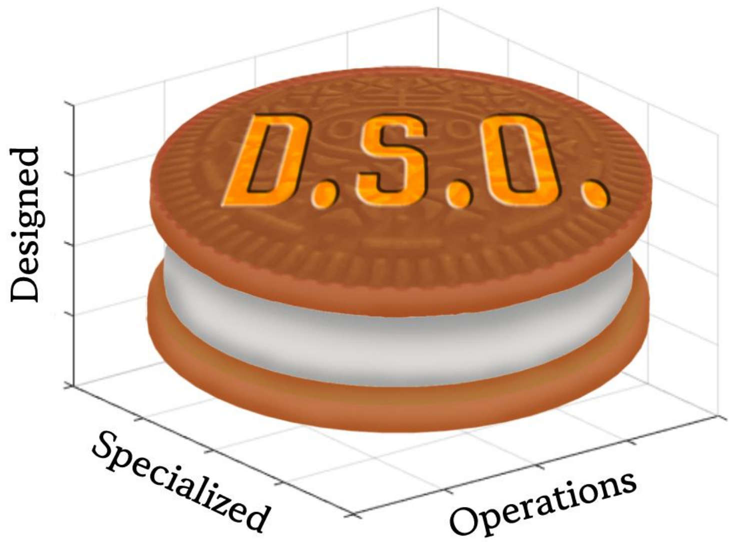
Compact Cable Case

Phase 3 Progress Report

28 April 2022



Designed Specialized Operations

ME 263 - Section 127

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Executive Summary

The purpose of this report is to prepare information regarding the problem Designed Specialized Operations took steps on how to solve, in accordance with research gathered for the problem. DSO saw a prevalent issue that many people face in their everyday lives and routines that could be improved quite easily. The problem that DSO chose to improve on is the transportation of cords, whether for computers, phones, calculators, etc. and the complications that come with tangling and portability when you need to take them somewhere. The second phase of this project includes new avenues of analysis that will be discussed in this executive summary and subsequent areas of the report.

The first step in phase three focused on more specific engineering drawings. These included, dimensioned, CAD drawings of each part involved in assembly. Additionally, all purchased parts have dimensioned drawings. A Design for Assembly was performed for each of our assembly sections and this was done to gauge areas of design for improvement (Appendix J). This type of analysis allowed DSO to better design parts and assemblies to meet customer needs more effectively.

The second task for phase three were all the engineering models performed by each team member. The first engineering model was on the shear stress that the railing piece of the lid experiences due to pulling by the carabiner. Finite element analysis was done in order to gain a better understanding on where the max stress occurs to avoid problematic areas. The second engineering model showed the force it took to open the lid of the product. This benefits DSO by understanding if this product is marketable to any age range and physical abilities. The third model focused on the internal assembly of the spring. This information included the retraction speeds that cords experience and helped DSO choose the correct internal spring with the correct properties. Lastly, the final model dealt with how the product reacted if it were dropped and the impact forces it experiences. This was especially important for determining the outer design and materials structure to go with to ensure that if it dropped the expected forces would not destroy the product.

The exploration done by Designed Specialized Operations from the various engineering models showed a better understanding to the team about improving computer models to ensure customer requirements are met. The main improvements are seen in the CAD and in the appendix of this document (Appendix E and I).

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Introduction

Technology has become an overwhelmingly large sector in the global industry today. One thing in common with all technology devices is the fact that they need to charge. Keeping chargers organized and commuting with them can be a really frustrating thing and people have been looking for a solution to this problem for years. This is such a broad issue that has personally affected everyone on Designed Specialized Operations, along with most of the surveyed individuals. DSO is to develop a product that simplifies cable organization and portability while being universal for all types of cables.

The purpose of this report is to detail the progress of DSO through the design process. The primary focus is on the phase 3 progression of the Compact Cable Case project. However, this report also encompasses all previous phases and their culmination. This report is split up into many sections, each of which details a specific segment of the design process of the project.

The first section is the customer and market research. This references back to phase 1 to establish the evidence in favor of pursuing this project. The report then transitions into the problem definition in which the scope of the project is further defined. The problem definition gives context to the project and validates the need for the product being developed by DSO.

After these preliminary sections, the report moves onto phase-3-heavy content. The design of the product is first analyzed. This includes the analysis of the functionality of the design, a summary of the bill of materials, and an assembly sequence overview. This section is complemented by the “Phase 3 Prototype” section a bit later in the report, which details the physical prototype and how it influenced the overall project.

The intermediate section between “The Design” and “Phase 3 Prototype” dives into the engineering modeling of the design. This section summarizes the engineering models and details key results from these models. It further details the practical application of the results. These results are then used to compare to the benchmarks of phase 1 in the benchmark section. This section occurs just after the phase 3 prototype section. It is a technical analysis of how the final design compares to the original goals set for the project.

The penultimate section of this report covers the economic analysis of the Compact Cable Case. This focuses on the real-world business scheme of this project. It involves the costs to maintain a company, develop this product, and how the investment will age over time (this includes the break even point, rate of return, and return on investment). This bridges into the conclusion which wraps up the project and summarizes everything done, not just in phase 3, but in all phases. Final analyses of the design will be made along with future planning and recommendations.

Customer and Market Research

To get a better idea of the market and gauge demand and customer interest for such a product, the team conducted customer research in the form of surveys. Through market research and the survey results, it was concluded that 54% of the population uses charging cables at least 3 times a day and that 83% get frustrated from cable disorganization and damage. This benchmark made it clear that there is potential for a prevalent demand to exist in the market. Furthermore, it was discovered that 93% of the population travel with their chargers every week. This made it clear that the product has to prioritize portability. Respondents have also shown that misplacing chargers and dealing with disorganization/clutter are also common issues, as shown by the survey results below:

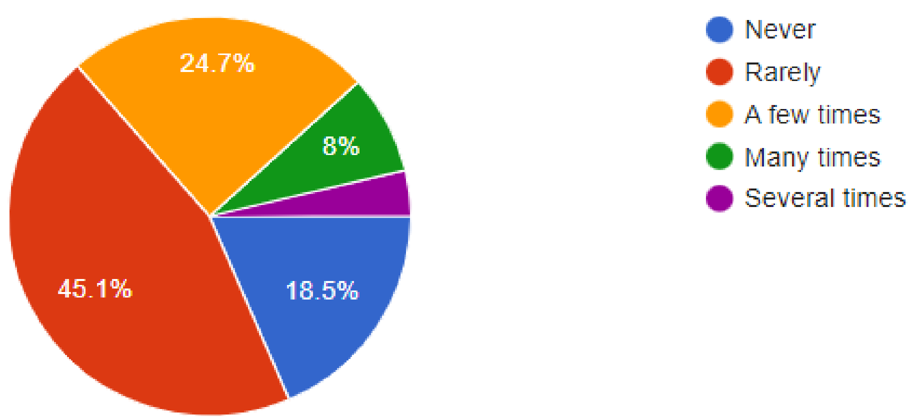

Figure 1: How often people lose their chargers

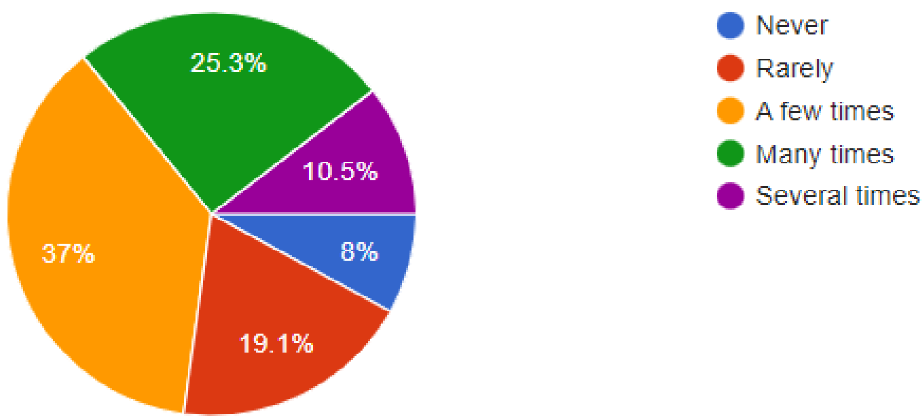

Figure 2: How often people deal with cable disorganization or clutter

There are some products in the market that solve such problems and cater to the population, however, there are none that have a generalized modular mechanism that allows the customer to swap out the charging wire inside. One competitor, BeatBuddy, is designed well for portability, but lacks durability and accessibility. Other competitor brands such as Global Industrial Cable Retractor and PC Nation also have similar issues as they lack aesthetic, accessibility, or adjustability. D.S.O. aims to develop a product that meets all of such customer requirements. A strong demand exists for a solution as 96% of the population claim they would be willing to spend more than $10 in purchasing a product and 43% are willing to pay over $20.

Apart from existing brands, there are also some notable patents that exist. The "Retractable cable assembly" (US20020040945A1) patents a particular design of a retractable cable assembly that employs a spring tension mechanism to retract a coiled cable. This design however, does not offer a removable/replaceable cable design. D.S.O. aims to develop a product that prioritizes accessibility and convenience by allowing users to use any cable with the product. Such a dynamic design has not been patented. Another notable patent that exists is the

“Retractable cord reel” (US8657087B2). This patent is of a specific retractable reel design that uses a conductor to pass a current with a spool when engaged. When disengaged, the ratchet cannot make electrical contact with the conductor on the spool. Neither of these designs are of severe threat to the team’s potential design and product as the customer requirements are different.

Problem Definition Review and Updates

While Designed Specialized Operations has gone through all phases of the design process, there have been no changes made to the problem definition. It remains unchanged from that developed in phase 1, as the idea and scope of the project is the same. That being said, the problem definition is as follows.

Designed Specialized Operations is to design a product for cable organization for individuals who own technology devices which will feature compact, non-tangling cable storage and portability. The target consumer audience is anyone owning a technology device such as a phone, tablet, computer, or anything else requiring cable charging.

People who own technology devices often run into problems with their charging cables getting disorganized, tangled, or even ruined. From a survey distributed by Designed Specialized Operations, it was found that 91.9% of people with tech devices deal with these problems on a regular basis (figure 2). From talking directly to a few survey takers, they described their frustration with chargers being cluttered on the floor and getting tangles in their chargers when commuting with them. The takeaway that DSO took from these conversations and the survey results was that a product needs to be designed to conveniently organize any cable of choice while being both portable and hard to lose.

Currently, consumers solve the problem of cable disorganization with many different solutions, one of the most prevalent being small cable hook guidelines. Another common solution when taking into account the portability of cables is retractable chargers. However, these solutions have their gaps. Cable hooks are a more temporary solution for when consumers hope there will be a better product on the market, which is what DSO. intends to make. The retractable charger products currently on the market are the inspiration for the product being designed by DSO. However, these retractable chargers are cheaply made, ineffective at charging, and non-durable. DSO. looks to use the concept of this product to design a much better quality, more durable, and more universal product.

The product being designed by DSO. is supposed to be universal to whatever cable is being used. The Compact Cable Case is to function similar to a tape measure, such that the cable will remain organized inside its casing until required use. Then, the consumer can pull out the desired length of cable for use. When finished with use, the consumer can let the cable retract back into the casing. There will be a carabiner attached to the casing of the product so it is easy for consumers to take with them on the go. Depending on what cable is being used, the consumer can open the casing and change out the cable to their choice.

Through different types of research, DSO. has come up with the most important customer requirements. These include being low cost, durable, portable, adjustable, aesthetic, ergonomic, and accessible. The engineering requirements associated with the customer requirements can be found in the House of Quality in Appendix A. From these engineering requirements, DSO. aims to make the solution under 100in^3 in volume, hard to break, able to fit up to 0.5in diameter cables, less than 24 ounces, and priced at or under $20.

In their survey administered, DSO. found that consumers would be most willing to pay for a product priced between $10 and $20. Through further research, DSO. discovered that in 2018, 69.6% of the US population has a smartphone [1]. This is equivalent to approximately 227 million people just in regards to one sector of usability for the product being designed [2]. From this number, a reasonable estimate for yearly sales would be 227 thousand units sold. DSO.

thinks they can reach 0.1% of the population in the US due to the newness of the product and the fact that human nature likes to stick with what they know works.

The Design

After a preliminary design was developed in phase 2, Designed Specialized Operations (DSO) created a final design for the Compact Cable Case in phase 3. The final design encompasses simple mechanisms to operate as desired. The three main components include the retraction mechanism, cable locking mechanism, and case closing mechanism.

The most important mechanism of the Compact Cable Case is the retraction of the cable. This includes a power spring connected to the inside of the wheel piece. The power spring is fixed in place, while the wheel is able to spin around a bearing to create tension. The tension gets greater as the wheel is winded and will retract the cable into the case once the lock is released.

As just mentioned, there is a locking mechanism that locks the wheel into place. The purpose of this is to keep the cable extended so it doesn't automatically retract into the casing. This locking mechanism is made up of a drop pin, a hole in the top cap, and 4 holes in the wheel. The drop pin and holes in the wheel can be depicted in their respective drawings in Appendix I. The lock works by dropping the pin through the hole in the cap so that it will fall into one of the 4 holes in the wheel. The pin will keep the wheel from rotating any further, so the cable will be extended at a fixed length according to the displacement of the wheel.

The last primary component of the Compact Cable Case is the closing/opening of the casing. As detailed in the drawings in Appendix I, the top cap and bottom body are the outer casing of the product. These two pieces come together as an assembly by a simple tolerance fit. A tight fit is applied between the outer radius of the bottom body and the inner radius of the top cap. The tight fit creates relatively large normal and friction forces between these two components, which is what keeps the cap and body fit tightly together.

All the parts that make up the overall design of the Compact Cable Case are detailed in the Bill of Materials, which can be found in Appendix G. This was revised once between the preliminary and the intermediate designs, and was again revised between the intermediate and final designs. The overall cost of the product was reduced significantly relative to the phase 2 BOM. The cost was brought down to $5.92 by minimizing the volume of the 3D printed designs (this includes the top cap, bottom body, drop pin, and wheel). This is a 50.91% decrease from what it originally was, which greatly helps the profit margins. These parts are made out of PLA filament and are 3D printed in order to reduce costs on manufacturing. The rest of the components of the model were sourced online and bought from vendors (this includes the power spring, key ring, suction cup, and bearing). These costs are fixed from the original BOM, so there are no significant changes there. The materials of these parts are pre-determined by the vendors, as the spring is made of stainless steel, the key ring of metal alloy, the suction cup of PVC, and the bearing of carbon steel. These parts are also manufactured by the vendors, so DSO does not have to worry about these manufacturing processes.

The final product assembly does have somewhat of a required process. However, this isn’t extensive, and only regards the 3 interior pieces: the wheel, spring, and bearing. In assembly, the bearing has to be attached to the inside of the wheel and the power spring into the designed slot in the wheel. The order of the assembly of these three pieces is irrelevant, but this sub assembly must be completed before attaching it to the bottom body. Once the bearing-wheel-spring subassembly is completed and attached to the bottom body, the rest of the assembly process has no particular order.

Engineering Modeling

The first engineering model performed was on the lid's railing piece that the customer can connect a carabiner to (referred to as the railing piece). This railing piece was selected for examination because it is the point of contact in which the user will exert stress and force on the longest. This is because as it is clipped in, the user may be walking for a variable amount of time which could include extensive periods.

Through the use of computer aided design, the shear stresses of the carabiner were able to be replicated inside the software. A finite element analysis (Appendix H) was done to determine how the anticipated location of contact force affected the railing piece. Through this, a maximum force was determined at the inside corner of the railing piece for a reasonable factor of safety.

By utilizing the results gathered from this engineering model, A more effective geometry was created to dissipate the force experienced by the railing piece. Now, with a more curved design, the stress is not focused on one singular point or section on the piece and can hold more of a load.

The second engineering model that was done looked into force required to open the casing of the design. Ensuring that the customer can open the casing with minimal effort while the producer still being within a fitting tolerance is important for design. This product may be used by more than the primary target consumer (college students), such as children and the eldergly, who possess less physical strength.

The key modeling results from this examination showed DSO the tolerance required for construction in order for the average consumer to easily open the design. This then accounted for the users above or below this threshold to also be able to open the casing. Additionally, when the values for static and kinetic friction were measured for when it switched over. This also shows the moment for when the lid can be opened. This aids in design by being able to adjust either the tolerances of design or the actual material if desired to obtain smaller coefficients of friction to conduce an easier opening.

The third engineering model focused on the internal spring forces of the design and the velocities of the cables when in use. This is important in determining the correct spring to handle the expected load from the average cable that most users will have.A key result found was the actual spring constant that would be best in maintaining longevity of the spring. This was based off the force applied to the spring by the cable that was placed into the design by the customer. There was also the torque due to the coiling and unwinding of the spring and helped in determining the results for the spring constant. The velocity of the actual cable, when in use, was given a certain threshold to make these calculations and set at a reasonable speed to evaluate. These results provide the data needed to correctly gauge which material to choose when selecting the spring. Additionally, the torque that is applied can be mitigated by adjusting the thickness and density of the material the spring is composed of which helps DSO in final product design.

Lastly, the final engineering model analyzed the bottom of the design experiences on an impact. It is not unreasonable to think consumers will not drop the product so the bottom casing needs to be strong enough to withstand a reasonable impact. Examining this aspect of design requires an assumption for the particular height that the product is typically dropped from and that affects the equations of modeling. The key result found was the maximum force that the bottom of the case can experience before failure, not deformation. The idea that the measured point was for failure and not deformation or cracking is important because it allows DSO to set an upper threshold for the design to ensure that the safety factor is maintained for everything below that. This is included in the final design by contouring the bottom casing to spread out impact forces so that no one point will take on too much of a load and cause an issue.

Phase 3 Prototype

The final prototype consisted of a variety of improvements that were deemed necessary from previous prototype versions as part of an iterative design process. One such improvement was removing the clip-mechanism, which was originally used to lock the cap on to the body, since it would add many manufacturing complexities and the friction between the cap and body was tight enough to create a secure lock by itself. Another improvement was threading an M3 hole into the bottom of the case so that any suction can screw into it. This not only makes the suction cup removable, but also makes the design modular as it isn't constrained to only be compatible with one type of suction cup - any cup that can thread into an M3 hole can work. Moreover, various thin protrusions were strengthened using filets and increased diameters, if not a critical dimension, as many parts in the original 3D printed prototype broke from basic handling. Many changes were also made to improve ease of manufacturing. In this case, the manufacturing method is 3D printing and thus, the design was modified to minimize irregular geometry, asymmetrical shapes, and structures. For example, the key ring loop was moved from the top surface to the side so that the top can become a flat surface and avoid needing structures. Filets were then used so that the loop gradually merges into the cylindrical geometry as opposed to an abrupt and thinner connection.

With respect to the main retracting functionality, a pin-drop mechanism was implemented to serve as a wheel lock for the retraction. A pin is allowed to be removed or dropped into a hole on the surface of the wheel which thus inhibits the rotation and stops the retraction. Furthermore, due to lack of real estate, the yin-yang mechanism was replaced with a protruding pin for the cable to wrap around, thus allowing it to become constrained to the wheel.

These improvements greatly improved the functionality of the team's prototype. In the future, the team plans to expand the design and continue testing the retraction mechanism. Since the current prototype is a scaled down version of the intended final model, the final product will not have many of the issues that our prototype faces which stem from size limitations. One example of this is the difficulty of loading in cables in such a cramped and small space. The final model will be scaled up and automatically solve this issue. Overall, the prototype is successful for medium fidelity expectations as it can demonstrate user intent, expected functionality, and meets a majority of functional engineering specifications. Technical specifications have not been completely met but this is primarily due to the fact that this is only a prototype and it is not made with the right material, is not the correct size, and does not use manufactured sub components.

Benchmark Comparisons

As Design Specialized Operations completed their initial analysis of the product, the team performed an in-depth analysis of the market to understand similar existing products on the market. The three main products that were similar to DSO's Compact Cable Case were the BeatBuddy Cable Organizer, the G.I cable retractor and the PCNation Retractable cable. All three of these products were sold with a cable attached inside that could not be swapped out. Additionally, all three of these models were noted to be flimsy which discouraged consumers to buy their products. To design a product that would better appeal to the clientele, Design Specialized Operations analyzed each of these products and designed improvements to create a more practical cable case.

The first major improvement is in regards to the accessibility of the product. Rather than selling the product with a cable attached inside, the team opted for a modular design in which the user can use their own cable inside the product. This allows the user to utilize the product for a variety of cables such as a phone, laptop or tablet chargers. This modular design is much more appealing to consumers since they can use their own cables and switch them out when necessary, rather than using a pre-attached cable as seen in the current products.

The second major improvement revolves around the durability of the product. A large number of reviewers noted that the products were flimsy and would break often. Rather than using a cheap plastic on the exterior of the product, the team opted to use a 3-D printed exterior case utilizing PLA filament. The hard exterior case ensures that the product is durable and will not break due to minor impacts.

The final improvement revolves around the portability of the product. None of the products on the market have features that make them portable or hard to lose. As seen in the House of Quality (Appendix A), portability was one of the features consumers desired the most. To ensure the Compact Cable Case is easily portable, the team added a carabiner to the product, which can attach to many common items, such as a backpack. Additionally, the team intends on adding a suction cup to the bottom of the product, which can attach to any surface. These design aspects ensure that the Compact Cable Case is portable and extremely hard to lose.

Economic Analysis

The economic analysis performed by DSO can be examined by looking at four different areas of interest; net worth diagrams, the break even point, rate of return, and the return on investment.

Net worth correlates to the total value of assets a corporation, in this case; DSO, owns without considering liabilities. The net worth diagrams in Appendix B show the projected net worth for DSO over a fifteen quarter period. One includes interest and shows the raw values whereas another accounts for interest and gives a more realistic conjecture.

The break even point refers to the time required for the profits from sales to equal the investment costs. There are many elements that affect when this happens, some include the annual production, production costs, and retail prices. DSO saw their break even point around the fourth quarter (Appendix B).

Rate of return (ROR) is the interest rate that makes the net present value of cash flows zero. It is desired for the ROR to be greater than the expected interest rate and allow the project to make money but this requires an estimate of the cash flow over the predicted life of the venture. Previously in PR2, we missed an area of design by having our retail price too high and this led to slightly unreasonable values but in PR3 it was corrected to the right retail price. Utilizing the "Goal-seek" function in excel the estimated ROR that Designed Specialized Operations came to was a value of 34.12% (Appendix B) which is greater than the annual interest rate.

Lastly, return on investment (ROI) is the percent return on an investment per year which essentially helps you understand how much profit or loss your investment has earned. The investment for DSO is represented by the capital investment costs that are paid in order to bring the product to market. The goal is to maximize the return on that investment and the value DSO came to can also be seen in Appendix B.

Conclusions and Recommendations

Overall, the problem definition remained the same as the first phase - Designed Specialized Operations is to design a product for cable organization for individuals who own technology devices which will feature compact, non-tangling cable storage and portability. Throughout the project, the team has primarily focused on developing a problem statement, conducting market studies, designing a concept that adheres to the trends discovered throughout the market research and modeling a prototype based on the concept designed.

During the first phase, the team conducted extensive customer and market research to understand the clientele and the current products on the market. A high number of customers agreed that they use their charging cables often and face cable disorganization on a frequent basis. Additionally, 96% of respondents agreed that they would be willing to spend $10 - $20 on the product since it would greatly convenience them. Furthermore, the team analyzed the current products on the market that are similar to the Compact Cable Case. DSO's analysis revealed that existing products were flimsy and had a cable pre-attached that could not be switched out. To combat these issues, the team developed improvements to ensure the Compact Cable Case was durable, portable and accessible.

As DSO moved into the second phase, the team performed an in-depth economic analysis to ensure the product was profitable and a good investment. The economic analysis performed by DSO examines many significant areas of interest; net worth diagrams, the break even point, rate of return, and the return on investment. The net worth diagram takes into account DSO as the single owner over a fifteen quarter period. As noted in the economic analysis, the break even point refers to when the profit from sales equals the investment cost. As shown in our analysis, the projected break even point is the fourth quarter. The rate of return (ROR) is the interest rate that makes the net present value of cash flows zero. Utilizing "Goal-seek" the team calculated DSO's ROR to be 34.12%. Lastly, the return on investment (ROI) is the percent return per year on an investment. The calculated return on investment for Design Specialized Operations was 47.02%, which shows a strong profit in the investment.

During the third phase, the team began designing and prototyping the product. The team utilized the concept generated in Phase 2 to begin modeling each component of the Compact Cable Case. Each part was revised to ensure the specifications fit the model in the most effective manner. Once DSO had finalized the computerized models, the team began modeling and prototyping the product. During this, the team noticed many minor flaws within the design that needed to be corrected. For example, the locking mechanism was not necessary and created unnecessary hassle for the consumer. Thus, the team decided to remove it for the future prototypes. While continuing to prototype, the team constantly made improvements and modifications to better the product.

Finally, the team performed engineering models on the prototype to ensure the product met the team's specifications and goals. The team first analyzed the shear stresses on the carabiner since it is a high stress point. After conducting Finite Element Analysis, the team slightly adjusted the design to ensure it can withstand reasonable force. Next, the team analyzed the force required to open the top case. From this, the team concluded that a very minimal and reasonable force was needed to open the top case, which confirmed that the product was accessible and easy to use. Third, the team analyzed the internal spring forces and the velocity of the cable when it retracted and extended. From this, the team was able to determine the necessary spring force needed which aided in selecting the necessary spring to use while designing the product. Finally, the team analyzed the force due to impact if the case was dropped. From the results, the team concluded the design was durable and reasonable force would not damage the product.

Overall, the prototyping and engineering models proved to be vital in the design process. As shown by the consumer surveys and economic analysis, an effective compact cable case is a well desired product. Design Specialized Operations has proven through economic analysis that the product is a strong return on investment, making it prime to succeed on the market.

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1. O'Dea, S. (2020, April 8). *Smartphone penetration in the U.S. as share of population 2010-2021*. Statista. Retrieved February 3, 2022, from https://www.statista.com/statistics/201183/forecast-of-smartphone-penetration-in-the-us/
2. *U.S. population 1950-2022*. MacroTrends. (n.d.). Retrieved February 3, 2022, from https://www.macrotrends.net/countries/USA/united-states/population

Appendices

Appendix A: House of Quality

HOUSE OF QUALITY	Who (Customers)			Calculations		How (Engineering Specifications)						Calcs.	Now (Benchmarks)		
	Travelers	Children	Students	Total Consumer Sum	Requirement Weight	Selling Price	Total Weight	Max cable Diameter	Ease of Use	Maximum Volume	Production Material	Totals	BeatBuddy Cable Organizer	Global Industrial Cable Retractor	PCNation Retractable Cable
						$	ounces	in	N/A	in^3	N/A				
What (Customer Reqs.)						D	D	U	N/A	D	N/A				
Low Cost	2	1	3	6	9%	9	3	0	1	3	9	25	2	5	5
Durable	5	4	4	13	19%	1	3	1	1	3	9	18	1	1	3
Portable	5	3	5	13	19%	0	3	3	1	3	3	13	5	5	4
Adjustable	3	2	3	8	12%	1	1	9	3	9	0	23	4	3	2
Aesthetic	2	2	2	6	9%	1	0	1	3	3	3	11	1	2	2
Ergonomic (simple use)	3	5	2	10	14%	1	1	3	9	1	3	18	3	4	3
Accessibility	4	5	4	13	19%	0	1	1	1	3	1	7	2	2	1
Totals	24	22	23	69	100%	13	12	18	19	25	28	115			
How vs What Calculations					Weighted Importance	0.167	0.167	0.167	0.167	0.167	0.167	1.000			
					% Importance	11.30%	10.43%	15.65%	16.52%	21.74%	24.35%	100.00%			
					Importance Ranking	1	6	3	2	4	5				
					BeatBuddy Cable Organizer	19.90	10	--	--	64.65	--				
					Global Industrial Cable Retractor	17.93	24	--	--	15.34	--				
					PCNation Retractable Cable	16.33	16	--	--	1.17	--				
			Performance Targets		Target (Delighted)	16	15	0.125-0.5	--	22	--				
					Threshold (Disgusted)	20	20	0.5	--	60	--				

Ratings Legends

Now vs What
1 = Reqt. not met
2 = Reqt. someetimes met
3 = Reqt. usually met
4 = Reqt. frequently met
5 = Reqt. fully met

Who vs What
User Scale: 0: low - 5: high

How vs What Correlation Strength
Values: (0, 1, 3, 9)

The House of Quality represents the culmination of market and customer research done by DSO. formulated in a graphical representation.

Appendix B: Project Economic Evaluation Spreadsheet

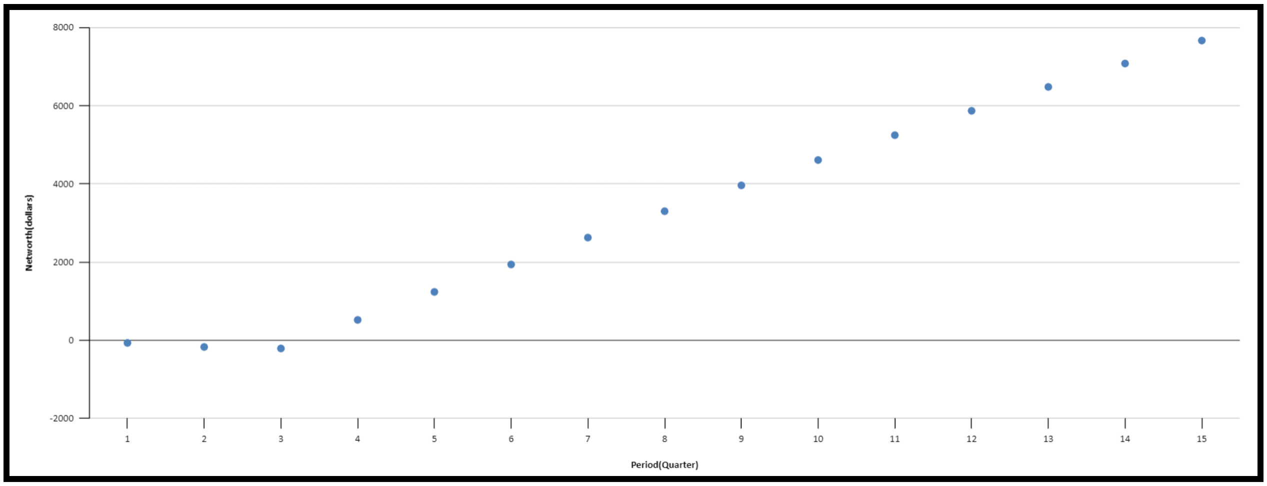
INPUT		
Interest Rate/ year=	8	%
Analysis Periods/ year=	4	#
Tooling and Fixtures=	80.85	(000)
Annual Production=	750	(000)
Estimated Cost of Purchased Parts=	4.89	$
Estimated Cost of Fabricated Parts=	6.17	$
Estimated Assembly Cost=	10	$
R&D Cost=	134.264(	(000)
Cost, % of Retail=	25	%
Return to Project, % of Retail=	30	%

CALCULATED			
Interest Rate per Period=	0.02	rate/period	
Estimated Mfg. Cost=	21.06		$
Retail Price=	19.99		$
Build per Period=	187.5	(000)	#
Total Program Build=	2250.00	(000)	#
Total Retail Sales=	44.9775	(10^6)	$
Return to Project=	13.49325	(10^6)	$
Net Present Value=	-28352.6	(000)	$
No Interest Present Value=	-34106.8(	(000)	$

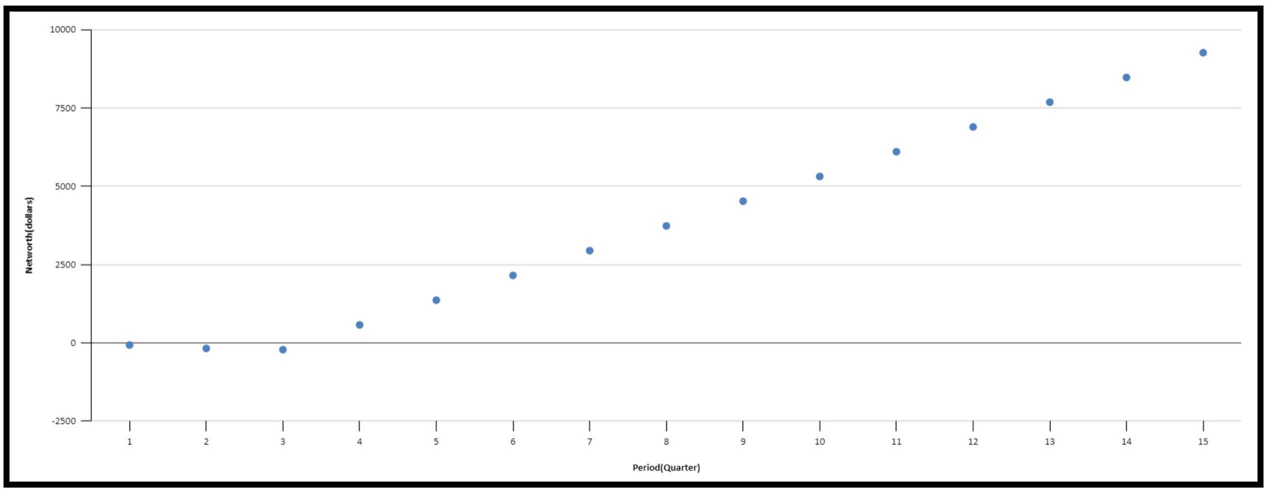
	Quarters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sum	
R&D Costs (000)	67.13	67.13	0	0	0	0	0	0	0	0	0	0	0	0	0	134.26	(000)
Tooling & Fixtures (000)	0	40.425	40.425	0	0	0	0	0	0	0	0	0	0	0	0	80.85	(000)
Production (000)	0	0	0	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5	2250	(000)
Cost of Production (000)	0	0	0	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	3948.75	47385	(000)
Plant "Sales" (000)	0	0	0	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	4738.5	56862	(000)
Sales Minus Cost (000)	0	0	0	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	9477	(000)
Net For Quarter (000)	-67.13	-107.56	-40.425	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	789.75	9261.89	(000)
Net Worth (000)	-67.13	-174.69	-215.11	574.64	1364.39	2154.14	2943.89	3733.64	4523.39	5313.14	6102.89	6892.64	7682.39	8472.14	9261.89		(000)
Present Value	-65.8	-103.4	-38.1	729.6	715.3	701.3	687.5	674.0	660.8	647.9	635.2	622.7	610.5	598.5	586.8	7662.9	(000)
Net Worth Present Value (000)	-65.8	-169.2	-207.3	522.3	1237.6	1938.9	2626.4	3300.5	3961.3	4609.2	5244.3	5867.0	6477.5	7076.1	7662.9		

Break-Even Point	4th	quarter
NPV	294.63	$ (000)
(ROI)	42.07	%
(ROR)	34.12	%
Min Production Without Interest	17.02	(000)
Min Production With Interest	19.75	(000)

These figures show the estimated evaluation based on projected inputs for the 15 quarter term outlined in the given documents.

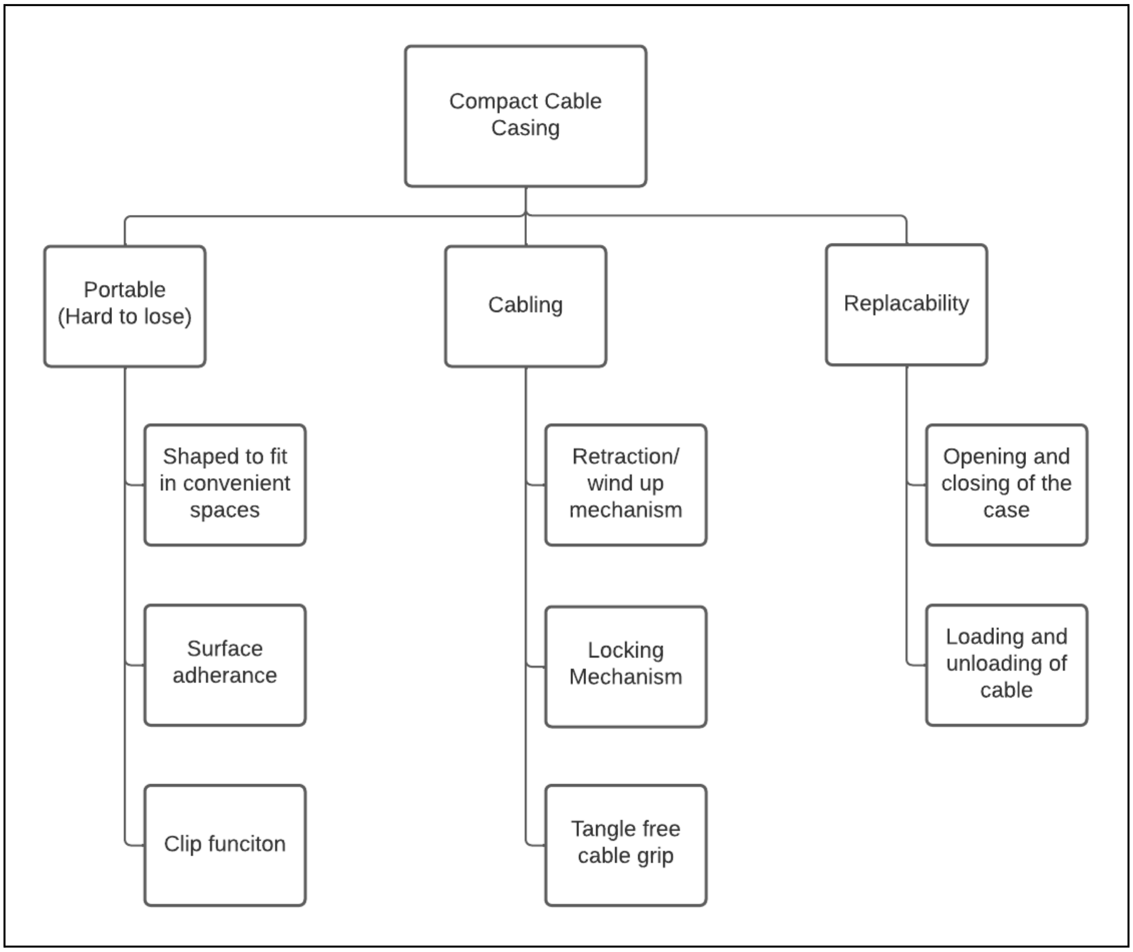


Net worth diagram with interest.



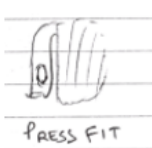
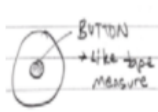
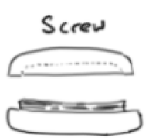
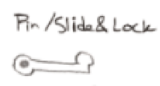
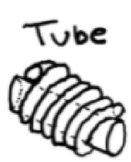
Net worth diagram without interest.

Appendix C: Functional Decomposition Diagram



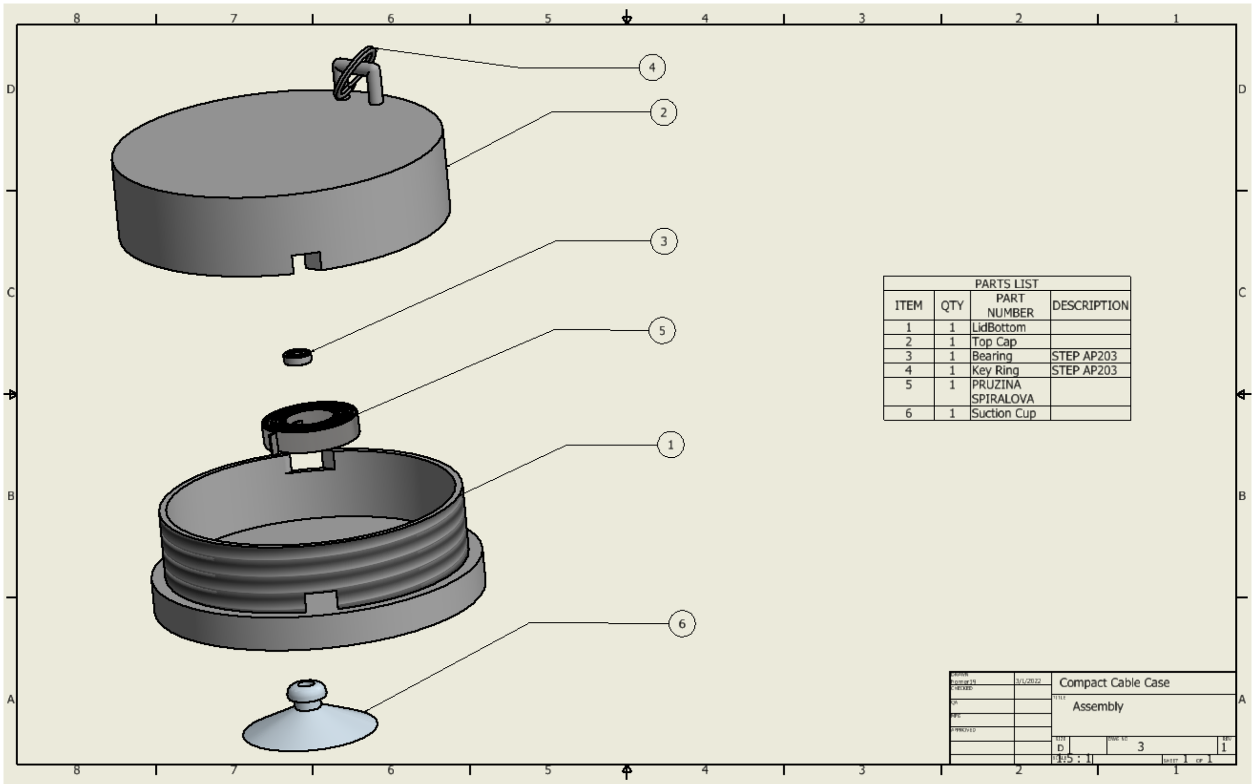
This is the functional decomposition diagram. It serves as a tree of functions and sub-functions. The three main functions include portability, cabling, and replaceability. There are multiple sub-functions for each primary function that branch off.

Appendix D: Morphological Chart

Product Sub-function	**1**	**2**	**3**	**4**
Shape (to Fit in Convenient Spaces)				
Surface Adherence				
Clip Function				
Retraction/ Wind Up mechanism				
Locking Mechanism				
Opening/Closing of the Case				
Tangle Free Cable Grip				
Loading and Unloading of the Cable				

This is the morphological chart which details each sub-function and the design to accomplish each sub-function. One design from each row will be chosen to be implemented into the final design.

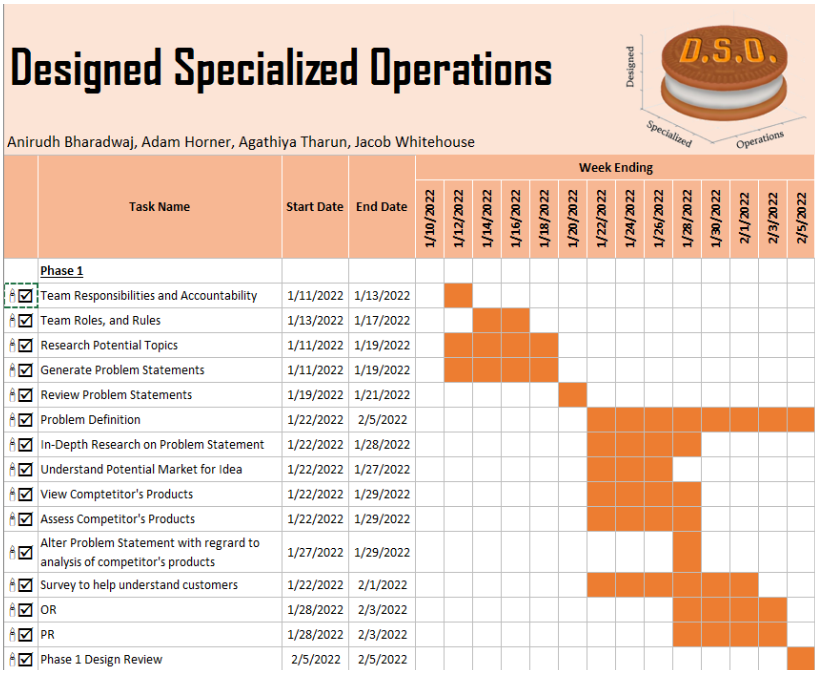
Appendix E: Exploded Assembly Design



ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	LidBottom	
2	1	Top Cap	
3	1	Bearing	STEP AP203
4	1	Key Ring	STEP AP203
5	1	PRUZINA SPIRALOVA	
6	1	Suction Cup	

This figure details the final design of the Compact Cable Case and its components. These include exterior casing, a keyring, a bearing, a power spring, and a suction cup.

Appendix F: Gantt Charts

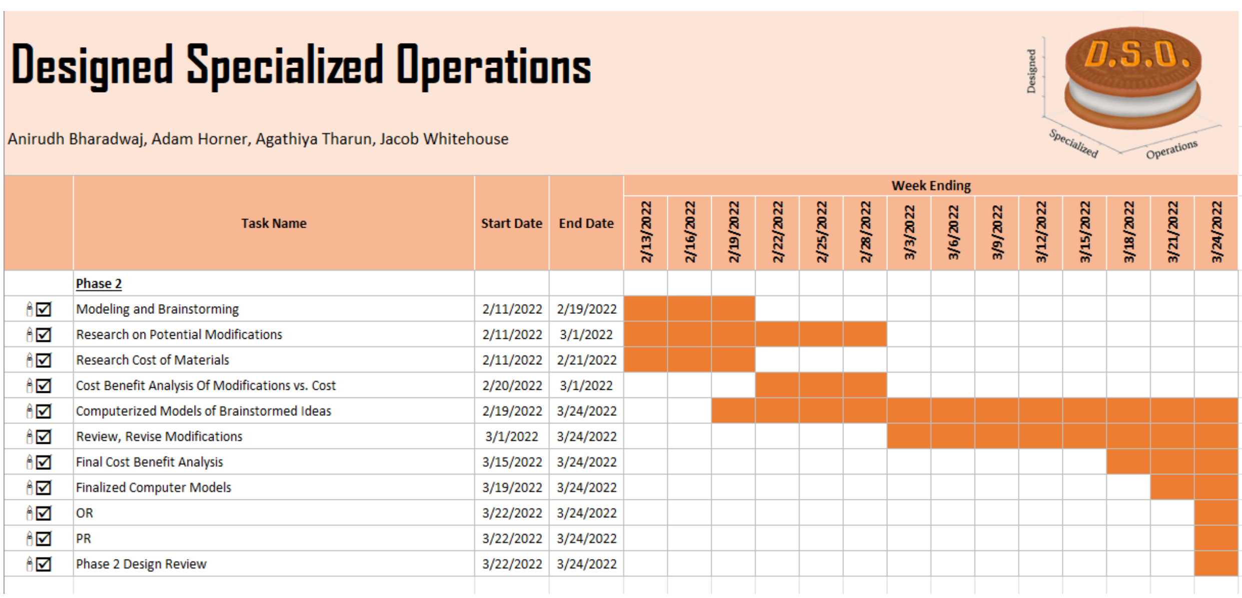


Designed Specialized Operations

Anirudh Bharadwaj, Adam Horner, Agathiya Tharun, Jacob Whitehouse

Task Name	Start Date	End Date	1/10/2022	1/12/2022	1/14/2022	1/16/2022	1/18/2022	1/20/2022	1/22/2022	1/24/2022	1/26/2022	1/28/2022	1/30/2022	2/1/2022	2/3/2022	2/5/2022
Phase 1																
Team Responsibilities and Accountability	1/11/2022	1/13/2022														
Team Roles, and Rules	1/13/2022	1/17/2022														
Research Potential Topics	1/11/2022	1/19/2022														
Generate Problem Statements	1/11/2022	1/19/2022														
Review Problem Statements	1/19/2022	1/21/2022														
Problem Definition	1/22/2022	2/5/2022														
In-Depth Research on Problem Statement	1/22/2022	1/28/2022														
Understand Potential Market for Idea	1/22/2022	1/27/2022														
View Comptetitor's Products	1/22/2022	1/29/2022														
Assess Competitor's Products	1/22/2022	1/29/2022														
Alter Problem Statement with regrard to analysis of competitor's products	1/27/2022	1/29/2022														
Survey to help understand customers	1/22/2022	2/1/2022														
OR	1/28/2022	2/3/2022														
PR	1/28/2022	2/3/2022														
Phase 1 Design Review	2/5/2022	2/5/2022														

The Gantt chart is used for project planning and scheduling. This is the team's Gantt chart for the completed Phase 1.



Designed Specialized Operations

Anirudh Bharadwaj, Adam Horner, Agathiya Tharun, Jacob Whitehouse

Task Name	Start Date	End Date	2/13/2022	2/16/2022	2/19/2022	2/22/2022	2/25/2022	2/28/2022	3/3/2022	3/6/2022	3/9/2022	3/12/2022	3/15/2022	3/18/2022	3/21/2022	3/24/2022
Phase 2																
Modeling and Brainstorming	2/11/2022	2/19/2022														
Research on Potential Modifications	2/11/2022	3/1/2022														
Research Cost of Materials	2/11/2022	2/21/2022														
Cost Benefit Analysis Of Modifications vs. Cost	2/20/2022	3/1/2022														
Computerized Models of Brainstormed Ideas	2/19/2022	3/24/2022														
Review, Revise Modifications	3/1/2022	3/24/2022														
Final Cost Benefit Analysis	3/15/2022	3/24/2022														
Finalized Computer Models	3/19/2022	3/24/2022														
OR	3/22/2022	3/24/2022														
PR	3/22/2022	3/24/2022														
Phase 2 Design Review	3/22/2022	3/24/2022														

This is our Gantt Chart for Phase 2. This is used to benchmark the team's progress.

Designed Specialized Operations

Anirudh Bharadwaj, Adam Horner, Agathiya Tharun, Jacob Whitehouse

Task Name	Start Date	End Date	Week Ending													
			3/24/2022	3/27/2022	3/30/2022	4/2/2022	4/5/2022	4/8/2022	4/11/2022	4/14/2022	4/17/2022	4/20/2022	4/23/2022	4/26/2022	4/29/2022	5/2/2022
Phase 3																
Finalize Computer Model	3/24/2022	3/27/2022														
Finalize Materials After Cost Benefit Analysis	3/24/2022	3/27/2022														
Design Low Fidelity Prototype	3/24/2022	3/31/2022														
Test Low Fidelity Prototype	4/1/2022	4/9/2022														
Analyze Results from Tests	4/7/2022	4/10/2022														
Design High Fidelity Prototype	4/8/2022	4/17/2022														
Test High Fidelity Prototype	4/11/2022	4/28/2022														
Use ME263 resoure to help enter then product on the market	3/27/2022	4/29/2022														
OR	4/24/2022	4/28/2022														
PR	4/24/2022	4/28/2022														
Phase 3 Design Review	4/24/2022	4/28/2022														

This is our Gantt Chart for Phase 3. This is used to set the team's schedule and goals during this phase.

Appendix G: Bill of Materials

Item No.	Part No.	Part Name	Units	Qty.	Make/Buy	Material/Description	Manufacturing Process
1	T1	Top Casing	in^3	2.962	Make	PLA Filament; Top attachment to case	3D Printing
2	B1	Bottom Casing	in^3	6.918	Make	PLA Filament; Bottom attatchment to case	3D Printing
3	B2	Wheel	in^3	1.273	Make	PLA Filament; Attaches to bottom and bearing to wrap cable	3D Printing
4	T2	Pin	in^3	0.059	Make	PLA Filament; Drops into the top cap to lock the cable	3D Printing
5	B2	Suction	pcs	1	Buy	PVC; Attachments to bottom	Injection Mold
6	T3	Key Ring	pcs	1	Buy	Metal Alloy; 32mm outer diameter, attached through the top	Casting
7	B3	Spring Loaded Wheel	in	60	Buy	Stainless Steel; Attached at the bottom to retract the cable	Spring Coiler
8	B4	Bearing	in	0.5	Buy	Carbon Steel; Attaches to bottom to spin cable	Casting

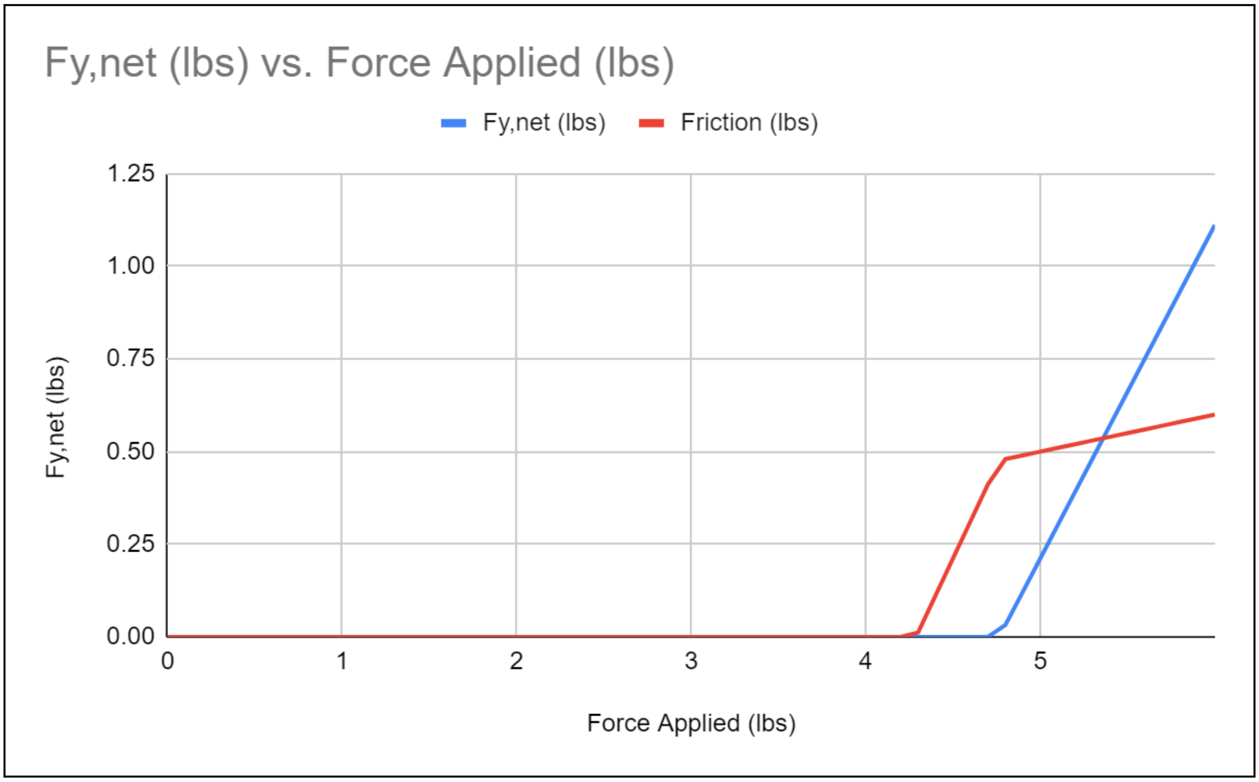
Source of Part	Catalog No.	Unit Cost ($)	Assembly Cost ($)	Line Total Cost ($)	Link
ME 3D Print Lab	-	0.1875	0.555375	$0.56	-
ME 3D Print Lab	-	0.1875	1.297125	$1.30	-
ME 3D Print Lab	-	0.1875	0.2386875	$0.24	
ME 3D Print Lab	-	0.1875	0.0110625	$0.01	
AliExpress	-	0.0244	-	$0.02	100pc Clear Suction Cups
McMaster Carr	90177A219	0.0806	-	$0.08	100pc Split Key Ring
AliExpress	-	3.48	-	$3.48	1540mm Long Power Spring
AliExpress		0.232	-	$0.23	10pc 624zz Bearing

PURCHASED	Total Purchased Parts ($)	3.82
	Total Custom Manufactured Parts ($)	2.10
ASSEMBLY	Total Assembly Cost ($)	2.10
UNITS PER HOUR		
	Total Cost ($)	5.92

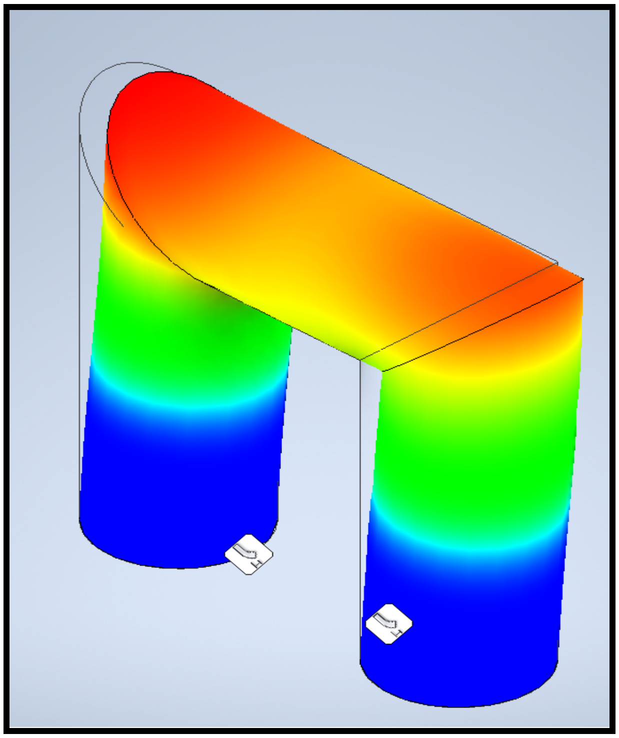
Expected Retail Price	19.99
Total Cost	5.92
Profit	14.07

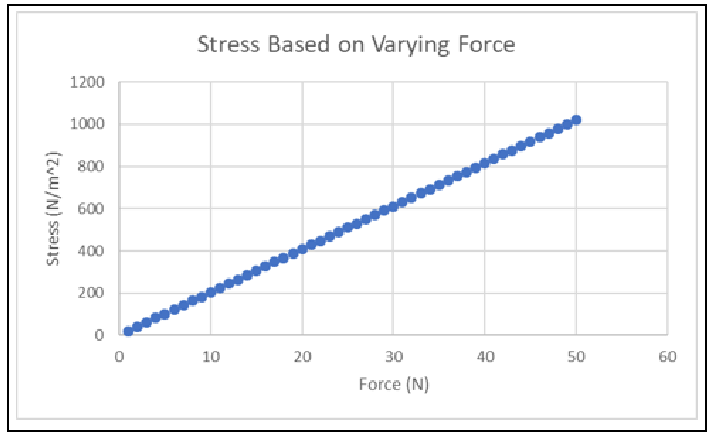
This is the updated Bill of Materials for the phase 3 design. It removed the slide lock and rubber pad and added a pin part. The total cost was reduced by $6.14 from the phase 2 BOM.

Appendix H: Engineering Models

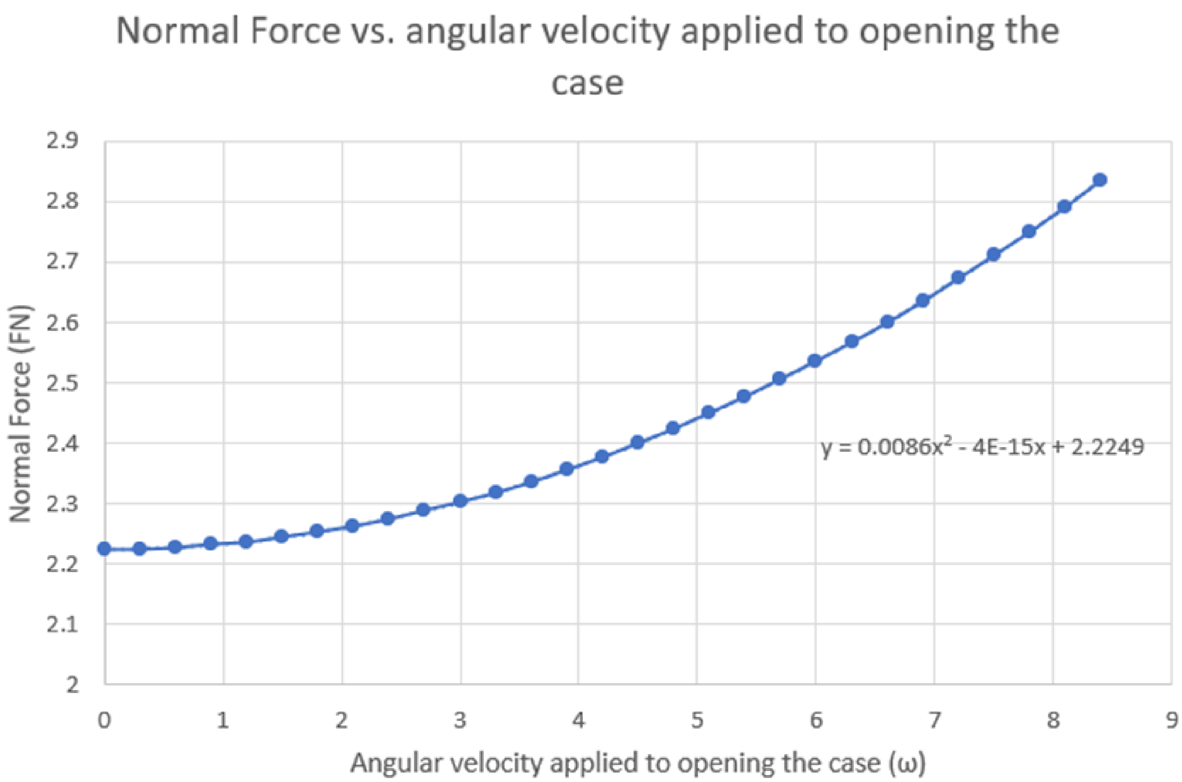


This graph models the amount of force needed to apply to the casing to open the Compact Cable Case.



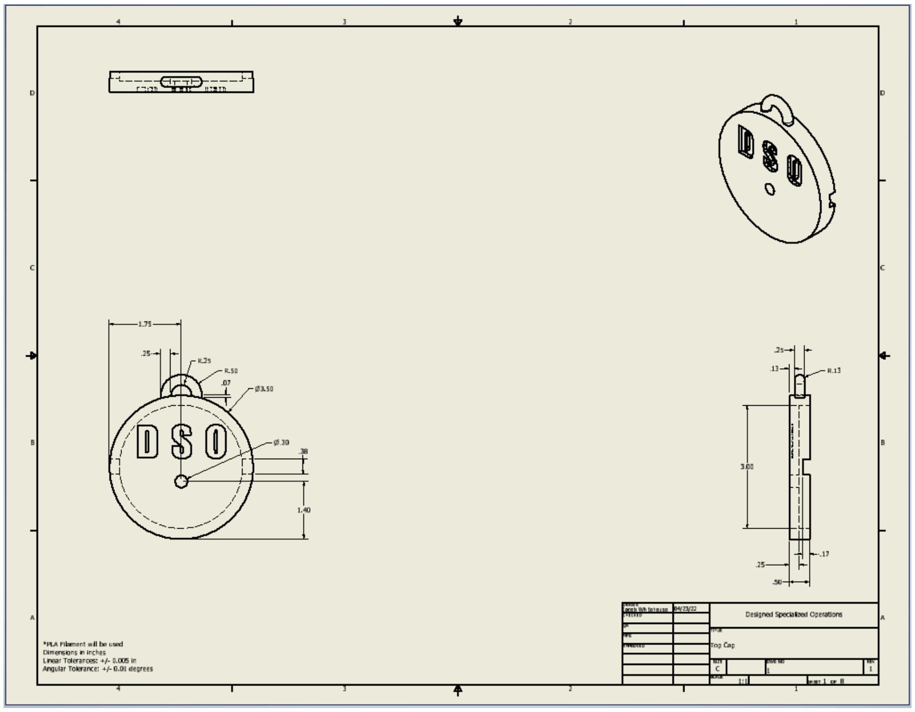


This image shows the stress analysis for the first engineering model mentioned in the above section.

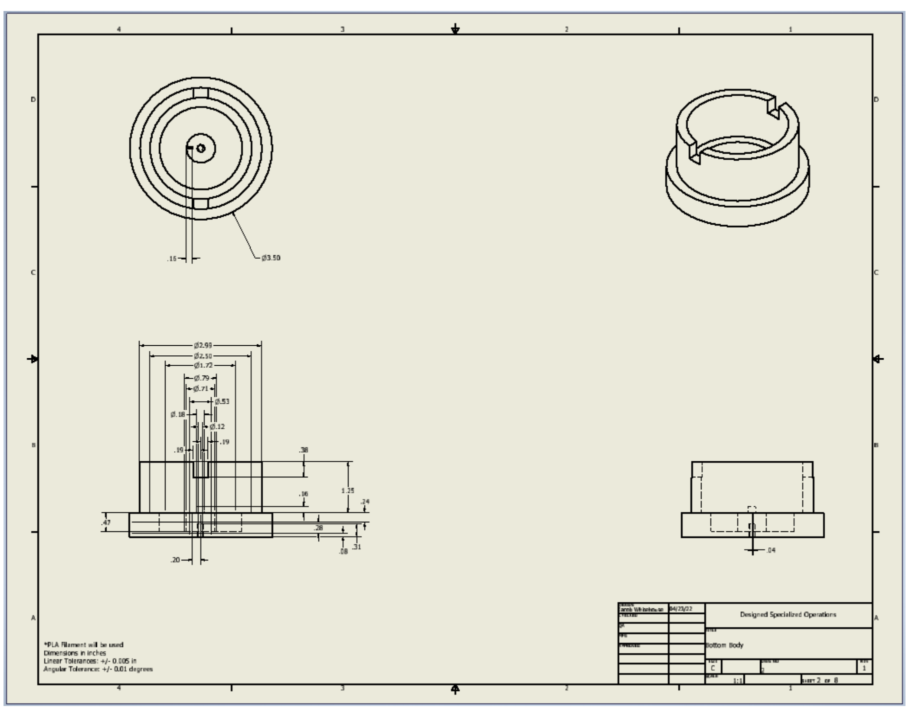


This image shows the Normal Force on the bottom of the case due to the angular velocity it is opened with

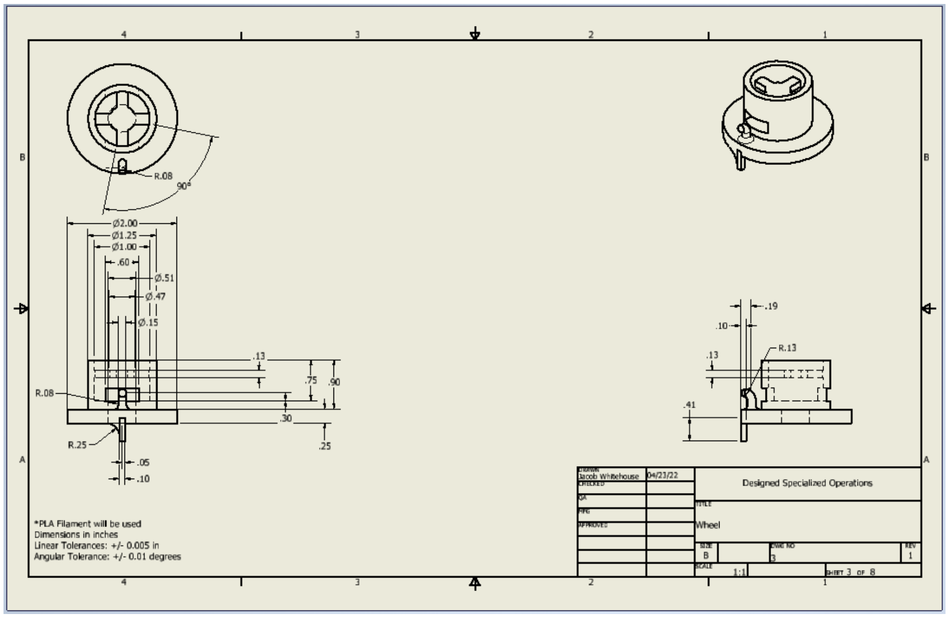
Appendix I: Part Drawings



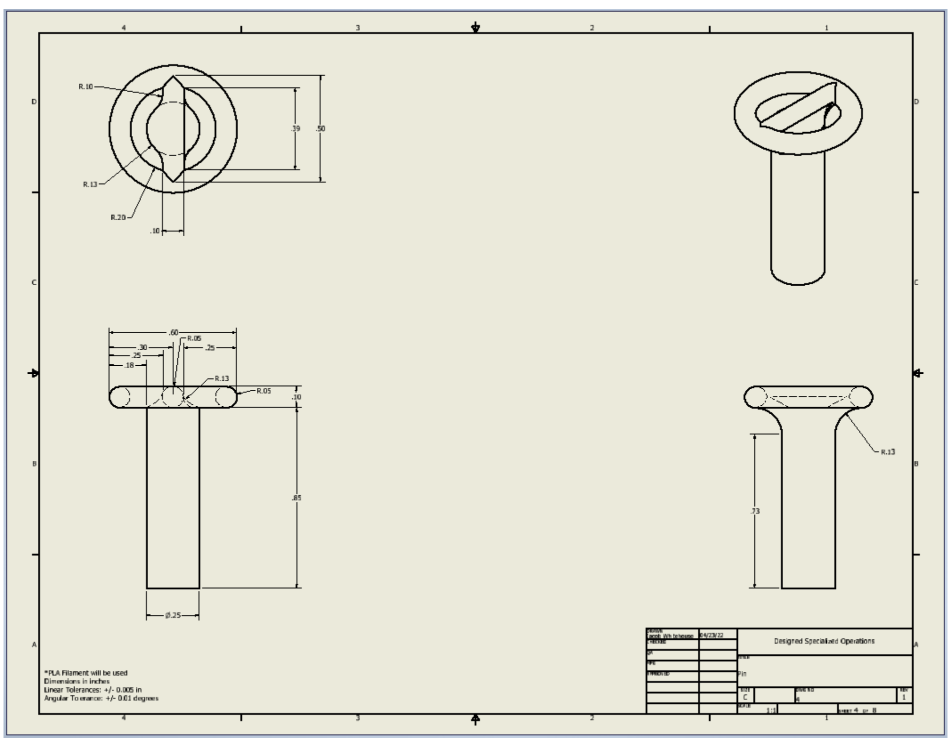
This is the drawing of the Top Cap.



This is the drawing of the Bottom Body.



This is the drawing of the Wheel part.



This is the drawing of the Pin part.

Appendix J: Design for Analysis