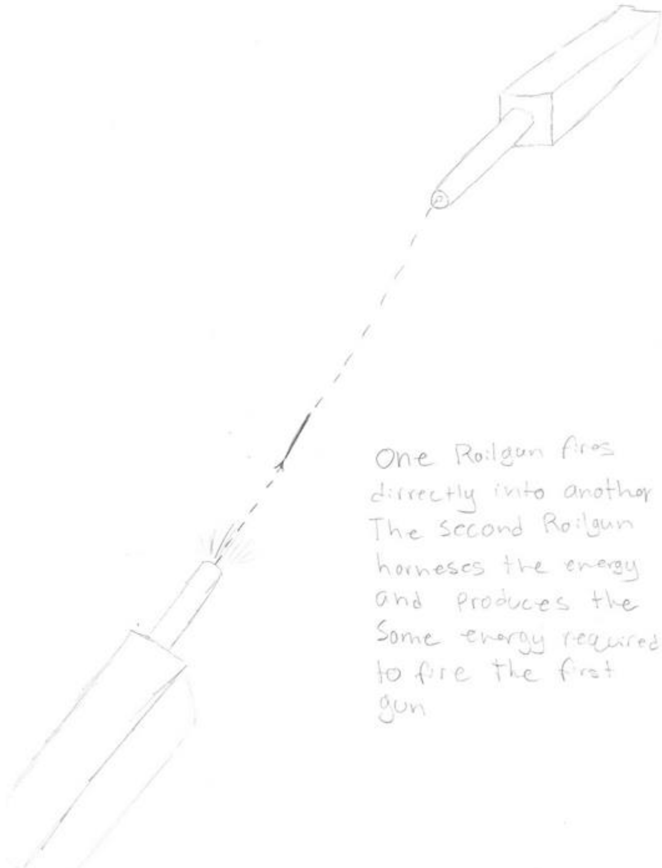

Figure 8.1.8: Railgun

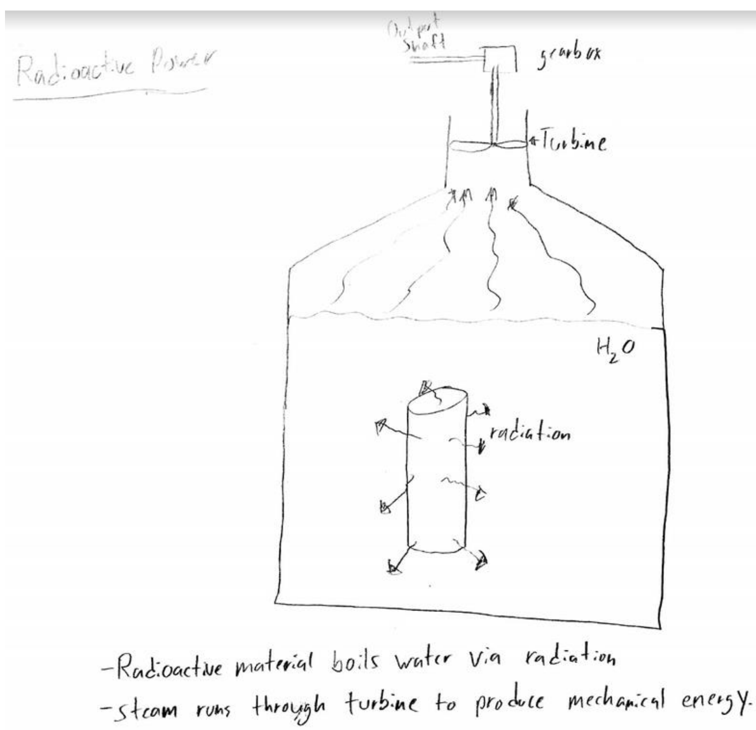

Figure 8.1.9: Radioactive Power

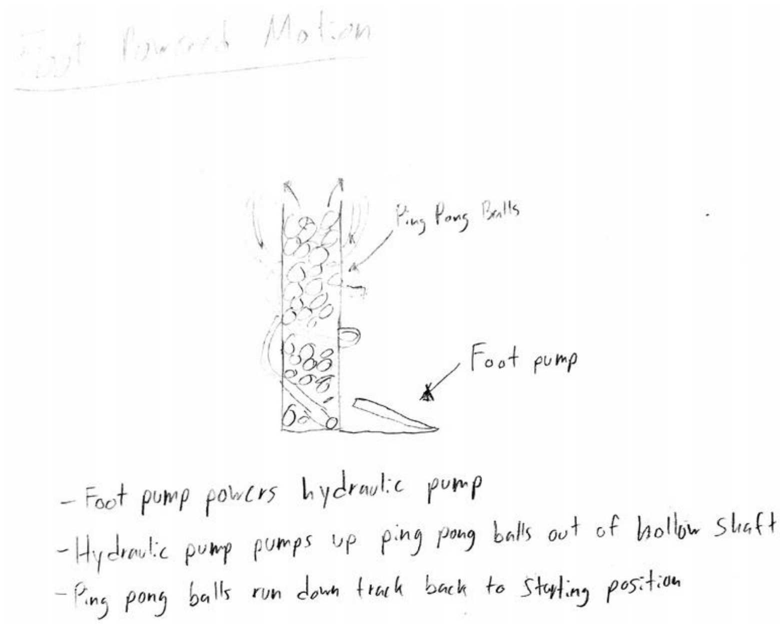

Figure 8.1.10: Foot Pump

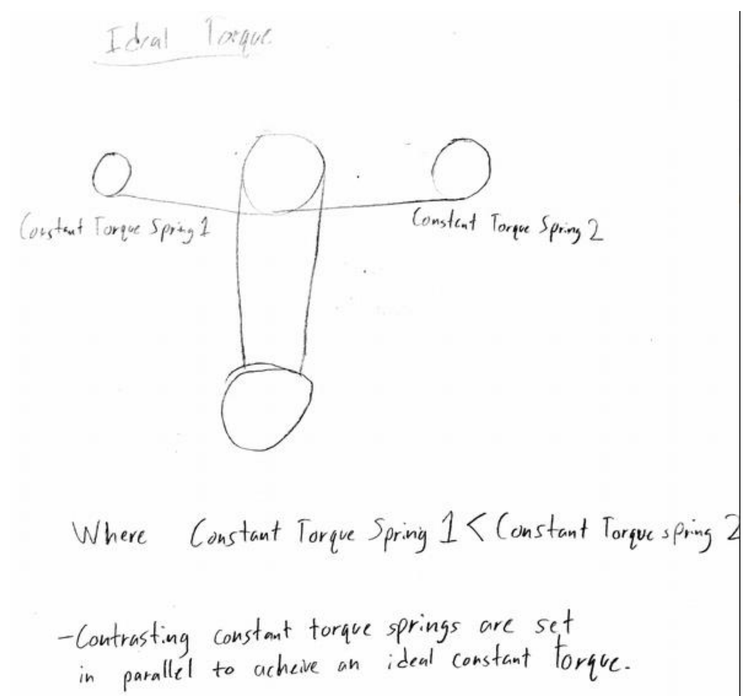

Figure 8.1.11: Ideal Torque

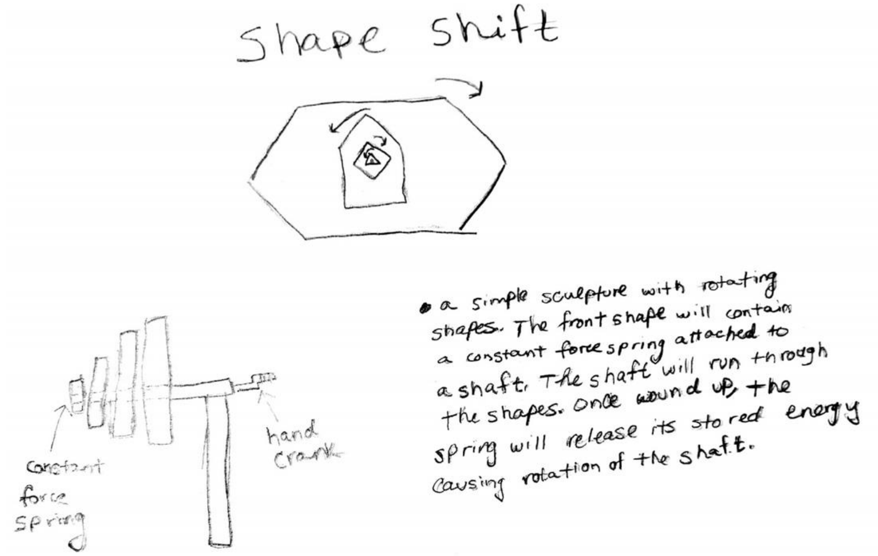

Figure 8.1.12: Shape Shift

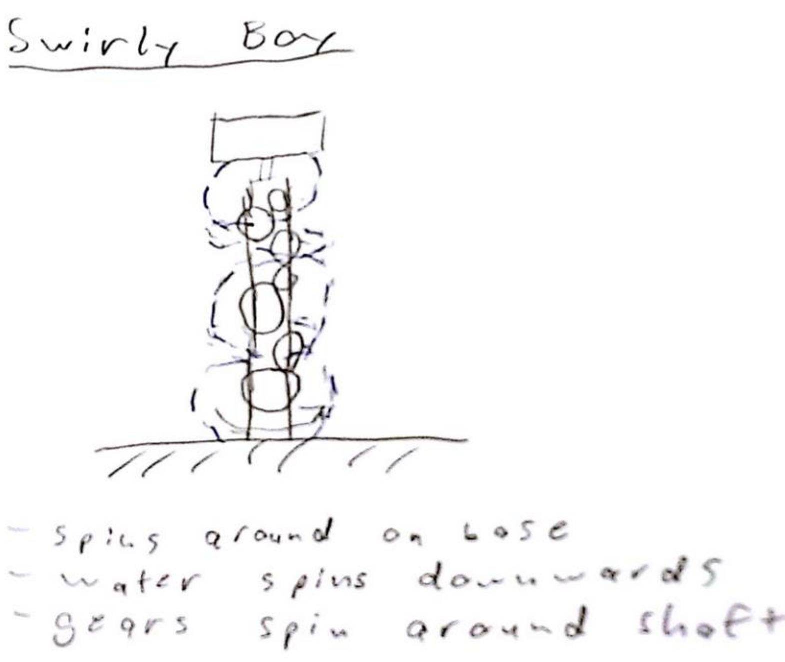

Figure 8.1.13: Swirly Boy

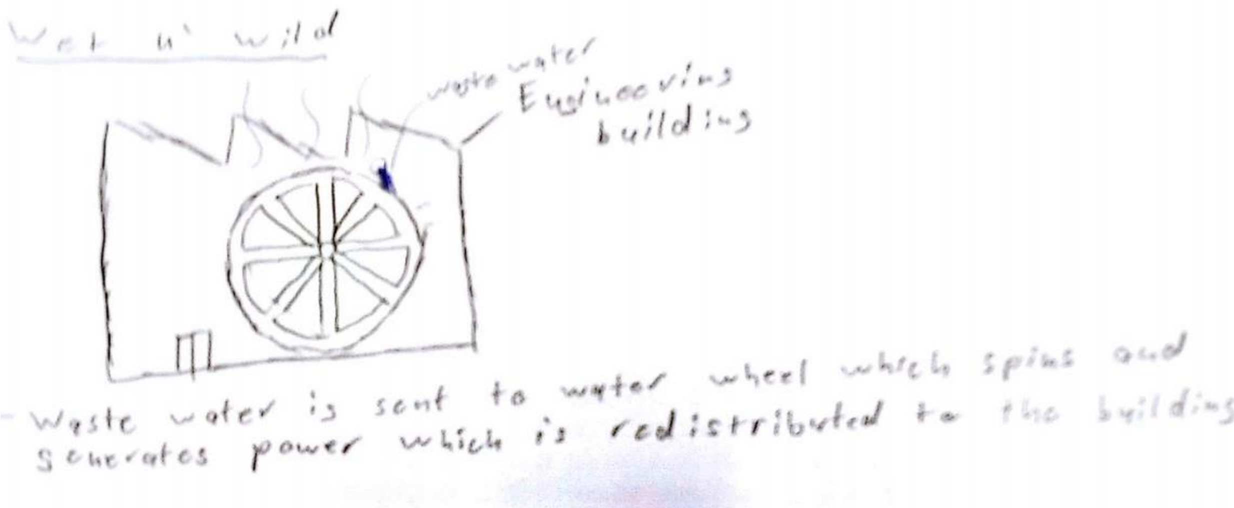

Figure 8.1.14: Wet N' Wild

8.2 Appendix B: Pugh Chart and Decision Matrix

Table 8-1: Pugh Chart

Criteria \ Concept	52 Card Shuffle	Archimedes Screw	60 Seconds	Run, Doggie, Run	Double Pendulum	Shape Shift	Solar System	OG	5 o'clock Somewhere	Block O'Gears
	1	2	3	4	5	6	7	8	9	10
Moveable (Can Fit Through Door)	-	D	S	#	S	-	S	S	-	S
Cost Effective	-	A	#	#	#	-	S	-	-	S
Durable	S	T	S	S	S	S	-	-	S	S
Represent Engineering Positively	S	U	-	-	-	-	#	S	-	-
Safe To Use	-	M	S	#	S	S	S	S	#	S
Visually Pleasing	#		-	#	-	S	#	-	S	-
Reliable	-		S	S	-	-	-	-	S	-
∑# (Positive)	1		1	4	1	0	2	0	1	0
∑- (Negative)	4		2	1	3	4	2	4	3	3
∑S (Same)	2		4	2	3	3	3	3	3	4
Total Positive or Same	3		5	6	4	3	5	3	4	4

Criteria \ Concept	Magnet Pendulum	Swirly Boy	Wet N' Wild	Magnetic Ball	Tech-tonic Plates	Radioactive Monkey	Railgun	Music Box	Bubble Blower	Radioactive Power
	11	12	13	14	15	16	17	18	19	20
Moveable (Can Fit Through Door)	-	-	-	#	-	-	#	#	S	-
Cost Effective	#	S	-	#	-	-	-	#	#	-
Durable	-	-	-	-	-	-	-	S	S	-
Represent Engineering Positively	#	-	S	-	-	-	#	S	-	S
Safe To Use	#	S	-	S	-	-	-	#	#	-
Visually Pleasing	S	S	-	#	-	S	-	S	S	-
Reliable	S	-	S	-	-	-	-	#	-	-
∑# (Positive)	3	0	0	3	0	0	2	4	2	0
∑- (Negative)	2	4	5	3	7	6	5	0	2	6
∑S (Same)	2	3	2	1	0	1	0	3	3	1
Total Positive or Same	5	3	2	4	0	1	2	7	5	1

Table 8-2: Decision Matrix

				Sculpture Concepts (Scale 0-100)						
		Criteria	Weight (RTI)	1 Archimedes Screw	2 60 Seconds	3 Run, Doggie, Run	4 Music Box	5 Bubble Blower	6 Solar System	7 Magnetic Pendulum
Engineering Requirements	1	Less Than 150 Lbs	21%	90	80	80	70	70	80	80
	2	Under 3x3x6	12%	90	80	90	70	70	60	90
	3	Under $5000	8%	90	80	90	50	60	90	70
	4	Material Strength	8%	70	60	60	50	50	50	40
	5	Hardness	3%	60	60	60	40	60	60	60
	6	Corrosion Rate	6%	60	70	50	70	40	70	90
	7	Factor of Safety	15%	20	50	40	60	80	80	40
	8	At Least 3 Principles	7%	100	80	100	100	80	70	100
	9	Operational For 30 min	6%	80	80	80	50	60	80	40
	10	Low Power Requirement	3%	80	80	80	50	70	80	80
	11	9/10 People Like	12%	90	90	80	90	90	80	70
			Raw sco	75.9	74.7	74.2	67.8	70.2	74.9	69.8
			Relative Rank	1	3	4	7	5	2	6