A glimpse into the mind of the Designing Engineer

Personal Handbook for Engineering Design

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“If it ain’t broke, it doesn’t have enough features yet”
— Scott Adams

1. Introduction

This Handbook serves as a comprehensive guide to engineering design, the target audience being my future-self and anyone else interested in learning about my personal approach to design. Over the course of this handbook, I go over my Positionality, my Design Philosophy, some tools and frameworks I employ for design and finally a few projects I have approached with intentionality in Design.

This handbook is in no way or form a comprehensive guide to engineering design; it is merely my personal interpretation of the same. Thus one should expect to encounter variations in the use of tools, models and engineering processes as I may have modified them in a way that suits me personally.

Finally I would like to acknowledge the fact that this handbook is incomplete. Not because of any conscious action by me but simply because, just like me my engineering process will also evolve as I gain new experiences. Thus this handbook can effectively never be complete as long as I grow as an individual; which is effectively as long as I am alive[1].

2. Personal Design Philosophy

Parth was the name given to the great hero Arjun by Lord Krishna during the legendary battle of Mahabharata. Its literal translation means, he who is focused and who never misses his target. Growing up, it was reinforced within me, every time I heard my name, that I could do anything I put my mind to.

[1] Please don't kill me in order to complete this handbook

That, in many ways has shaped me to be the person I am today. It has taught me to be patient, to plan ahead and to persevere in the face of failure to achieve my goals.

I am driven by innovation, efficiency and perfection. While the ideas innovation and efficiency may seem contradictory, they are backed by the same principle of perfection. Attaining perfection in the development of your design makes it innovative, and constantly trying to better it improves its efficiency. Both these factors are visible in my design process[2], the numerous loops of developing ideas allows innovation and the repeated iterations ensures efficiency. Both these factors together, make up perfection in design.

I personally find perfection to be a beautiful concept, perfection comes from intentionality in design and constantly improving upon it. However, when it comes to perfection, we can only do so much, but even then, we strive for the impossible, knowing it is unattainable, for we do not wish for miracles. It is this noble pursuit of the unattainable that makes our journey quenching. I thus aim to engineer perfection in every design project that I take on.

My definition of perfect however is subject to change. As I grow as an engineer, I learn more and more things, and surpass my own boundary of what I thought was possible.

3. Positionality

The essence of engineering design is solving the toughest problems, problems that plague mankind; and not stopping until they are solved. Something about the challenge of solving the unsolvable resonated with me and eventually led me to engineering. Now, as a student engineer, my obligation to my stakeholders and

[2] See PEDP Chart under 4.2

community hold me to the highest degree of commitment, ensuring quality in my work and not giving up until it is done.

As expressed above, I greatly value efficiency, innovation and of course perfection in my work. These values add to my strength and ensure rigour in every task I perform, however small or inconsequential it may seem.

But, although it sounds like a flawless process on paper, in practice, it is utopian and assumes ideal conditions for every task. This is where biases come into play.

As an amateur engineer, with a focus on innovation, I tend to be a little flexible with the communities' requirements in return for novelty in design. While this method definitely produces creative and newfangled designs, it works on the prerogative that the new design would be so groundbreaking that the community realizes it needed the product and would adopt it instantly. But not every product can be the iPhone, and admittedly, this practice oversteps my bounds as an engineer.

To overcome this, I implement additional framing cycle verifications after estimation and before the presentation of the actual design[3]

4. Personal Engineering Design Process

My *present* Personal Engineering Design Process (PEDP) is a play on the FDCR cycle taught in Praxis 1 with a few key additions and modifications.

1. Introduction to the Process

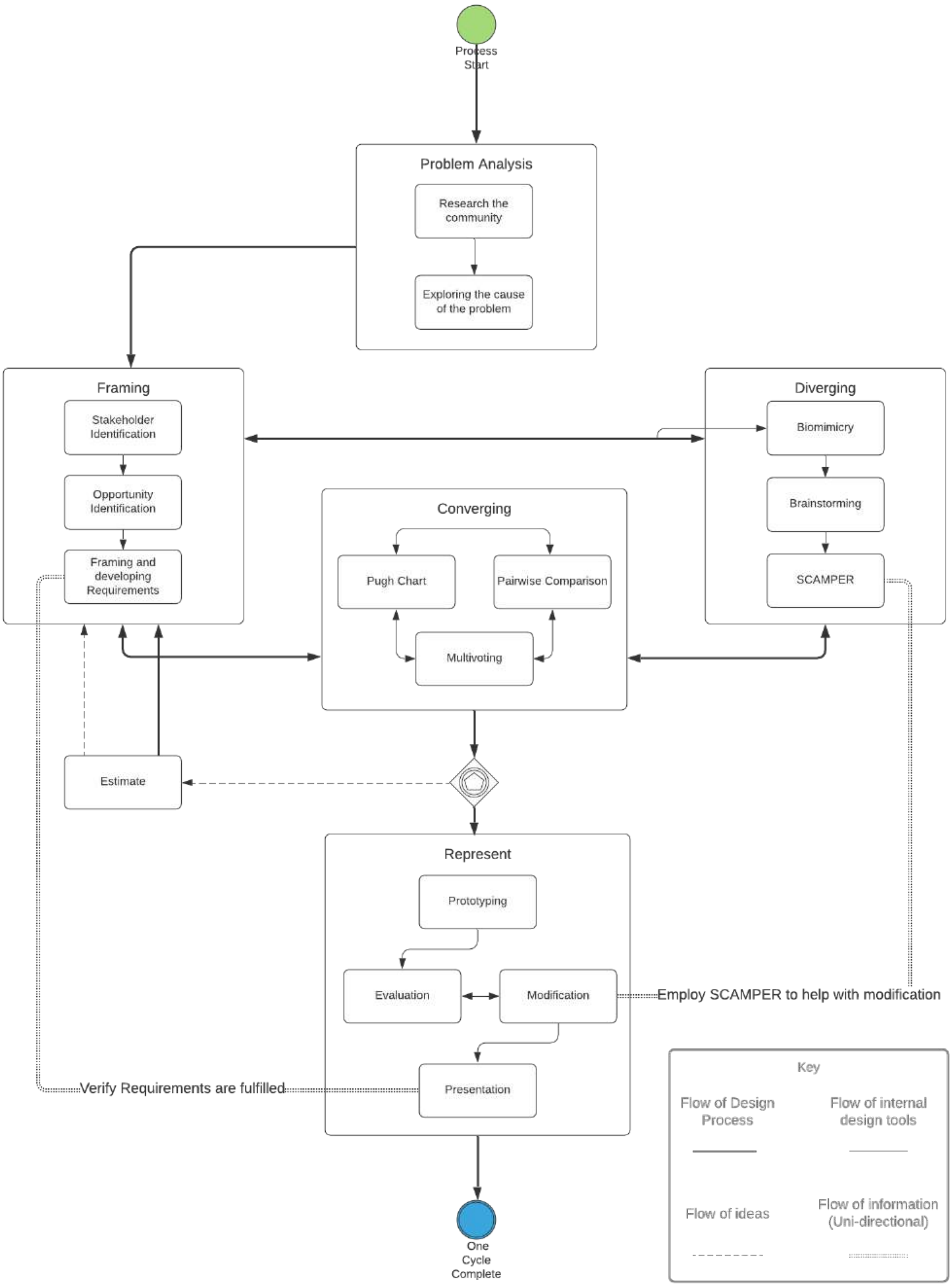
My *present* Personal Engineering Design Process (PEDP) is a play on the FDCR cycle taught in Praxis 1 with a few key additions and modifications. Namely,

[3] See PEDP Chart under 4.9

Problem Analysis, Estimation and the introduction of the flow of tools, ideas and information.

At first glance, the process resembles the FDCR Cycle. However when you delve deep into it, and actually work through the process, it becomes clear that although the skeleton of the process is structured similarly; the flow of ideas and information bears resemblance to iterative designing.

2. Graphical Description of Design Process



3. Problem Analysis

My design process begins with a 'Problem Analysis' where I analyze the problem statement, research the community and explore the cause of the problem. I do this as the first thing in my design process because it enables me to obtain background information about the stakeholders and helps me to plan ahead. Further, exploring the cause of the problem not only allows me to start thinking about its solution beforehand, but also helps me identify other potential problems that may arise as I begin to engineer possible solutions.

4. Framing and Stakeholder Analysis

I then move on to the framing part of my design process. Firstly, I identify the community and the stakeholders that are either directly or indirectly influenced by my actions. I define a community as a group of people sharing similarities in values, experiences or thoughts and have a common goal. I believe understanding the psychology and needs of the people with whom I'd be working with is of utmost importance if I am to design solutions for their problems.

I then identify an opportunity. This task is made simpler for me as I have now understood the needs of my stakeholders to some basic extent. I try to collaboratively find potential engineering opportunities where a design space can be established. This engagement usually includes me talking to a stakeholder or a member of the community I intend to assist. At this point, I make a list of candidate engineering problems and then decide on one that can be done the most effectively and is possible to do with my current skillset[4].

With an opportunity in mind, I now begin researching relevant topics that have some bearing on the opportunity. As I acquire a deeper understanding of the

[4] See Estimation in my PEDP

problem, I am also familiarized with specialized terminology that I can use to improve the quality of my research. At this point, I start to develop a preliminary requirements model that is improved upon repeatedly throughout the engineering process.

5. Estimation

The next part of my design process is called Estimation. In this process, I attempt to estimate an approximate solution to the problem we intend to solve, either numerical or a general idea is acceptable. As Professor Collins says, "To find the solution, you must know the solution", I firmly believe is true for engineering in general. Firstly, it is necessary to have a basic idea of what one is dealing with and to have some kind of prior experience so that safety is ensured. And secondly, because an initial estimate allows me to verify the correctness of our solution and helps me judge the efficacy of the design process used[5].

6. Diverging and Converging

I then move on to Diverging. Already done basic research on the opportunity, I find myself in a better position to diverge into multiple ideas. I think, if an idea is generated without research, it may violate some industry standards, or can have already existed, this not only wastes the time of the designer but can also compromise the safety of the stakeholders. While admittedly, researching beforehand may cause anchoring and hence create biases, I believe the benefits outweigh the disadvantages.

The first tool I employ is biomimicry. Looking at nature is something that comes to us naturally, and learning from it is an excellent starting point. I then

[5] More on this in Representation

move on to brainstorming and then SCAMPER to create as many candidate solutions as I can from the knowledge I have garnered from the above steps.

After Diverging, I Converge onto a final design solution. For this task, I prefer to use the Pugh Model of Controlled Convergence, Pairwise Comparison and Multi-voting. Going about a few rounds of diverging-converging, the pool of candidate solutions is reduced. Pairwise Comparison allows us to judge the superiority of each candidate design and finally Multi-voting prevents individual biases from creeping into the design process. After successful convergence, it can be expected that a design has been finalized.

7. Estimate Consistency

As a design has been finalized, I check it with my initial estimate. If the design is consistent with the estimate, the design process has been successful. However, if it is not, it is best to go back to the Framing sub-section of the design process. Where, I make another estimate, carry on with the converging-diverging cycle and then check the consistency of the solution with the new estimate.

8. Representation and Prototyping

If the above condition is satisfied, I then move onto Representing, where I prototype the selected design. This prototype helps me visualize the design as an actual 'thing' instead of just a representation. This allows me to assess certain parts of my design that I would not have thought of otherwise.

I then evaluate this prototype. At this point, I often ask myself, whether my design can actually be practical in a real world scenario. If not, I then modify my solution by going back to the drawing board of Divergence. I specifically (but not exclusively) use SCAMPER to improve upon the existing design and then evaluate it again. I repeat this cycle of evaluation and modification until I am confident it can solve the problems of our stakeholders.

9. Cycling back to Framing and Stakeholders

Finally, before presenting this engineering solution to the stakeholder and community, I verify that it satisfies their needs completely and fulfils their requirements. If not, I either change my design or change my requirements model depending on the situation I encounter. This added item on my design checklist helps me overcome my biases[6].

5. Tools, Models and Frameworks

1. Problem Analysis

Problem Analysis as explained in Section 4.3, is an integral part of my PEDP and is thus essential for me to get acquainted with the problem and the stakeholders. For this task, sources of authority are needed to verify our claims and strengthen our assumptions. These may be research papers, articles or other acknowledged sources of authority.

1. Journals and Papers

These are, in my opinion the highest authority on qualitative data, also verified by Praxis II[1]. One can be almost certain to find qualitative data on any and all topics with evidence backing up the same, verified by the top researchers of that field. Thus journals and research papers prove to be a crucial resource while researching the problem as well as making claims in the duration of the design process.

Another reason why I find research papers and journals to be indispensable is the idea of 'piggybacking' onto other papers. This idea becomes especially helpful when one is researching a niche topic in a not very commonly studied field. How it works is when you take the concluding data of one paper and use it as the initial

[6] As stated under Section 3: Positionality

conditions that are assumed by another paper. Since both papers are reputed sources of authority with universally accepted results, we can make very specific claims that span the breadth of multiple papers to justify our point.

An example of the same may be the research for justifying the scope of our Praxis Request for Proposal. The RFP required us to help children with epilepsy and tremor zip up their clothes more easily. In addition to focusing on aligning the zipper, we did not focus as much on the force required to pull the zipper up. We justified the same through:

In conclusion, 9-year-old children were more likely to plan their movements to end in comfortable postures, and have distinct representational structures of certain grasp postures, compared to the 7- and 8-year old children. However, the ability to plan for comfortable postures was related to the ability to separate uncomfortable grasp postures from comfortable grasp postures. Children who clustered by grip comfort satisfied end-state comfort in the simple as well as in the advanced planning condition, whereas end-state comfort satisfaction in children who did not cluster by grasp comfort was significantly lower for the advanced than for the simple planning condition. The results of the present study support the notion that the cognitive representation plays an important role in the planning of grasp postures.

Representation of grasp postures and anticipatory motor planning in children: Stoeckel et al.

We did, however, obtain statistically significant differences on all tasks for psychomotor speed. Slowing of psychomotor speed has been found in several other studies. Some consider this as a general effect of AED treatment (Thompson et al. 1980, Dodrill and Temkin 1989, Aldenkamp et al. 1993, Vermeulen and Aldenkamp 1995), but the absence of significant correlations with the PDD:DDD ratio is not in accord with such drug-induced slowing. The slowing effect we found was most prominent in younger children (4 to 8 years). Kowalski and di Fabio (1995) and Hernandez (2002) also found lower scores in younger children.

Others studies, however, have related psychomotor slowing to a general consequence of epilepsy; a general cerebral cortical inhibitory reaction to the epilepsy (Lopes da Silva et al. 1995). In animal studies, the synchronized neuronal discharge

Effect of epilepsy on psychomotor function in children with uncomplicated epilepsy: Boelen et al.

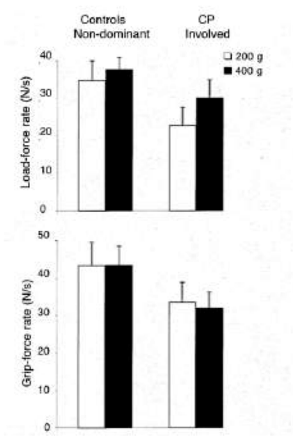


Figure 7: *Mean ± SEM load-force rate and grip-force rate from the non-dominant hand of the controls and the involved hands of the children with hemiplegia during one lift with 200 g and one lift with 400 g after lifts with the contralateral hands for each weight, respectively.*

Fingertip forces during object manipulation in children with hemiplegic cerebral palsy. II: Bilateral coordination: Gordon et al.

The paper by Stoeckel proves grasp postures and forces for epileptic children is a psychomotor function. The paper by Boelen goes on to verifies the fact that psychomotor functions are affected by epilepsy; that slows them down. The third paper by Gordon assumes children with slowed psychomotor functions and compares their grasp power.

From these we can make a grounded claim that while grasps are slowed down by epilepsy, it doesn't affect grip force as much for objects within 200-400g[7].

2. Articles

Subject Articles come just after journals and papers in the hierarchy of authority. Articles written by reputed sources are a great tool for providing an in-depth overview of a given topic. Due to their non-research oriented nature, they has more place for quantitative data and often times, the personal opinion of the author. Articles are a great way for a beginner to learn more about a topic without going into a ton of initially unnecessary detail.

One issue I personally encountered while using articles as a source of data is that it is often not easy to determine the reputability of a source. And many a times an article is just a reflection of the opinion of the author without any data backing up the same. These articles are no different than blogs; a source that has even lower authority.

An example of me using articles is while researching about ergonomic keyboards. During which, I came across two distinct articles saying almost the same thing but were wildly different in justifying their stand.

The first article was by the NYTimes a widely known website and the second was by SwitchandClick, a lesser known website. Both were justifying the need for ergonomic keyboards in a work setting.

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[7] Which is the average load range for pulling zippers up (obtained from research, see here)

Sources

1. David Rempel, Director of the University of California's ergonomics program, interview

2. Alan Hedge, Director of Cornell University's Human Factors and Ergonomics Research Group, interview

3. E. Fylladitakis, The Kinesis Freestyle Edge Gaming Mechanical Keyboard Review: Split Ends For Combined Comfort, AnandTech, February 5, 2018

About your guide

Melanie Pinola

Melanie Pinola is a Wirecutter senior staff writer covering all things home office. She has contributed to print and online publications such as The New York Times, Lifehacker, and PCWorld, specializing in tech, productivity, and lifestyle/family topics. She's thrilled when those topics intersect—and when she gets to write about them in her PJs.

NY Times - Melanie Pinola

Conclusion

An ergonomic keyboard is a simple fix to improve your comfort while working. It can solve many hand and arm strain problems and also support better posture.

Ergonomic boards provide much better comfort and can reduce the chances of having arm and wrist pains as well as carpal tunnel. In contrast, regular boards allow faster typing speeds and are also cheaper.

There are a variety of styles for ergonomic keyboards that can suit your preferences and the things you do regularly like gaming, typing, or just working. With Split and Unibody boards there are different types to choose from.

Happy Typing!

For more ergonomic tips, check out some home ergonomic office tips from the **America Occupational Therapy Association**.

Giacomo Coltorti

ClickandSwitch - Giacomo Coltorti

The difference here is that while both articles justify the benefits of ergonomic keyboards, Pinola has her sources listed for public consumption. Coltorti on the other hand doesn't reveal his sources, which makes one wonder whether he even had sources in the first place. While he may have irrefutable claims from verified sources, not listing them reduces one's confidence in his article which cannot be used as scientific justification.

3. Other Sources of Authority

Other sources of Authority include the personal experiences of people, conversations with the community and other observations made about the stakeholders during the design process. For example a blog page about a specific topic, or the opinions of the community members on a given topic. These are possibly the least accurate for obtaining qualitative data, since everyone has an opinion, perhaps based on their previous experiences which may or may not be backed by real data. Thus these sources, like the spoken word should only be used to get a deeper, more personal understanding of the stakeholders and should not be quoted as evidence towards making claims or engineering decisions.

One such example was during the Community Profile, when our Team was working with Zindagi Trust, a non-profit organization looking to teach basic horticulture to kids from lower income families. We spoke with the community representative Mr. Ali After Ghias who showed us the vegetable garden and gave us approximations about its size.

Zindagi Trust 2018

2. Diverging Tools

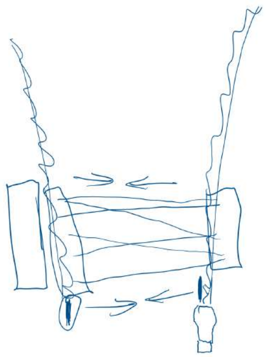
1. Biomimicry

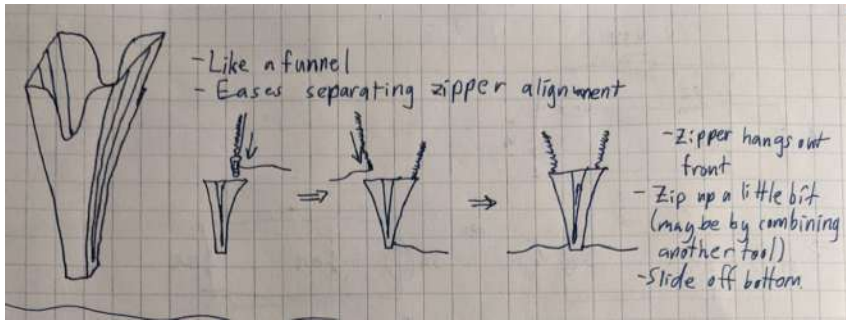
Over the thousands of years life has existed on earth, it is only the strongest, most efficient forms of life that have survived, either through inherent features or through evolution. I hence find looking at nature to be an excellent starting point to explore multiple ideas. Even though I may not know the exact science behind a nature-inspired design initially, I can be sure that it 'just works' as it has for thousands of years.

An example of the same may be when our Showcase Team had to figure out a way for a zipper to align properly with its ends. We were inspired by the Venus Fly Trap opening and closing.

Venus Fly Trap Open and Close - Barry Rice 2018

As visible in the image, the plant on the right is open and has a bigger surface area for a fly to reach. When the fly lands on it, it closes like the one on the left to reduce the overall surface area and brings the fly to its digestive tract. We used this analogy where the plant was the fixed end of the zipper and the fly was the slider.





We hence came up with two preliminary designs based on altering the area for aligning the zipper. The first one required manually changing where the zipper slider could go. The second one used the concept of altering the area and ensuring the slider lands in the right place, just like the fly. The second concept was later modified and refined to be our final design.

2. Brainstorming and Brainwriting

Brainstorming is perhaps the most obvious and universal diverging tool, however I'd quote Occam's Razor[8] as I believe the simple brainstorming is one of the most effective methods. Brainstorming and Brainwriting techniques are more effective than individuals generating ideas[2].

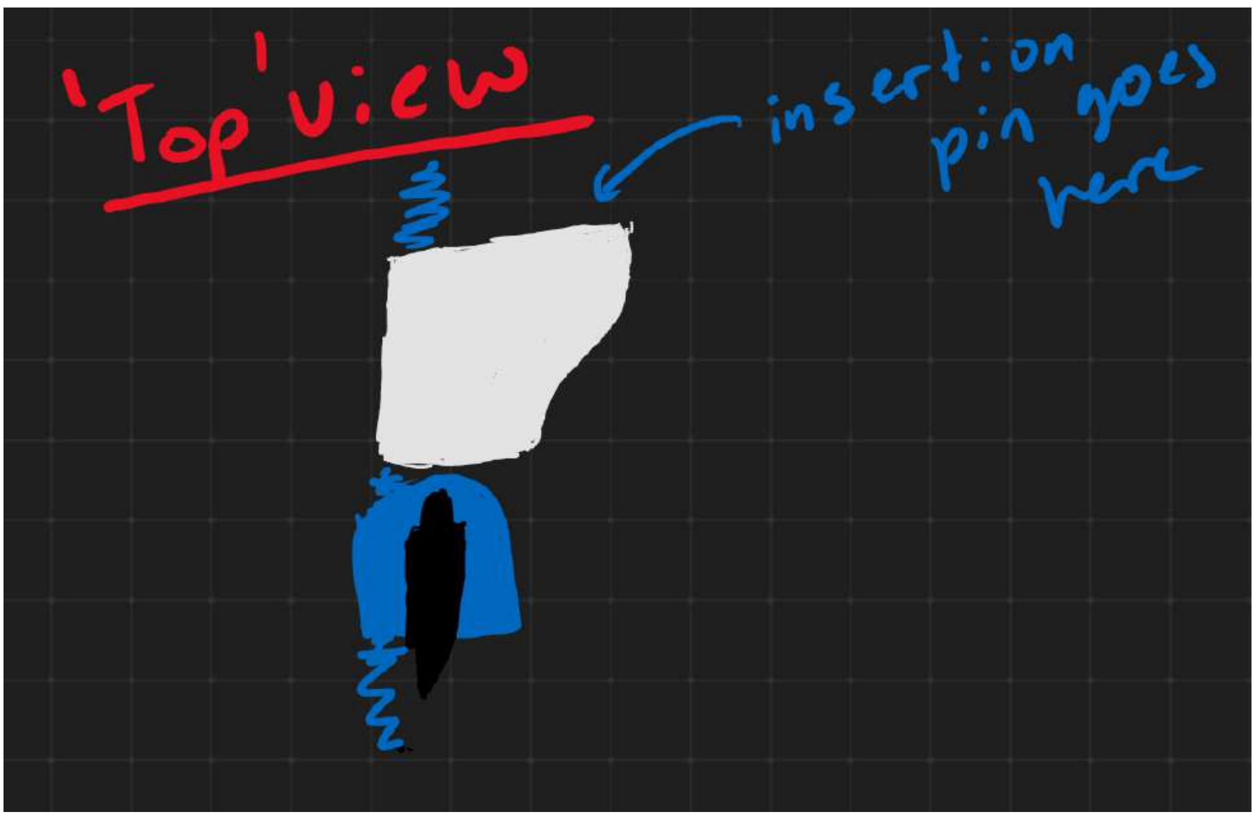
Brainwriting is almost a subset of Brainstorming. We proceed with simply jotting down our ideas instead of discussing them out loud. One obvious disadvantage of brainwriting is that, since verbal communication is hindered; the flow of discussion is protracted.

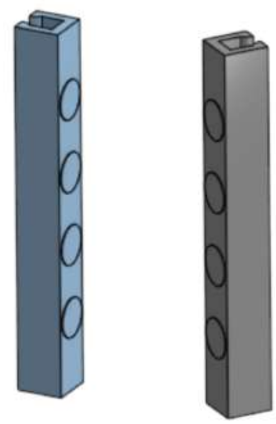
For the purpose of Praxis this year however, I found Brainwriting to be more beneficial over Brainstorming. This was mainly because all group discussions were

[8] The best idea is often the simplest one

majorly online and audio lag negatively affects one's flow of thought. To avoid such a situation I preferred having written points beforehand such that even if one's flow is interrupted, they can resume using by referring to their initial points. In addition, it also helps keep track of all the discussions that have occurred since there now exists written word of an otherwise verbal discussion. This enables one to refer back to their previous work and cite it.

Our Praxis II team majorly did our brainstorming work on Google's Jamboard which enabled everyone to draw, write and add media at the same time.





3. SCAMPER

SCAMPER stands for:

S Substitute (trial-and-error, see what part works and what all doesn't)

C Combine (add on previous/new ideas to create something new)

A Adapt (adapt current design to other uses)

M Modify (changing different design features in different ways)

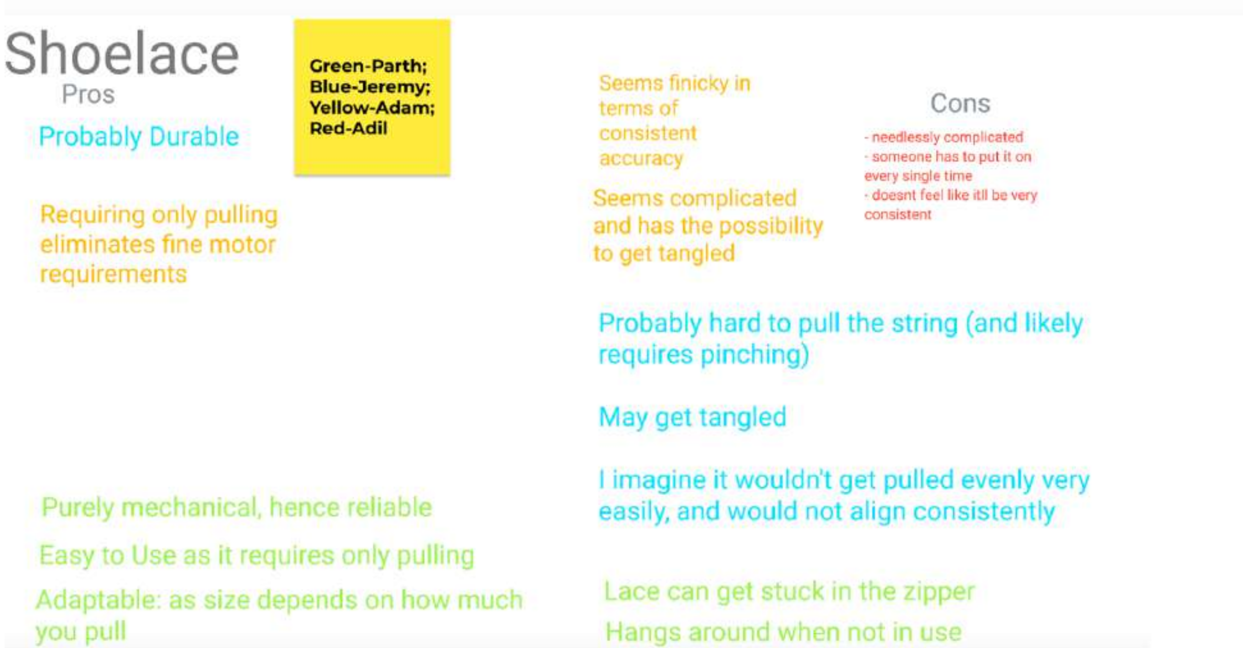
P Put to other uses (Other uses for design without altering it)

E Eliminate/Elaborate (remove unnecessary elements and add detail)

R Reverse/Rearrange (change the layout, sequence, structure)

To effectively carry out SCAMPER, it is imperative to know all the features of your current design. Otherwise there is conflict of ideas which yields imperfectly mutated designs[3].

An example of SCAMPER done right may be defining the features for all our designs in showcase:



3. Converging Tools

1. Pugh Chart

A Pugh Chart is a table made of rows representing criteria and columns representing designs, compared in terms of the chosen criteria[4].

A reference design is chosen as the standard and other designs are compared to it. If the design fares better than the reference in a given criteria, a “+” is marked, if the design fares equally as the reference, a “0” is marked, and if the design fares worse than the reference, a “-” is marked. The total positive points and total negative points are summed up separately and shown at the bottom for comparison.

An example of a Pugh Chart in use may be converging upon designs from Showcase:

	Scissor Pincher	**Magnetic Aligner**	**OG Funnel** (reference)	**Clip-On Funnel**	**Binder Clip**	**Shoelace Pull Design**	**Deflection Box**
Visual Appeal	-	0	0	0	+	-	0
Length	-	+	0	0	+	-	+
Width	-	+	0	0	+	+	+
Number of parts	-	-	0	0	-	-	0
Another person?	0	0	0	0	0	0	0
Predicted Relative Weight	-	0	0	0	+	-	+
Multiple zippers?	0	0	0	0	0	0	0
# of sharp edges	-	0	0	0	0	0	0
Perceived Effectiveness	+	+	0	+	0	N/A	N/A

2. Pairwise Comparison Matrix

The Pairwise Comparison Matrix (PCM) enables ranking and holistic assessment of multiple entities, typically criteria or designs [5]. These are written into a single row across the top, and again along a column down the left. In each box of the matrix is written the preferred design or prioritized criterion between the row and column entities.

Paired Comparison Analysis is useful for weighing the relative importance of various options. It's also useful where priorities aren't clear, or cannot be quantified. The PCM helps to show the difference in importance between said unknown factors.

A sample can be deciding among planters for our RFP: Teaching Horticulture to Economically Challenged Children in Pakistan's Zindagi Trust School. Here we wrote the letter of the most important option and scored their difference according to us. We got back the following Matrix

	A Ground Potting	B Step Planters	C Vertical Planters	D Pole Planters
A Ground Potting		A, 2	C, 1	D, 1
B Step Planters			C, 1	B, 1
C Vertical Planters				C, 2
D Pole Planters				

Thus, C=50%
A=25%
B=12.5%
D=12.5%

From this we can conclude that option C was considered the most viable. Followed by option A and option C & D.

3. Multi-Voting

Multi-Voting incorporates the use of everyone's preference to democratically select a desirable candidate. The team votes on which design they like best and then compare it with the results of the others. This way, everyone's opinion gets heard and a unanimously acceptable design is selected.

An example may be the Convergence Stage of the Showcase Design when we had to converge onto One Final Design.

1st	Gripper	Funnel	Funnel	Clip on Magnetic
2nd	Shoelace	Clip on Magnet	Winged Magnetic	Funnel
3rd	Clip on magnetic	Winged magnet	Gripper	Gripper
4th	Winged magnetic	Gripper	Clip-on Magnetic	Winged Magnetic
5th	Funnel	Shoelace	Shoelace	Shoelace

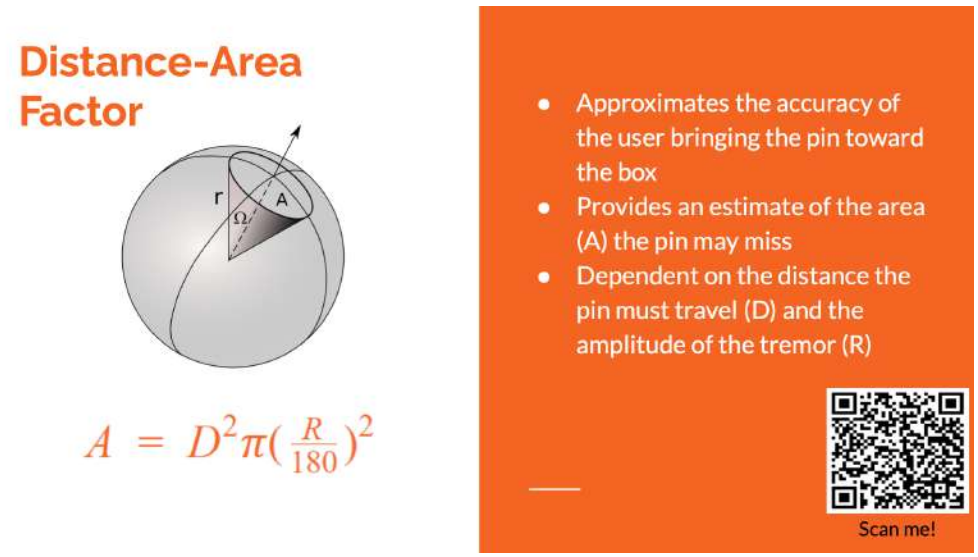
Green-Parth; Blue-Jeremy; Yellow-Adam; Red-Adil

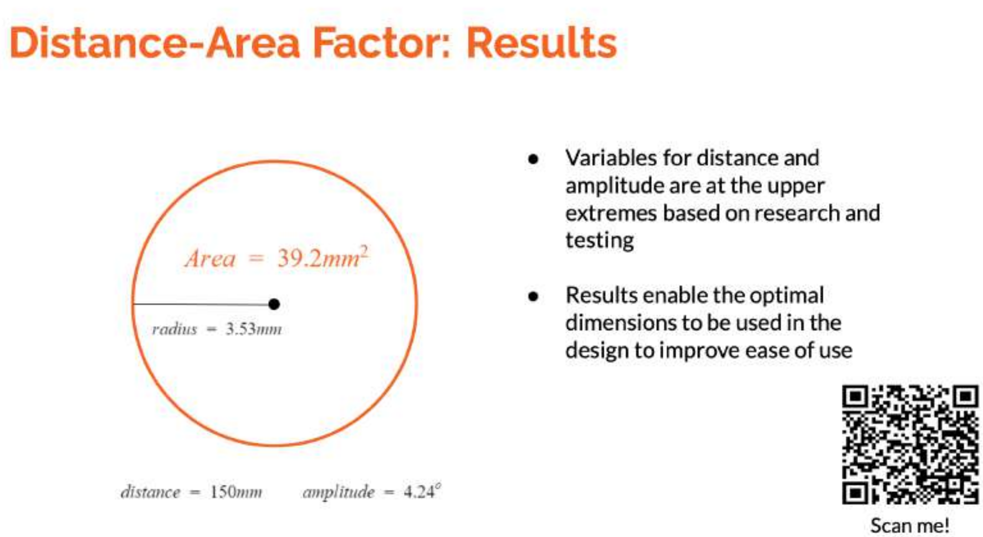
As visible from the image above used for the Showcase, the inconsistency in the ranking of the Funnel is a good example of the same. All my team members consistently ranked the Funnel design higher on position 1 or 2. I(green) however ranked it last. This happened due to a misunderstanding on my part which was later cleared up by my team members, thereby improving the overall quality of the design process.

4. Tests and Proxies

Tests and Proxies are another important part of the Representation process that often gets overlooked. Luckily for us, since our tasks were online and we did not have the luxury to perform a lot of tests, we focused hard on whatever tests we could do and Proxy tests that could circumvent the need for tests in the first place.

A major Proxy test we decided upon for Praxis II Showcase was to measure the offshoot distance of the zipper from the slider based on the frequency of hand tremor. (Slides from our Showcase Presentation)





6. Case Study: Zipper Attachment for children with Epilepsy

The aim of our design process was to ease the process of zipping up clothes for kids with epilepsy and hand tremor in the SickKids Epilepsy Classroom.

This case study is testament to the efficacy of my design process. Presented at the Praxis Showcase, we received an overwhelmingly positive response from the teaching team as well as other guests present. In this section we delve into the process of engineering a solution to the aforementioned problem. It is important to note that the Case Study alone doesn't do justice demonstrating the comprehensive design process employed for this task. This is since, working in a team, it includes the perspectives and adaptations from my team members, which makes some parts of the process a little varied. However I will majorly focus on the parts of the design process that were my own and analyze their overall contribution towards solving the Engineering Puzzle.

1. Understanding the problem

In order ease the process of zipping up for children with epilepsy, we first needed to get acquainted with the disorder and how it affects an individual. We began by studying the Epilepsy Classroom and the demographic they cater to. After identifying our target audience or stakeholders, we began analyzing the problems they face and started researching papers together.

Materials: https://www.zippersource.com/materials/
Hand tremor: https://iopscience.iop.org/article/10.1088/1742-6596/1262/1/012024/pdf
Acceleration mean=-1.388 to 1.397 ms^-2
// people w/o epilepsy ?ms^-2
More on Epilepsy: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1469-8749.2005.tb01189.x

Tremor Study (Practical):
https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Tremor-Fact-Sheet

Bilateral Control: https://link.springer.com/content/pdf/10.1007/s00221-007-0955-7.pdf

Sensory-perceptual-motor and cognitive function of hemiplegic children:
https://www.tandfonline.com/doi/full/10.3109/09638281003654789

Fingertip Forces in Children with cerebral palsy (Bilateral Coordination):
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-8749.1999.tb00577.x

Bilateral motor control in children with motor control disorders:
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-8749.1998.tb15398.x

Motor Planning in Autistic PreSchoolers:
https://www.sciencedirect.com/science/article/pii/S1750946710001583

Grasp postures and motor planning in kids:
https://link.springer.com/article/10.1007/s00426-011-0387-7

Movement planning in kids with dcd developmental coordination disorder:
https://www.sciencedirect.com/science/article/pii/S0167945718301519

Motor imagery in young kids 7-12:
https://www.sciencedirect.com/science/article/pii/S0001691819301489

Motor skills of Autistic Toddlers:
https://journals.sagepub.com/doi/full/10.1177/1362361311402230

Fine Motor Skills affect due to tremors:
https://www.frontiersin.org/articles/10.3389/fneur.2013.00050/full
Nice img:
https://www.frontiersin.org/files/Articles/47422/fneur-04-00050-HTML/image_m/fneur-04-00050-t002.jpg

Effect of epilepsymedication on motor skills: https://pubmed.ncbi.nlm.nih.gov/19751992/

Research Work on Tremor in Kids

2. Framing the problem and Developing Objectives

Understanding the ins and outs of the opportunity took a major chunk of our time after which, we began formally framing the problem. We scoped down our opportunity based on research[9] and our conversations with the community. We then developed a list of Objectives, in accordance with the needs and wants of our stakeholders.

This part was considered especially important since the community we were catering to was 7-11 year old kids with tremor. A major part we had to focus on was the safety and utility of our design. In addition, we also had to respect their wish to not be seen using an 'outrightly outlandish' device.

[9] See Example in Section 5.1.1

Primary Objective:

Ease of Use

- If we make it easier to use, regardless of if it improves time efficiency, we have at least done something positive

Stuff we can/should measure:

- Variety of muscles/muscle groups required in regular usage
    - Will show us if the design makes it easier to zip stuff up [verification]
- Duration of movement
- Fine muscles required for pinching and how they are affected by tremor (frequency of tremor comparison)
- Time delay in the overall tasks due to motor control dysfunction (math)

Safety - add this in detailed design phase (don't necessarily design with safety in mind, add it later)

- Because we are designing it for kids

Stuff we can/should measure:

- Size (so that it cannot be swallowed)
- A breathing hole (so that if it is swallowed it is not deadly)
- Blunt
- Non-toxic

Secondary Objectives:

Durability

- Should support multiple cycles of the zipping process (material science behind the building material- strain applied any given use// failing duration for any given material)
- Should not be brittle (shouldn't break if and when a kid steps on it)
- Should regain shape after deformation

Stuff we can/should measure:

- How many times we can drop it before it breaks
- Can we step on it

Aesthetics

- Just keep the definition in the RFP

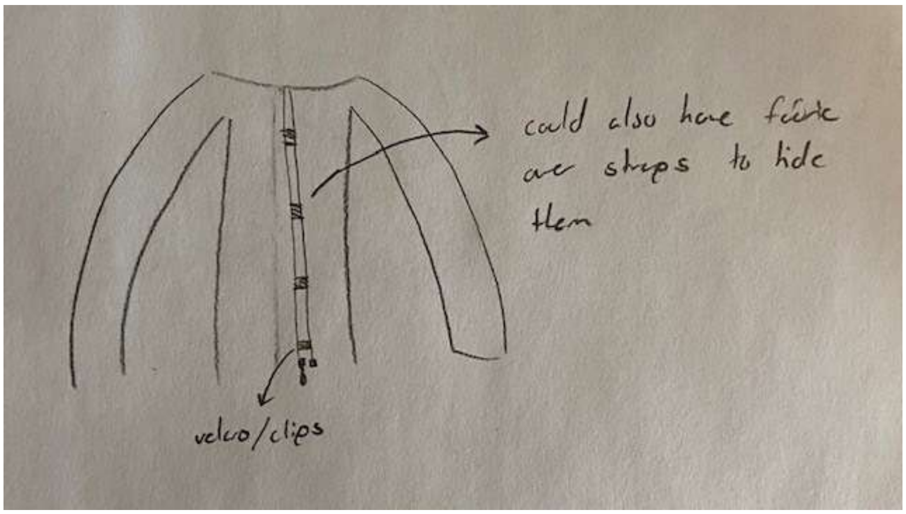
Tertiary Objectives:

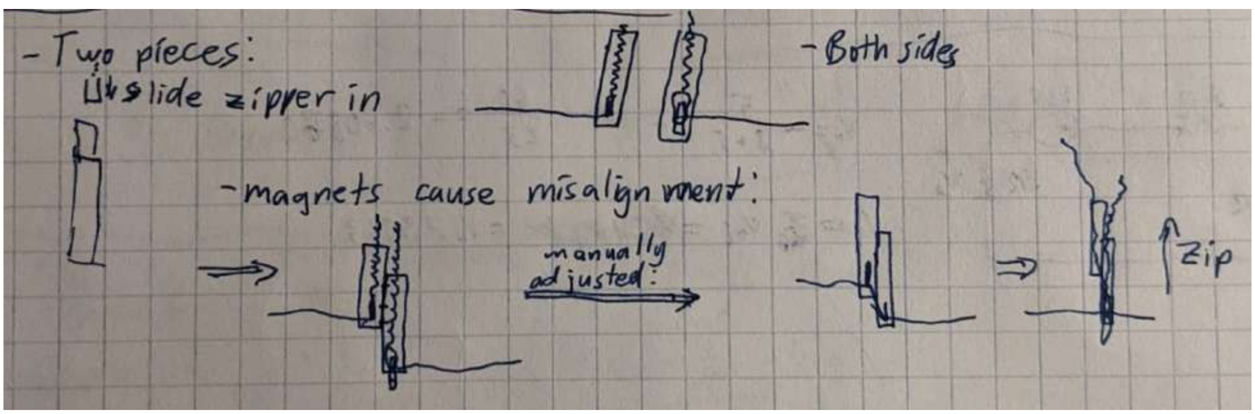
- **Portability and Adaptability**

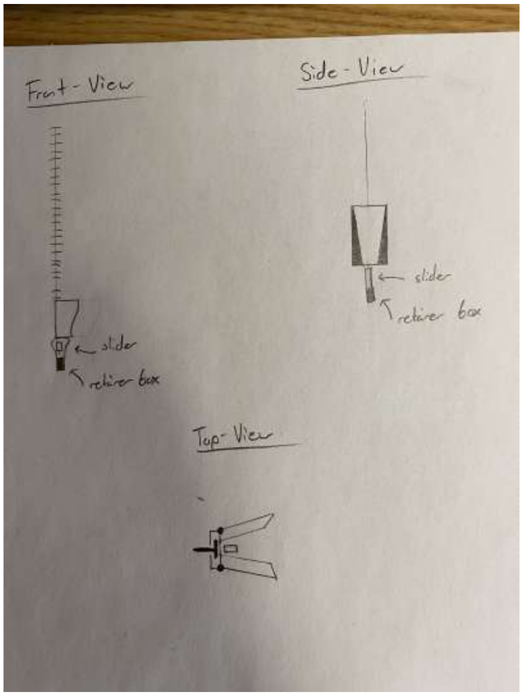
List of Objectives

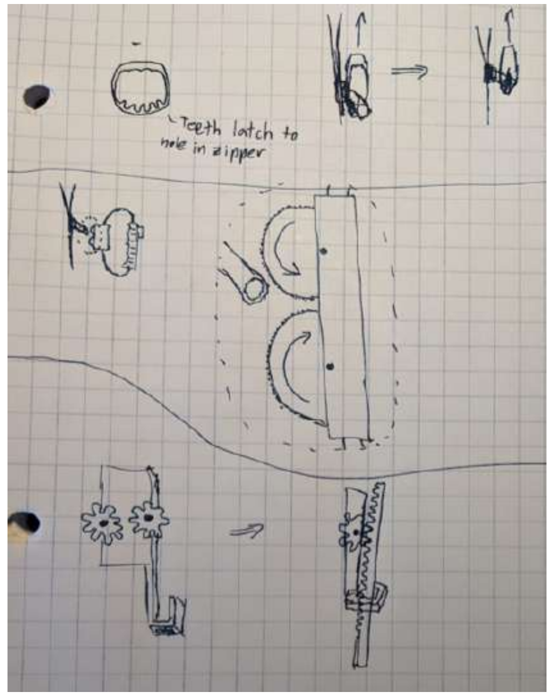
3. Estimation

Estimation in this scenario was a little tough since there were no quantitative values to be estimated. However we estimated the various designs that could be used to solve this problem. This process was a little similar to the diverging tool, ‘Wishing’, but instead of wishing for unrealistic designs, we limited our scope to the knowledge we garnered from the research. We hence approximated what the correct design may look like.





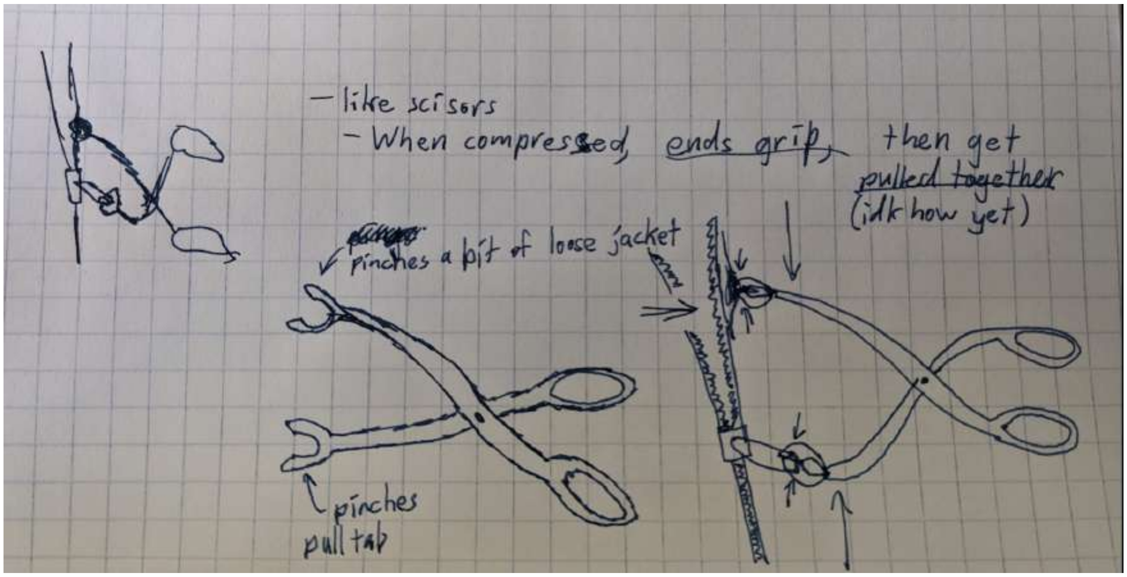


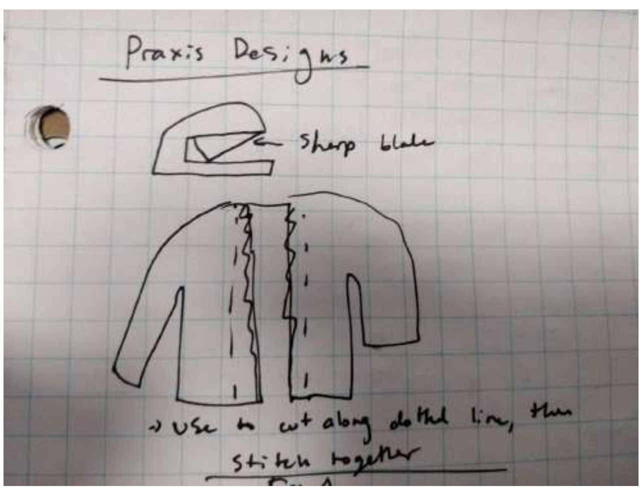


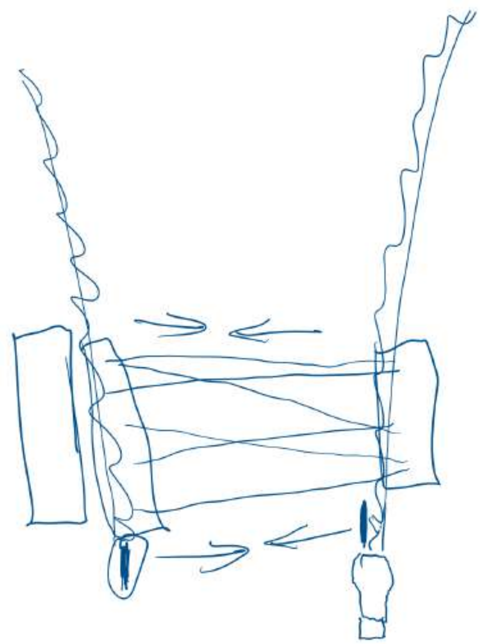
Freshly after defining the stakeholder Objectives, each member of the team made one estimate, totalling four estimates. This process helped us keep on track and discouraged us from neglecting the community objectives on more than one occasion during the diverging cycles.

4. Diverging and Converging Cycles

After a semester of Praxis I, Diverging and Converging came almost naturally to us. We employed biomimicry as explored in Section 2.1 and carried on with Brainstorming/Brainwriting.







After multiple rounds of brainstorming, we had numerous designs (not limited to the ones above). At this point anchoring began to set in and no one had any fresh ideas. Instead of mindlessly working towards new ideas that wouldn't adhere to the community guidelines anyway, we used this anchor to our advantage.

Among the many designs we produced, we used SCAMPER[10] for each to produce the best possible version for each design that we possibly could. This process helped merge the very similar ideas to yield the final few designs.

At this point we began our rounds of Converging. Employing Pugh Charts, we were able to directly compare our multiple designs with respect to our basic reference design.

	Scissor Pincher	Magnetic Aligner	OG Funnel (reference)	Clip-On Funnel	Binder Clip	Shoelace Pull Design	Deflection Box
Visual Appeal	-	0	0	0	+	-	0
Length	-	+	0	0	+	-	+
Width	-	+	0	0	+	+	+
Number of parts	-	-	0	0	-	-	0
Another person?	0	0	0	0	0	0	0
Predicted Relative Weight	-	0	0	0	+	-	+
Multiple zippers?	0	0	0	0	0	0	0
# of sharp edges	-	0	0	0	0	0	0
Perceived Effectiveness	+	+	0	+	0	N/A	N/A

Pairwise Comparison matrices allowed ranking and an overall holistic analysis of multiple designs. Finally we weeded out inconsistencies and biases through Multivoting[11].

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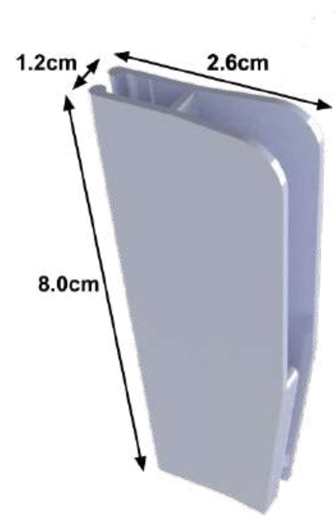
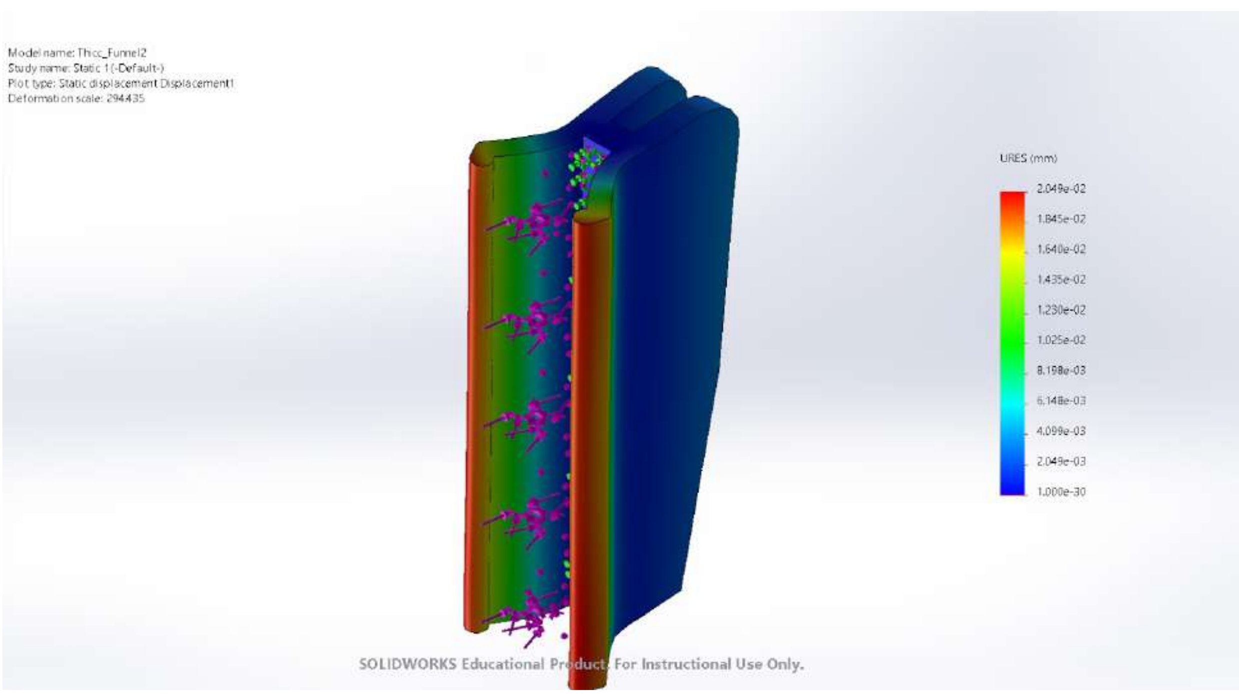
[10] See Section 5.2.3 for Evidence

[11] See Section 5.3.3 for Evidence

5. Prototyping and Representation

Prototyping for this project was a unique experience. Since everyone was working virtually, individual made prototypes had to be consistent among all the members. This reinforced the exact ideas and specifications and ensured a certain quality of work throughout the team. In addition to handmade prototypes, 3D CAD models of the final designs was built and tested in simulation softwares.

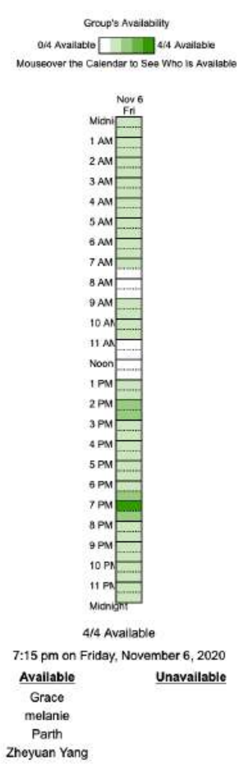




7. Past Projects

1. ESC101 Praxis I: Ergonomic Keyboard

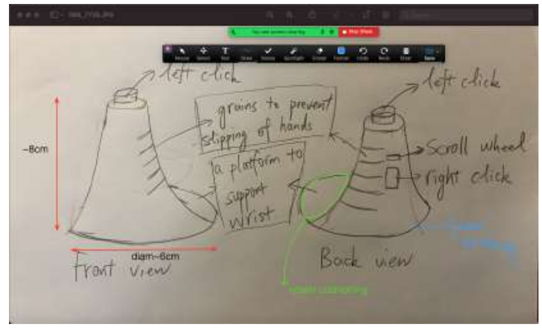
The *purpose* of this project was to analyze - Candidates and Tools Critique and diverge into various candidate (product) designs to solve. It was to further highlight *my* contribution to the same with respect to the interpretation of the topic, processes used and the various *Tools and Methods* incorporated. The aim of the Candidate Design and Tool Critique assessment was to find ways to ameliorate the problem of Carpal Tunnel Syndrome (CTS) through introducing ergonomics in Office-use Keyboards.



When2meet in action

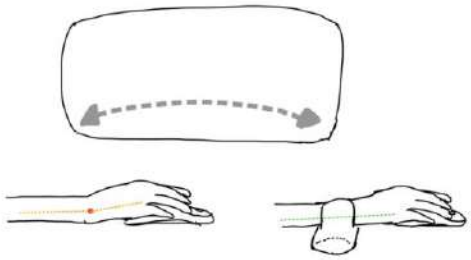
First of all, due to the majority of the team being in different time-zones, it was difficult to coordinate with everyone and ensure peak potential during the specified meeting time. To overcome this issue, *I* came up with the idea of having a meeting at a suitable time for everyone, decided upon by everyone simultaneously without hindrance by time-zone calculations. For this *When2meet* was employed which eliminated time-zone calculation redundancies and displayed the optimal time for the meeting i.e. when everyone was available.

For the transfer of information and sharing of ideas, a combination of *audio*, *visual*, *physical,* as well as *digital* modes were employed. Ideas were initially discussed on *Zoom Calls* and concurrently, rough sketches were made and shared on a Discord Server . For the sharing of ideas, the visual mode was observed to be the most productive since all teammates could provide their inputs on sketches directly as additions for which Zoom’s annotations were be ideal.

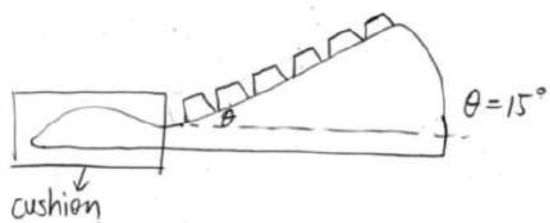


Using Zoom White-Board Functionality during team meetings

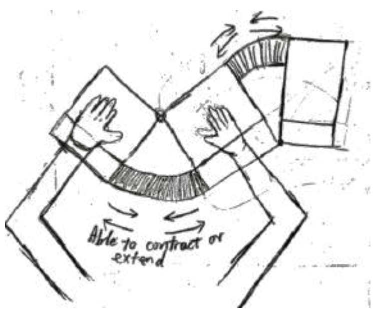
The design process involved all members in idea generation and its implementation. I proposed we begin with a Brainstorming session that enabled us to identify the ways of causing CTS, this helped us cover all the bases for the Candidate designs and effectively reduce anchoring at the same time. As everyone kept the causes CTS in the back of their minds, we moved on to Brain-Writing. Brain-Writing allowed the flow of ideas unhindered by judgement, it also allowed equal participation to all as no one could be assertive or shoot down ideas; even unconsciously. Now as each person was familiar with all the ideas, the Structured-Brainstorming session began. During this time, each person’s idea or grouped ideas was brainstormed upon rigorously one-by-one. This helped us get the input of 4 brains, one Candidate Design at a time. Each design was improved upon and useful comments were added as audio or addition to sketches Brainstorming proved to be a very systematic method to better each design and provide new perspectives for the candidate designs. Finally, as each member had one idea of their own, now improved after the brainstorming, each idea was researched upon individually. For the final idea, the PINC method was used and all residual ideas were filtered. This approach was fair to all candidate designs and gave a detailed result which was our (n+1) design Candidate. As each design was finalized after lots of research, Wishing was used to improve upon those candidate designs even further and new features were simply added to the Candidate Designs. Although done in the end, most new features were added to the Candidate Designs at this point since each member was wellversed in the research related to their designs and the bare-bones structure was already established from the Brain-Writing.



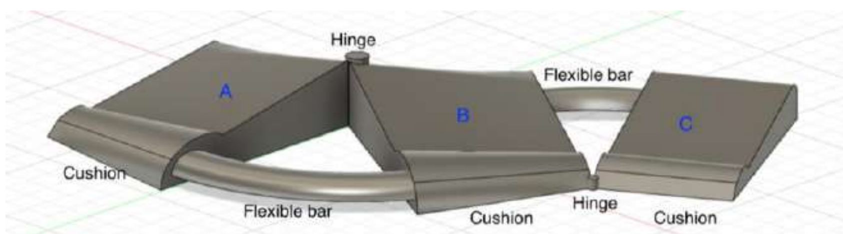
Brainstorming to find causes of CTS



Brain-Writing ideas to tackle the problem devised during reverse Brainstorming



Design finalized after initial Brainstorming



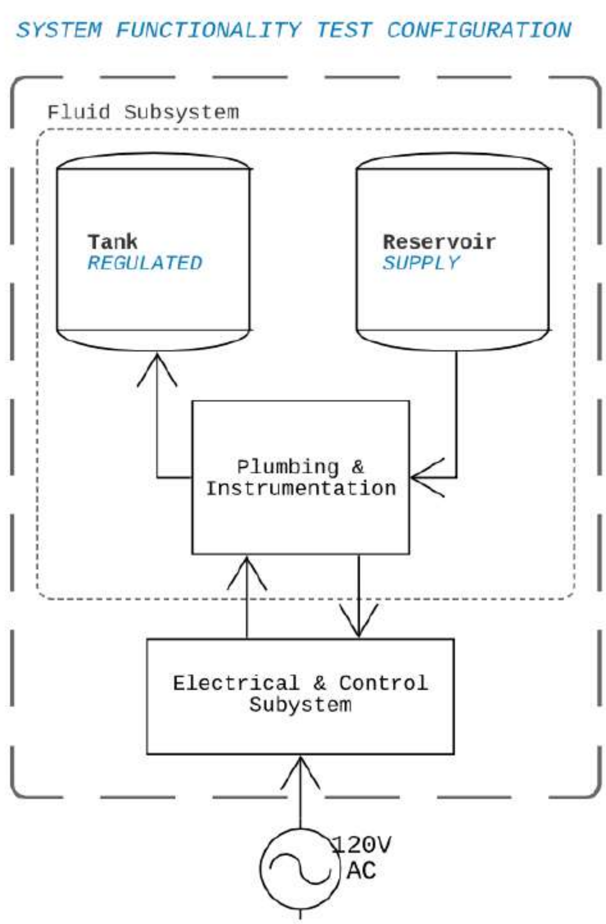
Final product obtained after Wishing

2. University of Toronto Aerospace Team: Pressurization System

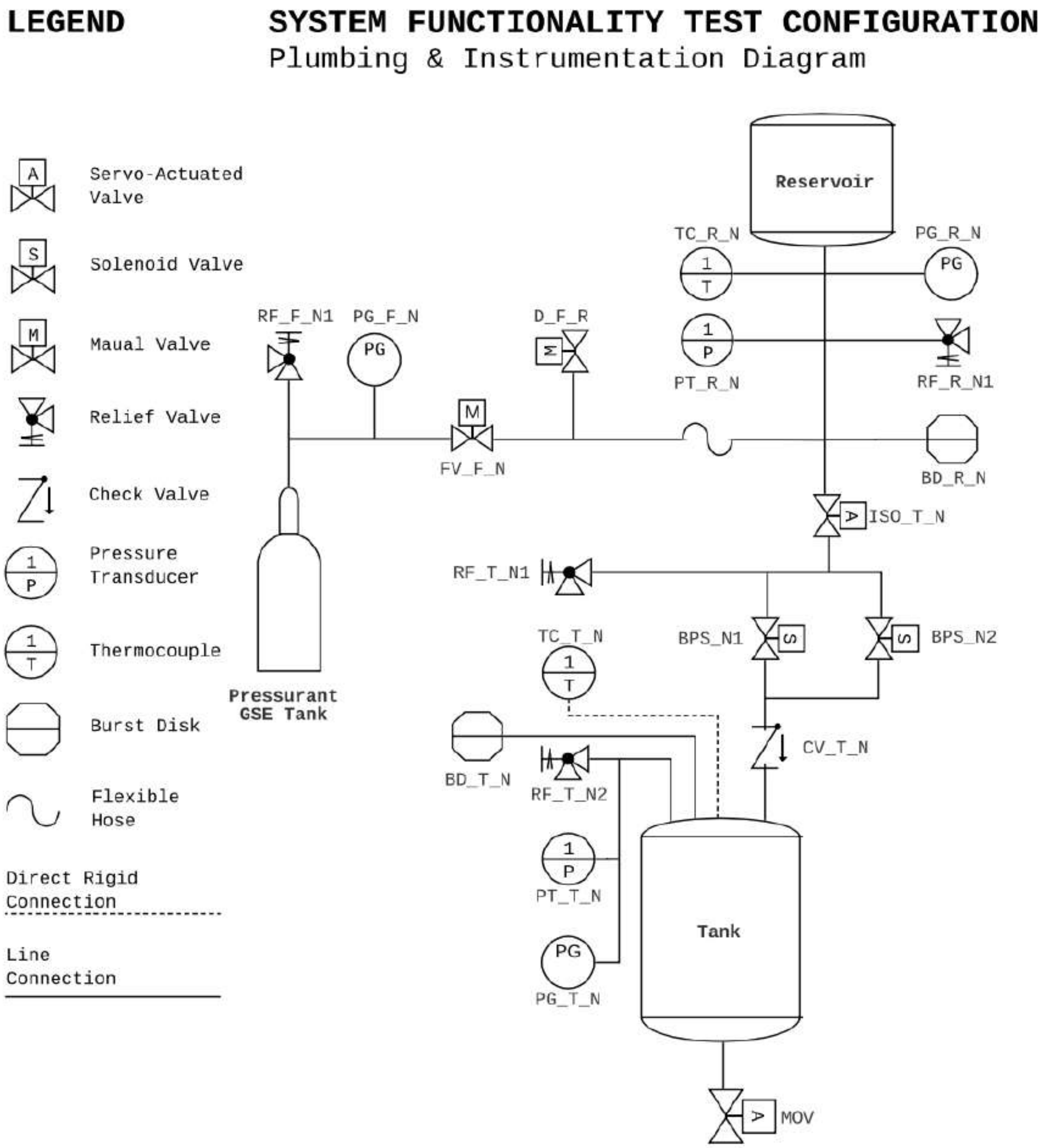
Working for the University Aerospace Team, UTAT I learned a lot. Although I didn't explicitly use any tools or models due to the nature of the project, I used the integral parts of my Design process. Namely, Problem Analysis, Estimation, Stakeholder Feedback and Representation.

My task was to design a Blowdown Pressurization System for The University Aerospace Team's first ever Liquid Rocket, Houbolt Jr. I approached the problem by first researching the topic of pressurization in rockets. After reading multiple Case Studies about Pressure systems in Solid Fuel Rockets, I realized that not a lot of Liquid Rockets utilized a Blowdown Model for pressurization.

This was mostly because the majority of Liquid Rockets were much bigger than the one we were designing and they utilized pump-fed systems that did not require active control over the pressurant. However, in our case, using a pump feed would inevitably double the mass of the entire rocket and cause the Routing&Plumbing Subsystem to change completely. Since this was an expensive proposition, both mass wise and cost wise, it was decided upon a blowdown model.

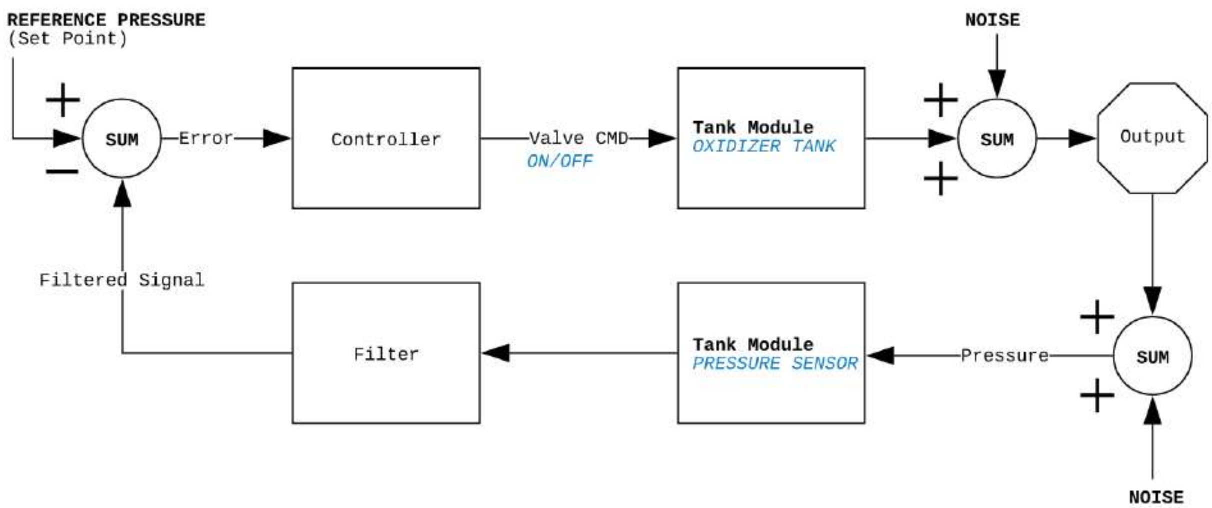


I began the actual designing process by taking input from the various propulsion subsystems and made a comprehensive block diagram so that I know exactly what my task is.



I then made an Estimate regarding the average Pressure within the Pressurant Tank to be approximately 6 MPa.

When I began simulating such a system, I referred to my initial estimate to verify that my formulas and mathematical functions are working properly.

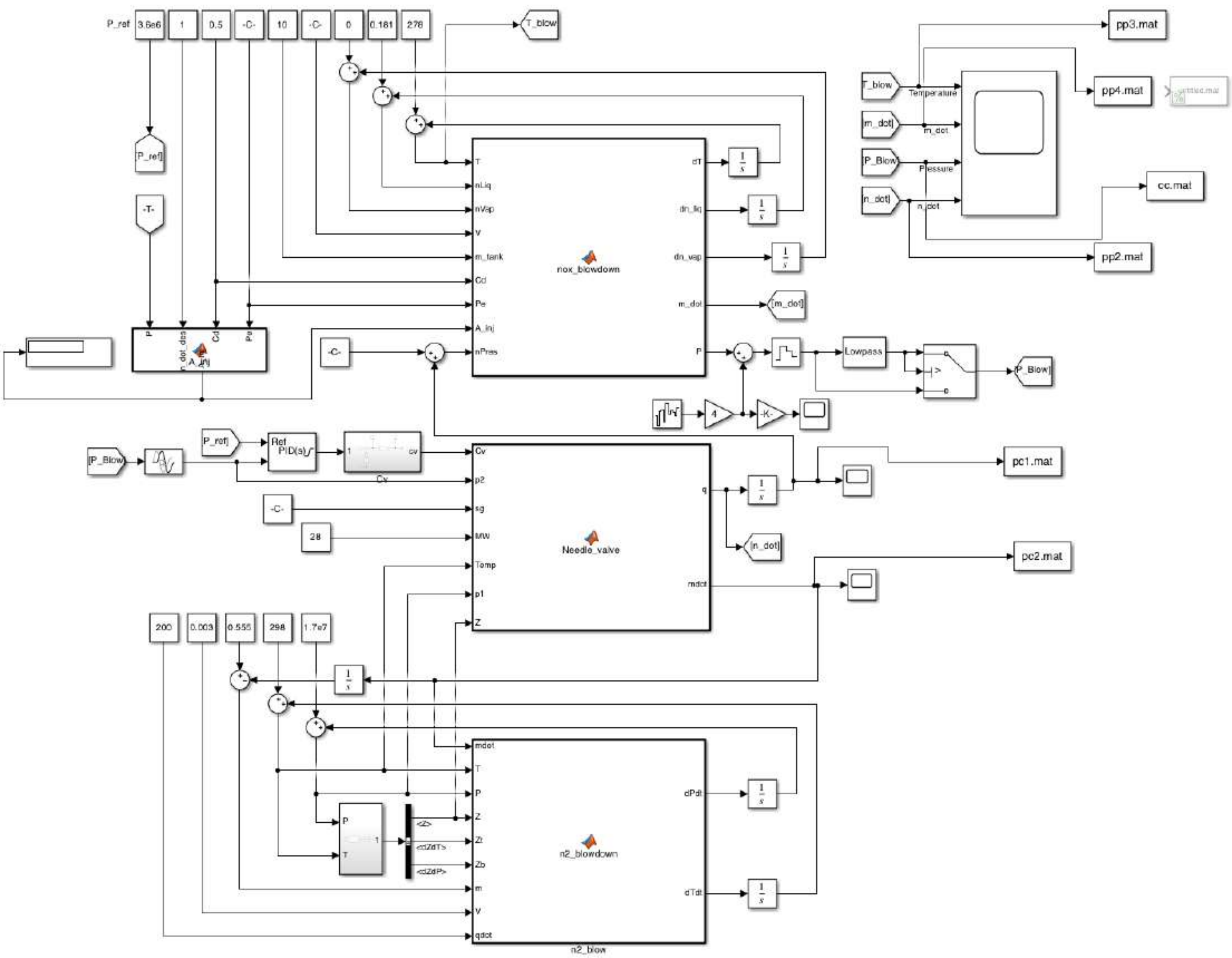


Using the above architecture, I designed a basic simulation for the Pressurization System. As the model seemed to function within a range of error, I began introducing more functions to account for more precise, real-world calculations.

When the simulation seemed to work fine for all the functions, I finally made the simulation itself a function of time for the 8 seconds of propulsion time. At this time I employed the use of dynamically changing time variables for the reduction in amount of oxidizer and fuel as the rocket burns through them. This made the initially simple model a complex dynamic multivariable simulation dependent on the same variables we initially verified.

At this point, the Pressurization System was connected to the other sub-systems and its performance was analyzed. It was observed that the mass flow rate was higher than expected and needed to be controlled. To solve this problem without altering any other dependent variables, I went back to the drawing board. I reverified all my formulas and worked backwards into finding the source for this inconsistency.

After solving the above inconsistency, in the next step, I reduced the overall complexity of the Pressurization System since integrating it with other systems required a lot of memory otherwise. The final product, now in use for the Houbolt Jr. Rocket is the following:



8. Key Takeaways

This section acts as a bulleted list for anyone who needs to identify all the important lessons I have learnt during Engineering Design but doesn't have time to sift through this entire document.

- Do not begin designing anything you don't fully understand
- In order to understand the ins and outs, do research
- Seek stakeholder feedback at every major step
- Do not put DFxs above community needs (however cool the idea may seem)
- If no design comes to mind, look to nature for ideas
- No testing data available? Justify claims through research
- Always discuss and talk out why someone else likes a design that you don't
- Weed out biases by incorporating input from multiple sources
- Solely Qualitative comparison is not an accurate measure of efficacy
- Begin prototyping early and ask for feedback
- Revise and redo your designs with input from stakeholders after prototyping
- If it works perfectly, it doesn't have enough features

9. References and Citations

[1] [Praxis II Lecture 5: Communities, Credible Sources, and Framing Perspectives]

[2] [Faickney Osborn, 1953, Applied Imagination]

[3] [O. Serrat, "The SCAMPER Technique," Asian Development Bank, Manila, 2009.]

[4] [Y. Haik, "Morphological Chart and Concept Generation," Florida A&M University College of Engineering, Tallahassee.]

[5] [F. Salustri, "Pairwise Comparison," Ryerson University, Toronto, 2005.]