The goal of this project is to design and manufacture an automatic badminton shuttlecock (birdie) feeder. The **intended scope** of this project, to name a few, involves possible coding, manufacturing, CAD, FEA, mechanical analysis and dynamics. It **aims to target** individuals who actively play the sport, and wish for a systematic (consistent) approach to training when alone.

Through this project, I hope to combine the design skills with the mechanical knowledge I've learnt thus far as a mechanical engineer, and create a fun personal project that helps me cement, and develop said skills.

Below I outline the **primary objectives** (initial goals) for this project:

1. The feeder must be able to consistently feed a certain type of shot without player input
2. The feeder must be able to include a level of variance in its feeding, so as to challenge the player, or feed different levels of one shot
3. The feeder must be able to be brought onto a court with ease

As this project progresses, these key objectives may shift / be expanded based on what becomes feasible.

Each of these primary objectives will be quantified through **functional requirements**:

1. Must be able to feed at least *12 shuttles within a minute*, with a *diametrical target range tolerance of 6 in*
2. Must be able to be coded to allow *random targeting within the 6 in diametrical target* zone, and be able to *place shots within a larger 20 in diametrical target zone*
3. Must *weigh less than 10kg*, *fit within 19.75 x 46.5 x 30 inches* (typical size of a trunk), and *be hand-carryable*

To hit these requirements, these are some design concepts.

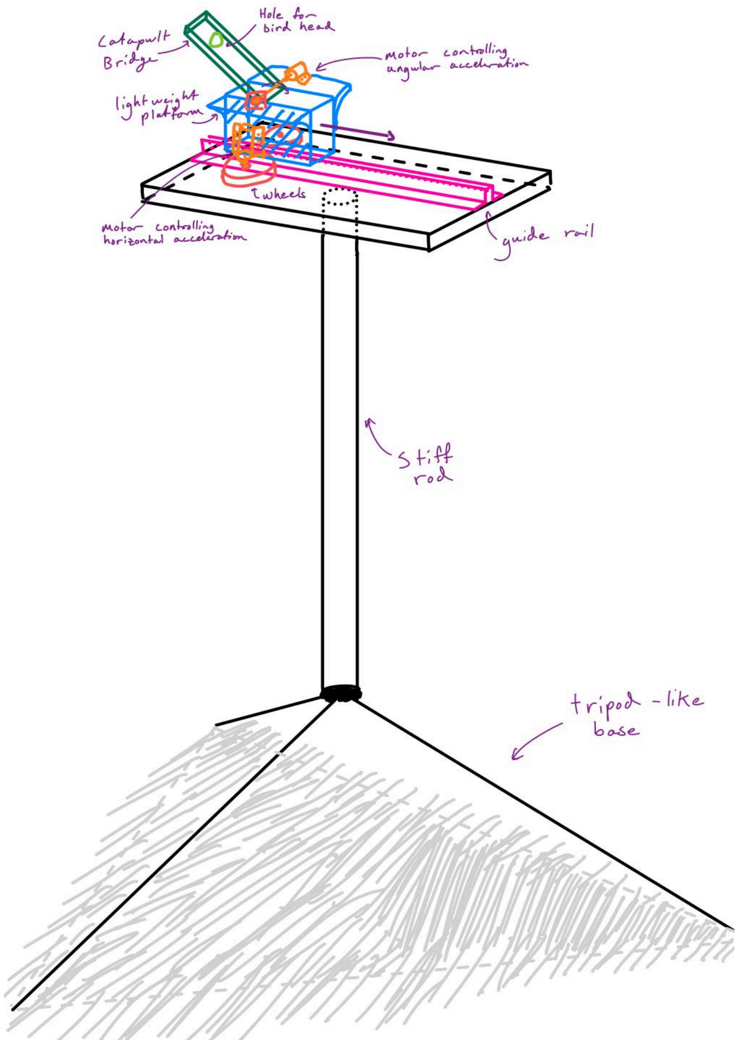

Figure 1.A: *Sliding rail catapult launcher*

The first design concept: a tripod-elevated sliding rail catapult launcher. My first idea was a launcher involving motion with two degrees of control. This would allow me more specifications to control the launch distance, arc and speed. The sliding rail (colored pink) used a single motor (orange) attached to a wheel (red), which itself was attached to a mounting plate (blue) for the catapult (green). A secondary non-motorized wheel would be attached on the opposite side of the mounting plate, to restrain the plate's motion to the horizontal axis. Atop the plate, a second motor would be mounted and fitted to a catapult bridge, hence creating the second degree of controlled motion. I wasn’t too concerned about the tripod base, thus it wasn’t flushed out in detail here.

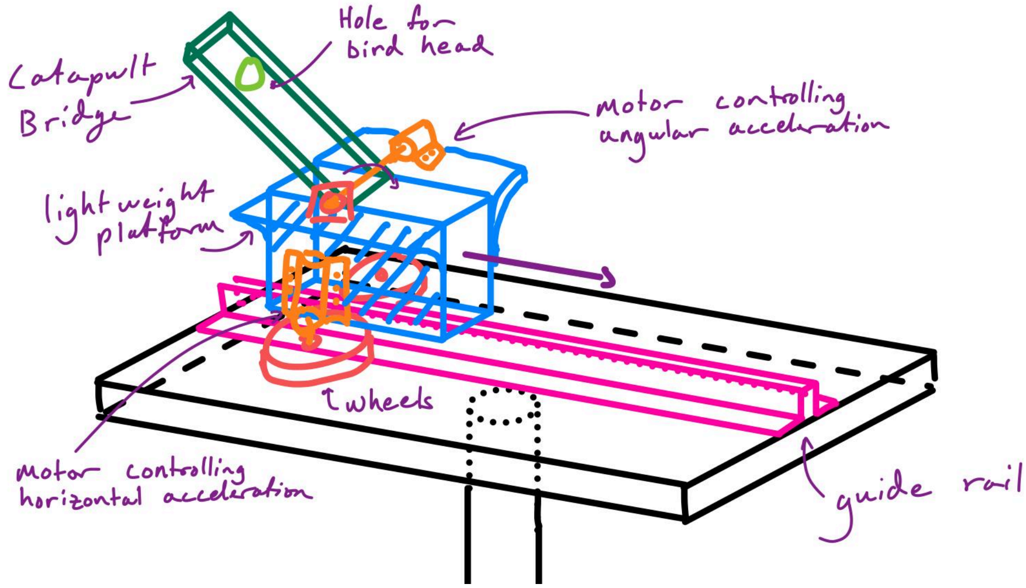

Figure 1.B: *Close up of critical mechanism in the sliding rail catapult launcher*

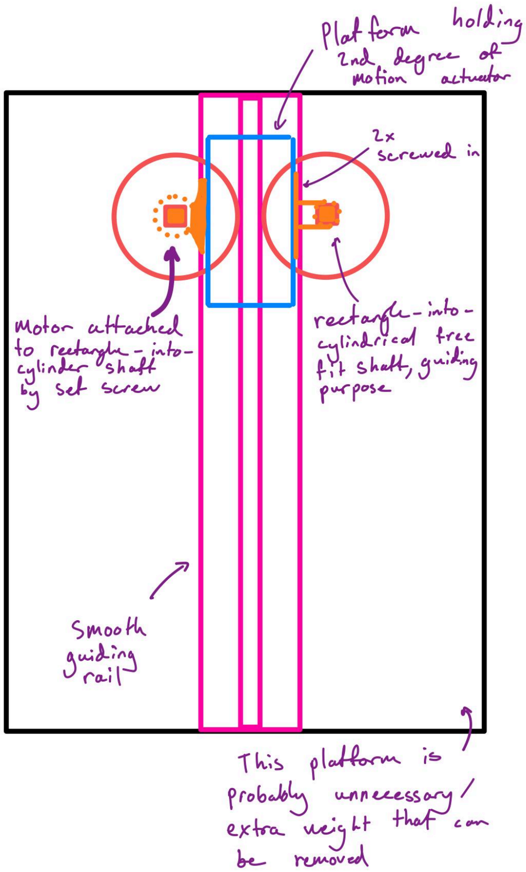

Figure 1.C: *Birds-eye view*

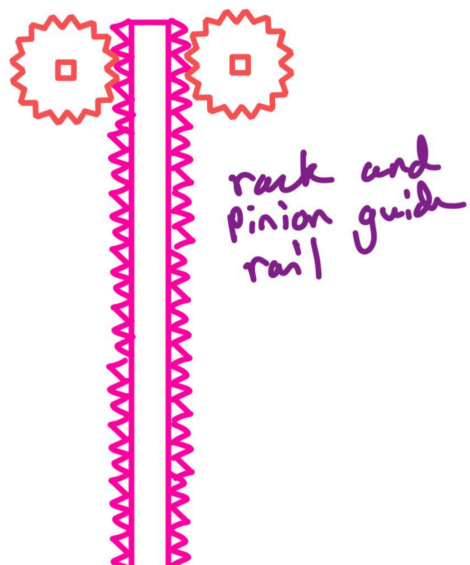

Figure 1.D: *Smooth guide rail substitute*

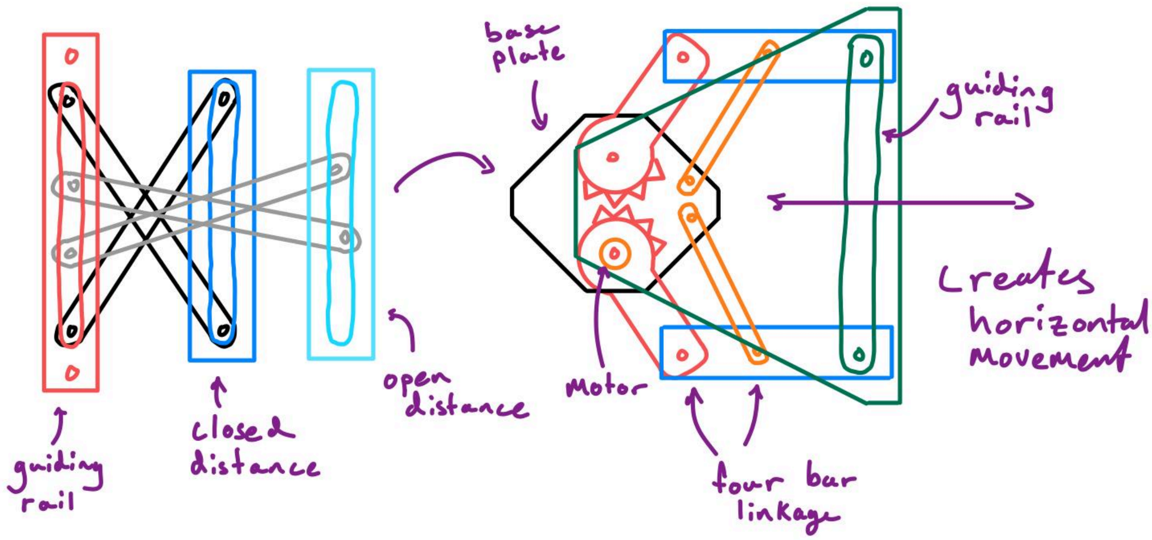

Figure 1.E: *Alternative guiding rail mechanism. This uses a four bar linkage with one motor to extend the guiding rail out horizontally. The slot in the green plate allows the bolts extending out of the blue plates to close together, thus creating horizontal movement on the green plate. Compared to designs in Figures 1.C and 1.D, this has a lower actuation range and more manufactured parts, but doesn't require as high quality interfacing of components as the wheels and pinion.*

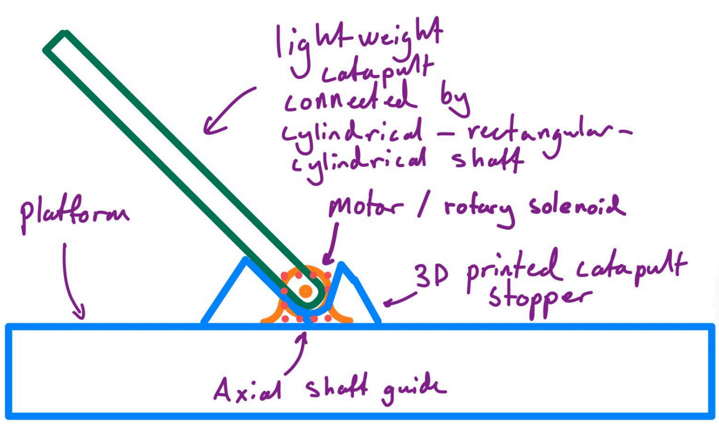

Figure 2.A: *Catapult design #1*

This catapult involves a 3D printed catapult bridge (green) which is infilled to withstand the moment and torque exerted on it by the shuttle and motor. The bridge is connected to the motor (orange) with a machined rectangular- cylindrical shaft and a set screw. A bushing support (red) is concentrically placed on the opposite end. Stoppers are 3D printed to control the bridge's rotation.

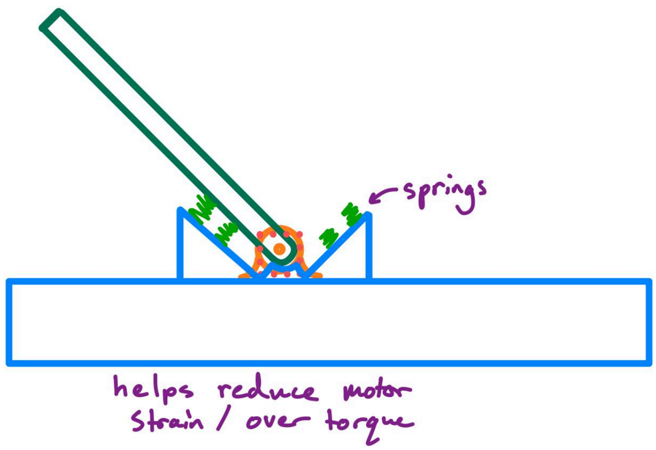

Figure 2.B: *Catapult design #2*

This is similarly designed to Figure 2.A, but involves springs to help prevent damage to the stoppers, motor and bridge. The springs are designed to be small enough with the stoppers to allow the full degree of motion required, but also stiff enough to act as a stopper. This design would likely need to be reworked to place the front stopper at a steeper angle such that the catapult is effective.

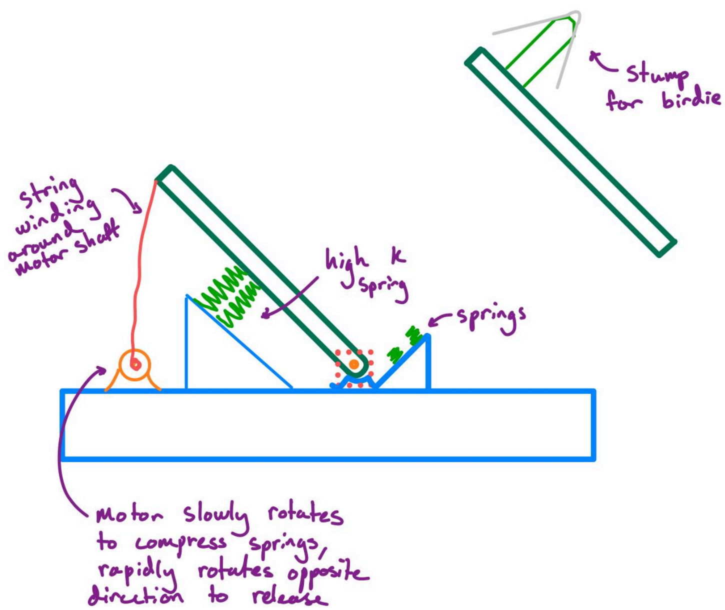

Figure 2.C: *Catapult design #3*

This design is more eccentric, using a motor to wind up a string and compress a high stiffness spring. The bridge is still constrained axially with a shaft and bushing support, as in Figure 2.A. It is rotationally constrained by the front springs and stopper (as in Figure 2.B, this likely needs to be made steeper). The motor slowly rotates counterclock-wise to load the spring, and rapidly clockwise to deload the string, launching the bridge and bird. The springs on the front stopper are stiff enough such that the bridge bounces back to its initial position for the next shot.

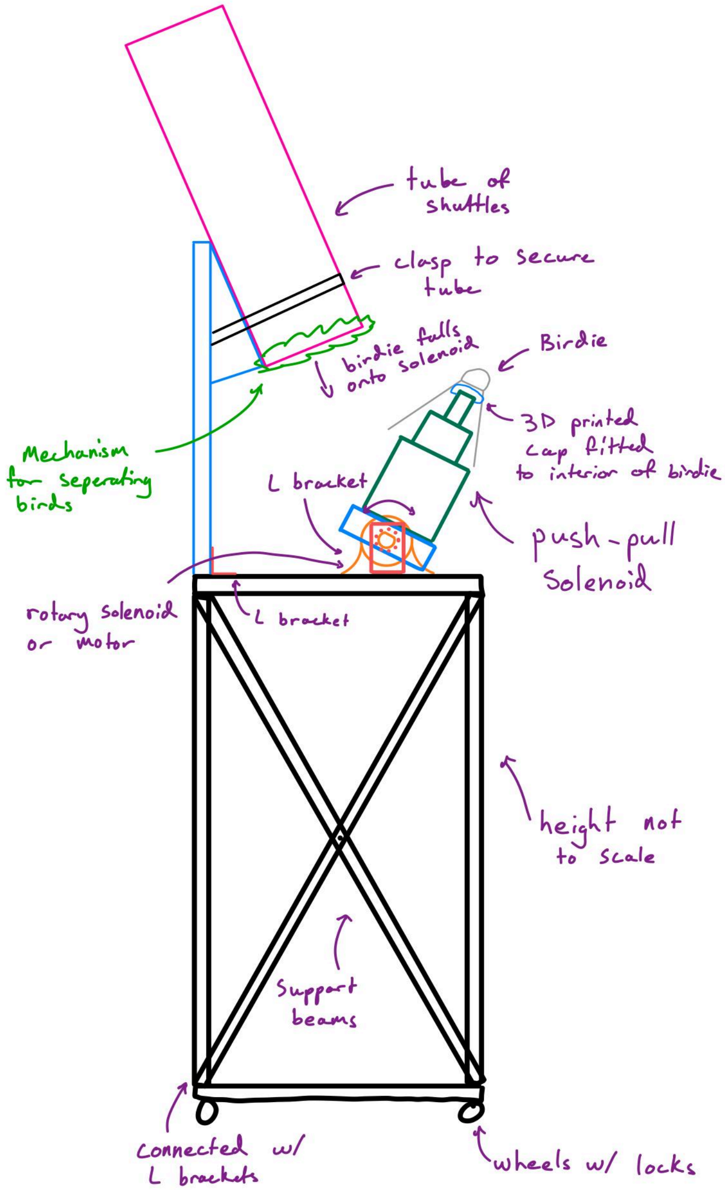

Figure 3: *Push-pull solenoid launcher*

This design uses a push-pull solenoid which actuates rapidly to punch the bird as a launching mechanism. A 3D printed cap will be fitted onto the solenoid to create an even interface with the bird. The solenoid will be mounted onto a platform, which is then mounted axially onto a motor and bushing support. This motor creates controllable degrees of rotation for the launch. It also allows a tube to be placed behind the solenoid at an angle, and have the solenoid rotate back and forth to alternate between launching and setting in a new bird. A release mechanism (not drawn here) will be attached to the tube). The entire device is placed on a trolley of sorts with lockable wheels, to ensure mobility and stability at the same time. I decided to add cross support beams to enforce stability as well, given the height of the legs of the cart will likely be quite long which can invoke swaying upon sudden motions like the solenoid actuation.

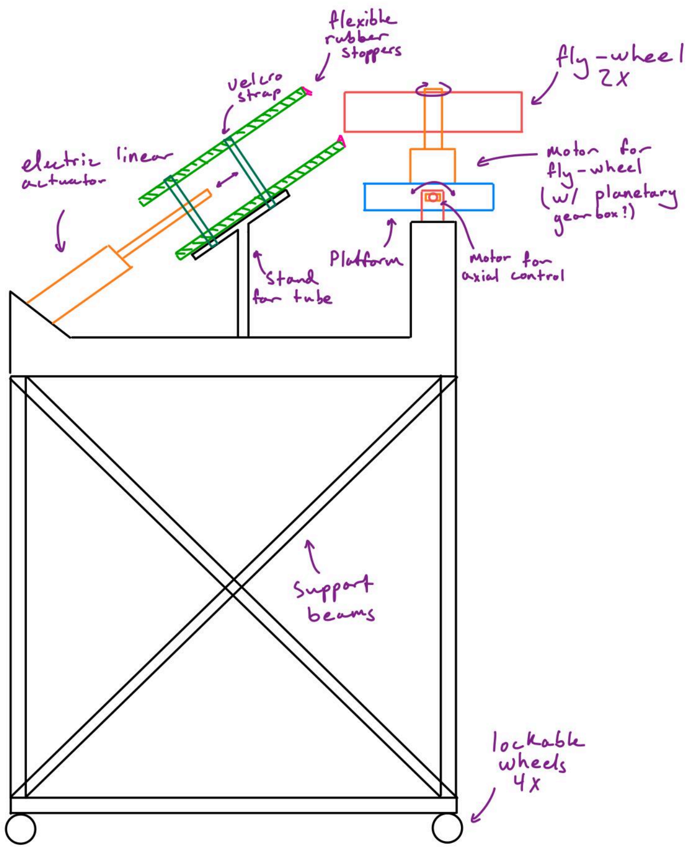

Figure 4.A: *Fly-wheel launcher*

The fly-wheel launcher uses two motor driven wheels to rapidly launch a bird that's pushed into its drive path. An electric linear actuator will be used to push a line of birds through a loose-fitted tube and past flexible rubber stoppers. These stoppers ensure that only one bird is placed into the fly-wheel at one time, as they are sized to clip onto the edge of the bird's feathers and prevent further movement. The driven wheels and motor are placed on a platform whose rotational axis is controlled by another motor, thus allowing various launch angles and playable shots. The variable launch angle also allows the support frame (cart) to be lower, providing greater stability than the design in Figure 3.

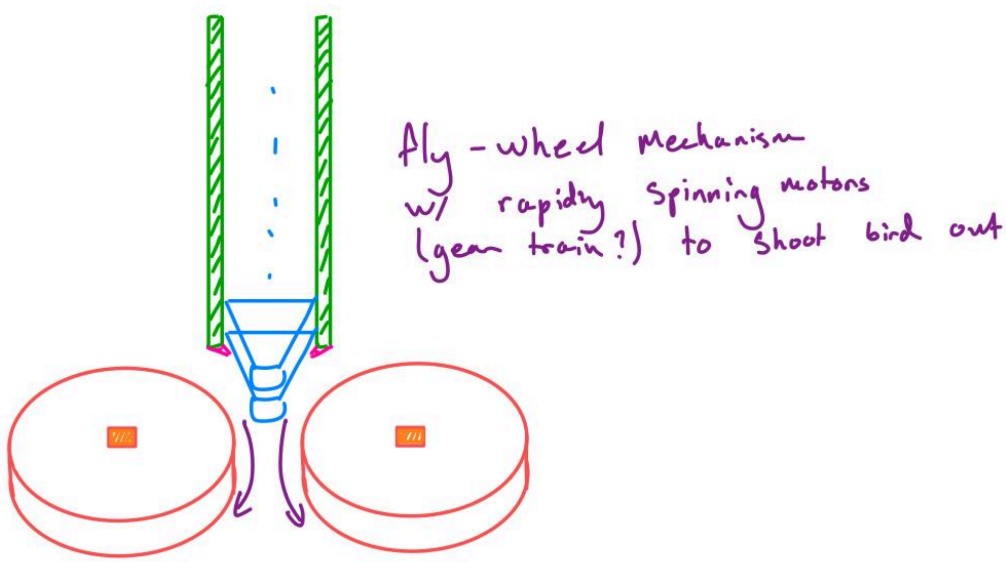

Figure 4.B: *Front view of fly-wheel. Each drive wheel rotates in opposite directions, and is driven by a gear train or planetary gearbox to increase RPM.*

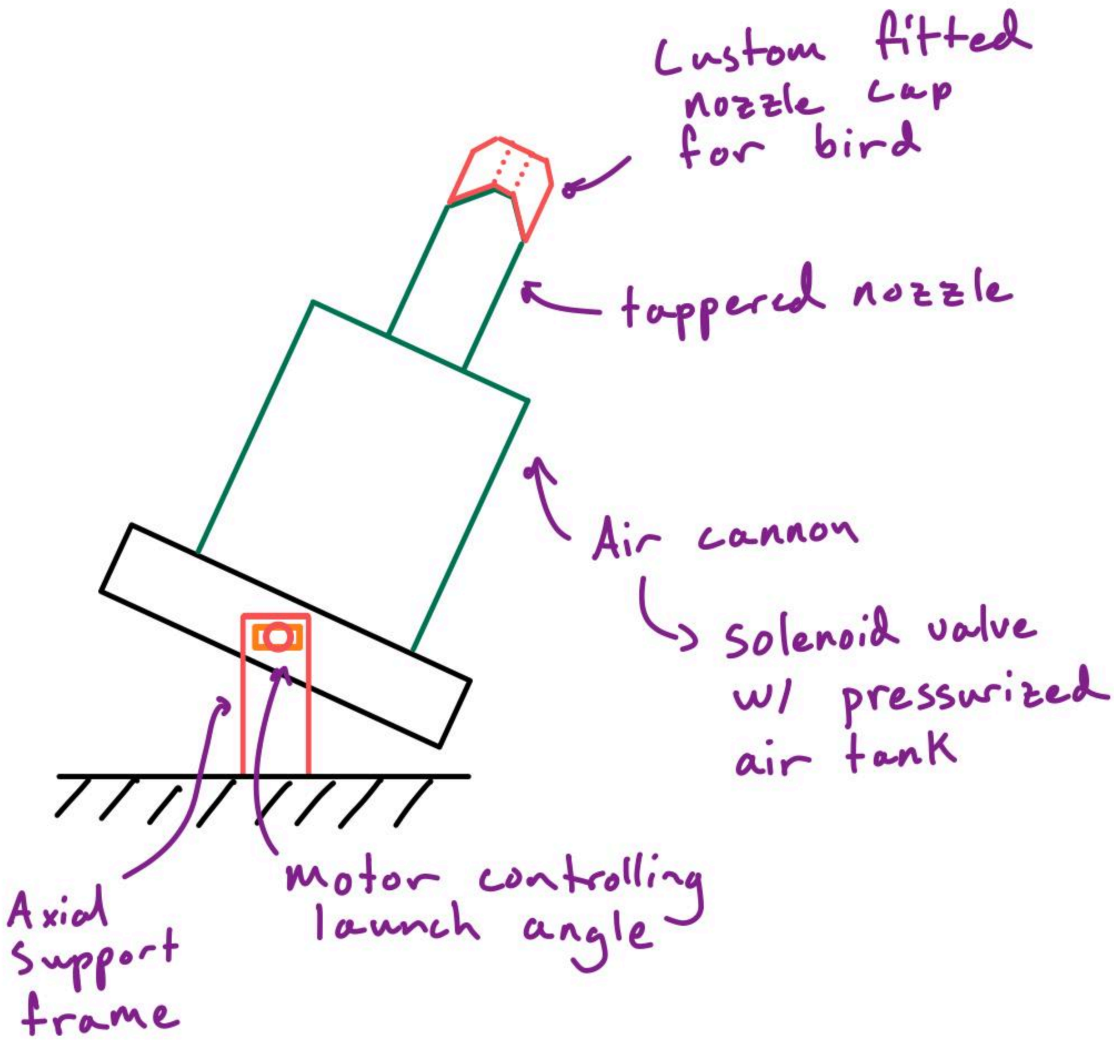

Figure 5: *Air cannon launcher. A pressurized air tank is opened and closed through a solenoid valve, and acts as the launch mechanism. The nozzle is fitted with a 3D printed cap to fit the bird without losing air pressure from a larger outlet and nozzle piece. As in Figures 3 and 4, the launch mechanism is mounted onto a platform whose axial rotation is controlled by a motor and bushing support.*

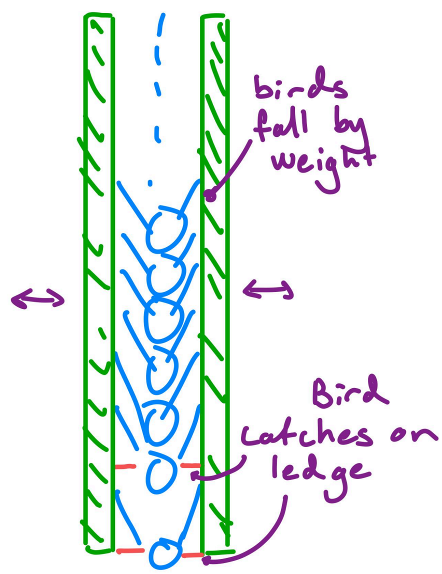

Figure 6.A: *This loads birds by catching and releasing them through ledges (red) installed within the loose-fitted tube (green). The tubing is split into fourths: two static and two dynamic fourths. The ledges are attached to the dynamic walls and open and close to drop and catch the birds.*

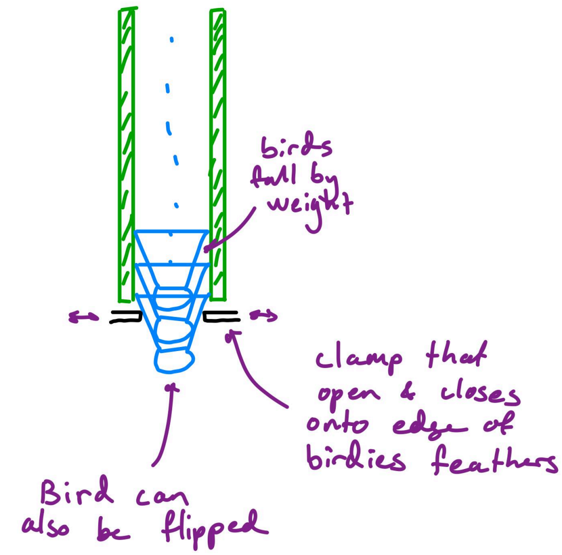

Figure 6.B: *Birds are loaded through a clamp that rapidly opens and closes onto the edge of the bird's feathers, thus ensuring only one bird is dropped at a time. The clamps can be actuated through a four bar linkage as in Figure 1.E, or through push-pull solenoids. The birds continue to fall by weight.*

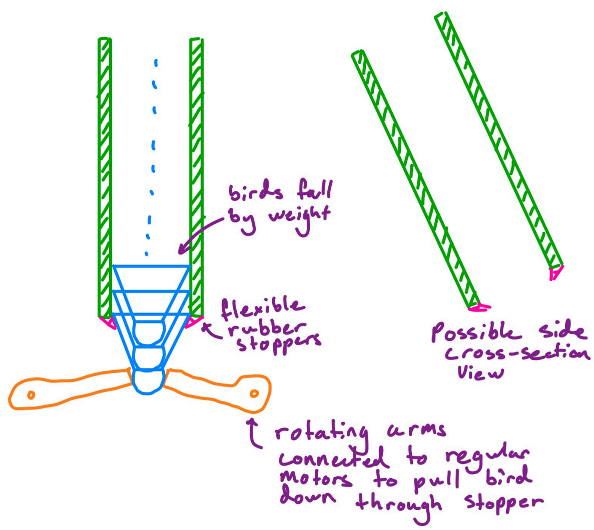

Figure 6.C: *Birds are loaded into a launch mechanism by rotating arms which pull a single bird through flexible rubber stoppers. The birds behind it fall into sequence by their own weight.*

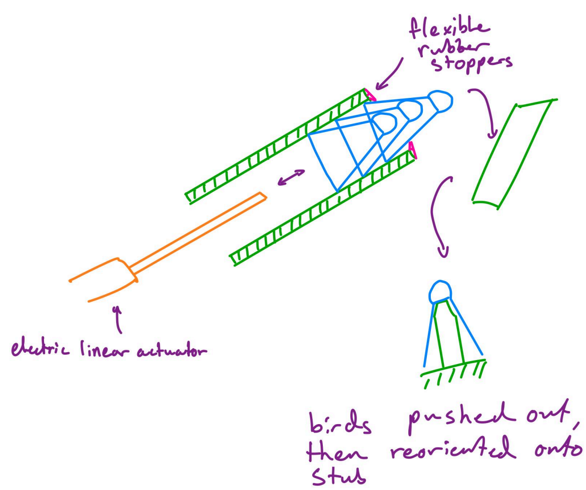

Figure 6.D: *This loads birds head-up orientation by having them pushed out through stoppers by an electric linear actuator onto a landing block to reorient the bird for an easier launch.*

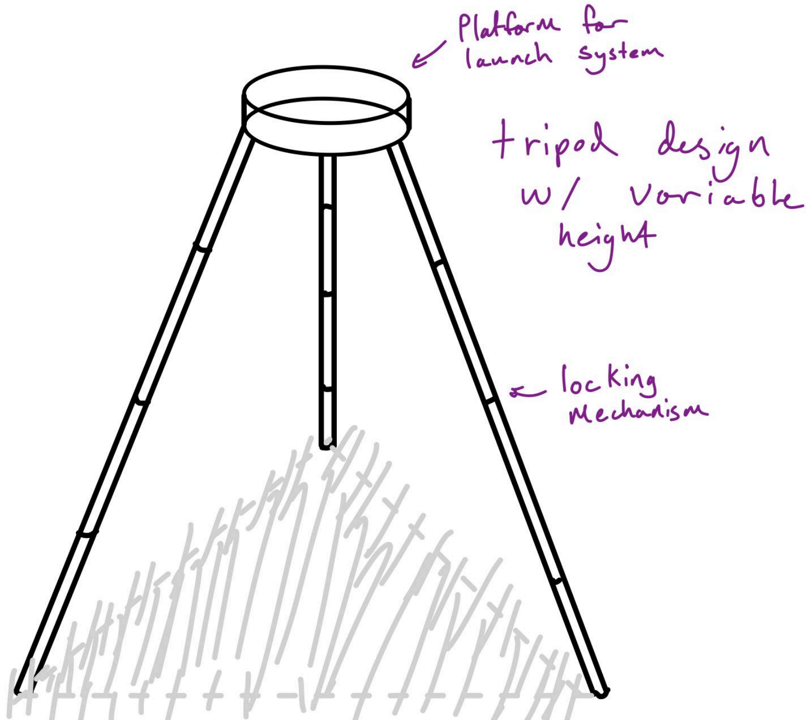

Figure 7: *Tripod stand base. Although previously drawn in Figure 1, I wanted to flesh out this idea slightly more, given that my second idea for a base is already well depicted in Figures 3 and 4.A. This design splits each leg into segments to achieve variable height and greater storability. These segments are lengthened out and made stable through locks.*

To decide on a final–though tentative–design, I decided to make a weighted chart that highlighted whether each design choice supported the set functional requirements.

Requirement	Weight	DC 1 (Rail catapult launcher)	DC 2 (Push-pull solenoid launcher)	DC 3 (Fly-wheel launcher)	DC 4 (Air cannon launcher)
Feed 12 shuttles within a minute, with a diametrical target range tolerance of 6 in	4	-1	0	+1	0
Allow random targeting within the 6 in diametrical target zone, and be able to place shots within a larger 20 in diametrical target zone	3	0	0	0	0
Must weigh less than 10kg, fit within 19.75 x 46.5 x 30 inches (typical size of a trunk), and be hand-carryable	2	+1	+1	+1	+1
Creativity	1	+1	+1	0	+1
Manufacturability	3	0	+1	+1	0
Total		-4+2+1 = -1	2+1+3 = 6	4+2+3 = 9	2+1 = 3

Each of the functional requirements were given weightings based on how important I think they are for the feeder to be usable. F.R. 2 gives the feeder greater flexibility but is not a necessity. Likewise, F.R. 3 is more of a convenience factor. I decided to weigh creativity and manufacturability as they are design aspects, but valued manufacturability considerably more as this is a project that I plan to actually build out, and hope to design for larger scale manufacturing.

Through assessing each design, I noticed that they all technically fail part of F.R. 2 (hence the zeros) as the target range of each launcher is purely linear (‘a target line’ if you will). To account for this, I plan to include an additional motor which attaches to the launch platform and creates planar rotation, allowing a circular target zone.

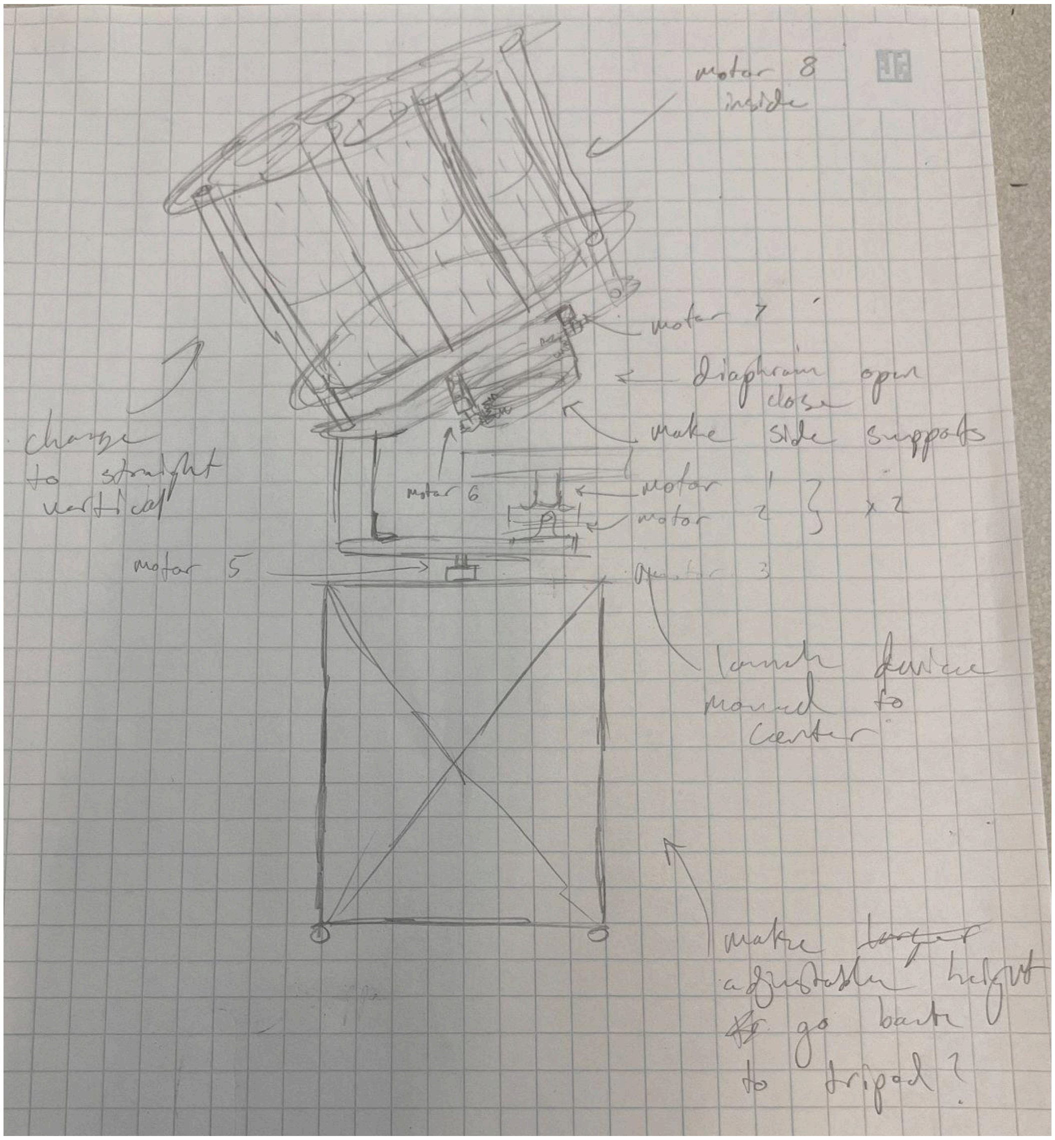

Figure 8: *Rough sketch of the final design iteration. After drawing this iteration, several concerns became clear, most of which are noted: the loading mechanism will be made completely vertical rather than slanted in consideration of manufacturability and designing support beams; rather than a cart for the base, a tripod with lockable wheels would be more appropriate as it increases the flexibility of the feeder.*

Another notable change is the loading mechanism. The design is based on Figure 6.A, but in researching how I would practically achieve the desired motion I came across a video by RiedeProjects on YouTube called “BADMINTON SHUTTLE FEEDER PART 2: dispensing mechanism (diaphragm)”. In his video, he creatively attached two motors to a frame and designed slots which force a two level shutter system to open and close. The design that I will be going with is heavily inspired by his.

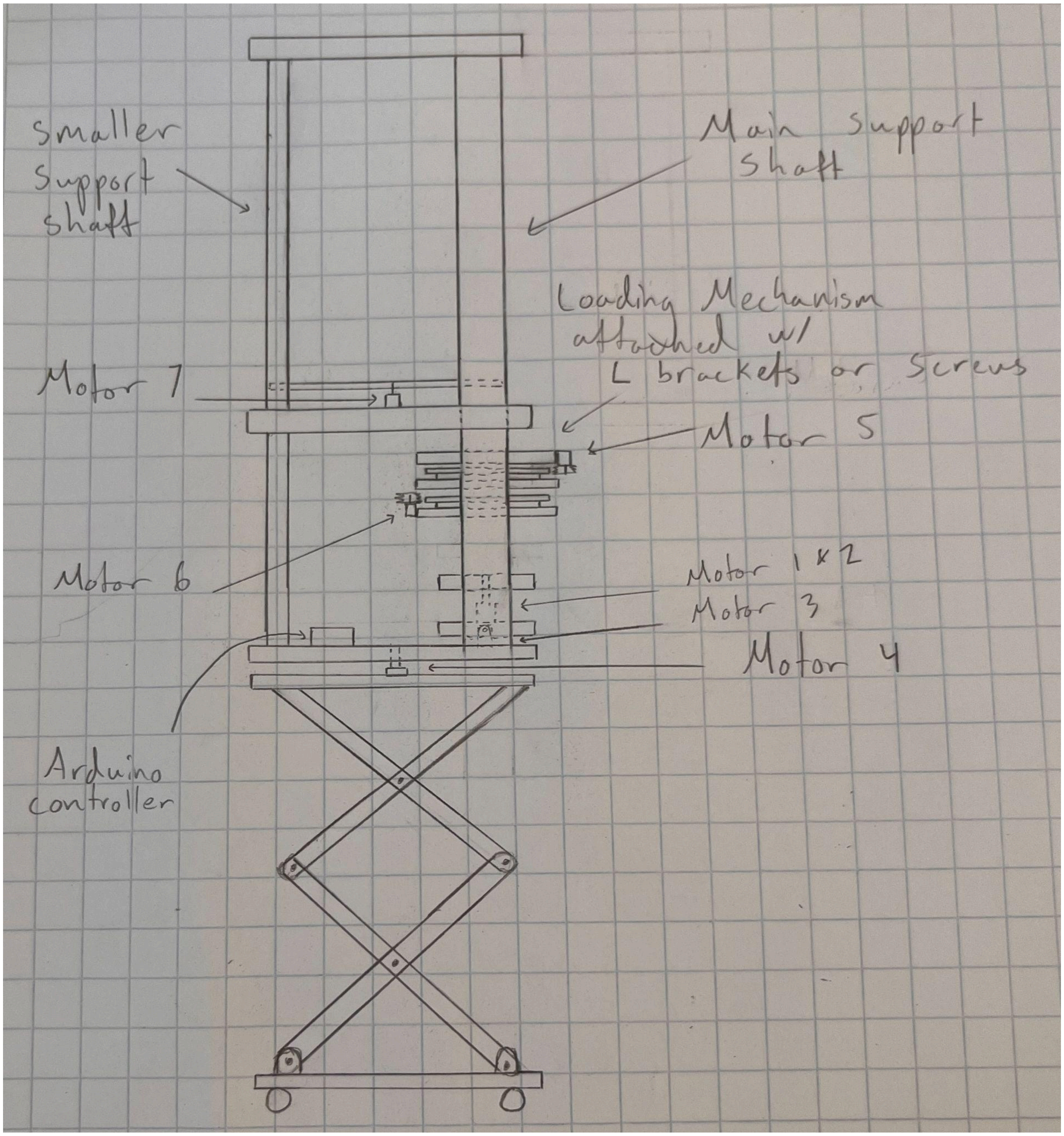

Figure 9.A: *Side profile of final design for the Fly-wheel based shuttle launcher. It uses seven motors: motors 1 & 2 for the two fly-wheels; motor 3 for axial rotation; motor 4 for planar rotation; motor 5 & 6 for the diaphragm loading mechanism; and motor 7 to rotate a series of tubes filled with shuttled into the loading mechanism like a revolver's cylinder. The launcher will be mounted on a scissor lifted platform for adjustable height. Lockable wheels allow easy movement of the feeder. The launcher will be supported by two large main shafts and a thinner (and less load bearing) support shaft, all of which are connected to the rotating*

planar platform attached to motor 4. The loading mechanism will be connected to the two main shafts through screws or L brackets, and will likely have its frame 3D printed to allow flexibility in its geometry. All of the motors are planned to be controlled through an arduino.

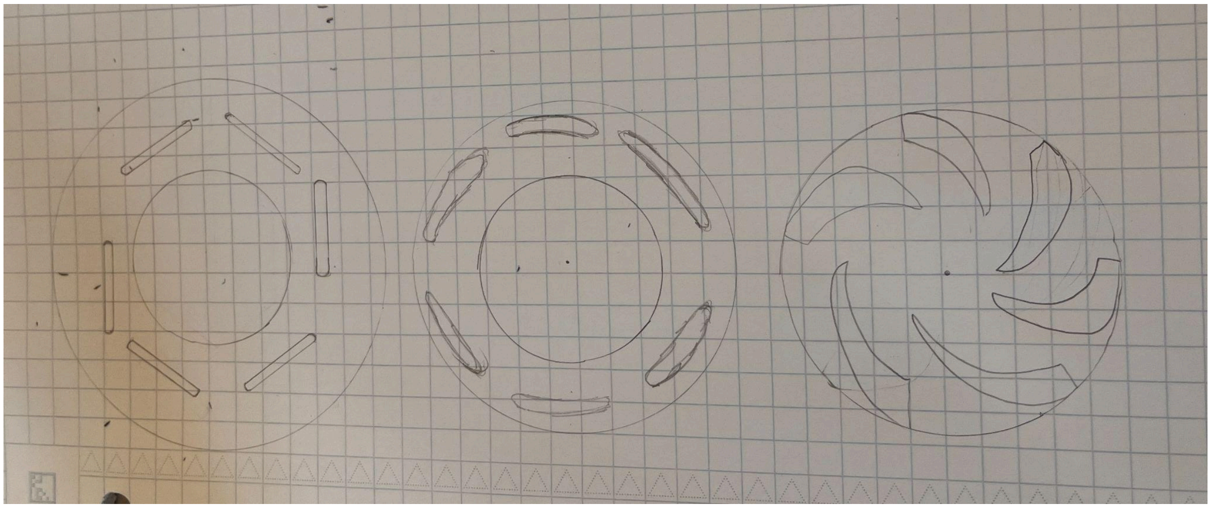

Figure 9.B: *Draft idea for one half of the diaphragm loading mechanism, composing 3 of the total 6 layers. The left-most base layer is fixed, while the middle layer actuates to a motor through gear teeth. The right-most layer is composed of six blades and is sandwiched between the base and actuating layers. All 3 layers are connected through rods which makes the blades dependent on both the actuating layers rotation and the base layer's slots. This design is subject to the most change and will likely require many design iterations.*

Looking through diaphragm shutter designs, I decided to go with six curved blades as it allows the shuttle to be more carefully and easily gripped. My reasoning for this is due to how the condition of each shuttle's feathers vary and will likely hinder consistent gripping if a lower number of blades were used. This also allows me to grip the shuttle further up along its feathers without it losing balance (as compared to say 4 blades). There are also shutter designs where either the base or actuating layer have pins rather than slots, and this is something I plan to consider as I iterate designs for the loading mechanism.

The next step is to further ideate the flywheel launcher design, but more concretely with CAD. I am choosing to learn and use Catia V5, as it's a CAD software that I don't have familiarity with and have heard is extensively used in industry. I decided to shy away from softwares I'm already familiar with like Solidworks or NX given this project is as much a learning opportunity as it is a means of combining my interests. To start

I am following a general [Catia V5 tutorial playlist] from CAD CAM Tutorials on YouTube. At first glance Catia has a lot of similarities with NX. It differs largely in its GUI and accessibility compared to Solidworks and Fusion, but it also has a lot of short cut tools and design features which, when mastered, will likely make it much more efficient than the two.

Before fully delving into the CAD process, I want to decide on the motors that I will be using, so that the components I design fit around them. Changes can be made in the future without much hassle, but it is nice to have some defined pieces.

I plan to control all of the motors through a single Arduino, which is attached to the base plate. I am choosing an Arduino over something like a raspberry pi due to the lower cost and lower complexity level of the motor functions. Referring to Figure 9A, motors 1, 2 will be low torque (high RPM) DC metal motors to achieve the high velocities needed to launch the birds through the flywheel. Motor 3, 4 will be stepper motors, as they offer higher torques and angular rotation than RC servos while offering precision control, both of which are needed to allow precise angular axial and planar rotation. Motors 5 and 6 will be RC servos as they are lower cost, and smaller, all while offering the same control needed to open and close the loading mechanism. Motor 7 will be a stepper motor as it requires full 360 degree rotation.

To decide which specific motor I go with, several calculations are required to determine the specifications like RPM, torque and control.

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