



IMPROVING VIDEO GAME CONTROLLERS

DESIGN PROCESS JOURNAL
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BACKGROUND



Video games are a worldwide phenomenon. There are over 31 million gamers in the UK, and in 2019, the industry reached a total market value of £152.1 billion. Gaming is a cornerstone of culture, offering a form of entertainment for everyone, regardless of age, gender or race.

Before I focused on accessibility, the project started with a look into controller customization and modularity, after I experienced some frustration with repairing my own controller. Improving a users relationship with their controller could lead to a reduction in e-waste and encourage other electronics industries to take a more user-friendly approach to repairs.

After the first few weeks of the project had passed, it became clear that the problems I was trying to solve were not the most critical. As my research continued, issues with accessibility became more and more pronounced. With the input layout of standard gamepads hardly changing over 20 years, this means that issues with accessibilities are still present for gamers unable to make full use of all inputs.



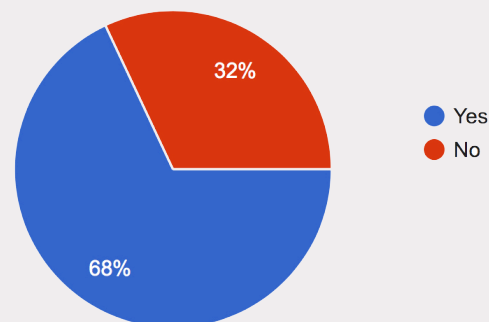
Early Timeline

I first took a look into current gamepads and their level of customization and repairability.

Key Findings: Identical layouts, no modularity, customization mostly reliant on third-party components, broad range of difficulty in repairs.



Would you be interested in a modular controller, with customizable components?



Interviewed 25 users gamers to understand their habits.

Key Findings: Positive response to modularity. Mixed response in repairing own hardware.

Video game controllers, also known as “gamepads” feature roughly the same layout as seen here.

Re-evaluated the repair process of a DualShock 4 (the gamepad for a PS4).



Key Findings: Tedious, but not as bad as my first time. Doable by most people of any skill level.

I interviewed three users, each that played on a different console to understand what they liked and disliked about their controllers.

Key Findings: Modularity would be interesting, but more interested in button remapping through software. No real issues with functionality, but wouldn't hesitate to buy a new controller instead of repairing. The cost is worth the time spent using the product.



Discovered an existing controller called the eSwap Pro that allows users to swap some modules with ease.

Key Findings: I was initially disappointed in the discovery of an existing product, but the eSwap Pro validated the demand for premium and modularity gamepads. While there are some definite improvements to be made, there was not enough to justify my entire project around it.



USERS & INSIGHTS

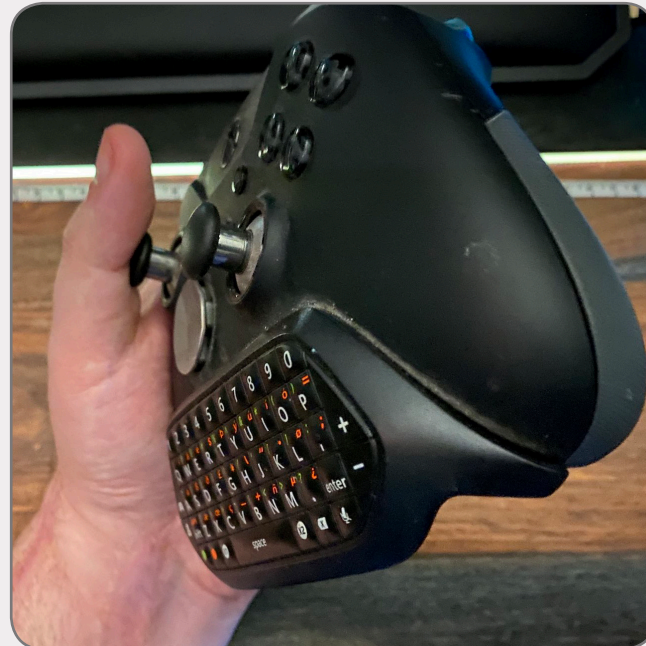
Due to the COVID-19 pandemic, I was unable to interview potential users in person. However, I reached out to an online forum for disabled gamers and interviewed three individuals with varying disabilities. We spoke about what hardware and software solutions they have tried, what kinds of games they played, and what they would like to see in an “ideal” controller. Each user coincidentally used the Xbox Elite Controller, a premium gamepad marketed towards a hardcore gamer user base. Retailing at approximately 3x the price of a standard controller, it features some adjustable inputs, 4 additional digital inputs on the rear, and the ability to remap any button through software. Though it is not the perfect solution for each user, it is the most consistent. The biggest drawback is that it still retains the exact same shape as a regular Xbox One controller. Remapping controls is great, but has its limits when not all inputs can be reached. Each user was consulted with several times throughout the project.

User Overview



USER #1

Suffered from a stroke and is unable to use their left hand. They often played with the controller rested against a surface.



USER #2

Experiences muscle tremors and has difficulties holding a regular controller and sensing button presses. Also used a variety of software solutions to get other peripherals to work on different platforms, some of which were finicky.



USER #3

Has cerebral palsy, and is unable to fully use their right hand. Can confidently use right hand to control either the face buttons, OR the shoulder buttons.

User Requirements

It can be difficult to list strict design requirements for a product that accommodates varying levels of accessibility, as two users with the same condition can have completely different levels of ability. However, I still wanted to have a guideline to follow when designing a solution:

1. The final product should be able to adapt for different users.
2. The final product should take the form of a standard controller.
3. At a minimum, the main inputs of a standard controller should be accessible.
4. Assembly and modification of the final product should be possible with one hand.

Xbox Adaptive Controller

Users #1 and #3 had tried to use the Xbox Adaptive Controller, a video game controller targeted at users with disabilities. It allows users to plug in their own input devices. Neither felt that their mobility was limited enough to take full advantage of its features.

In addition, modules can get expensive. While the Elite Controller is not a cheap controller in itself (£150), a single button for the Adaptive controller can cost upwards of £50.



Key Findings

There exists a need to adapt a standard gamepad for a user with a disability. The Adaptive controller shows the need to reach a wider audience, however the Elite controller shows the desired form factor.

INITIAL CONCEPT GENERATION

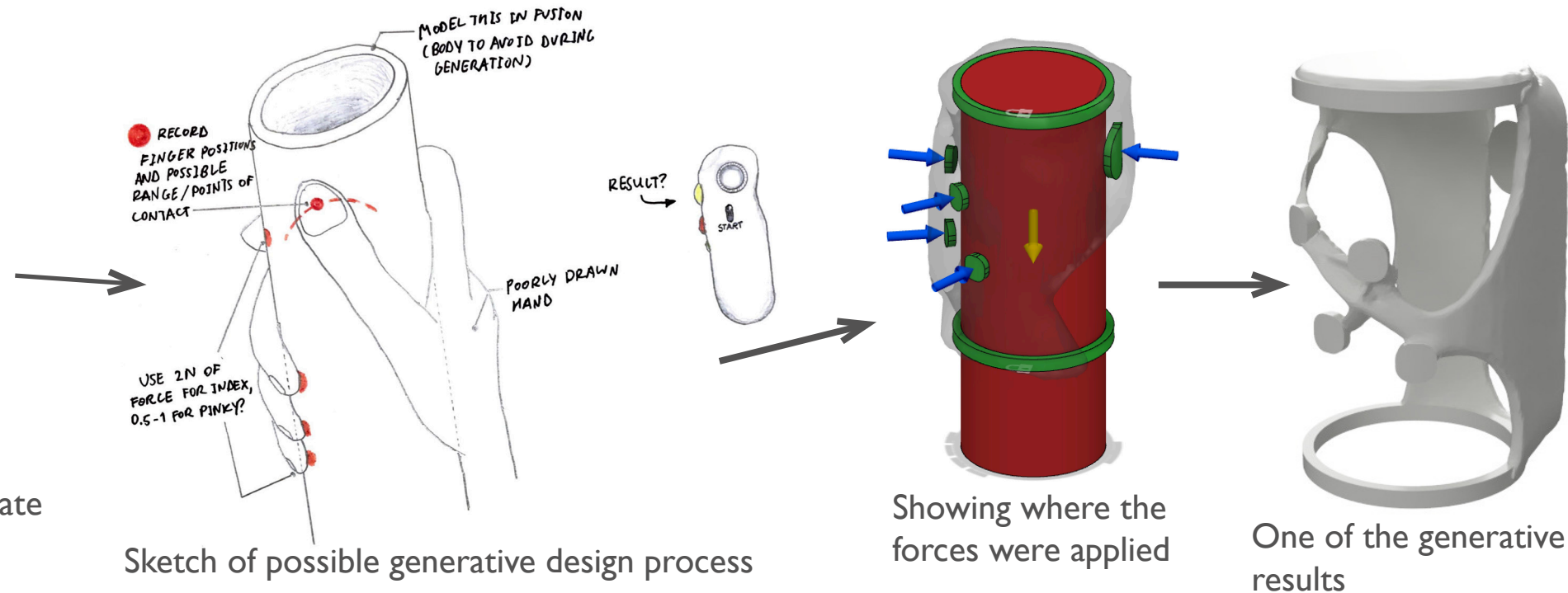


Before I settled on a modular design, I initially started thinking about bespoke solutions, to see if there was a way to rapidly design a controller that not only used the same internal components as a regular controller, but offered a completely new shape for the user to hold. All three users shared images of preferred hand positions when holding a controller. I considered the use of generative design to see if it was possible to come. However, it was obvious that each controller would require custom electronics that would make it really difficult to adapt existing controllers to.

Generative Design



User #2 using a can to demonstrate comfortable hand position



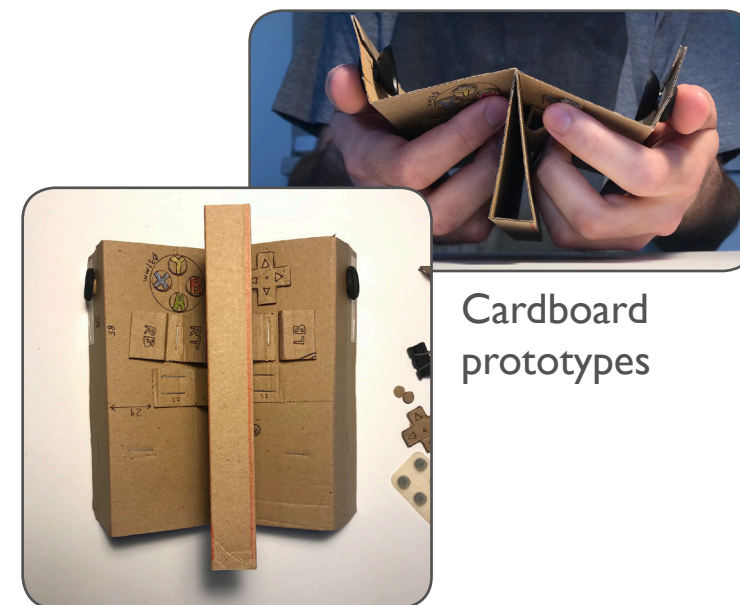
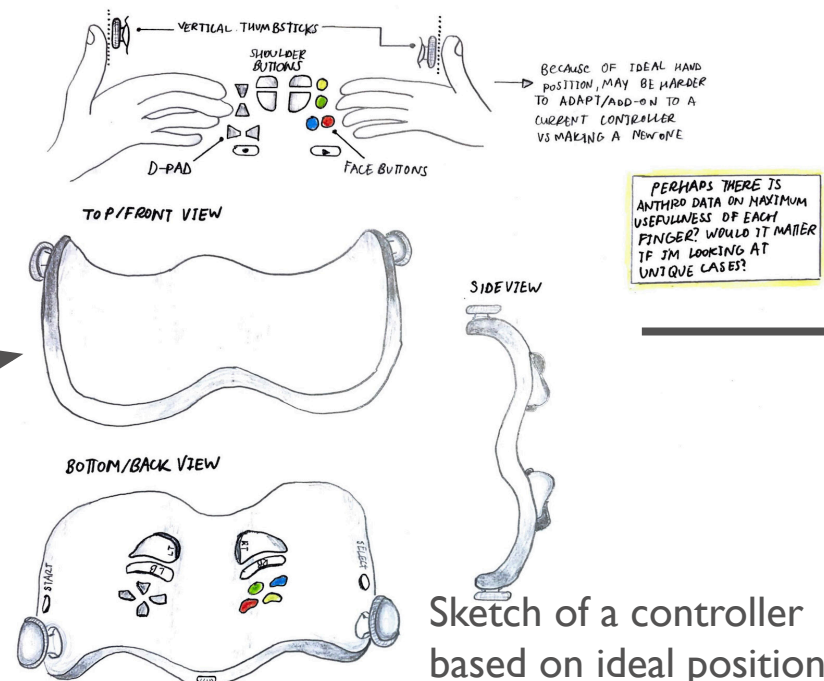
Conclusion:

User #2 was unique because their ideal controller would either be two separate pieces (like the Joy-cons) or something completely bespoke. The generative design software was also difficult to use and not entirely applicable.

Bespoke Design



User #2 showing an ideal hand position. I started to approach this design after the results from generative design weren't entirely helpful.



Conclusion:

This was a step in the right direction based on the feedback from User #2. In addition, these first physical prototypes served as a good exercise in prototyping from home with available materials.

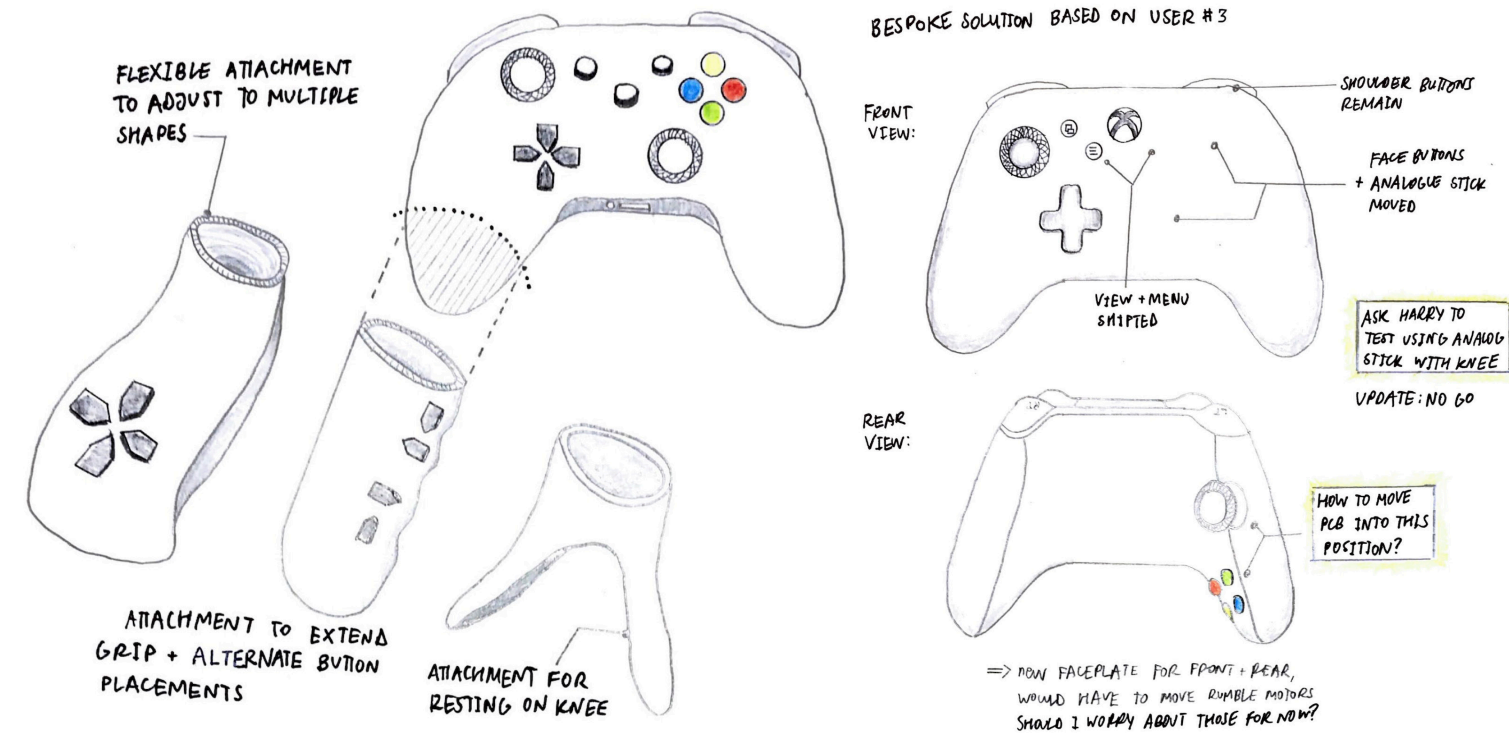
CONCEPT DEVELOPMENT

At this point I turned my attention to Users #1 and #3, and focused on how I can adapt existing controllers to fit their needs. I also used this as an opportunity to re-visit my initial idea of a modular controller. For both users, it was clear that the issue was reaching existing inputs. No matter how much they remapped the buttons through software, they were still unable to have access to the same amount of inputs that an able user would. I asked myself, is it possible to move these inputs around?

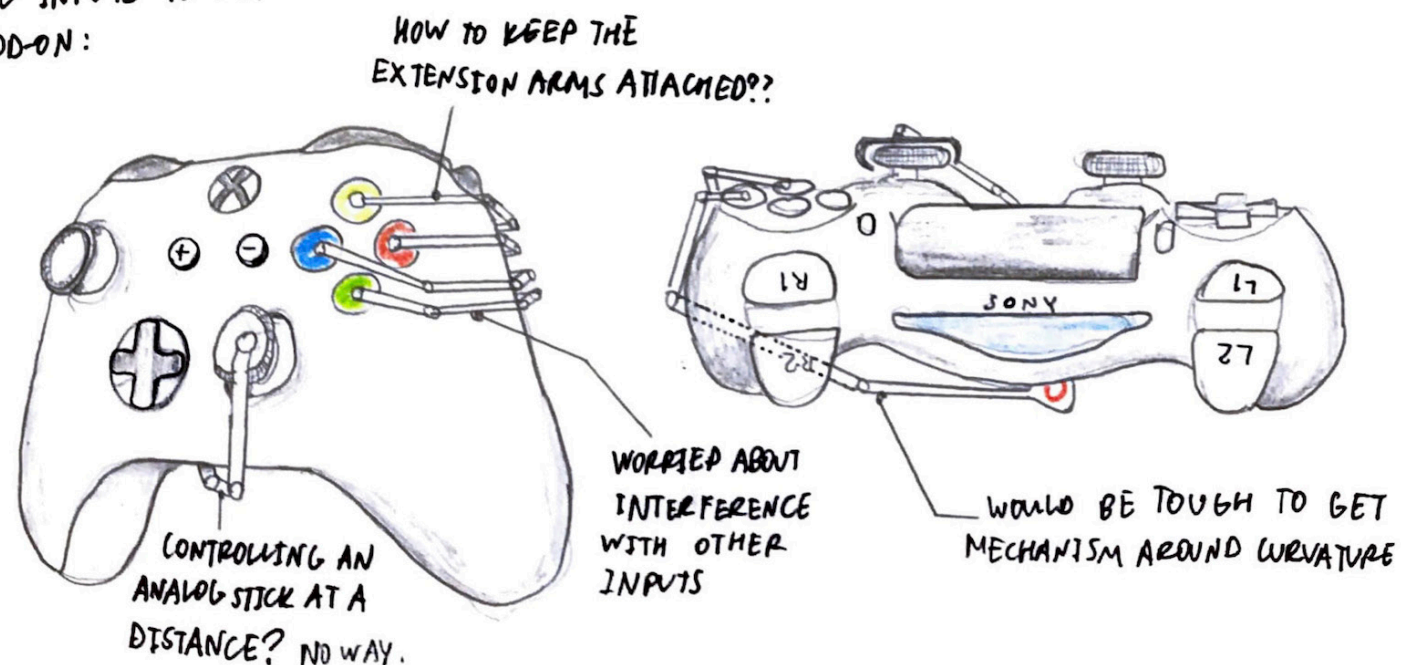
Defining the Design Direction

First I considered attachments for existing controllers. Perhaps they could extend the reach of the handles, or provide a proper resting surface so that users can hold them in a different way. Selling add-ons would be a much more enticing approach financially as well. My technical supervisor had also suggested some kind of mechanism that serves as an extension of the inputs so that they may be accessed on the reverse. Neither of these solutions were chosen for two reasons:

1. Current controllers all have static components on the PCB such as soldered connections and touch sensors. Using some kind of add-on would require significant expansion in current gamepad circuitry, overcrowding an already small internal volume.
2. For a mechanism that fits over top of the controller, it would be too mechanically complex, cumbersome and may get in the way of other inputs.



MOVING INPUTS TO REAR VIA ADD-ON:



User #1 said they always used their controller while it was resting against something. This led me to sketch an add-on that offered more stability.

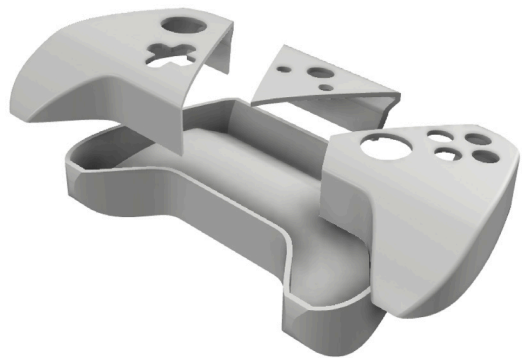


User #3 shared a 3D printed frame for their Joy-Cons (a separable controller used for the Nintendo Switch) that allows them to access all inputs with one hand. This led me to try and think of a similar approach for their Xbox controller.

Continuing with the idea of modularity, the next step was to figure out the easiest way to take the controller apart so that a user may adjust the physical layout. I reflected on my experience repairing my own controller. It can be a tough challenge to separate both halves of the plastic controller shell, even with two hands and proper plastic prying tools. And once you have access to the inside, you now have to deal with everything that is (or isn't) soldered to the main PCB. I concluded that there were two important design challenges to focus on for my project: the plastic controller shell, and the PCB.

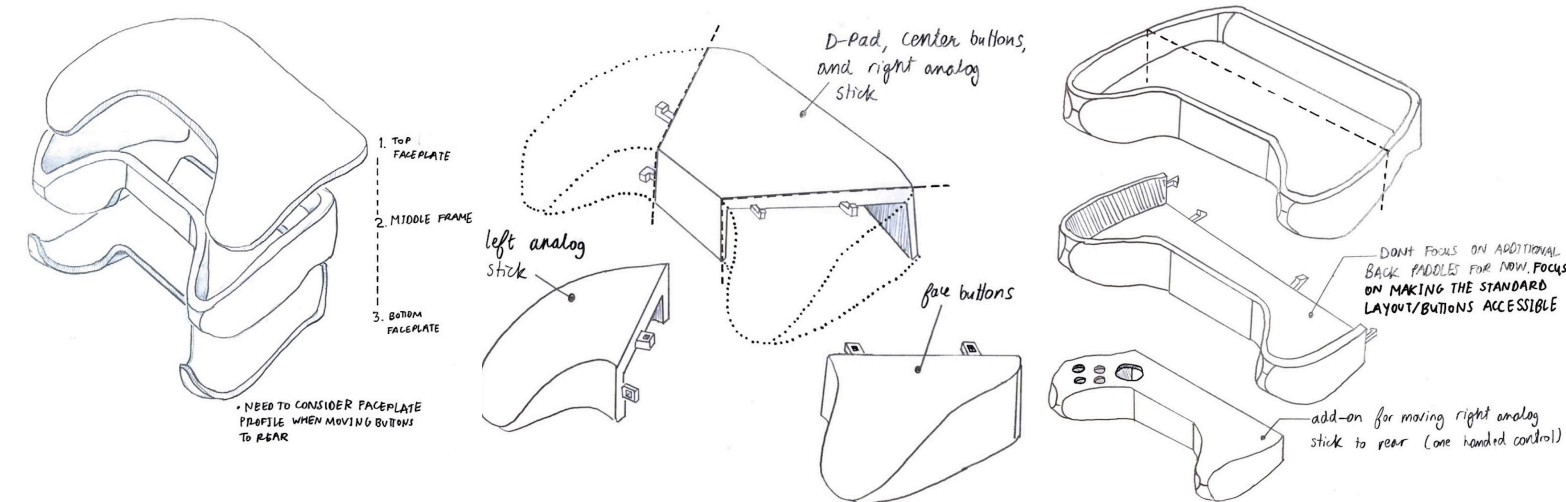
Plastic Shell

I considered two ways to secure the controller. The first would have involved some kind of plastic clip mechanism akin to what is already being used. I did not want to pursue this option because as previously mentioned, it can be quite difficult to pry apart, and would not be suitable to my one-handed assembly requirement..



Instead, I opted to use a magnetic connection. When holding a regular video game controller, it is in a state of compression. This, along with the contoured profile, I wasn't concerned about the faceplates falling off during gameplay.

Regarding the faceplates themselves, I initially thought about splitting up each face into smaller sections. The idea behind this was that if a user only needed to move the components on the right side of the controller (such as User #3), then they could just replace that part of it, instead of the whole faceplate itself. However, this would increase the amount of components in the gamepad, leading to an increase in cost and design complexity, and a likely decrease in stability.



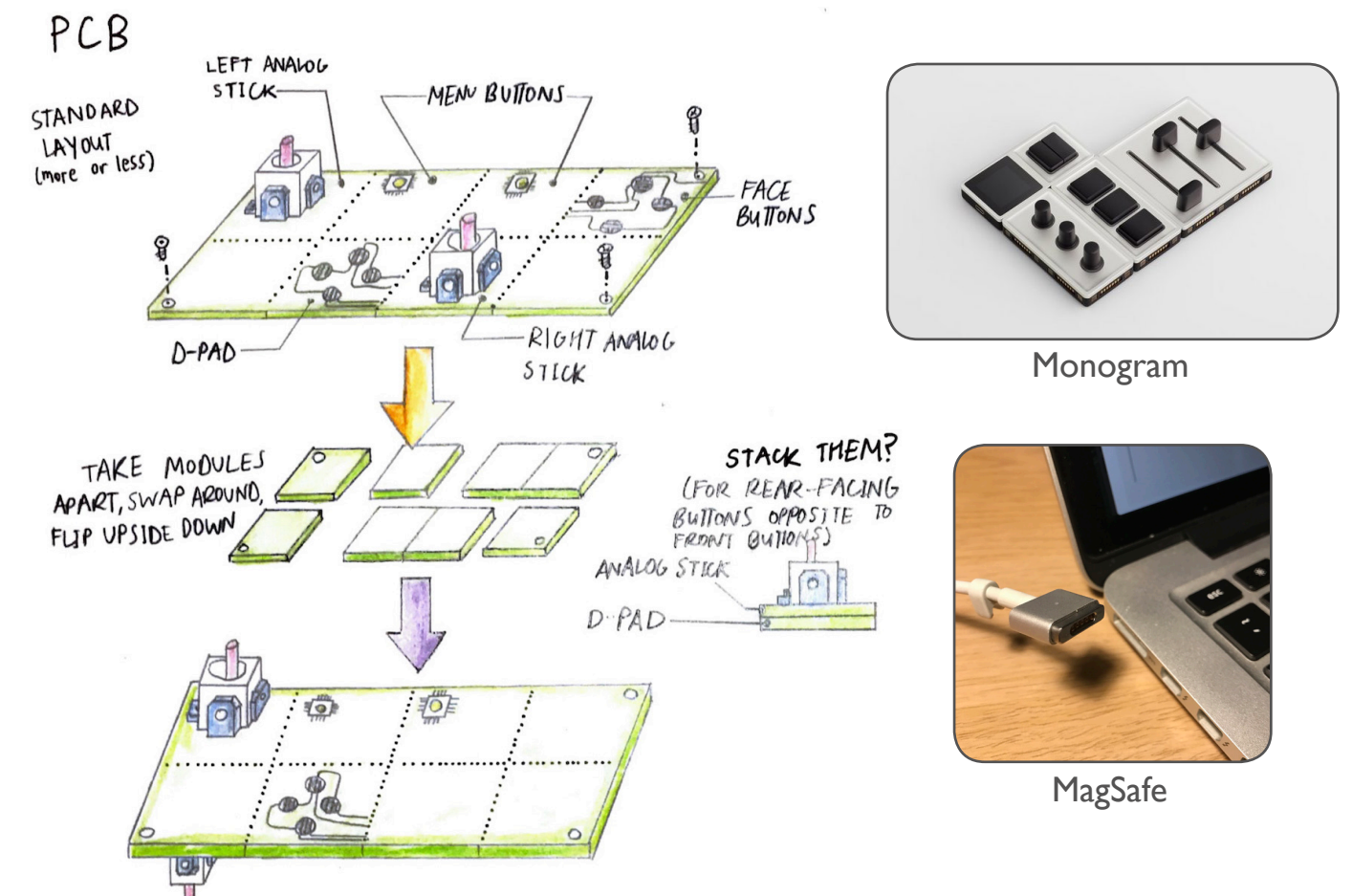
I settled on a 3-piece design. A top and bottom faceplate and a middle frame to act as a right spine to secure the PCB and other components. With this, a user could simply purchase a new faceplate that has their desired input layout.

PCB

Current gamepads have a variety of internal designs. For example, the DualShock 4 features both a flexible PCB and a regular PCB that connect with conductive contact pads. The Xbox One controller has two separate motherboards, along with various components that rest on different planes. Making these designs modular would be very challenging.

In addition, it is not possible to remove many of the components on a controller without the use of a soldering iron. Analogue sticks and some buttons are soldered to the PCB, whereas other buttons use silicone rubber pad to transmit inputs directly to the PCB.

I thought about making the PCB modular as illustrated below. This would allow the user to re-use the components of a controller without a laborious disassembly process. I was inspired by the MagSafe connector seen on previous MacBook Pros, as well as Monogram, a modular workstation with analog and digital inputs. Both products use pogo pins and magnetic connections to transmit data and power.



Cardboard

Before ordering a 3D printed model online, I made one out of cardboard to get a feel of where my design was currently at. I had ordered some magnets, but had underestimated their size. (they were 2 mm in diameter and 0.5 mm in thickness, half the size of the magnets used in the final product). While I was waiting for magnets to be delivered, I tried to use a sliding mechanism to fit the pieces together. It worked surprisingly well given the thickness of the material, however it stole a lot of volume from the internal components. It was extremely difficult to fit a **PCB** and the inputs with the room available.

The feedback gained from the cardboard prototype was extremely valuable. In the end I learned that I had a fair amount of space to work with on the inside after comparing the prototype with my Xbox and PlayStation controllers. More importantly, the ease at which the layout could change gave me confidence in the direction i was heading with the design.



3D Printed

Taking what I learned from the cardboard model, I then adjusted my 3D model in CAD. I shrunk down the size of the controller and was able to add a slight curve to the handles for comfort. Similar to the cardboard prototype, I printed a second set of faceplates based off of User #3's preferred hand position.

Ultimately the the 3D model was smaller and more comfortable. After assembling it with some mock components, I once again adjusted my 3D model in CAD as I inched closer towards a final design, namely to accomodate for all of the internal components, and ensuring they have enough room if they are moved around.

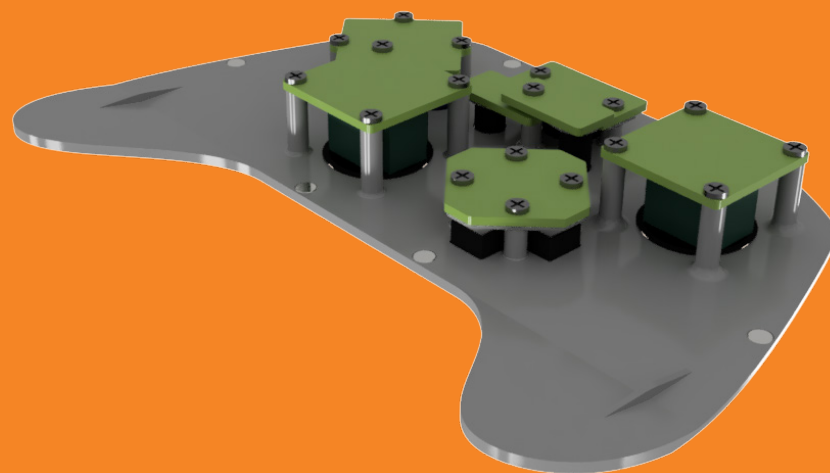
In order to test the force required to remove the faceplate, I tied a string to the cover with an plastic cup (negligible weight) on the other end. Using a measuring cups, I slowly filled the plastic cup until the faceplate came off. The static pull force required was approximately 2.5 N, which is a reasonable force to overcome. The Measure of Man and Woman, (Dreyfuss, 1993) lists small switches of having maximum 4.5 N of resistance in their design.



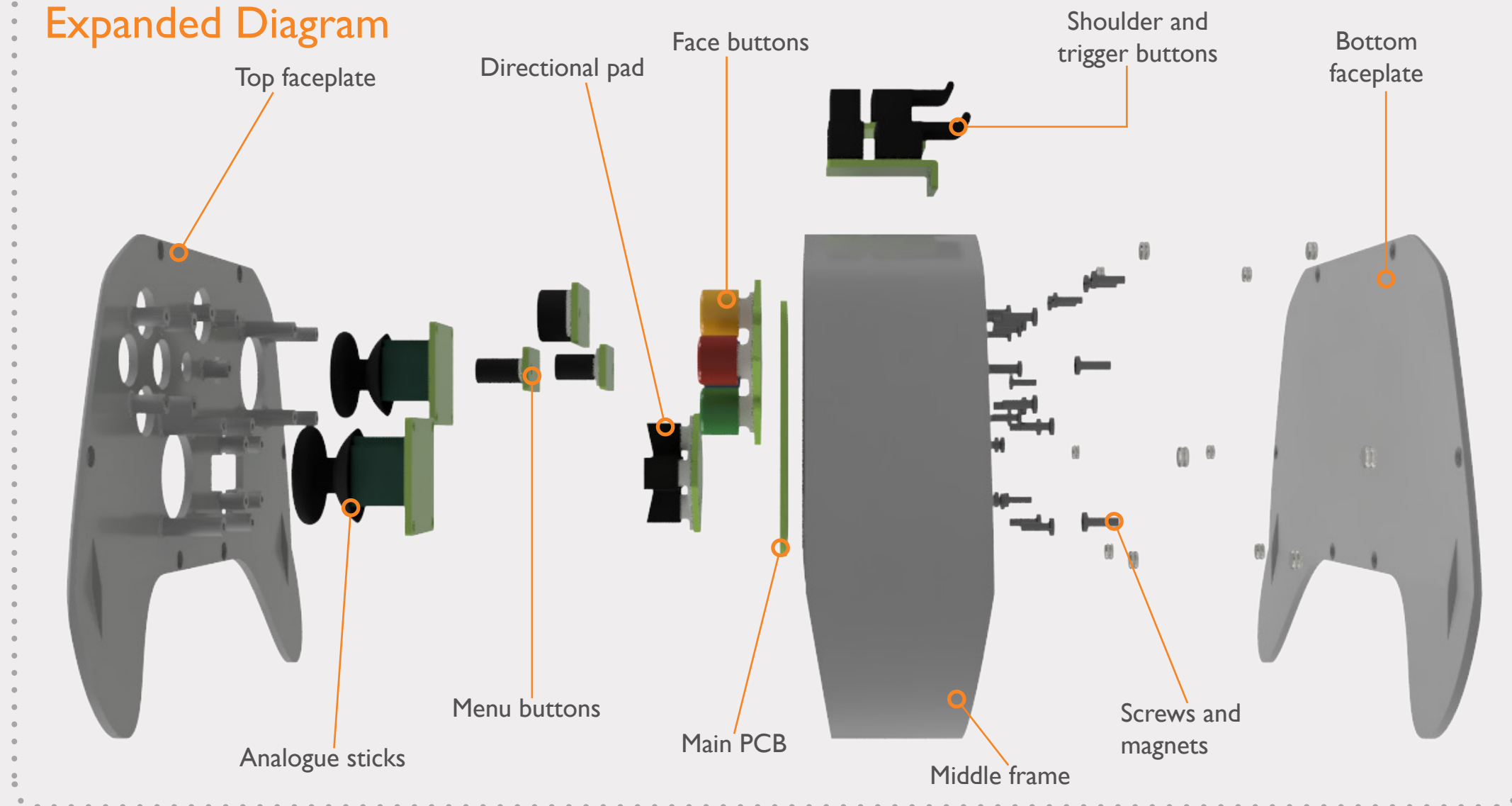
The final design is a video game controller that takes the shape of standard gamepads currently available on the market. The top and bottom faceplate can be removed and replaced with faceplates that feature a different layout. Users can purchase a different faceplate, or 3D print their own. Each input can be removed and placed elsewhere within the limits of the shell. Dimensions for the controller were based on a mix of those taken from the DualShock 4 and Xbox One controllers.



Instead of a soldered connection to the main PCB, all of these miniature input assemblies attach directly to the inside of the faceplate. Every single input is directly connected to its own PCB module. These modules then connect to the main PCB via magnetic ribbon cables that snap to conductive contact pads. Because they are magnetic, they can be easily attached and removed with one hand.



Expanded Diagram



I was initially worried about the comfort of a flat profile, but realized there are many examples of video game controllers with a flat surface for inputs. The Nintendo Switch and Nintendo 3DS both feature flat surfaces and are tremendously popular consoles. Even the face of the upcoming Xbox Series X controller features a more flat layout. In addition, the prototypes proved to be rather comfortable in my hands.



Early designs featured curvature closer to that of an Xbox One controller. The decision to change to a flat profile was made so that it was easier to fit inputs on both the front and back. For example, User #3 had said that they want to control the right analogue stick with their left fingers that rest on the rear of the controller. However, the rear of their controller has contoured faces that would not fit the profile of the analogue stick protruding from the surface. In addition, there may not be enough room to accommodate for the actual analogue sensor component.

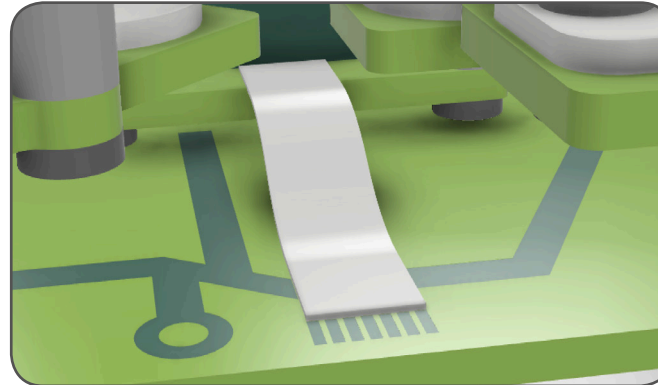
ADDITIONAL CONSIDERATIONS

Changing Connection Type

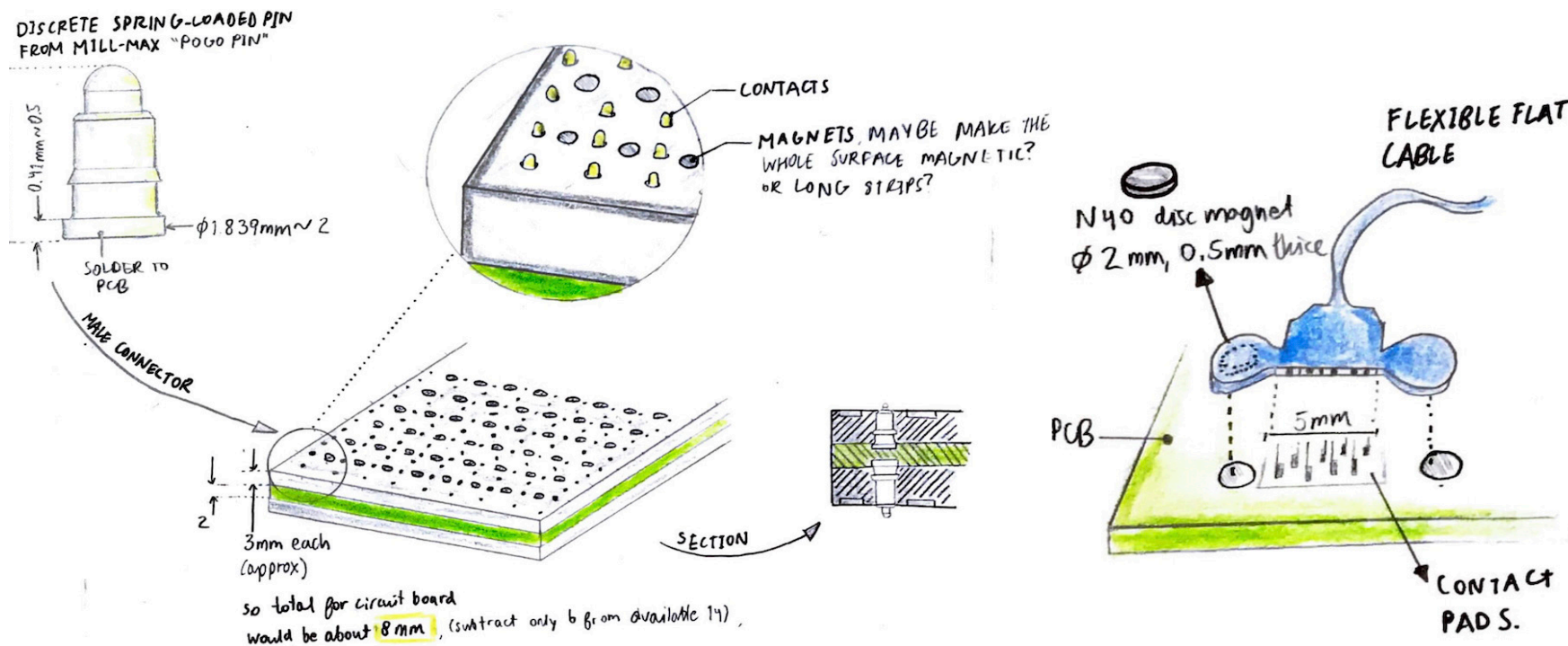
The first PCB design that I fully explored was the use of low profile spring-loaded pins, otherwise known as “pogo pins”. This was considered after researching how MagSafe connections work. Plus, the magnetic snap fit of the MagSafe makes it easy for one handed assembly.

In addition to the technical challenge of ensuring that pogo pins were passing the correct type of data through new connections, and ensuring proper power management, this solution would be expensive, at an estimated £ 72 per unit for the pogo pins alone.

Flexible flat ribbon cables, which are currently in use in the DualShock 4 can be thinner than 0.5 mm, and are flexible. I had the idea to use them after noticing that the DualShock 4 used both a regular and flexible PCB. The flexible PCB is compressed against contact pads on the main PCB when the controller closes, creating a connection.



Ribbon cables are used in slotted components that can be a little tricky to remove, even with two hands. Wanting to encourage assembly with one hand, I thought of turning them into a magnetic connection.

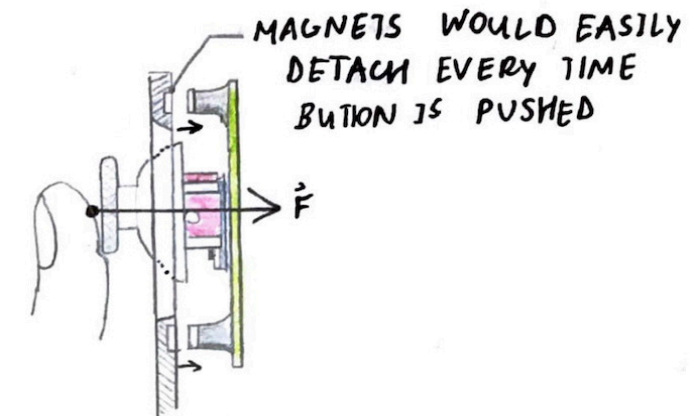


Component Omissions

To simplify the design for the scope of the project, I decided to omit some features present in controllers. Namely the capacitive touch pad as seen on a DualShock 4. The touch pad is largely seen as a gimmick and is rarely used in moment to moment gameplay.

One-Handed Assembly

When I decided to change from the pogo grid setup, I had to think of a way to attach each input component to the faceplate. Before I decided to attach the inputs to the faceplates themselves, I considered using another magnetic connection. This would be incredibly easy to assemble, however I soon realized that every time a button is pressed, the component will fall out.



I had considered screws, but when testing one-handed disassembly of the DualShock 4, it was difficult to hold the controller still. There is little control and parts may come loose. A separate fixture to hold the controller would work, but that brings another expense to the user for an item that will only likely be used once.

I then noticed that the box for one of my controllers had a perfect packaging mould. So I designed the packaging to be able to hold onto the controller so users can confidently take apart their controller without any assistance.



STORYBOARD



1. The user enjoys playing video games, but is limited to movement in their left hand. This can cause frustration during gameplay as they cannot utilize their full potential, with 3 fingers on their left hand not having access to any inputs.



2. It is difficult for the user to access all of the buttons on a standard gamepad. Some buttons can be remapped through software, but there are still less inputs available for them to access.



3. The user purchases a new video game controller which now has modularity introduced in its design.



4. Browsing the manufacturer's website, the user can pick out popular faceplates with layouts that can assist them. Or the user can 3D print their own if they have a unique disability.



5. The front and back faceplates are connected with magnets and offer a connection that is both secure during gameplay and easy to remove for modification.



6. The packaging acts as a fixture and the user can easily remove the components and install them in a new faceplate.



7. The magnetic ribbon cables are easy to attach to the components and PCB. Whenever a user purchases a new faceplate, they come with ribbon cables that accommodate for the new position of the modules.



8. Now that the user can access all of the inputs with their left hand, they can enjoy video games to the best of their ability.

FUTURE + REFLECTION

Future Direction

I am confident in the small size of the components and the modularity aspect of this product, but the next step would be to ensure that all technical challenges can be overcome, namely with the magnetic ribbon cables.

In addition, there needs to be consideration of what the buttons are used for versus where it is possible to move them. For example, User #3 could consistently access either the face buttons or the right shoulder buttons, but **not both**. The right analogue stick was unusable and had to be moved to the rear. Given that the geometry of the face buttons was easier to relocate than the shoulder buttons, it made sense to move those, and User #3 agreed.

However, I later realized that this perhaps was not the correct action. Between the directional pad and the face buttons, the face buttons are utilized much more frequently, and can often feature prompts to be pressed repeatedly. This isn't an issue for a regular player, as their right thumb will be performing the action. By moving the face buttons to the back left side of the controller, User #3 can now access them, but it will still be difficult to hit buttons repeatedly with their ring and pinky fingers, as those fingers are typically not used as frequently for repeated actions.

This can be fixed by instead placing the directional pad on the rear, and the face buttons on the left side. Insights like this show that there is more work to be done in terms of designing alternate input layouts.

Personal Reflection

Looking back on this project, two things immediately stand out: my decision-making habits and motivation.

With regard to decision-making, I often shied away from more challenging decisions. For example, I knew from the start of the project that accessibility will be an issue worth looking into. Having never worked with a disabled user group however, I was intimidated and wanted to first explore repairability, something that I had experience with. Though I still learned a lot from my first few weeks' research, I do wish I had come around to my final project direction sooner.

And with motivation, the COVID-19 pandemic genuinely crushed my spirit. At the beginning of March, I was incredibly excited to complete a project of my own choosing, and even though I did not fully know the direction, I was excited to analyze one of my favourite hobbies from a product design engineering perspective. After the lockdown started however, I only felt really excited by my project in the second half of the term. Not only was I trapped indoors, I also felt trapped in a situation where I couldn't get proper resources. Eventually, this feeling disappeared as I slowly learned more and more how to cope with my surroundings and what resources I had at my disposal. But just like my decision-making, I wish I had found that confidence sooner.

One part of this project that I am proud of is ensuring that this product can be assembled with one hand. Nick had mentioned it in a Tutorial and I thought it was a great point, and wanted to fully commit to it.

