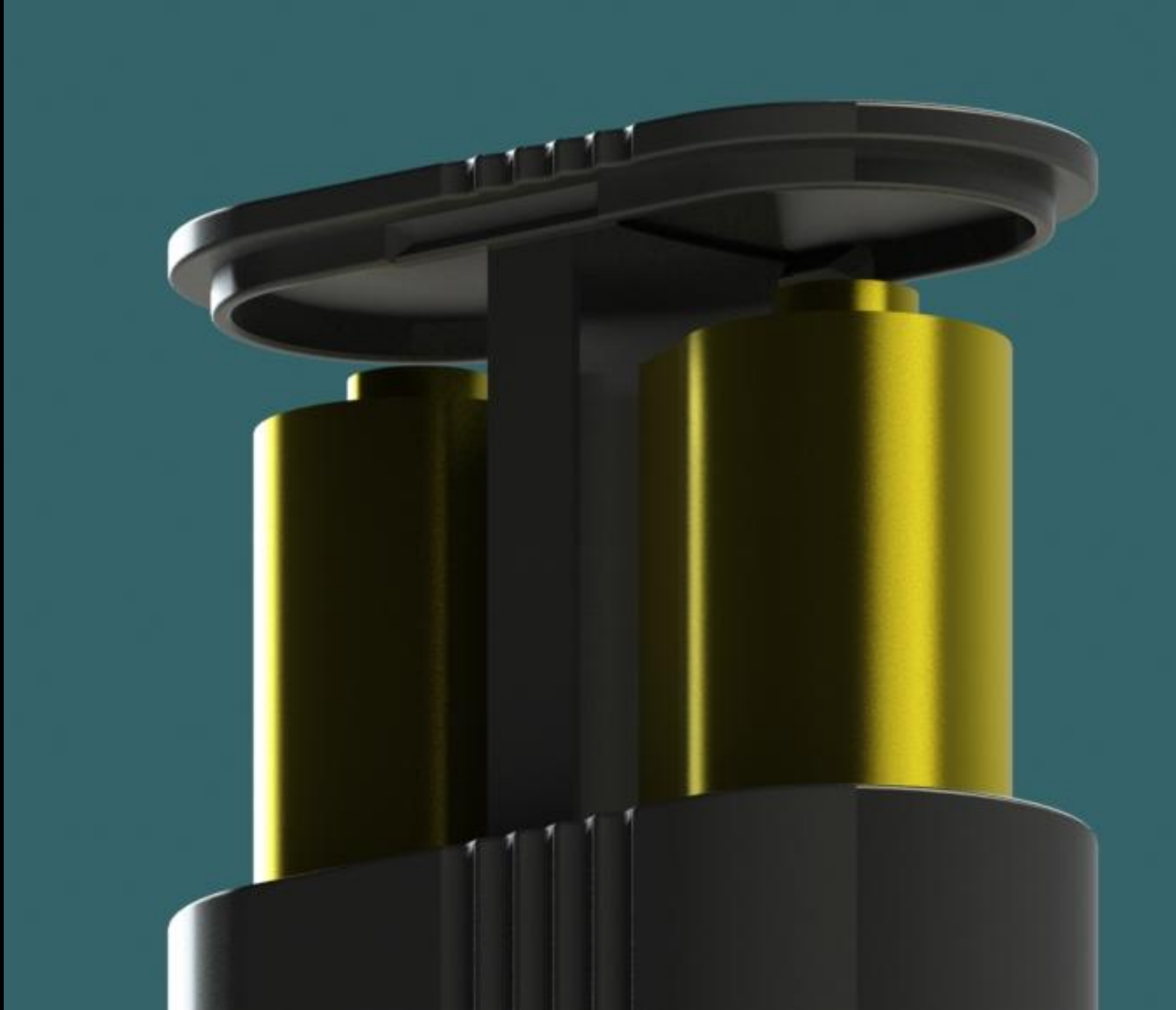
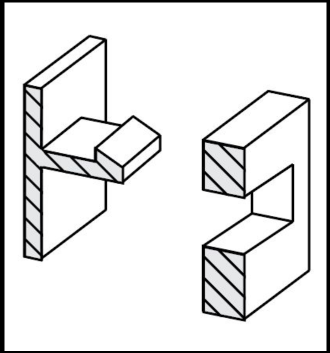
# Film Magazine

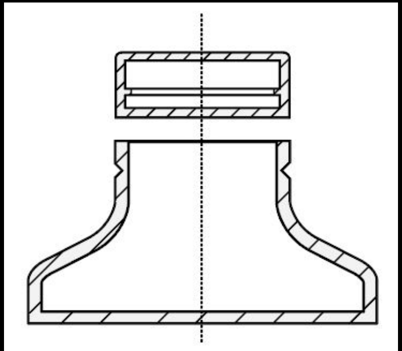
3D Print Design Challenge

October–November 2020

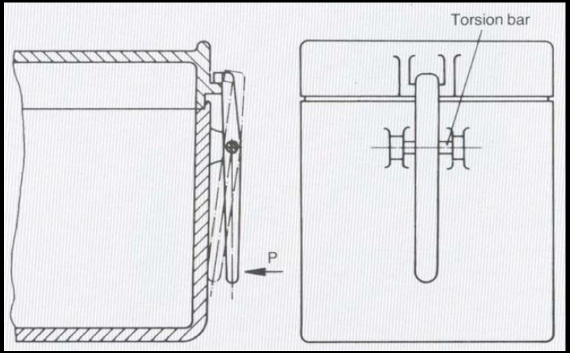




Cantilever



Annular




Torsion

Images pulled from the two articles

Read through these two articles (1 and 2) about designing snap-fit joints for 3D printing. There are three primary joints: cantilever, annular, and torsion. Cantilever, which involves a beam with a hook protrusion at the end, seems to be the most well-documented and popular type of joint. All of the calculations necessary for this type of joint can be completed using basic algebra. This is something to consider when designing my parts in the future.

[Assignment](#)

Film photographers always carry with them extra rolls of film so that they won't run out of shots. The rolls are usually stored either in the photographer's pockets or in a bag they have with them.

The problem is that (1) rolls of film come in individual canisters that are bulky and (2) they tend to slide around wherever you store them.  Additionally, (3) these canisters require two hands to open which often means that the photographer must put their camera or bag down in order to load another roll; this all takes a significant amount of time, which is not always a luxury in photography, especially since many photographers shoot various things and scenes that last only for a brief moment. The ability to quickly obtain and load a roll of film can mean the difference between getting the shot and not.


Film is loaded into the back of the camera, a process that already requires two hands.
Source

These film canisters are a poor storage solution.
Source

Box designs. Seem like an effective means of protecting the film and storing multiple rolls at once. The right container even has a “push to pop open” button. But, these designs use separated lids and probably require more than one hand to open.

Source


Source

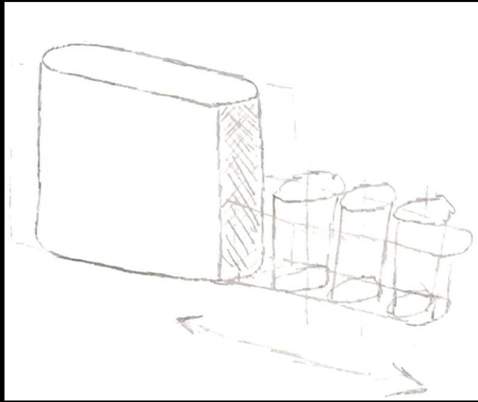
This bandolier design is interesting. Makes film access very quick as the rolls are attached directly to the side of the camera. I am skeptical of the practicality of the form factor and the potential of the rolls falling out, however this “wearable” approach is intriguing.

Source

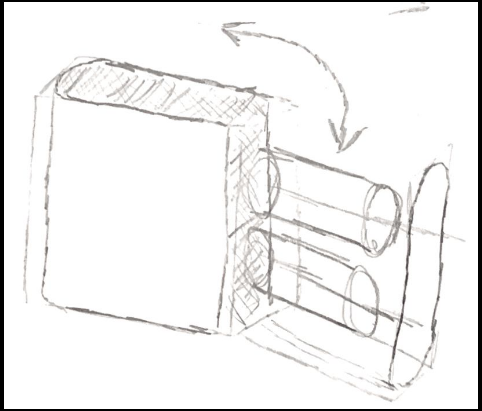
I did not find very many pre-existing designs to be honest. Common designs I found were various boxes and strap-based designs.

| | |
|---|---|
| Design Constraints | (1) Stores two rolls of 35mm film (**demand**)<br>(2) No detaching parts (e.g. lids) (**demand**)<br>(3) Minimal form factor (< 4' x 2' x 3') (**demand**)<br>(4) Wearable (i.e. attaches to camera strap, belt loop, etc.) (**wish**)<br><br>*PROVIDED DESIGN CONSTRAINTS (all **demand**)*<br>*Can be held in one hand comfortably*<br>*Contained within a 12" x 12" x 12" cube*<br>*Three to seven 3D printed parts*<br>*Each part contained within a 5" x 5" x 5" cube*<br>*Parts use PLA filament*<br>*Total filament under 200 grams*<br>*Parts combine without tape, glue, etc.*<br>*Interacts with a non-3D printed object*<br>*Does not draw structural integrity from non-3D printed object* |
| Functional Requirements | (1) Can be opened with one hand (**demand**)<br>(2) Aesthetically pleasing (**preferred**) |

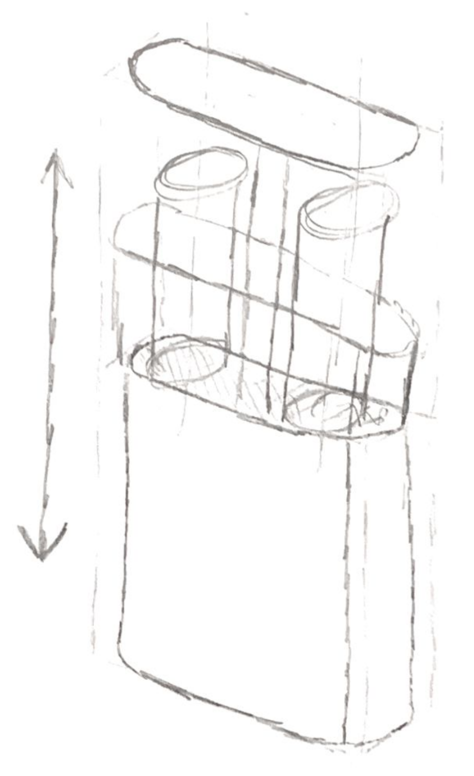
The proposed solution to the problem is a magazine that stores two rolls of 35mm film (what I usually carry around when I take photos). It is lightweight and can be opened with a single hand.



Horizontal slider



Flip-out compartment



Vertical slider

All of my brainstorms feature a rounded prism form as this seemed to be the most efficient and protective means of storing the film. Experimented with different mechanisms such as sliders (left and right) and a flip-out compartment (middle). These were the result of trying to eliminate any separable parts from the container.

| Comparison Criteria | Weight |
| --- | --- |
| Mechanism efficiency | 20 |
| Form factor | 20 |
| Aesthetics | 10 |

TOTAL: 50

Horizontal Slider

| Score | Weighted Score |
| --- | --- |
| 6 | 120 |
| 6 | 120 |
| 8 | 80 |

TOTAL: 320

Flip-out Compartment

| Score | Weighted Score |
| --- | --- |
| 8 | 160 |
| 7 | 140 |
| 9 | 90 |

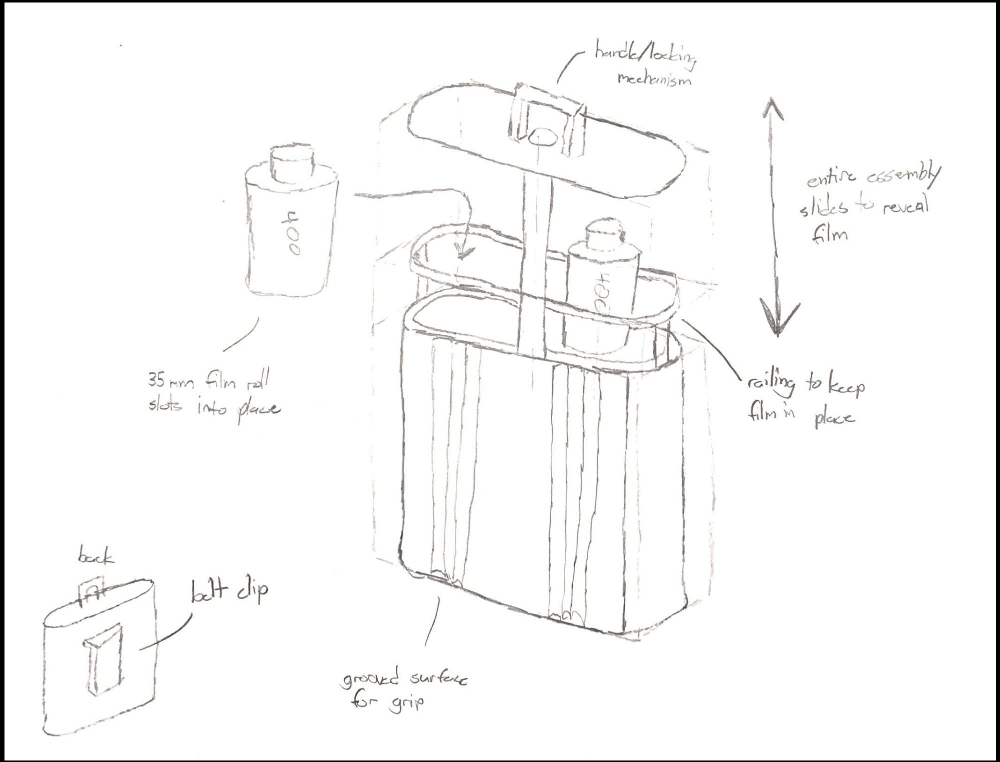
TOTAL: 390

**Vertical Slider**

| **Score** | **Weighted Score** |
| --- | --- |
| **9** | **180** |
| **9** | **180** |
| **8** | **80** |

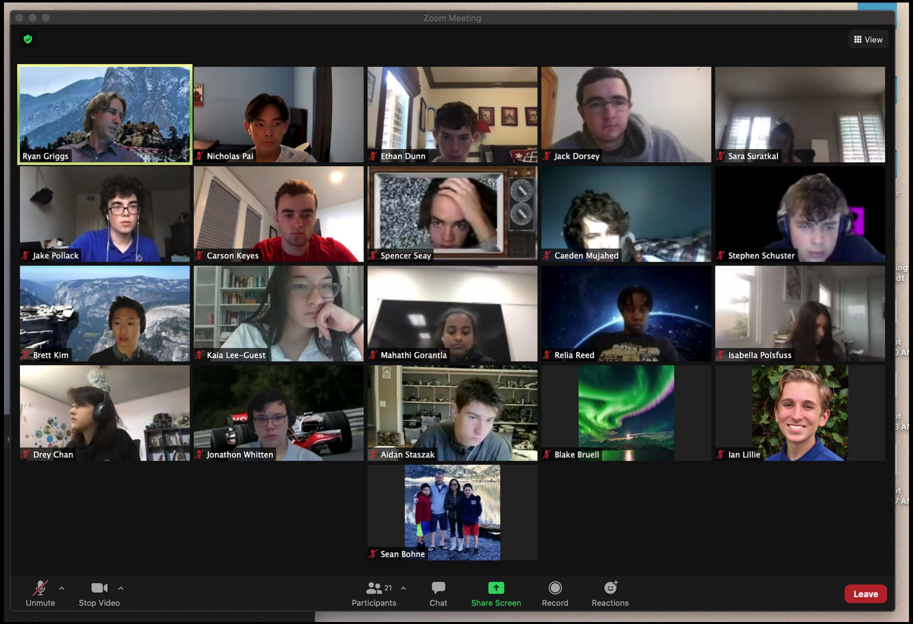
**TOTAL: 440**

Weighted objectives table. Most weight was given toward mechanism efficiency (i.e. can it be opened with a single hand, quickly?) and form factor as these coincide with the demand specifications outlined. Less weight was provided for aesthetics, a preferred specification. Going to pursue the vertical slider design based on the final scores.

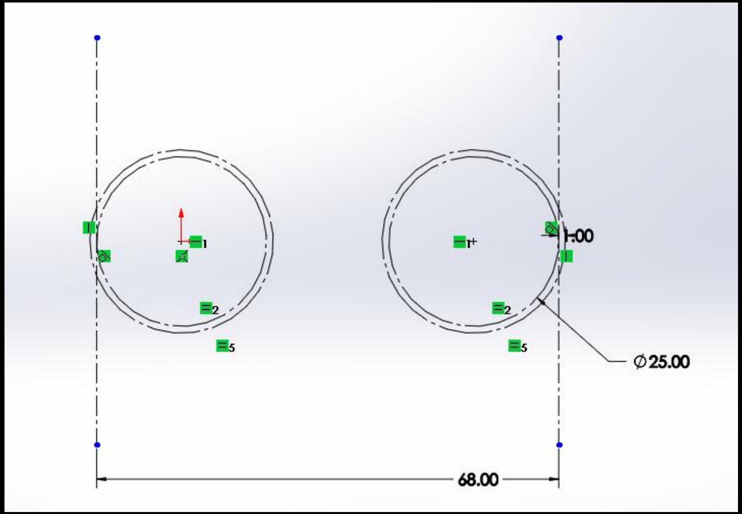



I decided to focus on the third design as it seemed to be a compact and relatively simple solution to the problem. Pictured are the various features (left) and potential use cases by a photographer (right).

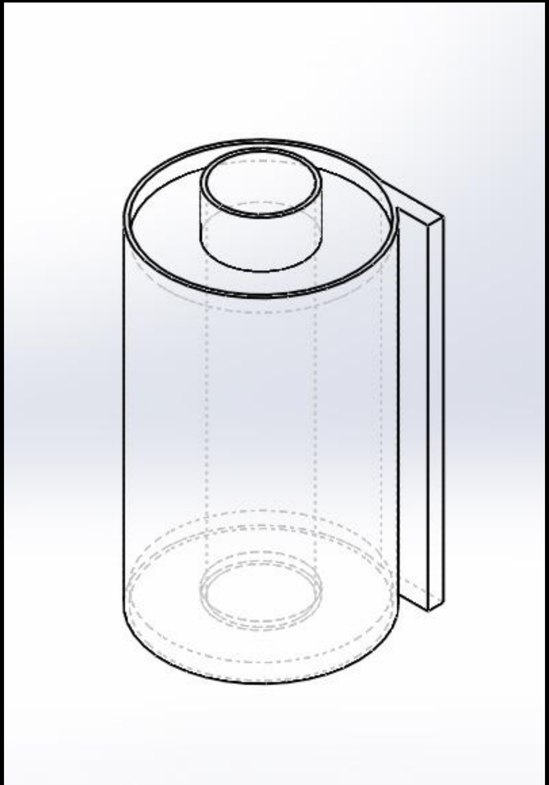
The vertical slider design was presented during the in-class design review. Feedback was overall positive; my peers especially liked the intended functionality of the film magazine as a method to quickly access rolls of film. Positive feedback was also given to the vertical sliding mechanism of the design due to its efficiency and minimal form factor, which corroborated with my personal assessments. A point of recommendation was to carefully plan out the actual dimensions for this design because it incorporates a few small moving parts, such as the guide rails on each edge and the handle; in trying to achieve structural rigidity with these parts, the minimal form factor may be compromised. Through my own ideation and sketching process, I largely agreed with this feedback. My next steps will be to conduct extensive prototyping of the various moving and snap-fit mechanisms of the magazine.




First Design Review | 10.28.2020 | Step 8: Present



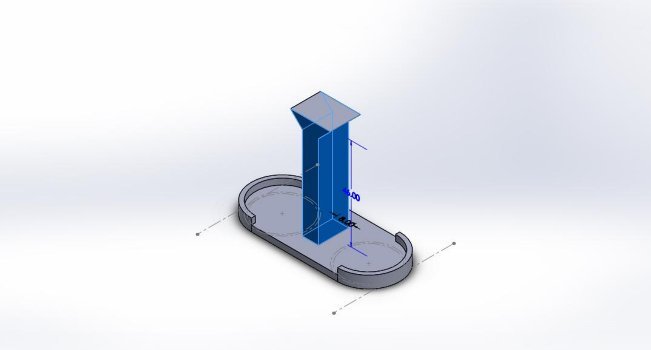

The inner pair of circles represents the diameter of a standard 35mm film roll and the larger pair represents the size of the guidance forms I will use to keep the rolls in place.



The 35mm film roll has a diameter of 25 mm but also has a small lip that protrudes out (on the right), which extends the diameter to 30 mm. It is 47 mm high.

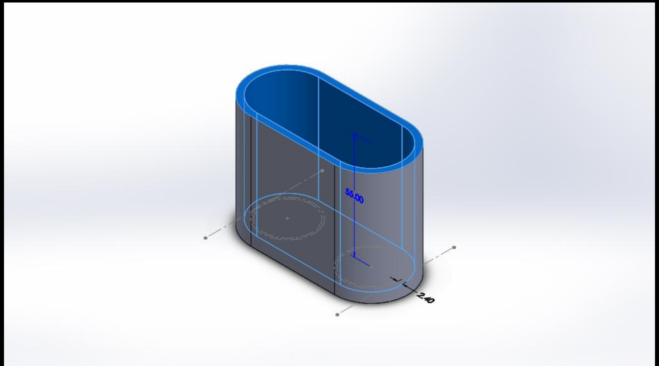
I started to CAD out the basic forms for the various parts of the magazine using this sketch, which I copied into the top plane of each part. The design intent of this was so I could easily change any of the major dimensions for all of the parts using this standardized sketched. I also modeled an actual roll of film for a 3D reference.

(1)




*Slider.* Began with this part as this will determine the dimensions for the prism below that houses it. Added two raised lips around the edge of the base for the film rolls to fit in and completed a central extrude with a dovetail joint on top (which will attach to a lid). This joint will probably need to be refined with more prototyping.

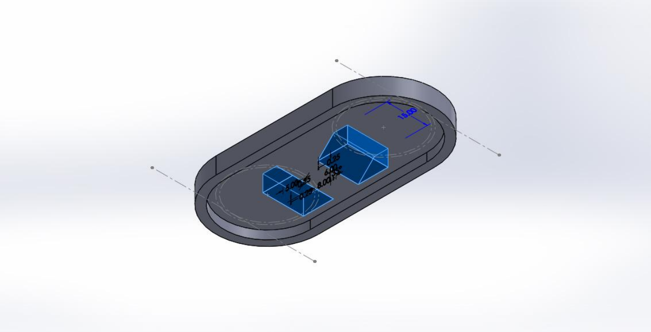
(2)




*Prism.* This is the primary enclosure of the magazine. It can contain the Slider with a 0.4 mm clearance for a loose fit and is made with a shell of 3 mm thick walls.

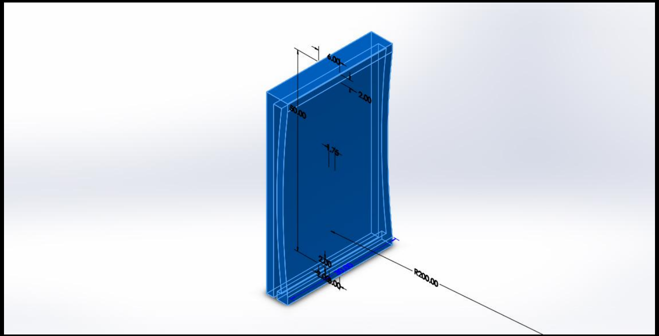
Designing the base magazine form, continued

(3)



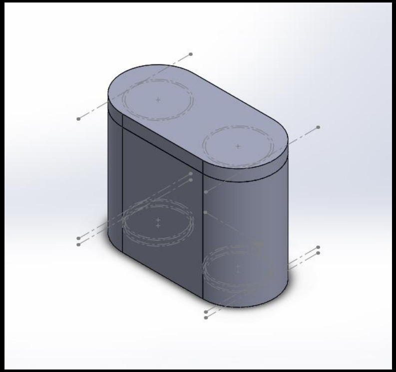
*Lid.* Connects to the slider with a dovetail joint and will rest on top of the prism. Need to prototype a snap-fit mechanism to keep lid attached to the prism when closed.

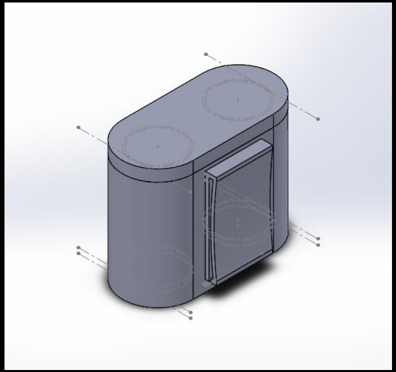
(4)

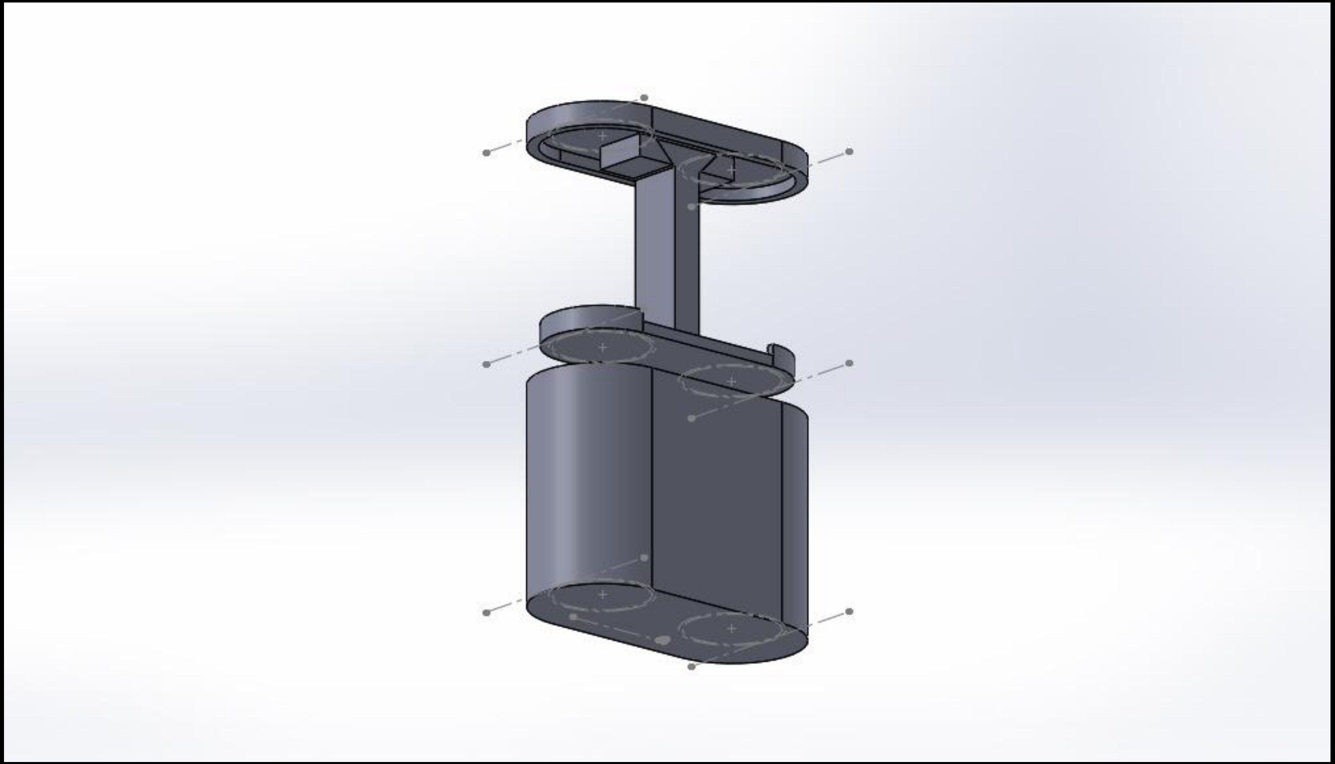


*Clip.* A simple clip design that attaches to the back of the prism. The outer extrude is concave in order to attach to a camera strap tightly and has a raised lip at the bottom to keep the magazine from slipping. Need to prototype a snap-fit mechanism to attach this to the prism.

Designing the base magazine form, continued

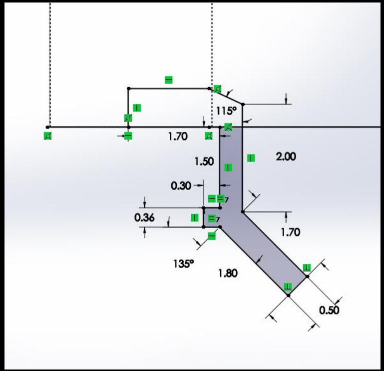


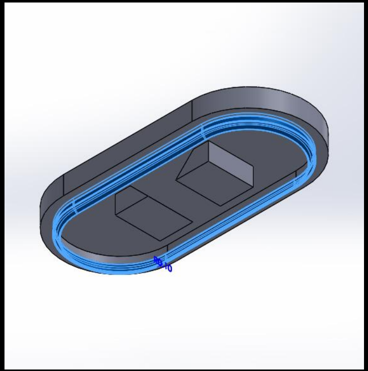
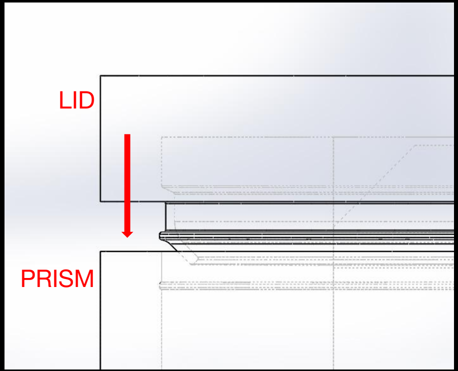




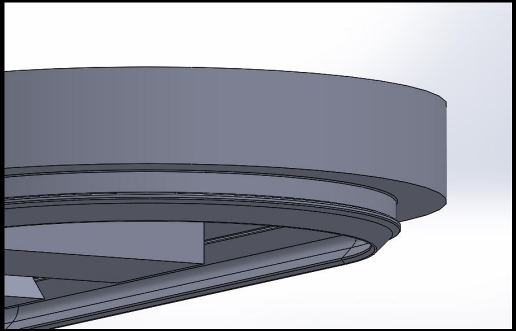
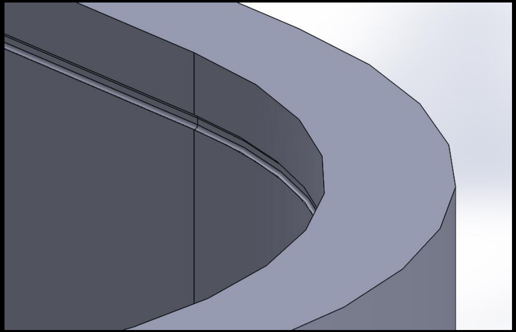
The first iteration of the magazine, all assembled. On the right is what it will look like when opened. Also visible are the standardized sketches that I used on the slider, prism, and lid.

Designing the base magazine form, continued



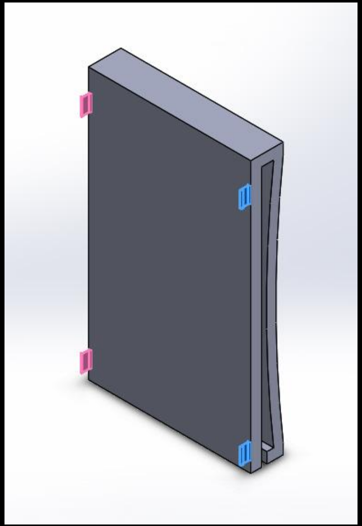



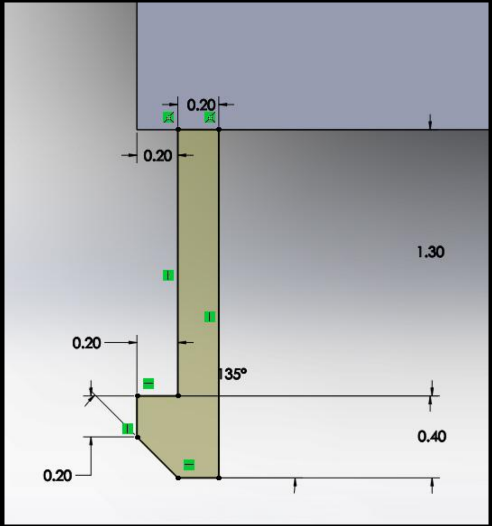

Annular joint sketch, revolved around the lid. The form is bent inward in order to help guide the prism onto the snap-fit and the perpendicular protrusion locks the prism into place. Fillets were added accordingly to ensure a non-permanent fit. I used a Cavity feature on the prism to achieve a corresponding indent to fit the joint.

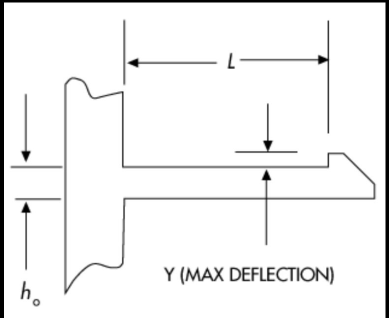
Closeups of the annular joint on the lid (top) and prism (bottom)

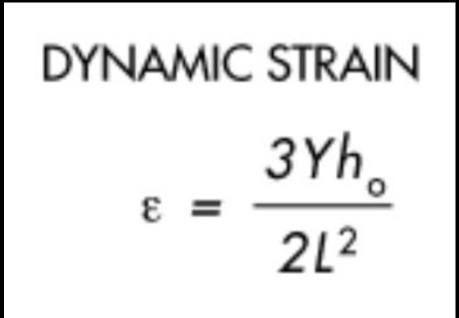
Prototyped the various snap-fit mechanisms necessary to hold the assembly together. Began with the lid mechanism. Followed this tutorial to design the annular joints, which provided me with these dimensions that supposedly work, but physical prototyping will be necessary to see if this is actually the case.






Cantilever beams added to each corner of the clip. 0.20 mm fillets were also added to the base of the beams to ensure structural flexibility.



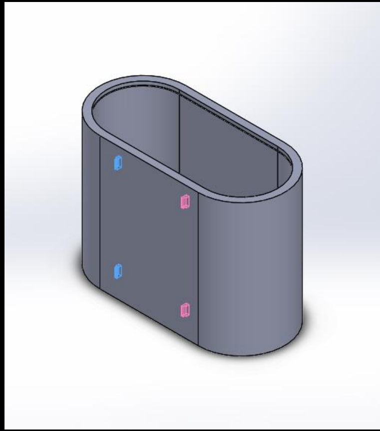

| | |
|---|---|
| Y (maximum deflection) | 0.20 mm |
| $h_0$ (thickness at base) | 0.20 mm |
| L (length) | 1.30 mm |

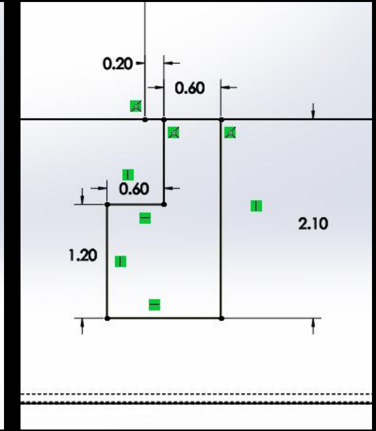
**ε (dynamic strain) = 0.0355**

These dimensions should theoretically work because the calculated dynamic strain is less than the maximum dynamic strain for PLA.

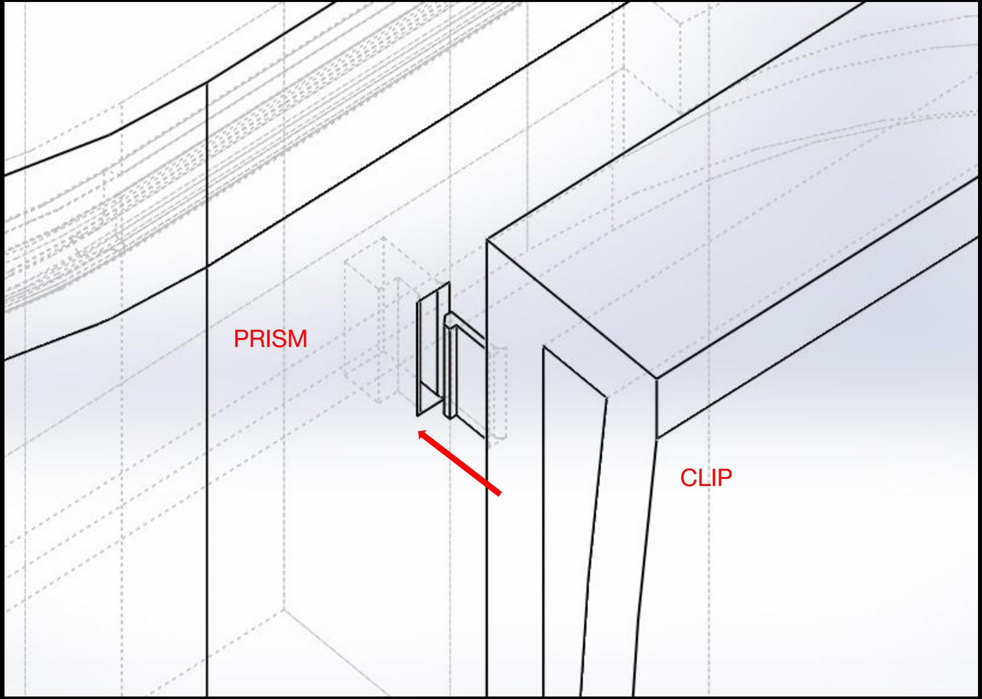
Next are the snap-fits for the clip. I chose to use cantilever joints because these would offer a permanent fit.  I calculated the acceptable dimensions using this dynamic strain calculator knowing that the maximum dynamic strain for PLA is 4% (0.04) according to these specifications.

Prototyping snap-fit mechanisms, continued



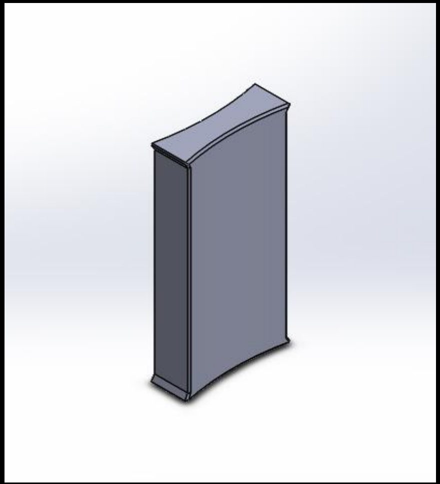


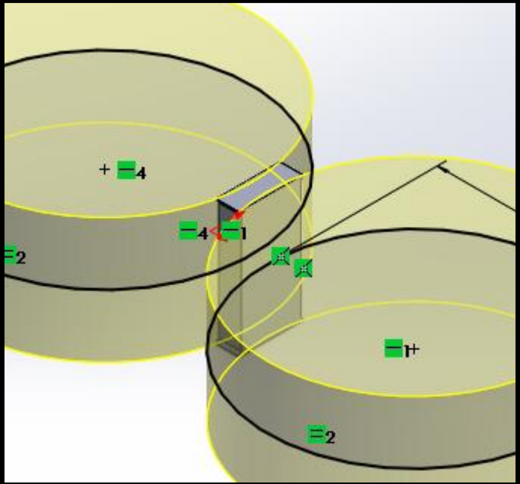

The corresponding Cut Extrudes for the cantilever beams (on the prism).




Closeup of the clip inserting into the prism.

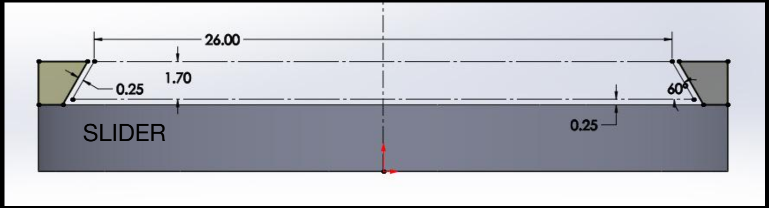
Prototyping snap-fit mechanisms, continued





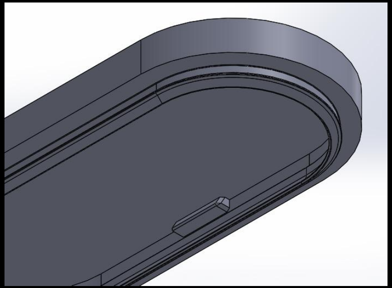
The shaft will connect the base of the slider and the lid. As pictured on the right image, there is a slight concave Cut Extrude on either side of the shaft to mirror the shape of the film rolls that will be placed on either side of it. A 0.5 mm chamfer was added to the edges of the dovetail joints to ensure the parts are easy to fit together, per recommended by this article.

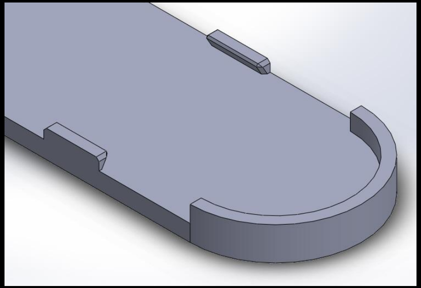
Profile views of the dovetail joint. The extrusions on the actual joint are relatively narrow as I wanted very little material contact between the two parts to aid with ease of construction. The female dovetail joint provides 0.25 mm clearance, ensuring a friction fit.

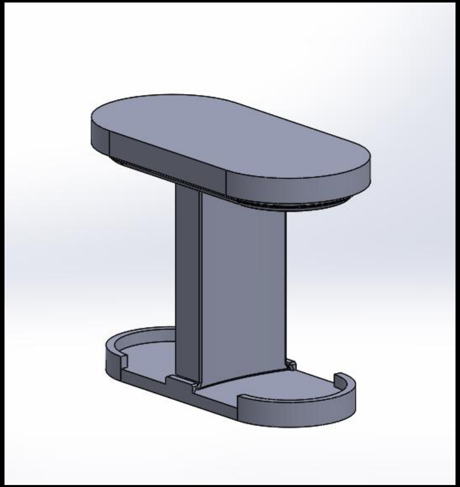

The final joints are for connecting the slider to the lid. Divided the slider into two parts: the base and the shaft (pictured above). This will enable me to print the shaft on its side, an orientation that offers higher structural rigidity. I am using dovetail joints that attach with a friction fit as their minimal form factor offers ease of construction in the narrow spaces within the enclosure.

Prototyping snap-fit mechanisms, continued

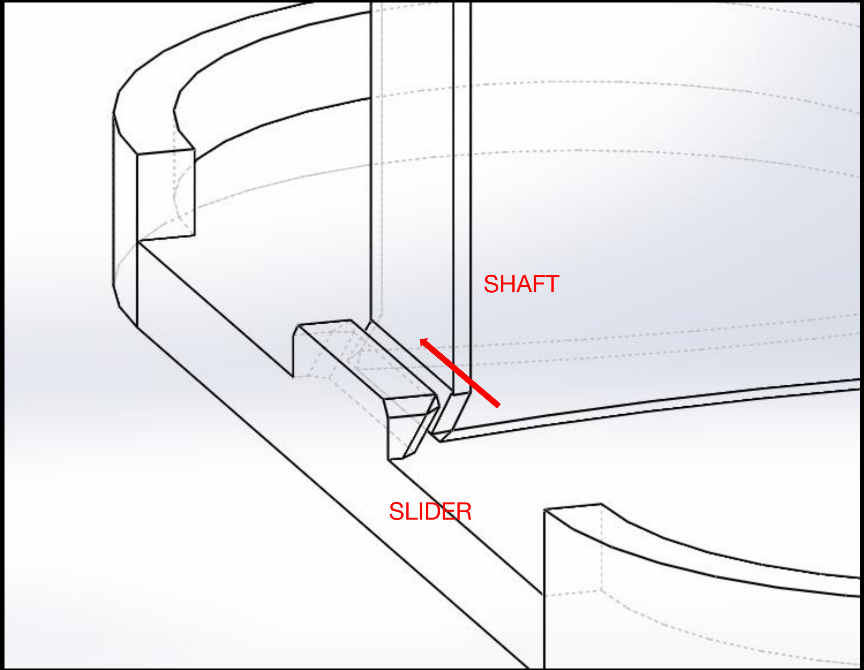




Female dovetail joints on the lid (left) and slider (right).

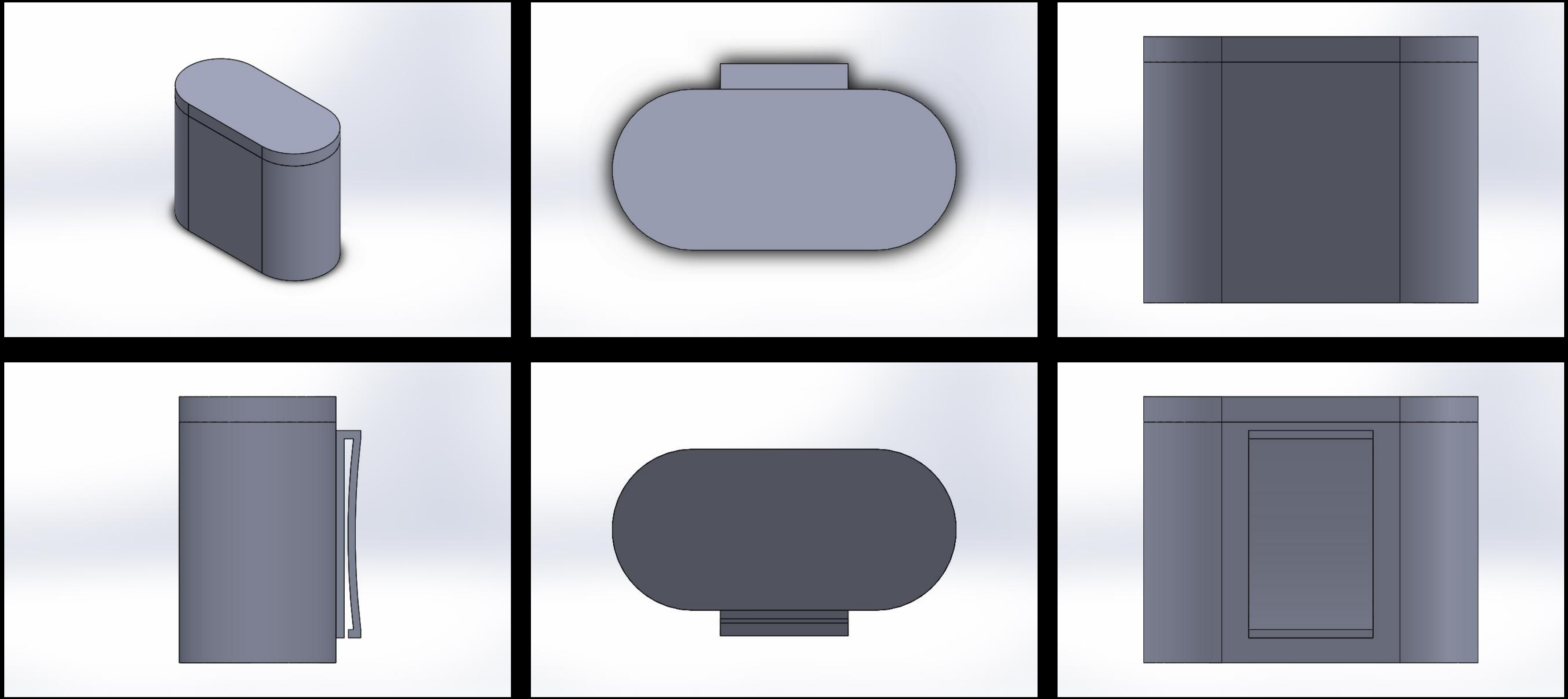


The entire lid, shaft, & slider assembly.

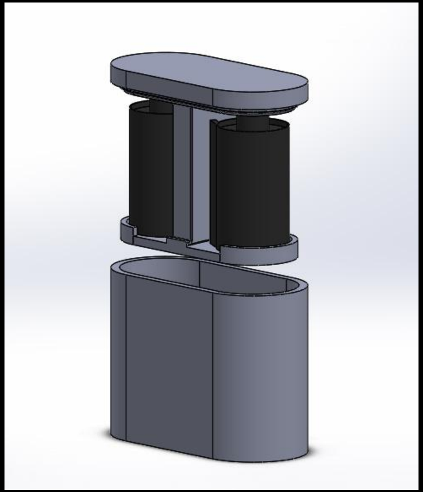


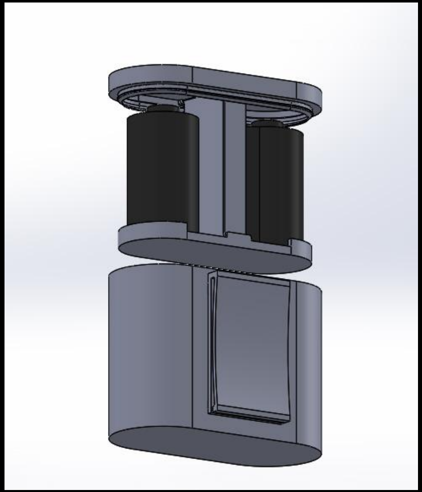

Closeups of the joint.

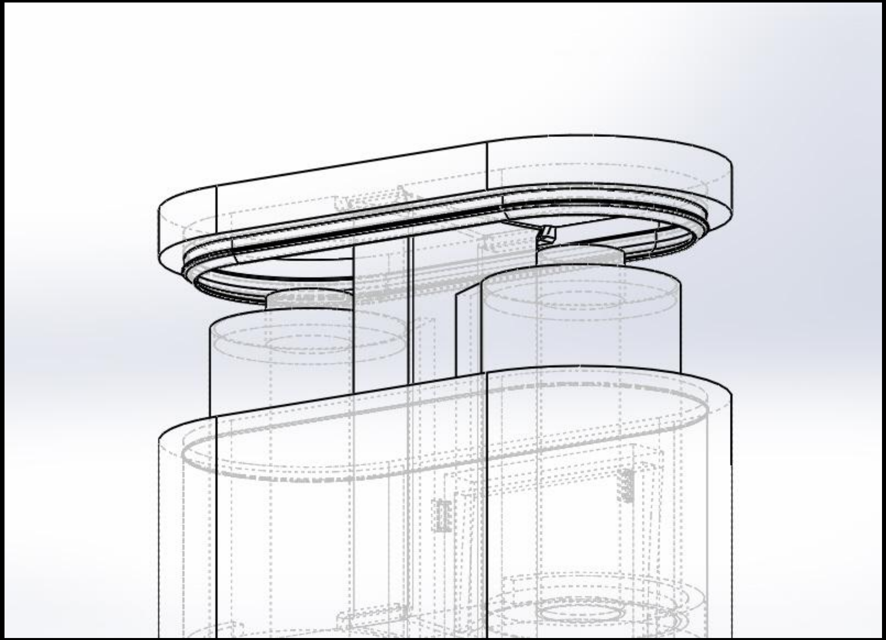
## Prototyping snap-fit mechanisms, continued



All angles of the magazine. Initial impressions for this first iteration are positive. I think I implemented the vision from my sketches adequately with an efficient use of SolidWorks features. The design is simple (for the most part) and has a minimal form factor.



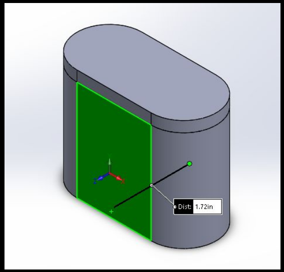


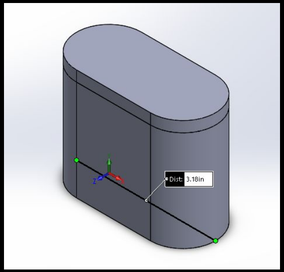


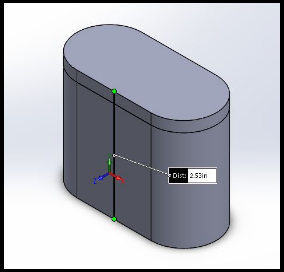
As pictured in this transparent view, there are many snap-fits and geometries housed within the enclosure.

Here is the magazine in its open state. One thing I would change is the annular joint that connects the lid to the prism; as is, it is currently too complex with many small fillets and protrusions that I do not think can be produced accurately on our 3D printers.

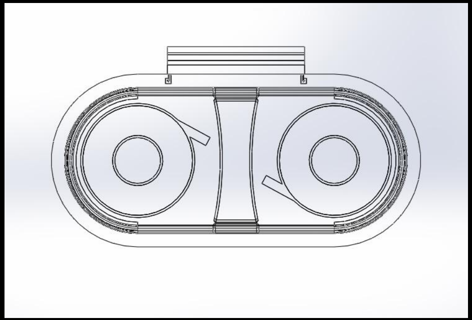
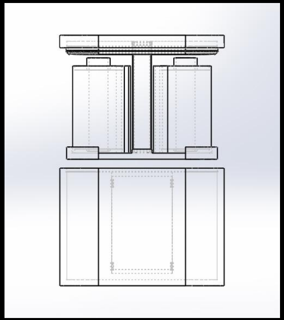
A first, functional design, continued



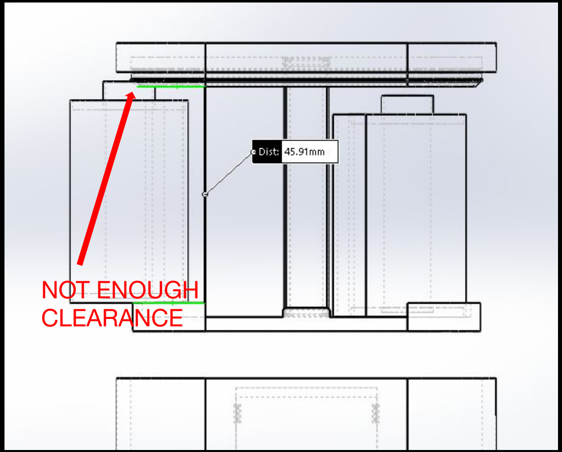




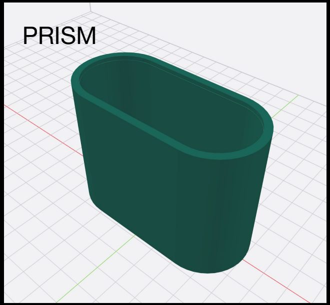

The depth, width, and height of the magazine (when closed) achieve the dimensional design constraint I determined (< 2’ x 4’ x 4’, design constraint (3)). Since all the parts are contained within these dimensions, this also means that the magazine also achieves the dimensional design constraints outlined by the assignment.

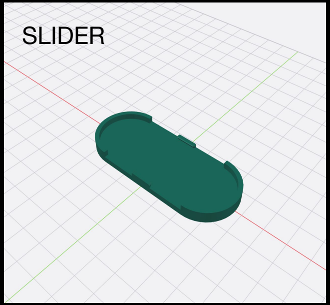



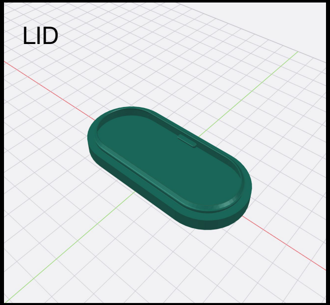
The magazine can hold two rolls of 35mm film in the stowed position (two images above). However, there is not enough clearance between the lid and slider to insert and remove the rolls, so this iteration fails design constraint (1).

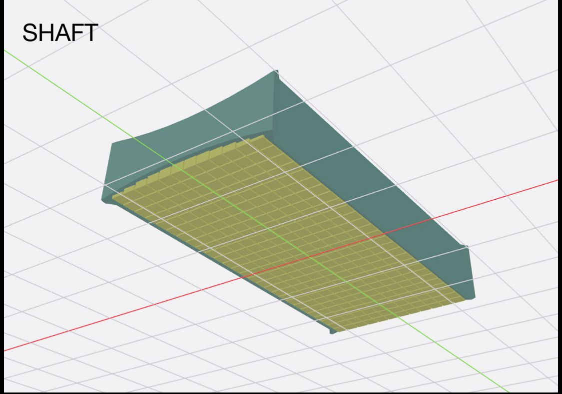


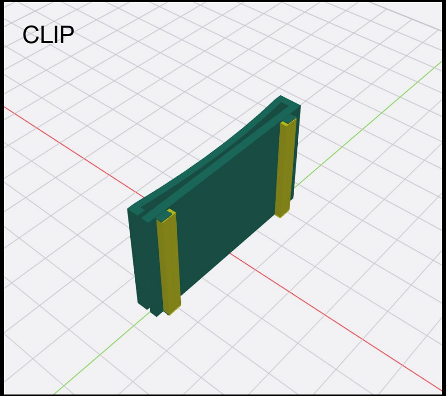

Various elements of the magazine can now be tested to determine if all of the design constraints and functional requirements are met. I first assessed the dimensions.












Slicer Masses

| Part | Mass (g) |
|---|---|
| Prism | 39.5 |
| Slider | 5.8 |
| Shaft (with support) | 6.4 |
| Lid | 9.0 |
| Clip (with support) | 7.5 |

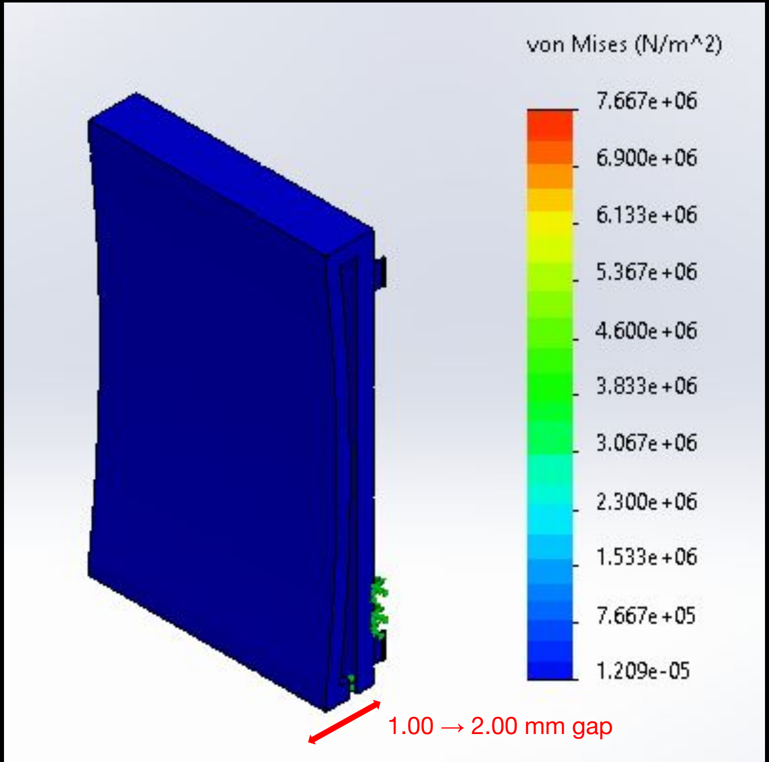
**Total mass = 68.2 g**

These masses were achieved using a 0.1000 mm layer height and 10% infill. I selected the highest print resolution because some of the parts contain complex geometries and 0.20 mm fillets. 10% infill should be sufficient for the relatively light load of the film rolls the magazine will be holding.

Pictured above are the print orientations for each part. The shaft and clip will require supports. According to the slicer, the total mass of these parts is 68.2 g which will allow for multiple iterations to be printed while remaining under the 200 g filament limit.

Testing the magazine, continued

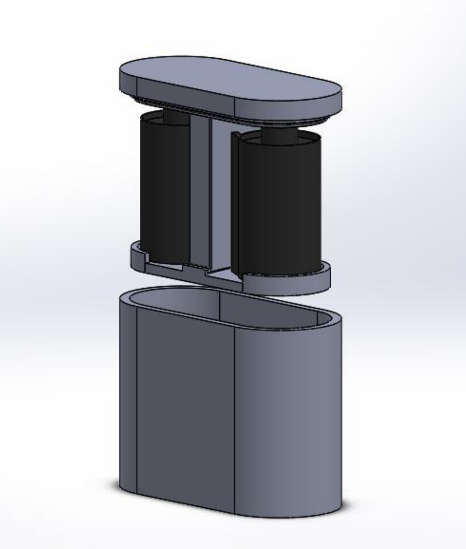
I used the SolidWorks Simulation feature to test the clip on the back of the magazine. In its resting state, the gap between the body of the clip and the tip is 1.00 mm, which is half the thickness of my camera strap (2.00 mm). Setting the back of the clip as a Fixture and implementing a displacement load of 1.00 mm to the base of the clip, I ran the simulation that can be seen on the right. Doing some research on von Mises stress, I found that the maximum yield strength of ABS plastic is 5.1e7 Pa, which is far greater than the maximum von Mises stress the clip experiences of 7.667e6 Pa according to the simulation. Therefore, it is indeed possible for the clip to be stretch by 1.00 mm to be attached to a camera strap without it breaking. One thing to consider is that I used ABS as the material to conduct the simulation since SolidWorks does not have a PLA material model. After some research, I found that ABS plastic can handle a bit more stress than PLA plastic. However, I believe it is safe to assume that the PLA would also survive this stress test because the loads being experienced here are far less than the maximum potential. Additionally, I would set the infill for the clip part to 100% in order to maximize structural rigidity.



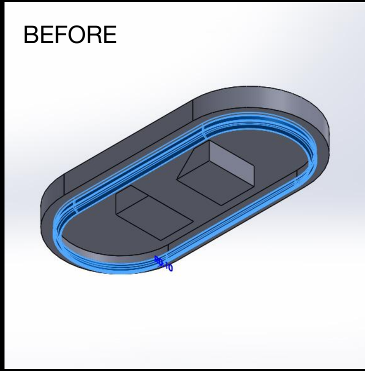

Testing the magazine, continued

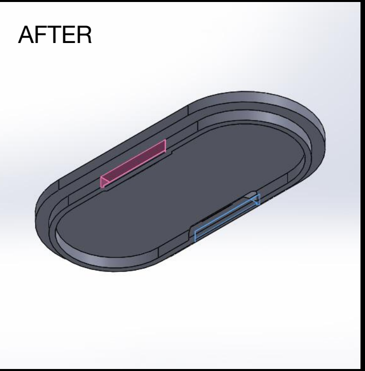
| | |
|---|---|
| Design Constraints | (1) Stores two rolls of 35mm film (**demand**) - **NOT ACHIEVED**<br>(2) No detaching parts (e.g. lids) (**demand**) - **ACHIEVED**<br>(3) Minimal form factor (< 4’ x 2’ x 3’) (**demand**) - **ACHIEVED**<br>(4) Wearable (i.e. attaches to camera strap, belt loop, etc.) (**wish**) - **ACHIEVED**<br><br>*PROVIDED DESIGN CONSTRAINTS (all **demand**)*<br>*Can be held in one hand comfortably - **ACHIEVED***<br>*Contained within a 12” x 12” x 12” cube - **ACHIEVED***<br>*Three to seven 3D printed parts - **ACHIEVED***<br>*Each part contained within a 5” x 5” x 5” cube - **ACHIEVED***<br>*Parts use PLA filament - **ACHIEVED***<br>*Total filament under 200 grams - **ACHIEVED***<br>*Parts combine without tape, glue, etc. - **ACHIEVED***<br>*Interacts with a non-3D printed object - **ACHIEVED***<br>*Does not draw structural integrity from non-3D printed object - **ACHIEVED*** |
| Functional Requirements | (1) Can be opened with one hand (**demand**) - **UNABLE TO TEST**<br>(2) Aesthetically pleasing (**preferred**) - **ACHIEVED** |

To recap, the magazine achieves all design constraints and functional requirements, except for being able to store two rolls of 35mm film. This, of course, is the most important design constraint and will need to be revised. Additionally, functional requirement (1) cannot be tested without a physical model.



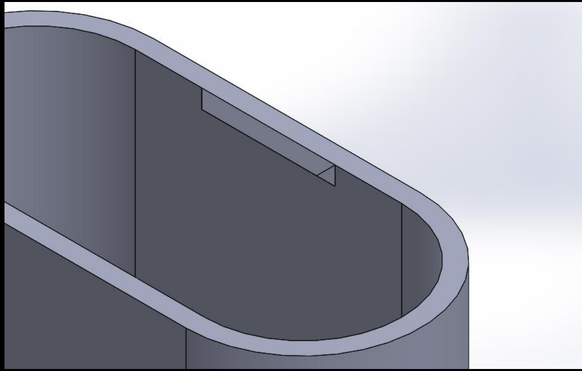
Testing the magazine, continued

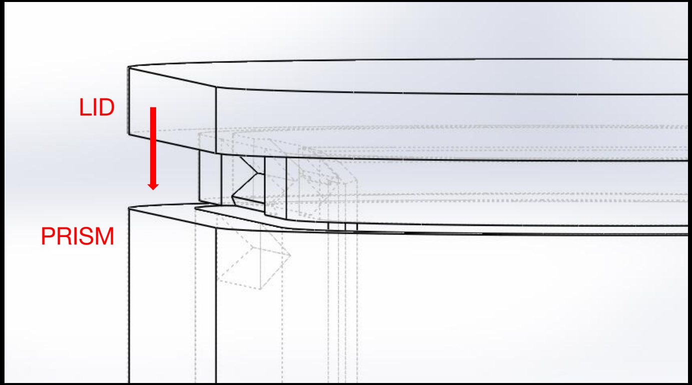


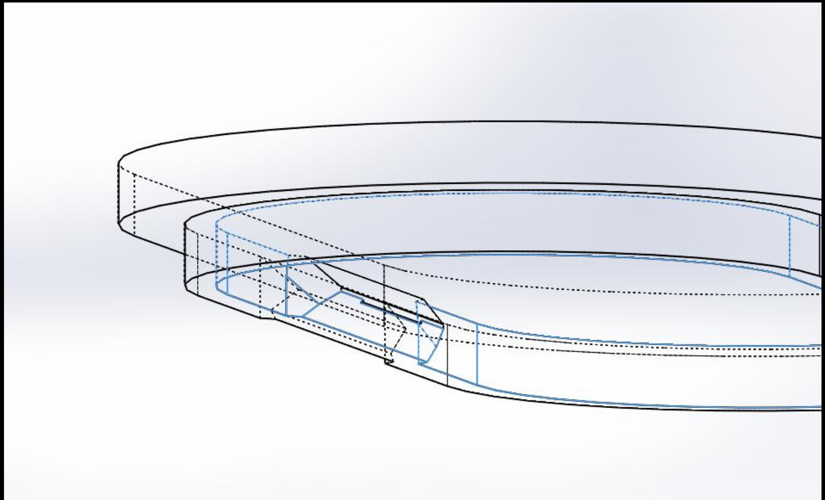

The new snap-fit uses a simple rectangular Cut Extrude with a 45° inward draft.

The opposite Boss Extrude on the prism is offset to provide a clearance of 0.20 mm for a friction fit.

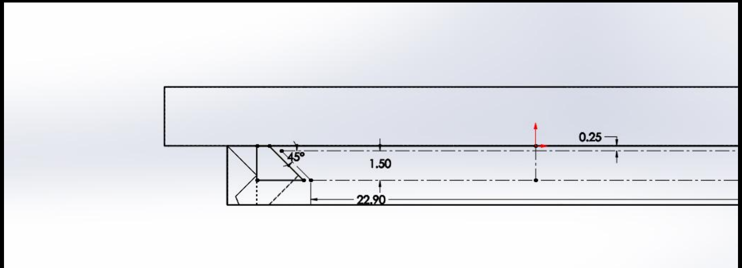


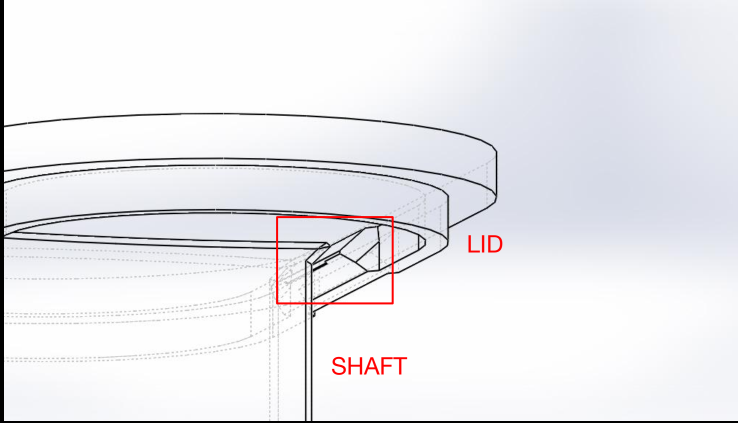



One thing I wanted to revise from the first iteration of the annular joint on the lid and prism. It seemed rather intricate and flimsy. So I followed this tutorial for a simpler snap-fit joint that seems rather successful given the comments below the video.



The new snap-fit mechanism utilizes a 1.5 mm shell, which results in a triangular extrusion facing the inside of the lid.

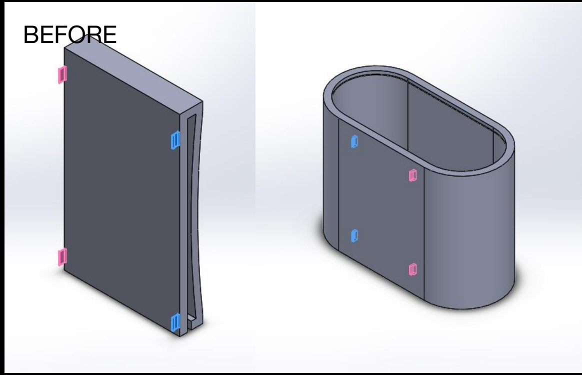


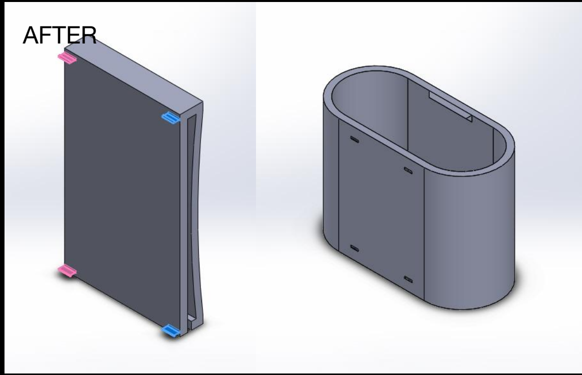

Realizing that I could use this extrusion as the female dovetail joint to attach the lid and shaft, I updated the dimensions of the shaft to fit. The new dimensions are pictured on the top image, where the construction lines represent the top of the shaft.

I moved the dovetail joint that connects the lid and the shaft to the inward extrusion created by the lid's shell. This provided the clearance necessary to insert and remove a roll of film, achieving design constraint (1).

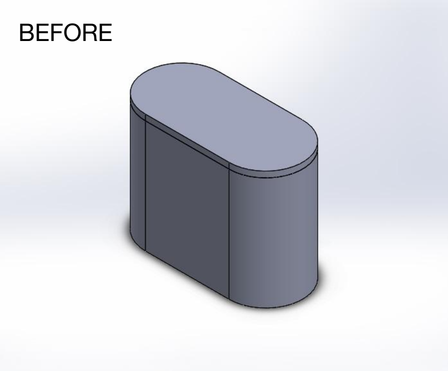
Final touches, continued



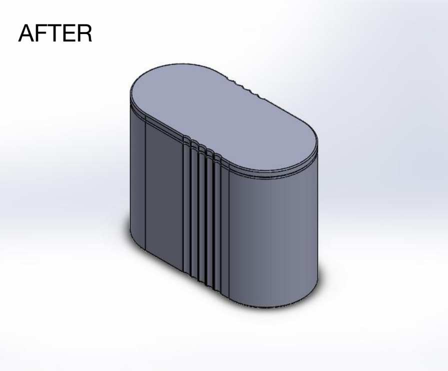

Rotated the cantilever beams on the clip to be horizontal and did the same with the corresponding cutouts on the prism. This will strengthen the beams because the layers will now be perpendicular to the direction of flex when printed.



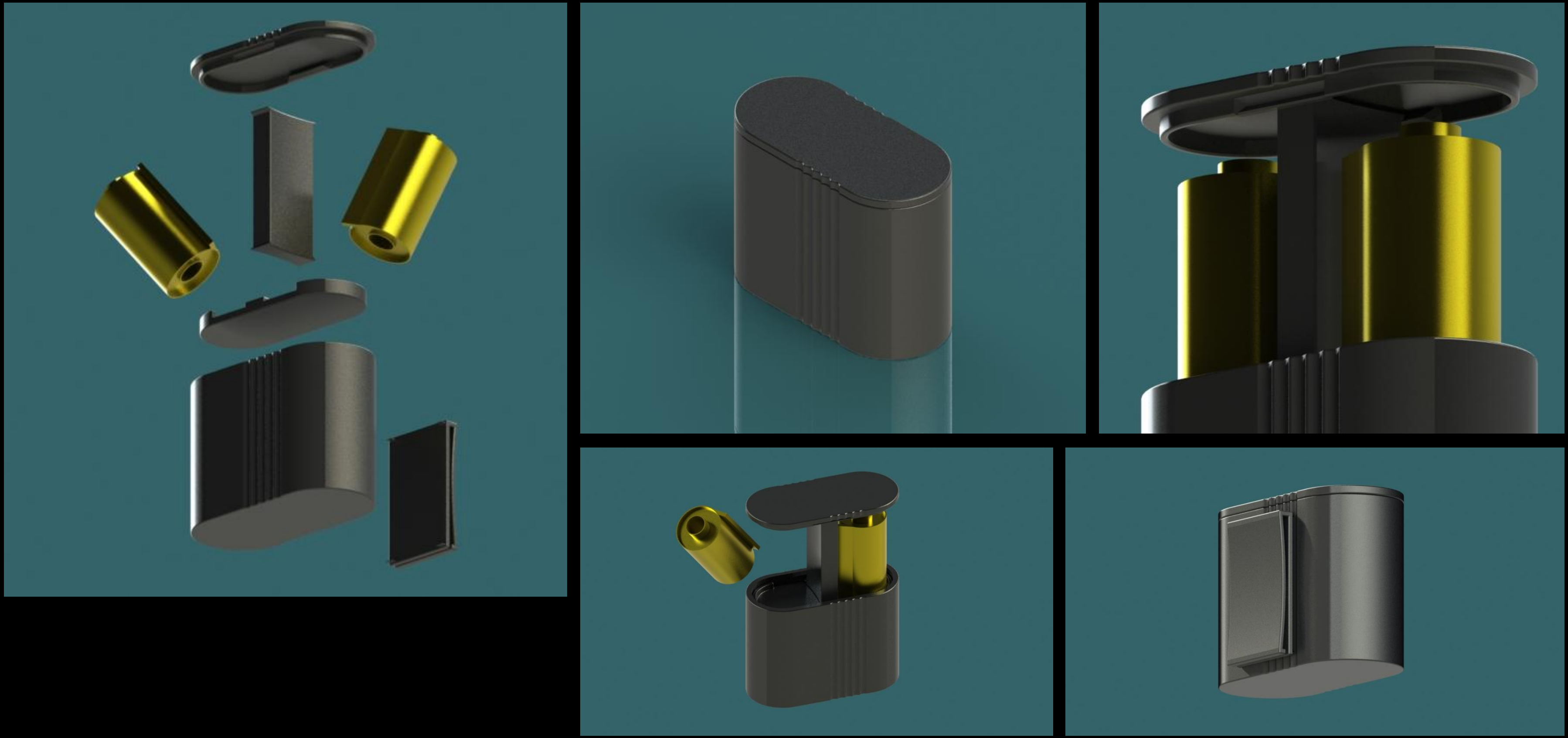

I refined a few other minor details to aid with the aesthetics, functionality, and strength of the magazine. After this, all of the design constraints and functional requirements have been achieved.




Finally, I added a series of grips to the front of back of the lid and prism using a linear pattern of circular Cut Extrudes. I also added 0.50 mm fillets to most of the edges of all of the parts to round off the magazine, making it more comfortable to hold.




Final touches, continued



Some renders to help visualize the final product.

Overall, I believe I successfully implemented the magazine design in CAD. The final model is very similar to what I had envisioned through brainstorming in my head and in my sketches. One aspect I found to be difficult through the process was dimensioning all of the pieces so they would properly fit together. I definitely want to do more research about adding various dimensional relationships between parts within an assembly. Excited to start fabricating the magazine with some physical prints.

Final thoughts | 11.14.2020