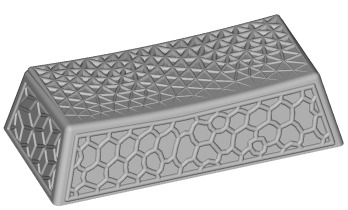
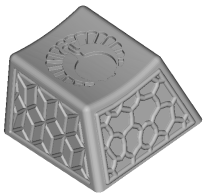
Group 8 Design Project Prototype Product

Product Choices

We have decided to proceed with customized keycaps as our primary product and keep topologically structured drone bodies as our secondary product. Keycaps are used on keyboards specifically for mechanical keyboards as the interaction between the user's fingers and inputting commands to a computer. By 3D printing the keycaps, it allows for customization of the individual keycaps as some people prefer a specific texture for key or graphic in place of simple letters. One idea of a custom keycap that the group had is our thanksgiving keycap that is shown in the figure below:





Figures 1 and 2: Textured Shift Bar (Left) and *Thanksgiving Keycap (Right)*

The secondary product that the group decided would be a good alternative product is a topology optimized drone frame. Feedback that was given on a prior project proposal was to specify a specific drone frame that can be optimized. The team identified the DJI Phantom 4 Pro drone in order to base the product on given it is relatively bulky compared to other drones of the same type and vastly popular among enthusiasts. An example of a topology optimized drone that was designed by a different individual but is of the same vein of idea that this group may choose to propose is figured to the right:

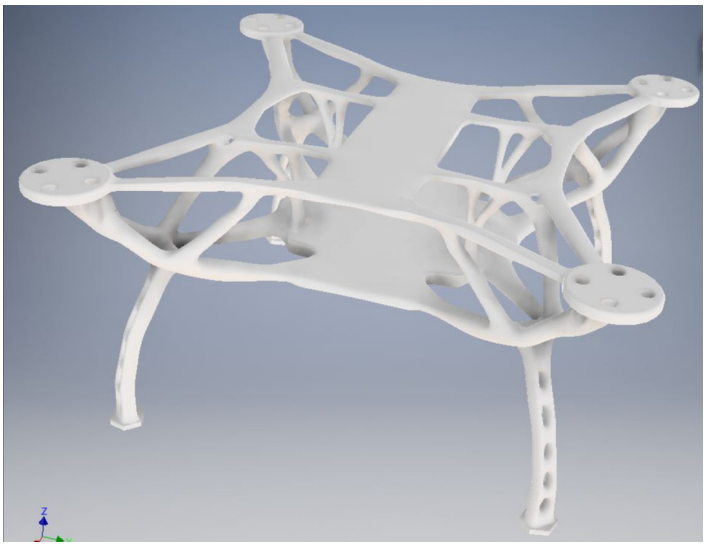


Figure 3: Topology optimized drone [1]

Market Analysis #1

On Pinshape, the listed *Thanksgiving Turkey* and *Christmas Tree* keycaps received a total of 3 likes and 73 views. Other keycaps exist on the site with view counts on the order of 1000 to 5000 views with a similarly small amount of likes, on the order of 1 to 5 likes. There appears to be a limited selection of keycaps available on Pinshape, about 60 premade variations.

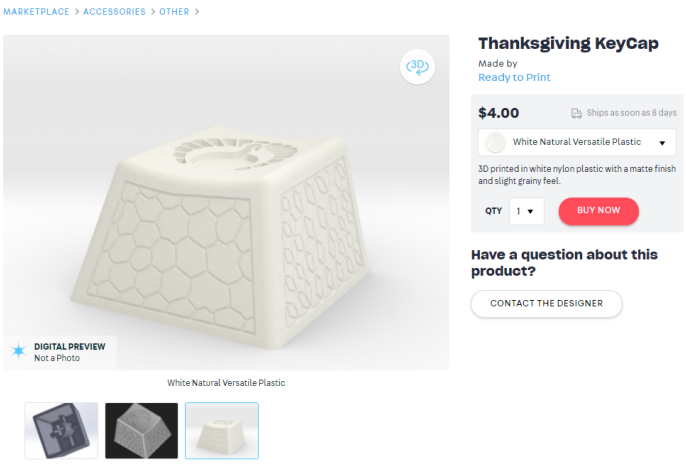
On thingiverse our *Thanksgiving Turkey* and *Christmas Tree* keycaps received a total of 1 download. Thingiverse has a much broader selection of keycaps, roughly 80 pages however there are many duplicate/blank keycaps. The most popular keycaps get roughly 3800 likes with 20 makes. Most keycaps get very few likes and makes. Most other keycaps are between $0-4.

Our keycaps performed well on Pinshape given the short amount of time to gather data but performed poorly on thingiverse. We believe that there is interest for such a design as the most popular products on thingiverse are also roughly on the same scale of likes/makes. The overall popularity of keycaps seems high but since there are so many variations most of them get lost on later pages of the search. In order to stand out from the other options in this market, the keycap that is delivered will need to be of superior quality as our customers would be paying a premium for this luxury good. Since our product design revolves around user customized and personalized keycaps, customers would seek out our product since it would be tailored to their desires. Most user comments on other keycaps mentioned issues with downloading so an accessible user interface is likely important to the final product.

Market Analysis #2

The cost estimate from shapeways for a textured keycap of regular size was $4.00 for the white plastic and significantly more for other colors. An optimistic estimate would reduce the price down to around $2.00 for bulk order yet this is still multiples times over the current market rate of $0.50 for the simplest doubleshot keycap. As a

Figure 4: Thanksgiving KeyCap on Shapeways



result, Shapeways and other third party manufacturers do not seem like a cost effective solution to production as it would leave very little profit margin even if our keycap was sold at a significant premium. Furthermore, this is one of the simpler keycaps and it is quite likely that the Shapeways` quote would increase for more complex designs. The quote for *Thanksgiving Keycap* is provided here, however a screenshot of the webpage is included above due to possible issues of the page not appearing.

Market Analysis #3

Custom keycaps on the market range in quality and price with their functions in practicality or luxury. Double shot models are created with practicality in mind where two layers of ABS or PBT polymers are used to increase durability and prevent legend fading. This adds a bit more complexity to the injection molding process and thus varies in price from under $0.50 to over $1.00 per keycap. On the other end, luxury keycaps such as those from Jelly Key sell handcrafted artisan keycaps with intricate details ranging from $50 to over $100 per keycap.

Figure 5: Artisan keycap from Jelly Key (left), Double Shot keycap (right)

Our 3D printed keycap would serve customers searching for a medium to high end luxury product with a more palatable price. The SLA process of the Form2 printer is able to capture the intricate shapes embedded in artisan keycaps, however it underperforms in the area of color detail which is often done by hand. The automation of this process would allow for a higher throughput than handcrafting while capturing a significant amount of intricacy of artisan keycaps allowing for a wide range of enter the market at.

Printed Primary Product

The keycaps were printed with several different processes (FDM, SLA), support configurations, and postprocessing methods to measure the quality and duration of each. The

first keycap was printed with both the Form2 and Dremel printers with neither being able to fit in the switches of the keyboard. The dimensions of the keycap and its connection to the switch were accurate; however, the shrinkage from curing the Form2 print and the irremovable supports of the Dremel print prevented the keycap from fitting properly.

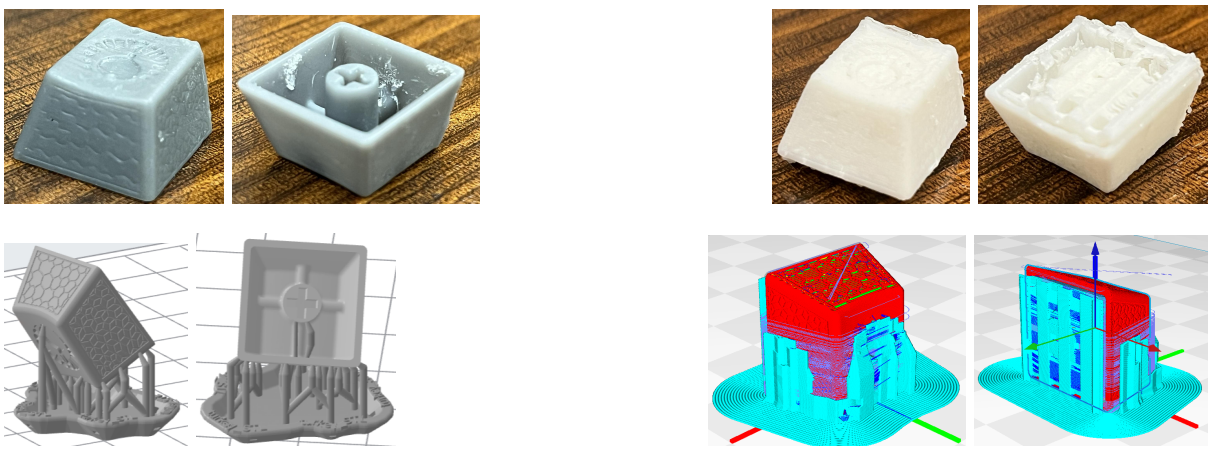


Figure 6: Form2 gray (left) and Dremel white (right) prints with their respective supports below. The Form2 SLA print captured far more detail than the Dremel FDM print.

The next couple of prints were more successful as the FDM print done with the Creality 5 Plus was done without supports and the Form2 print was done with clear resin and minimal supports as well. For these, the prints were successfully detailed and connected well with the switches on the keyboard.

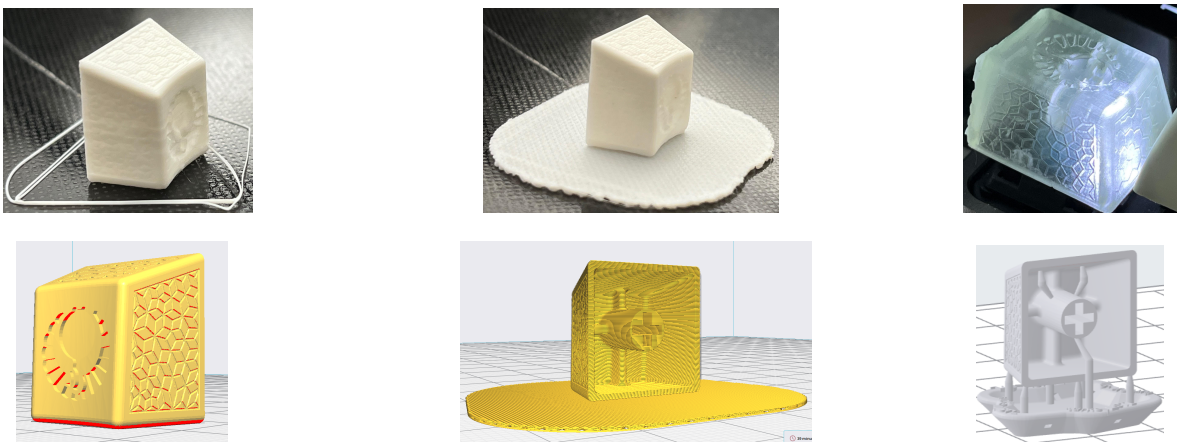


Figure 7: Creality Ender 5 Plus white (left and middle) and Form2 clear (right) with their respective supports. The Form2 SLA print still captures more details however Creality Ender 5 Plus FDM print details were not too bad either with both skirt and raft adhesion.

The last set of keycaps were for the caps lock and shift and printed using the Form2 printer with varying supports and curing. The first print attempt utilized the minimum amount of supports and failed leading the subsequent prints to incorporate more supports. The latter prints were successful however the UV curing process significantly warped the keycap leading to one final print to skip the curing process. The last set of keycaps were treated with the alcohol bath process and simply air dried, leading to dimensions that were within specification.This is possibly due to the fact that the supports were removed before UV curing as suggested by TechSpark and will be investigated in future prints. One common issue that was encountered was the excess resin that collected above the keycap which later solidified adding to a slight bulge at the top of the keycap. This excess can be scraped off however results in scratches at the top and additional printing angles will be explored in future prints to resolve this issue.

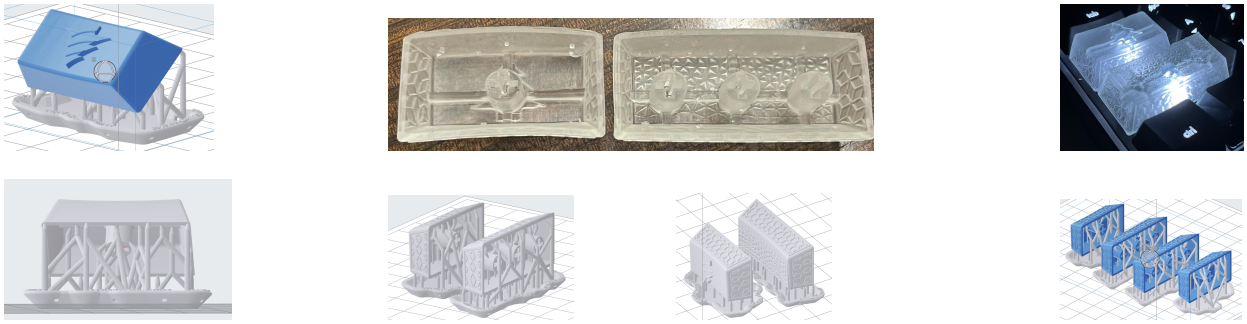


Figure 8: Failed print (left), warped print from curing (middle), and uncured print (right)

The Form2 printer is capable of producing high quality keycaps with fine details however the challenge lies in tuning supports, orientation, and postprocessing steps to obtain consistent results. Some notable issues included warping from the curing process and print failures due to lack of adequate supports. These challenges were later resolved with some tuning and the next step would be to scale up this process to print with larger batches with reliably consistent results.

Analysis Summary, Next Steps

One of the challenges for this product is to produce the print such that it fits within the small tolerances of a keycap. Over the course of several iterations, most of the issues encountered during the printing and post processing stages were ironed out leading to consistent print qualities. One specific challenge the team faced on this front was through cure of excess resin when printing with SLA printers. Through cure occurred because resin was not properly draining out of areas of high tolerance requirements such as the keyboard mating interface and causing geometric distortion which clogged the mating feature from functioning properly. The team will try different printing angles for the part so that the curing process does not negatively affect the final part this way in the future. Through cure also negatively affected the print by causing bending in the parts, specifically the longer keycaps such as the shift and it is believed the space bar will give the same problems at a higher magnitude. The group will adjust the curing parameters via the power and velocity of the laser to limit the bending of the parts in the final product.

Another area of improvement would be to better understand the features within the luxury keycap market that drive appeal in order to foster greater interest in this product. That way the keycap designs can be improved with these properties in mind so that our product can best serve this niche. In the initial proposal, the idea was to include a web interface that would allow for people to upload an image that would be converted to a modifier to the group's existing stl file and allow for the keycap to be specific to the user. This interface would not work well with shapeways and needs to be hashed out in the final portion of the project.

For the final design the intricacy and scalability of producing these keycaps will be explored. This includes testing out more intricate designs that better utilize the unused space within specific keycaps such as the spacebar. Optimization of the printing process will be further explored to determine the limitations of batch printing and implementing small changes to improve quality. Additionally, fixes to issues within the post processing UV curing step will be investigated to prevent warping and yellowing of the final product.

Resources:

[1] https://grabcad.com/library/nature-quadcopter-drone-frame-generative-design-1