UNIVERSITY OF Waterloo

Department of Mechanical and Mechatronics Engineering

ME100: Dragonfly Launcher Toy Design

dragonflight

A Report Composed For:
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Ms. Mollie Jameson,

We have prepared our report, entitled ME100: Dragonfly Launcher Toy Design, to submit as our design project for ME100: Introduction to Mechanical Engineering Practice I. The purpose of this report is to apply our knowledge of this course in order to refine a toy concept and present our progress towards the development of this product. For this project, we engineered a toy that uses a flywheel mechanism to shoot out dragonfly shaped projectiles. These dragonflies autorotate downwards for children to catch in nets. Competitive and action play are highlighted in the game, catering it specifically towards children 6 to 9 years old.

The ME100 course is an introduction to key concepts and skills of Mechanical Engineering, including the process of design and professional communication. In this report, we culminate our learnings by communicating the results of our Dragonfly Launcher Toy design in the form of a work report to Spin Master Ltd.. This report contains exhaustive details on the ideation of the Dragonfly Launcher Toy design and extensive analysis of the success of the implementation of these design elements done by our team. Through the Dragonfly Launcher Toy project, we sought to display our capacity to learn Mechanical Engineering skills in practice while modeling a toy that would succeed in today's market and captivate children in our target audience. This report was written entirely by the undersigned and has not received any previous academic credit at this or any other institution. Thank you for taking the time to review our work. Please do not hesitate to contact any of us with questions or concerns.

Best Regards,

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Summary

The Dragonfly Launcher Toy is a concept where dragonfly-shaped projectiles are launched outwards and upwards into the air; played in an open space for children ages 6 to 9 to catch in their nets. This competitive game involves mechanical aspects to control the movement of the projectiles out of the system into the air, and to control the downward motion of the projectiles to be in a helical motion. Throughout this report, the creation and refinement of the Dragonfly Launcher are thoroughly explored. The report takes into consideration its precedent toys, specifically Elefun® and the Nerf® Hyper gun. The Dragonfly Launcher was built by taking the concepts from these toys such as the creation of air resistance and the use of launch wheels.

In the Dragonfly Launcher toy, there are two main aspects of mechanical design. The first is the launching mechanism which is a flywheel with two launch wheels that use rapid rotational motion to accelerate projectiles between them. The projectiles are designed using the concepts of leading-edge vortices to create lift and autorotation, thus when entering freefall, they can helically plunge downwards. While designing the toy, the main constraint considered was to have the flywheel launch the projectile at a minimum distance of 1.0 m forward and 2.5 m upward.

The final model of the dragonfly projectile has plastic wings that fold into a cylindrical shape when compressed which easily extends when released. The projectile is designed to minimize air resistance when being launched and to maximize air resistance during free fall; designed to steadily autorotate, which requires the leading-edge vortex and the application of a low centre of mass on the axis of rotation.

The flywheels were made from layers of laser-cut acrylic, with evenly spaced-out holes in the flywheel to reduce the flywheel's weight and load on the motor. With the precision of the laser cutter, all flywheels have identical shapes and are more than capable of grabbing and launching the dragonflies out of the system.

The reloading mechanism uses a compressed spring, with a low spring constant, to push the loaded projectiles out of a tube and into the flywheel to be launched.

The newest base prototype was also made from laser-cut acrylic to increase precision. It includes a slide feature with the ability to test the optimal space between the flywheels. It also features the beginning of the safety cage that will be fully integrated in the future.

In summary, with successful projectile and helical motions generated by the flywheel and dragonflies, many useful solutions to the Dragonfly Launcher problem have been produced by this project. This project proves that the implementation of leading-edge vortices, upwards curvature, low centre of mass, and lightweight plastic and foam materials allow for the helical downfall sought in the projectile. There were also many positive results with the flywheel and the base. Using laser-cut acrylic also allowed the parts to be mass-produced by either injection molding or just laser-cutting parts in batches. The base also successfully implemented a sliding feature to rapidly test the ideal width between the flywheels.

The results of the Dragonfly Launcher project have incited promising potential advancements to the design and refinement of the toy. Future modifications in the dragonflies include decreasing stress in the wings, improving manufacturability, and creating smooth interfacing between the projectile wings and the flywheel. Future optimization of the flywheels is to be done by making sure the flywheels are safely enclosed and pose no threat to the children playing. Furthermore, the base can be better developed by considering on changing from the adjustable base to a fixed.

Introduction

The Dragonfly Launcher Toy was developed as a toy that launches fun-shaped projectiles for children to compete in catching using nets. In designing the mechanics of this toy, the aim was to create efficient systems that would allow for complex gameplay. Overall, the objective of this toy, in the context of its target audience, is to create a challenging dynamic activity for the kids to run and catch the most projectiles possible (Figure 1). This would encourage the growth of the children's reaction time and gross motor skills relative to the selected age range for the toy (6 to 9 years old).

Figure 1 Gameplay of the Dragonfly Launcher Toy.

1.1 Play Pattern / Age Range

This toy project is categorized as a children's game oriented towards the 6 to 9 age range; however, it may require parental supervision due to the electrical components in the toy. This action patterned game can be either competitive or individual at the child's discretion. It requires a minimum of one to two players, equipped with nets, where they must compete to catch as many projectiles as possible. The player who accumulates the most dragonflies wins that round. Otherwise, if the individual wants to play alone, they can reattempt to beat their high score of how many dragonflies they managed to catch prior to each round. At this age, children are playing well with their friends and combining different gross motor skills; for example, running in patterns to kick a ball [1][2]. With the combined running and swinging actions involved in the Dragonfly Launcher toy and the competitive nature of the game, the target audience would be kept challenged and entertained.

1.2 Comparable Products

A similar product to the general idea and gameplay of the Dragonfly Launcher is the game Elefun®, invented by Hasbro Inc., for ages 3 and up (Figure 2). This toy's play pattern was inspired by Elefun®'s play pattern. In Elefun®, the player who catches the most butterflies wins the game. This game consists of nylon fabric butterfly shapes that are launched into the air vertically through the elephant's trunk, powered by a motor that creates air flow, pushing the butterflies into the air for the children to catch [3].

Figure 2 The Elefun® game invented by Hasbro Gaming in 2016 [1].

While Elefun® pushes the butterflies vertically upwards, forcing the gameplay to be close towards the elephant system, the Dragonfly Launcher shoots the projectiles outwards at an angle. This requires a larger game space while increasing the difficulty of the game to be appropriate for the 6 to 9 age range. Additionally, the butterflies in Elefun® have to be light weight, in order for them to be lifted and float in the air. With the Dragonfly Launcher, the form of the projectiles is made to consider air resistance and autorotation.

A comparable product to the inner mechanism of the Dragonfly Launcher is the Hyper Nerf® gun which uses a flywheel to accelerate bullets horizontally (Figure 3). Using a similar mechanism to launch the dragonfly projectiles would allow for greater speed and height compared to the flow of air created in Elefun® [2].

Figure 3 The Hyper Nerf® Gun launching system [2].

1.3 Technical Background

Dragonflies, other insects' wings, as well as helicopter seeds, can have leading-edge vortices (LEV) on their wings that allow them to generate lift, as shown in Figures 4 and 5 [3]. The form of this vortex will be further investigated in the design of the dragonfly projectiles. The projectiles are shaped similarly to helicopter seeds, providing them the ability to autorotate. The wing's ability to create lift initiates torque that spins the seed about its centre of mass, which lies on its vertical axis [4]. When such a winged-shape object is launched, it enters free fall and a steady-state of auto rotation, or auto gyration, which allows it to move downwards in a helical motion. The leading-edge vortex of helicopter seeds creates a vortex in the flow of air that enables high lift and autorotation of the seed [3].

Figure 4 Helicopter seed shape with leading edge [3].

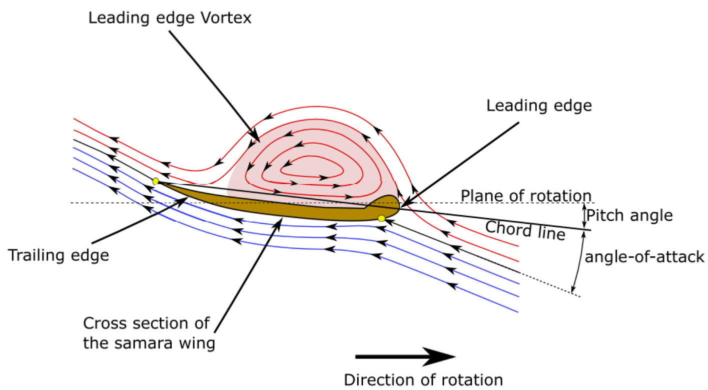


Figure 5 Cross section of leading-edge vortex on a helicopter seed [3].

1.4 Objective

The main objective of this report is to present the most effective solutions when creating a toy like the Dragonfly Launcher. This will be explored through the results of experimentation and research. This report outlines the engineering decisions taken to develop the Dragonfly Launcher prototype and its design process. Through repeated testing, analysis of results, and modifications, the viability of the toy was determined, and recommendations were formulated for future development.

2.0 Problem Definition

In the design of the Dragonfly Launcher Toy, there were two primary problems needed to be solved: how to make the projectile autorotate on its way downward and how to launch the projectile into the air. From here, several secondary problems ensued, including the synergy between the projectiles and the flywheel, which is addressed in the creation of the base of the toy, and the reloading mechanism of the projectiles for fluid gameplay.

2.1 Required Functions

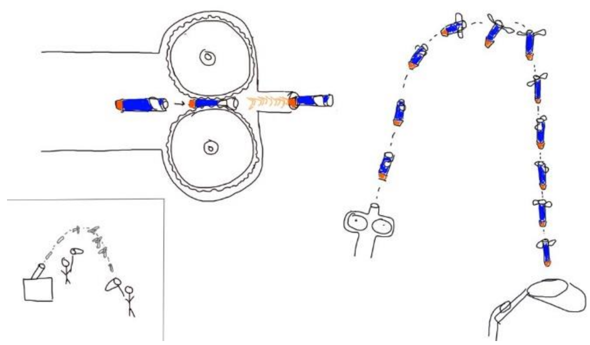


Figure 6 The overall gameplay of the Dragonfly Launcher and its two main functions.

The first of the two required functions: the dragonfly projectile must be shaped as a cylinder with furled wings when it is launched upwards at an angle, then must change into a cylinder with unfurled wings on its way downwards. The wings should reduce the acceleration of the projectile and stabilize the projectile in free fall - using the principle of autorotation. This should enable the projectiles to fall straight down from its peak height. The second required function is the ability of the toy to automatically launch the projectiles. The launching mechanism must be able to transfer its rotational energy to the linear energy of the projectile [5].

2.2 Codes, Standards & Patents

When carefully considering the safety codes and standards during the making of the Dragonfly launcher toy, thorough research was done to prevent any possible concerns in the foreseeable future. The "Industry Guide and Regulation to Health Canada's Safety Requirements for Children's Toys and Related Products" implemented by the IRCC (Immigration, Refugees and Citizenship Canada) [6] was a document used when brainstorming, prototyping and designing this toy, as it is mandatory to consider laws and regulations to ensure the safety of the intended toy user. For example, this toy cannot be used by children 3 years and under because of choking hazards (Section 7 of the Toys Regulations). Generally, there are several requirements where electrical and mechanical parts must not be accessible to children to avoid injuries. Specifically, to projectile toys, the ends must be covered by tips that cannot be removed by 44.5 Newtons of force (Section 16 of the Toys Regulations). The main relevant patent in this project is the aforementioned Hyper Nerf® gun (Figure 7).

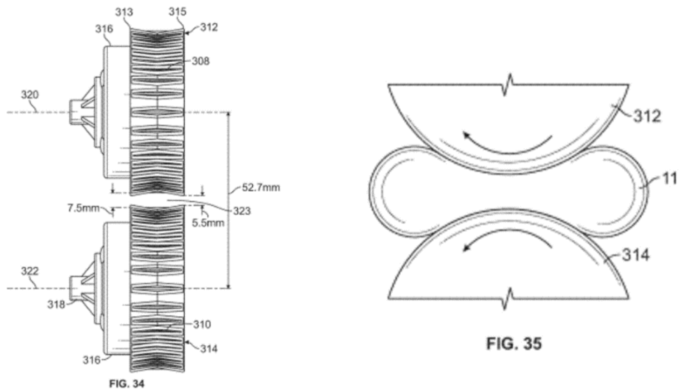


Figure 7 Patented Nerf Hyper Launch Wheels [7].

This patent explains the use of launch wheels transferring energy to the projectile, and how this system is reasonably cost-effective to produce [7]. While the launching mechanism in the Hyper gun is used to compress and shoot spherical projectiles, this project adapts the concept to cylindrical projectiles. Momentarily, the Dragonfly Launcher Toy does not meet the code requirements. The toy accelerates too high and too quick that the intended player will not have enough time to react. This opens a possibility of the player getting injured (e.g., tripping). The toy also does not have a proper placement for the electrical and mechanical components which poses a safety hazard - especially for children. However, with future modifications, this toy will meet the code requirements. This toy already includes goggles to prevent the player(s) from getting hit in the eye by the projectiles. There is a plan to hide the electrical wiring components inside of the main body of this toy and have the switch pop out from the front-right side. Regarding the mechanical component, the flywheel mechanism will also have a case. This prevents the user from putting their fingers in between the flywheel and getting them stuck when the switch is on.

2.3 Constraints and Criteria

In terms of the constraints in this project: the projectile must be able to fit between the two 10 mm flywheels and not get stuck. To obtain this, a base that hold both motors was constructed, with the correct spacing in between both motors, to reach consistent functionality of the launching system. The toy dragonfly attained a horizontal distance of at least 1.0 m and a vertical distance of at least 5.0 m, so that its maximum height reaches approximately 2.5 m. It is recommended to set a maximum height that is slightly less than the average ceiling height of homes, so that the projectiles do not hit the ceiling and therefore accelerate downwards at a quicker pace. This was accomplished by prototyping with different motors of different speeds. The final verdict was to choose the motor that obtains the greatest speed since the higher the speed of the motor, the faster the dragonflies would be launched, and therefore reach a further distance. The projectile must also unfurl its wings 1.0 s after reaching its peak. The wings should help slow down the dragonfly so that it is rotating downwards, at a speed equal to or less than 1.0 m/s, as it hits the ground. On the other hand, the inner diameter of the flywheel (Figure 8) must be a tight fit to prevent it from fitting loosely on the motor's shaft and avoiding any possible accidents. The optimal size for the inner diameter of the flywheel was 0.41 mm, value obtained through prototyping.

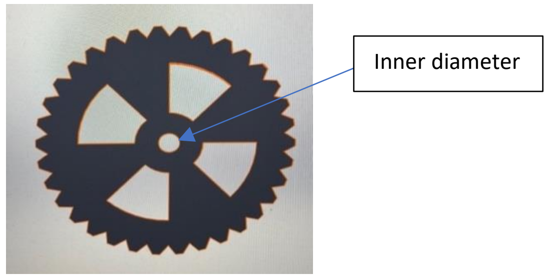


Figure 8 Flywheel's inner diameter that is attached to the motor's shaft.

In terms of the criteria in this project: the weight of the dragonflies should be as low as possible to minimise falling velocity and danger to children; which was accomplished through prototyping with different materials to get the optimal design of the dragonfly. Furthermore, the amount of potential landing spots of the projectiles should be maximized in order to increase children's movement throughout the game. Overall, the costs of the project should be minimised such that a refined version of this product could be sold for a retail price of approximately $50 CAD, with other considerations including the use of as few batteries as possible to make the toy accessible to a wide audience of families. Although the costs of this project were not low enough for a retail price of $50 CAD to be reasonable, with bulk sourcing of materials for mass manufacturing, the production cost of this toy could be significantly cut to achieve the target price.

3.0 Technical Progress

In this section, technical progress and material, and design choices in all prototypes was explored. Overall, the Dragonfly Launcher is made to emulate the function of the Elefun® game but considers improvements to its mechanics by implementing aspects like Nerf® flywheels, catering to a higher age range. Additionally, it incorporates an original unfurling projectile that permits high velocity ejection and low velocity impact. The evolution of these design elements from ideation to conception is defined as follows.

3.1 The Dragonfly Projectiles

3.1a Solutions Considered

To recall, the objective of the dragonfly projectiles is to retain a cylindrical shape when compressed, to reach a height of at least 2.5 m and displacement of at least 1.0 m when launched, and to release its wings as it flutters down. Initially, the projectiles were meant to be shaped as butterflies, however the large surface area of a butterfly's shape and wings would have created more drag in the air than a cylindrically shaped one with slim wings. This would prevent the butterfly from being compressed into an aerodynamic shape for maximum launched height. For the reason of retractability of the wings, the cylindrically based dragonfly shape was chosen. Initially, the dragonfly was ideated to be a stagnant shape, with its wings permanently outspread, but this would interfere with the rotation of the flywheels and would generate drag on the way up. The dragonfly is also shaped very similarly to helicopter seeds, simplifying the process of creating an autorotating system compared to a butterfly. Through the study, experimentation, and implementation of concepts such as centre of mass, drag, curvature, and material; eight iterations of the dragonfly projectile were formulated to determine the best solutions possible.

3.1b Progress to Date

Air Resistance

The first function undertaken was the ability of the dragonfly to flutter down like a helicopter seed. Considering the constraint that the dragonfly must have cylindrical form, the basis of its body started as a lightweight cylinder of Styrofoam. In the earlier prototypes, the centre of mass started off at the top of the cylinder, using sewing needles to add weight. Based off a helicopter seed, the first prototype used wings made of translucent tape that were positioned on the y-plane (Figure 9).

Figure 9 First prototype of projectile with wings on the y-plane.

However, this positioning of the wings caused the dragonfly to float horizontally rather than upright and swung back and forth on the x-axis. As a solution, the second prototype implemented wings on the x-plane rather than the y-plane, which generated enough air resistance for the dragonfly to float down while maintaining a vertical orientation. The tape wings were supported by a lightweight 26-gauge wire pierced perpendicularly through the axis of rotation of the dragonfly.

Autorotation

To create autorotation in wings that can lift, a leading-edge vortex was incorporated into the shape of the rectangular wings, as described in Section 1.3. Implementing this shape in the wings allowed the third prototype to autorotate about its y-axis, as needed (Figure 10).

Figure 10 Incorporating a leading-edge shaped wing.

Nonetheless, this autorotation was not stable, oscillating irregularly. This problem is addressed with the centre of mass of the projectile below.

Curvature of Wings & Centre of Mass

In order to have the wings conform to a cylindrical shape, the fourth prototype incorporated paper wings that were attached to the body of the dragonfly - folded down and wrapped around the body. This created a downwards curvature in the paper which inhibited the lift and autorotation of the dragonfly. Moving forwards, the wings were folded in such a way that allowed the upwards curvature of the wings (Figure 11).

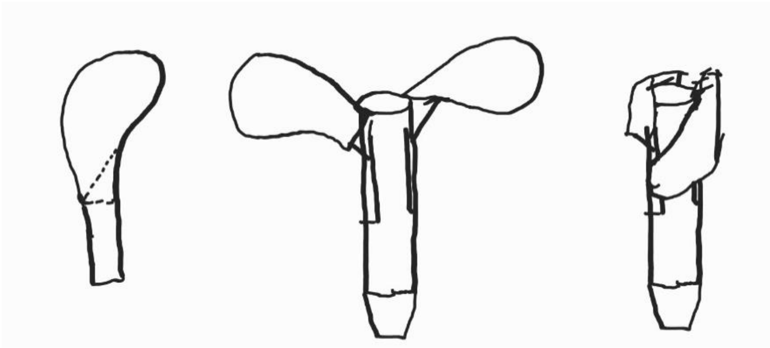


Figure 11 Folding of the dragonfly wings.

The body of the dragonfly progressed to Nerf® bullets to allow for consistency between all projectiles. The Nerf® bullets was selected as the main body since their rubber tips allow them to be grabbed by the flywheels more easily. Furthermore, the centre of mass was moved from the top of the projectile to the bottom of the projectile after extensive testing because it was determined that this positioning would allow for the most stable free fall of the projectile mass.

Material Prototyping

While the translucent tape and the paper worked sufficiently to create lift and autorotation, they held their shape too well to be able to change from a cylindrical shape to an unfurled shape. It is as such that a plastic sheet material was implemented into the design for the wings of the dragonfly (Figure 12).

Figure 12 Experimenting with plastic wings.

Culmination

The final dragonfly model consists of a Nerf® bullet base with the tip pointed downwards, clear plastic retractable wings attached perpendicularly to the axis of rotation (Figure 13).

Figure 13 Final dragonfly model.

To prevent the wings of the dragonfly from being caught in the flywheels, a cap to contain the wings to the body of the dragonfly has been prototyped from scotch tape. This addition aided the dragonfly to enter the flywheel more smoothly and was loose enough for it to allow for the separation of the dragonfly from the cap in the air. However, this function would require for dragonflies to be recapped after every game, causing inconvenience to the users. After much experimentation with the insertion of the projectile through the flywheels, it was determined that a cap was not a reliable or an effective option. Using the reloading mechanism discussed in Section 3.3, it was much easier to prevent the premature unraveling of the dragonfly wings, as the tube of the reloading mechanism keeps the dragonfly tightly contained. It was established that keeping the rubber tip of the projectile at the bottom was crucial to the centre of mass and autorotation of the projectile. However, the rubber tip also needed to be at the end of the projectile being inserted through the flywheel. This is because the flywheels grabbed the rubber much easier than the foam end of the dragonfly. Thus, the orientation of the dragonfly was perpendicular to the flywheel was as shown in Figure 14.

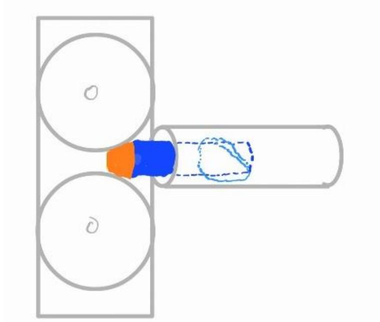


Figure 14 The projectile's orientation through the flywheel. After reaching it maximum height, the projectile rotates such that the heavier side faces the ground.

3.1c Remaining Challenges

The remaining challenges to improve the projectiles is to consider solutions to prevent the premature wear of the dragonfly wings over multiple uses. Due to the nature of the folding of the wings, there are points of high stress, which over time, may prevent the dragonfly from unfolding and floating down as intended.

Another factor that needs to be considered is the safety of the projectiles. Since the wings of the dragonfly are made of thin sheets of plastic and the projectile will be rotating, there is concern of sharp edges cutting children as the dragonflies float down. As such, different, softer materials would need to be researched or developed to ensure that the dragonflies are not a hazard.

3.2 The Flywheel

3.2a Solutions Considered

Over the course of the project, many different solutions were considered to launch the projectiles into the air. One of the earliest solutions was to use air pressure to have butterfly shaped figures float into the air. However, this solution was very similar to Hasbro's Elefun® game. As reviews were read about how the game was not long enough, or not as entertaining as promised, other solutions were considered. The main solution thought-about was to use a flywheel similar to the launching mechanism of specific Nerf® guns (Figure 15). Since the objective was to launch projectiles into the air at high speeds, the flywheel system was implemented. The launching of the dragonflies should be at high speeds which is why the flywheel system was considered. This is because it was researched that the inner mechanism of some Nerf® guns shoot at a high speed because of flywheel systems [8].

Figure 15 Nerf® gun's inner flywheel mechanism [8].

3.2b Progress to Date

The process initiated with producing one cohesive design of the flywheel with all the inputs. The design consisted of a 3D-printed wheel (Figure 16), a 9V motor and battery, and a Styrofoam base. This system was flawed in several aspects. Firstly, the wheel loosely fit onto the shaft of the motor, preventing proper rotation and testing of the flywheel. Another issue with the flywheel was the weight of the design itself, it showed to be too top heavy compared to the small size of the motor. The shaft of the motor was too small in comparison to the 3D printed prototype's diameter and weight, therefore causing inconsistencies to the system. The motor itself was too weak and slow to be able to launch any lightweight projectile as it lacked in power and speed, which proved that it was not the right choice of motor for the intended purpose of the Dragonfly Launcher toy.

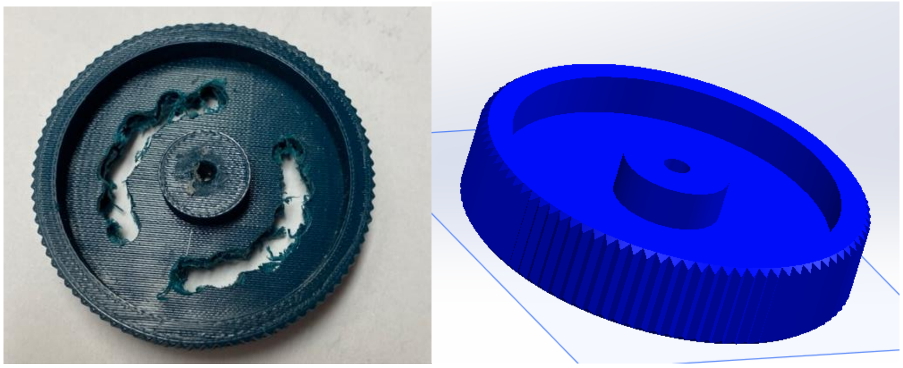


Figure 16 The 3D printed flywheel and SolidWorks design.

Material Prototyping

As stated before, the material envisioned for this part of the design was 3D printing PLA filaments because it was thought of to be the most convenient and the least expensive. However, it was discovered that 3D printing was not the right approach as one single prototype took 3.0 hours to print. This method was deemed counterproductive as testing had to be done but the production of the prototype took longer than expected which reduced prototyping time. To conclude, the ideal process discovered for the production of the flywheel was laser cutting acrylic sheets to obtain quick, sturdy and safe prototypes at zero cost - as the acrylic sheet was recycled. This could also be beneficial when mass producing as a large amount can be produced at once.

When proceeding to see if laser cutting was the right decision, a new design of the flywheel was created with gear teeth. This was made so that the dragonfly prototype could shoot out at the intended velocity. Holes were also added to the design (Figure 17) because on the first 3D printed flywheel, the flywheel was too heavy and therefore made the motor run slower. Various flywheel cuts were made, because it was necessary that the diameter of the inner circle on the flywheel was the right size. It had to be a tight fit with the motor's shaft to eliminate any possible risk that might occur to a child. This testing process with the diameter and the shaft was repeated thrice to make sure that the flywheel fit as tight as possible to the motor.

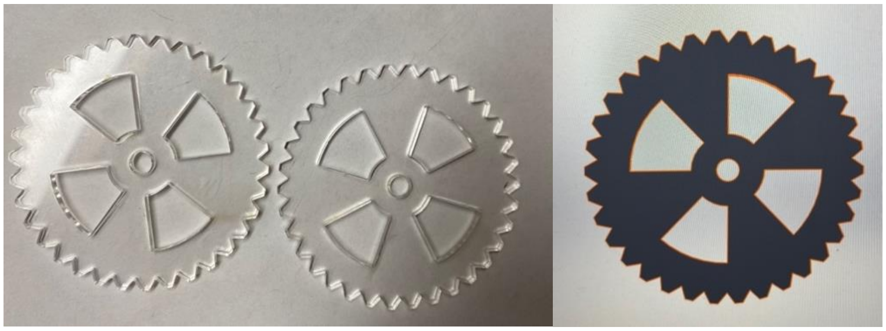


Figure 17 The first laser cut flywheel prototypes and SolidWorks design.

Motors

Originally, a 9V motor was acquired with the hope that that motor had enough velocity and torque that it could perform the objective of shooting a dragonfly like a bullet using the flywheel mechanism. It was seen during the prototyping process that the 9V motor was not able to provide enough speed to the system for the dragonflies to be launched as there was not enough voltage. Possible solutions were sought to find the right type of motor, it was researched that in the case of a DC motor, higher voltage of the motor means it will go faster and therefore the projectiles will be launched at a higher speed [9]. The motor was then exchanged with a 12V motor, and through testing, it proved to be the right decision. It had enough velocity to launch the dragonflies and therefore for the mechanism to work as hoped.

Motor and Flywheel Assembly

The flywheel prototyping process was near completion: three flywheels were attached together (Figure 18) to obtain the required width of the flywheel, so that the bullet could efficiently shoot through at its maximum capacity. The three flywheels attached together were then wrapped around with tape to prevent the flywheels rapid rotational speed from cutting through the foam dragonflies. On the other hand, this was also done as a safety measure to prevent the flywheels from flying off the motor shaft even if the inner diameter of the flywheel was a tight fit. The motors were then connected to an 12V battery using alligator clips (Figure 18) and tested.

Figure 18 Final product of the 3 flywheels attached together and the tape wrapped around it.

As alligator clips were just a temporary fix, the motor was connected to a switch used to regulate on or off of the system (Figure 19) using wires instead of alligator clips and covered with electrical tape to prevent hazards in case of overheating. The motors and switch were then connected to a single battery as the least number of batteries used to power the system was one of the ideal situations kept in mind to satisfy the user/audience.

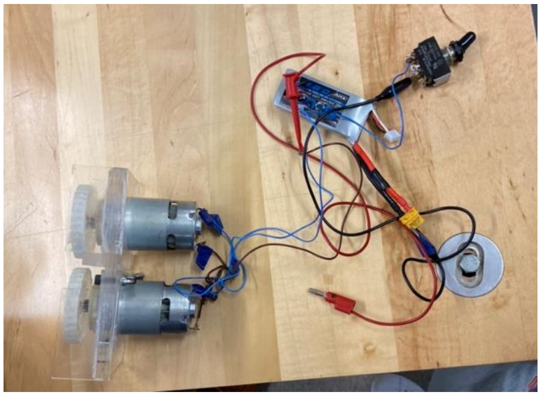


Figure 19 Motor system attached to battery and switch.

3.2c Remaining Challenges

As remaining challenges, it can be mentioned that during prototyping, the pace of consumption of the batteries was not ideal as both motors require too much power from the batteries to work. During testing, three batteries were used as they tended to discharge within 10 minutes of powering it on. Moreover, the switch cabling attached to the motors and batteries should also be reconsidered; currently, the toy has its cables connecting the whole system on an open space (Figure 20). However, that is something that should be revaluated as it is a safety concern if not enclosed because a short circuit may occur if by any chance it encounters water, or a younger consumer starts connecting and disconnecting the cables differently.

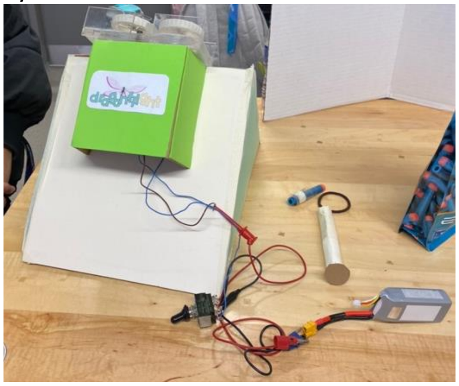


Figure 20 Motors connection to the battery and the switch on the final prototype.

3.3 The Reloading Mechanism

3.3a Solutions Considered

It is expected in the final iteration of the Dragonfly Launcher Toy that the projectiles are automatically reloaded, minimizing the amount of adult participation needed during gameplay. For the reloading mechanism, solutions considered included using gravity to reload the bullets into the flywheel. Ultimately, this solution was not practical, because of the expansion of the flywheel wings, which prohibited them from moving down a tube without additional force. Moreover, their somewhat rigid shape would prevent them from passing through a vertical tube to an angled flywheel without additional force. This additional force could be supplied by two motors connected by a belt, continuously moving the projectiles forward and towards the flywheels. However, considering the cost of adding more motors into the toy, a cheaper solution was developed. This solution involves the use of a spring at the end of a tube that reaches maximum compression (Figure 21) when all the projectiles are loaded within the tube. As projectiles are taken in by the flywheel and launched, the spring decompresses, allowing the next projectile to be launched until the tube is empty and the spring is at its full length.

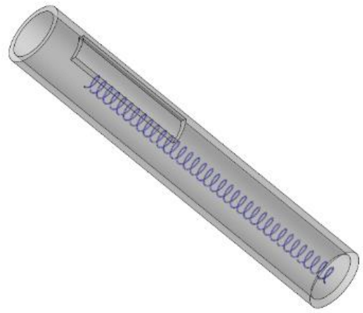


Figure 21 3D CAD model of the spring relaunching mechanism.

3.3b Progress to Date

Currently, a cardboard tube and an appropriate spring has been sourced for the relaunching mechanism. The diameter of the spring had to fit into the diameter of the tube, which is slightly larger than that of the cylindrical projectile. Secondly, the spring constant had to be relatively low, according to Hooke's Law in Eqn. (1).

$$F = kx \tag{1}$$

Where F is force (N), k is the spring constant (N/m), and x is the displacement of the spring [10]. Since the displacement of the spring should be its entire length, the force of the spring is dependent on the spring constant. A smaller spring constant would create a smaller force, while a larger spring constant would create a greater force. In this situation, the spring is only required to push light projectiles, thus a great force is not needed.

Moreover, with a large spring constant, in order for the spring to reach its maximum compression, the projectiles would need to exert a great force on the spring. Seeing as the projectiles are mainly composed of a soft foam, this would not be possible. Thus, springs with low spring constant were sought out. The only springs that the soft projectiles would be able to withstand the force from were not long enough for the reloading mechanism, thus three springs were soldered together to achieve an appropriate length (Figure 22). The spring must be long enough such that the distance from the end of the spring to the opening of the flywheel is less than the length of one projectile. In this way, once all but one of the projectiles are launched from the force of the compressed spring, there is still some compression in the spring to push the last projectile into the flywheel. After the connecting process, it was discovered that soldering is used for electrical connections between metals whereas this mechanical connection should have been welded or brazen to endure higher stresses [11].

Figure 22 Connected springs for reloading mechanism.

The figure below shows how the spring and tube would be combined. This prototype however fits only one projectile. Anymore and the spring deforms within the tube. The prototype successfully releases one projectile but needs to be held by a human to the edge of the flywheel.

Figure 23 The reloading mechanism prototype.

3.3c Remaining Challenges

With the spring and tube attained, the next steps would be to source longer tubes and springs with larger diameter, lower spring constant and greater length. The greater diameter will prevent the spring from deforming within the tube; the lower spring constant will allow for greater compression, thus more projectile stored; and the greater length will increase the number of projectiles that can be reloaded. A slot that would allow the user to refill the reloading mechanism with projectiles would also need to be considered. Then, experimentation would be needed to attach the reloading mechanism to the base of the flywheel allowing for automatic reloading. In future iterations of this toy, longer springs and tubes should be used to allow for a maximum number of projectiles to be stored and launched.

3.4 The Base

3.4a First prototype

The first base prototype was a foam structure with a hole for one 12V motor and a side with an extended height to replicate the second flywheel by keeping the dragonfly in contact with the first flywheel. Instead of having to work with two different motors, only one side of the system was built to optimize that one side and later replicate it for the other side; this was done to cut cost and save time. Foam was chosen as it was readily available, using excess from our first dragonfly prototypes, and easily manufactured. However, the foam seemed to be an unreliable material to use as a base, as its friction with the Nerf® bullets used as the main body of the dragonfly disallowed even the Nerf® bullets without wings to be launched. Additionally, the foam was not even close to replicating what the second flywheel would do, as friction with the second flywheel would only push the dragonfly to the exit, while friction with the foam wall heavily slowed the dragonfly's exit speed. The friction between the foam and the Nerf® bullet also prevented the bullet from being launched at a high speed. After thorough consideration and analysis of the situation at hand, it was decided that the best approach would be if both motors were assembled to full capacity as it would truly show if the design accomplished the set objective. Thus, another iteration of the foam base as the motor holder (Figure 24) was created.

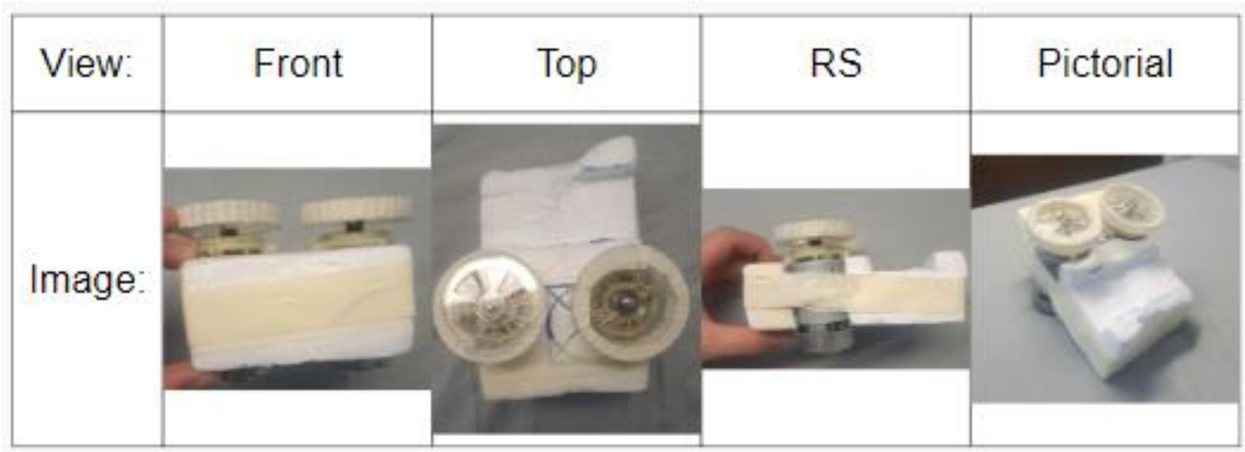


Figure 24 First prototype base made of Styrofoam and tape (had both 12V motors with flywheels installed).

3.4b Second prototype

From there, plywood was considered as the next material for the base as the friction between wood and the dragonflies would be less than the friction between the Styrofoam and the dragonflies. Using plywood also allowed us to reduce costs for the second prototype as it was inexpensive. The second prototype incorporated two motors and a new sliding mechanism (Figure 25 and 26) to hold the second motor and adjust the width between the motors. This way, this prototype could be used to find the ideal width for the dragonflies to pass through. However, the plywood failed due to its lower quality and the screws were driving its layers apart. Additionally, machining the sliding mechanism was a difficulty as inaccuracies in the machining caused the effect sliding feature to be underwhelming. The screws particularly caused some trouble as they were difficult to adjust and would not always be able to move easily. Lastly, having to use a screwdriver to tighten or loosen the sliding mechanism made the design impractical. Due to all these factors, it was decided that the materials of the base and the screws needed to be changed.

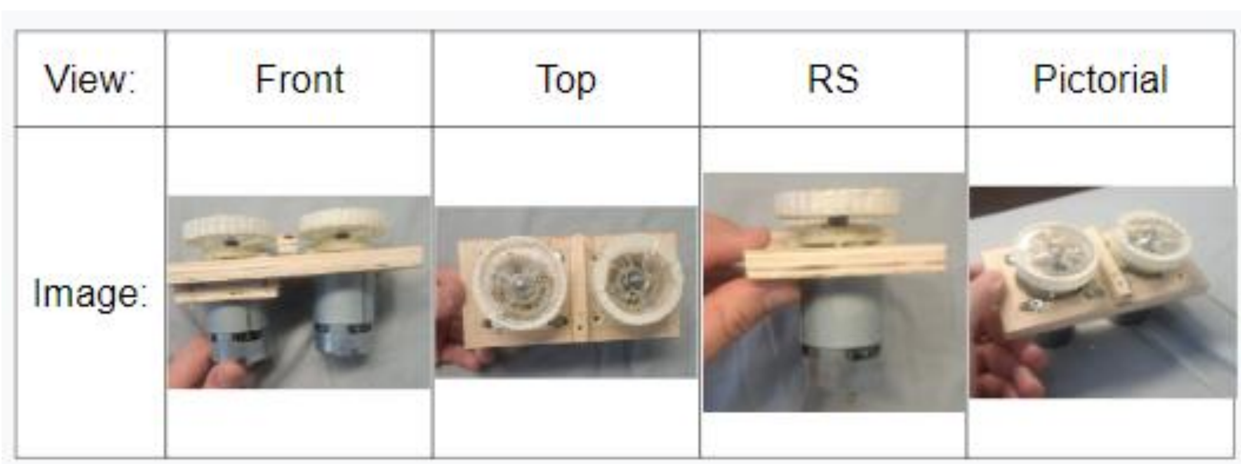


Figure 25 Second prototype base made of plywood, screws and wood glue (had both 12V motors with flywheels installed).

View:	Leftmost position	Rightmost position
Image:		

Figure 26 Sliding mechanism inmost and outermost position.

3.4c Third prototype

For the third and most recent prototype, acrylic and superglue were used. Acrylic was chosen as the second prototype of the base because of its rigidity and ease of manufacturing showcased by the flywheels. By using the rapid prototyping centre as previously done when creating the flywheels and more recycled acrylic from the MESS hall, a third prototype was created at a low cost. Instead of using screws, the design incorporated wing nuts and bolts, so that the tightness of the clamping mechanism had the ability to be adjusted manually and without a screwdriver. As the width of the acrylic was only 3.0 mm as opposed to the previous 12 mm of the plywood, several layers were made and stacked onto each other and held together with superglue. Additionally, using acrylic allowed the removal of the inaccuracies in the machining that was holding back the sliding feature in the second prototype shown above, leaving the sliding feature significantly improved as demonstrated by Figure 27 and 28. Lastly small panels of acrylic were added to the sides of the prototype to show what type of safety could be attached the base to stop fingers from going into the flywheel.

View:	Front	Top	RS	Pictorial
Image:				

Figure 27 Third prototype base made from acrylic and superglue (had both 12V motors with flywheels installed).

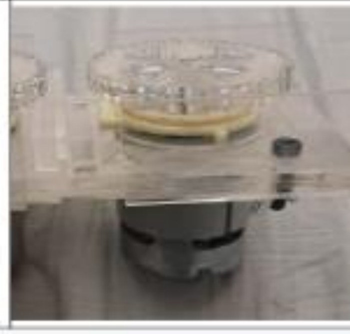
View:	Leftmost position	Middle position	Rightmost position
Image:			

Figure 28 The new and improved sliding feature (can be adjusted easily between positions).

3.4d Remaining challenges

The construction of the base was more complicated than it should have been. To decrease the manufacturing needed to produce the base, the sliding feature should be removed (i.e., the second motor will be fixed at the optimal distance). Additionally, the main mechanism needs to be closed to ensure no fingers could be caught into the flywheel. The safety box has yet to be completely closed as the prototype is not finished and the insides will need to be accessed in the future. The reload mechanism, batteries and wiring also needs to be integrated into the base. This means that there will need to be another iteration of the base that has no sliding feature but is compatible with all other systems. It should also stop fingers from getting near the flywheels and therefore remove any possible dangers to the user.

4.0 Conclusion

4.1 Conclusions

The results of this project are having developed a projectile that enters a steady-state of autorotation, and a battery-powered flywheel system that can launch projectiles at a high velocity, as shown in Figure 29. It has met the constraints of the project, where the projectile smoothly goes through the flywheels, reaches a maximum height of 2.5 m, a minimum horizontal distance of 1.0 m, unfurls its wings after less than 1.0 s of reaching its maximum height, and hits the floor with a speed of less than 1.0 m/s. As such, the project has yielded several effective solutions when creating a toy like the Dragonfly Launcher. Successes of the flywheel that can be mentioned is that a working prototype of the flywheel was attained, such that the prototype has proven effective when testing and no complication with the structure itself have presented. The base implemented several successful designs through its three iterations. First, it can support and hold the motors, holding them in place for consistent launch. Also, the second and third iterations successfully implemented a sliding feature, although the second prototypes sliding feature was underwhelming it was thoroughly improved by the third prototype, now featuring a manually adjustable and consistent sliding feature. It also showed how a safety feature could be easily incorporated into the design by using acrylic sheets around the flywheels. Though the third iteration of the base has yet to be fully connected to the reloading mechanism and electronics, the base design shows that it will likely be able to neatly incorporate additional systems by making new models to laser cut.

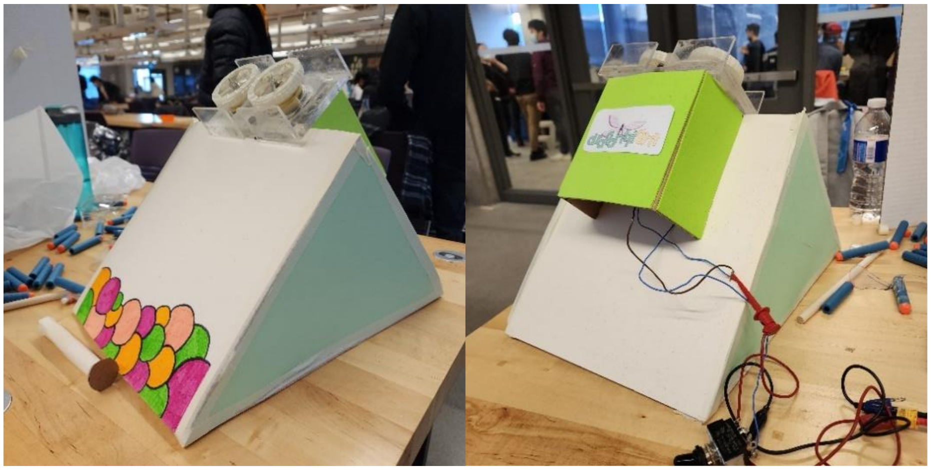


Figure 29 The back and front of the final Dragonfly Launcher Toy prototype, dubbed "Dragonflight".

4.2 Recommendations

Moving forward, all the separate components engineered in this project must be thoroughly tested together in the hopes of building a cohesive system. This means that the projectiles must be tested with the flywheel to find the optimum distance between the flywheels and to determine the best way for the wings of the projectile to not be caught between the wheels. The reloading mechanism must be fitted to the base of the flywheel mechanism for automatic dispensing of projectiles into the system.

Each of these components can be further improved individually. Adjusting the design of the projectiles to be optimized for inexpensive mass production would be the next step for the dragonflies. This would involve safer and cheaper material deliberation, particularly for the wings of the dragonflies. The reloading mechanism can be reformed with a longer spring that has a lower spring constant and a larger diameter to accommodate for a larger number of projectiles, which will increase gametime and thus children's entertainment. On the other hand, the flywheels must be encased within the base with another structure to prevent any possible risk of children putting miscellaneous objects through the flywheel system. As costumer safety should be prioritized, not only should the flywheel mechanism be enclosed but also, the cables connecting the motors to the switch and the battery should also be enclosed; by doing so, short circuits and connectivity issues can be avoided as no kid would be able to alter the cable connections.

To randomize the landing location of the projectiles further, there are several upgrades that could be made to the design of the toy. One such upgrade would be putting the entire toy on a 360° rotating base, having the projectiles shoot out from all directions. Another option would be having two flywheels pointed in opposite directions, to have competitors playing on opposite sides of the field. Finally, the incorporation of a variable speed motor would add more difficulty to the game, keeping the children interested for longer.

In conclusion, the work done on the Dragonfly Launcher Toy provides highly relevant information to the projectile toy industry, as it presents the successful solutions and undeveloped future paths for the project.

References

[1] Ultra Board Games, "Ultra Board Games," [Online]. Available: https://www.ultraboardgames.com/elefun/game-rules.php. [Accessed November 2022].

[2] Blaster Hub, "Blaster Hub," BlasterHub, 06 29 2021. [Online]. Available: https://blasterhub.com/2021/05/nerf-hyper-mach-100-review/. [Accessed Novemberr 2022].

[3] D. Rezgui, I. H. Arroyo and R. Theunissen, "Model for sectional leading-edge vortex lift for the prediction of rotating samara seeds performance," *The Aeronautical Journal,* vol. 124, no. 1278, 2020.

[4] S. Chang, K. Varshney and J. Wang, "The kinematics of falling maple seeds and the initial transition to a helical motion," *IOP Science,* vol. 25, 2011.

[5] V. Development, ""Understanding V5 mechanical launging systems"," VEX DELOPMENT PLUS, 11 October 2022. [Online]. Available: https://kb.vex.com/hc/en-us/articles/10004528811412-Understanding-V5-Mechanical-Launching-System. [Accessed October 2022].

[6] IRCC, "Canada Coustomer Product Safety," IRCC, [Online]. Available: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/industry-professionals/industry-guide-safety-requirements-children-toys-related-products-summary/guidance-document.html. [Accessed October 2022].

[7] "Nerf Hyper Patent," United States Patent Application, [Online]. Available: https://blasterhub.com/wp-content/uploads/2021/04/Nerf-Hyper-Patent-US-2021-0102769-A1.pdf. [Accessed October 2022].

[8] Wiki Nerf Fandom, "Nerf Wiki," [Online]. Available: https://nerf.fandom.com/wiki/Flywheel. [Accessed November 2022].

[9] H. Macdonald, "Quora," 2021. [Online]. Available: https://www.quora.com/Does-higher-voltage-mean-a-faster-motor. [Accessed 11 2022].

[10] The Editors of Encyclopaedia Britannica, "Hooke's Law," 13 January 2020. [Online]. Available: https://www.britannica.com/biography/Robert-Hooke. [Accessed 19 November 2022].

[11] Universal Technical Institute of Illinois, Inc., "THE DIFFERENCES BETWEEN WELDING, BRAZING AND SOLDERING," 10 September 2010. [Online]. Available: https://www.uti.edu/blog/welding/brazing-soldering-welding. [Accessed 19 November 2022].

[12] PARKER BROTHERS, "HASBRO ELEFUN," HASBBRO, [Online]. Available: https://www.hasbro.com/common/instruct/Elefun.PDF. [Accessed October 2022].

[13] R. Kurak, "What is Drag?," 21 July 2022. [Online]. Available: https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/what-is-drag/. [Accessed 18 November 2022].

[14] Seattle Children's Hospital, "Toys and Play: 6- to 8-Year-Olds," [Online]. Available: https://www.seattlechildrens.org/health-safety/keeping-kids-healthy/development/toys-and-play-6-to-8-year-olds/. [Accessed 24 November 2022].

[15] Raising Children Network (Australia), "6-8 years: child development," 17 March 2022. [Online]. Available: https://raisingchildren.net.au/school-age/development/development-tracker/6-8-years#:~:text=At%20this%20age%2C%20children%20enjoy,cartwheels%20and%20catching%20small%20balls.. [Accessed 24 November 2022].