GNG2101

Design Project Progress Update

F1.4

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Table 1. Acronyms

Acronym	Definition
BOM	Bill of Materials
DFX	Design for X
FEA	Finite Element Analysis
IP	Intellectual Property
NPV	Net Present Value

Table 2. Glossary

Term	Acronym	Definition
Finite Element Analysis	FEA	Virtual simulation that predicts the behaviour of a design with the implication of outside forces.
Net Present Value	NPV	Determining the present value of money that will be incurred in a future time, taking into account the interest rate.

1 Introduction

For PD E, the team focused primarily on furthering the development of the first prototype, along with developing test methods that conjoin with the critical assumption analysis formulated for PD D. A major critical assumption further analyzed in PD E is the assumption of the telescoping mechanism being operational, allowing the structural tube segments to collapse upon each other, along with the telescoping mechanism in combination with the structural segments providing load bearing support for the entire cane structure. A few DFX factors are considered when tackling this critical assumption for further testing. Following preliminary analysis, the first prototype was created. The team opted for a low fidelity analytical prototype that aims to undergo testing defined from the criteria of the critical assumption. The first prototype aims to provide insight in the tube-segmented structural system. The outer shells encasing our internal mechanism's must provide load-bearing support in conjunction with the internal telescoping mechanism. This model also provides an accurate visual representation that can be evaluated and iterated upon as the project progresses. Testing and analysis versus previously derived target specifications will be provided, as the team evaluates the first prototype.

For PD F, the group will focus on the greatest design constraints highlighted by the DFX factors, as well as further developing higher fidelity prototypes that will help bring the team towards the end of goal of providing a complete, life-scale model to Design Day. The two limiting DFX factors are considered as Usability and Reliability. These were chosen as simplicity in operation of the product is a key factor that must be considered at all stages of development, as well as safety during operation of the product. For Prototype 2, the team has updated the initial concept design of the telescoping subsystem, as the new design introduces further simplicity in design and manufacturing. Additionally, the new system design will be more reliable and lightweight. Prototype 2 introduces the full CAD model and a physical 3D-print of the telescoping mechanism. The CAD model is a comprehensive, analytical, high-fidelity prototype. The idea is to finalize the design for the cane, as well as test the functionality of the telescoping mechanism.

For PD G, the group delves into Economic and IP considerations for the developed prototype. In terms of an economics focus, the team assumed a startup format of development. The strategy relies on minimizing costs to lift the startup off the ground to incur revenue. Based on market research and data involving the cost classification, a 3-year income statement was developed. Within the 3-year timeline, a NPV analysis was done to determine the startups breakeven point when it comes to expense versus income. All assumptions developed in the economics portion of PD G has been justified following the report. An IP report is also conducted, where the team has found two IPs that are closely related to the developed product. With these two IPs, its format is analyzed, as well as its important and legal constraints that these designs would place on the development of the team's prototype.

2 Prototype 1, Project Progress Presentation, Peer Feedback and Team Dynamics

2.1 Prototype 1

2.1.1 Critical Assumption Analysis

As mentioned in PD D, a critical product assumption that the team has made is the proper functionality of the telescoping mechanism because the overall design of the folding cane relies on this mechanism to work correctly and with rare mechanical errors. As a quick reminder, the telescoping mechanism utilizes the force of gravity to either lock the rods in place when the cane is right-side up, or to have the rods collapse when the cane is upside down. The first prototype does not include the complete mechanism, but rather simply contains the telescopic rods that will be sliding on top of each other.

When testing this prototype, the team will put a substantial amount of effort into highlighting any issues to define a proper plan for the next prototype, for which the team aims to eliminate any problems with the telescopic sub-system. The team will be attempting to test the collapsibility of the cane, to ensure the proper collapsed length. The table below describes any tests that the team plans on conducting when the initial prototype is built:

Table 3: Critical Assumption Analysis' Tests

Test No.	Reason for Prototype	Evaluation Criteria/Determine Measurables	Level of Prototype	Kind of Prototype	Metrics	Test Description	Analysis Method
	Communication, Performance Measurement, Risk Management, Learning/Understanding	*What are you testing with your concept (target measurable attributes)?*	*HiFi/LoFi Focused, HiFi/LoFi Comprehensive*	*Visual, Analytical, Physical*	*What metrics will you test?*	*What specifically will you test*	*Specifically, how will you test, include things like duration, sequence of test, equipment, etc.*
1	Performance Measurement	Telescopic Rods	LoFi Focused	Analytical, Physical	-Collapsed Length < 50 cm -Mechanism Functionality	- Collapsibility of the Telescopic Mechanism -Functionality of the Mechanism	Via CAD Software, testing analytically the retractable length, and mechanism functionality.

The test in the table above, which will be an analytical test. Essentially, the team will be trying to simulate the collapsing of the rods (sliding them on top of each other) to ensure correct margins between each segment. The friction can't be too high, because it means that the cane won't collapse, but it also can't be too low, because it means that the cane will collapse too quickly.

This critical assumption relates to more than one DFX factor outlined in the team's PD B, namely, the design for reliability and design for safety DFXs.

<u>Design for Reliability:</u> Ensuring that the cane collapses correctly relate to this DFX. The entire point of the cane is that it's collapsable, so a telescopic mechanism that gets stuck and fails to collapse due to very high friction and incorrect margins between segments is not reliable.

Design for Safety: Ensuring that the cane collapses at an appropriate speed relates to this DFX. A foldable cane that collapses too quickly can cause serious damage and harm to the user (like a tape measure that closes too fast), making it a grave safety concern.

2.1.2 Concept Development

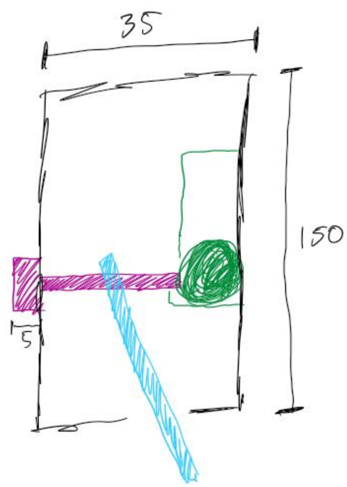


Figure 1: Concept Handle-Telescopic Integration

Figure 1 includes the basic handle subsystem, which includes integration with the telescopic subsystem using the trigger button and safety mechanisms. The safety mechanism uses a metal ball that prevents accidental release of the telescopic mechanism through regular use.

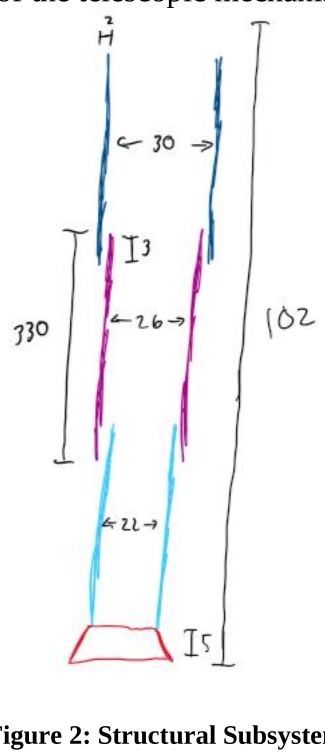


Figure 2: Structural Subsystem

Figure 2 represents the aluminum structure of the cane, with three segmented tubes that allow for telescopic retractability via the telescopic subsystem.

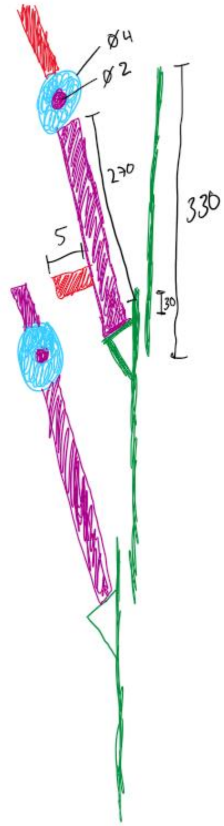


Figure 3: Telescopic Subsystem

Figure 3 represents the premise of the telescopic subsystem, which allows the cane to collapse into a more portable form factor. It utilizes push rods that extend and allow load bearing support for the entire structure.

2.1.3 Prototype 1 Goals + Model

Prototype 1 aims to provide further insight into the structural subsystem. As a low fidelity initial prototype, the team will utilize prototype 1 as a tool to ensure proper margins and sizing of the three-piece segmented system. Additionally, the initial prototype will provide a clean visual representation of the discussed ideas in previous deliverables. This initial design allows the team to further iterate and improve this design, ensuring that all needs desired by the user are met with effectiveness.

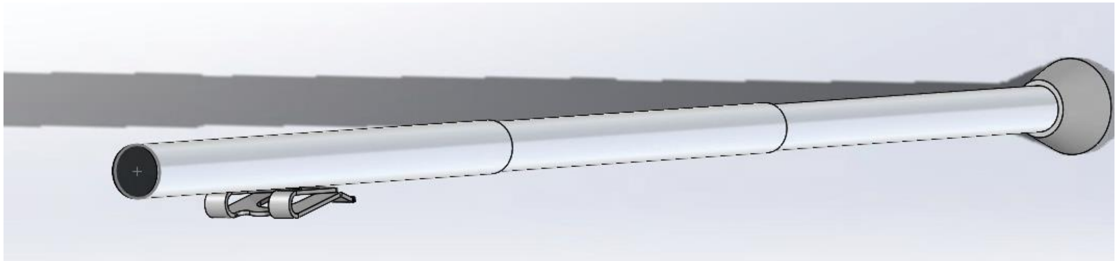


Figure 4: Three-Piece Segmented Structure

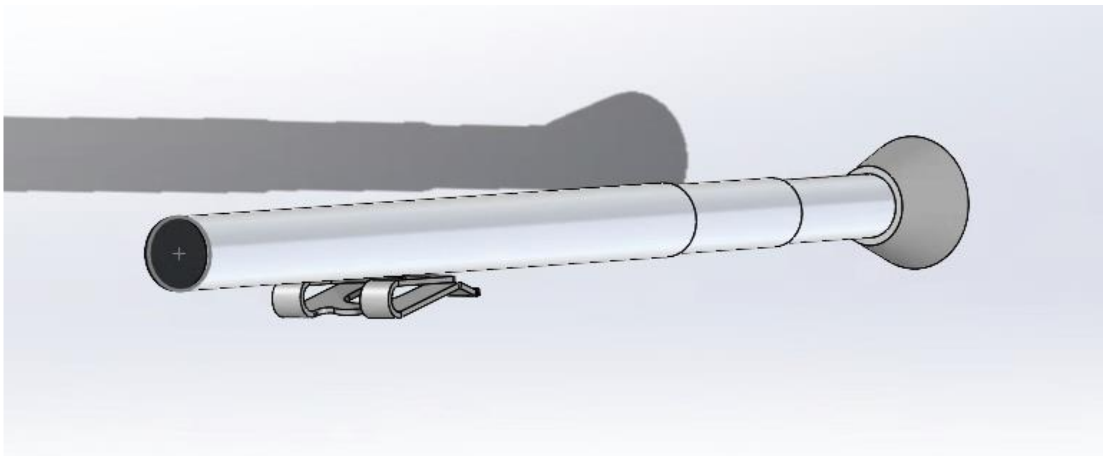


Figure 5: Collapsed Segmented Structural System

2.1.4 Prototype 1 Testing & Analysis

Because the cane will use a premade outer shell, the potential length of that shell when collapsed had to be tested before any internal or structural tests took place. Most of the load bearing capabilities of the cane come from internal rods, and those rods' lengths depend on the length of the outer shell components. The shell components were less variable than the rod lengths, so we decided to test the shell first.

The initial prototype also provides a qualitative aspect initial design concept, providing a 3D representation of the initial design concept. As mentioned prior, the initial design allows for further steps into future iterations of the design. It provides a solid foundation to further out efforts to meet the criteria specified.

Table 4: Prototype Quantitative Testing

	Initial Goal Length	Adjusted Goal Length	Measured Length
Extended	90-100cm	90-100 cm	105cm
Collapsed	45-50cm	35-40cm	55cm

2.1.5 Prototype Evaluation against Targets

Using this prototype, our first test will allow us to test if the metallic cane segments would collapse into each other in an efficient manner. This has been proven to function as intended. Each segment of the cane has been able slide into each other, halving the total length of the cane. Referring to Table 4, the total length of the cane reduces from 105 cm to 55 cm. Since the second meeting with the client the team understands that the folded length of the cane is still too high. Our target folded length is 35 – 40 cm, which has not been met. This provides insight to the team to continue iterating on the design to meet the desired target.

2.2 Project Progress Presentation

[Design Progress Presentation.pptx]

2.3 Project plan update

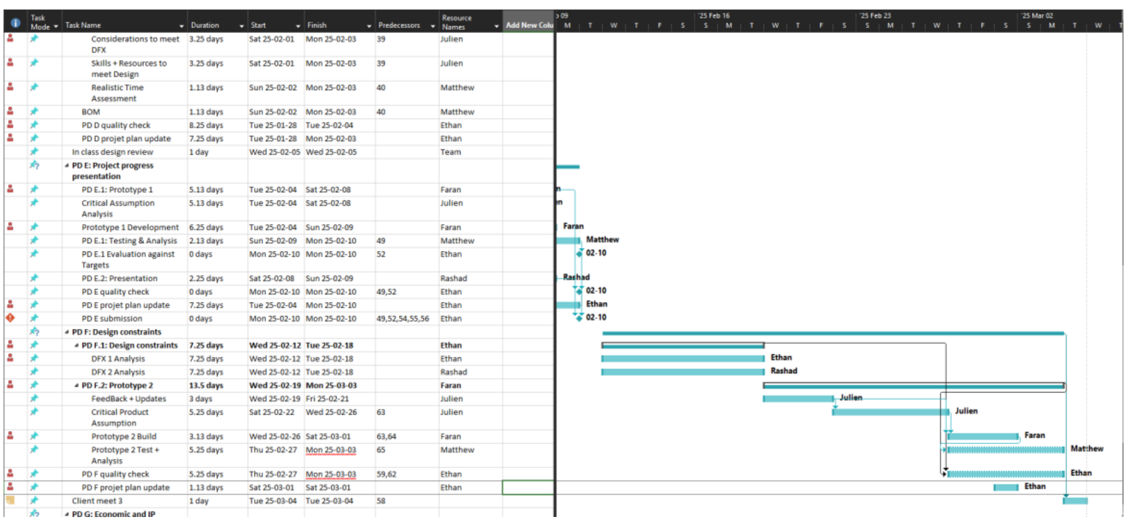


Figure 6: Gantt Chart PD E + F

3 Design Constraints and Prototype 2

3.1 Design constraints

For the design of the one-handed folding cane, the two most important non-functional design constraints (DFX factors) are designated as:

Design for Usability

Design for Reliability

These non-functional DFXs are considered the most critical whilst furthering development of our prototypes as the top priorities of the design encompass a reliable, yet simple operation for the design of the cane. This will ensure that the product will not fail on the user and remain easy to operate through day-to-day usage. Any failure of the product while in usage could result in a potentially dangerous situation.

3.1.1 DFX Factor 1

Design for Usability

Design for Usability is a critical design constraint for the development of the one-handed cane and is a strong factor when considering design choices. The premise of usability and simplicity of operation for the product is a driving factor when deciding on design choices. For this reason, the telescoping mechanism was chosen to satisfy the usability constraint. Specifically for the user, as only the sole use of one-hand is preferred, the operation of the product must be as simple as possible. This resulted in the design choice of a gravity based telescoping extension system, along with a simple locking mechanism to ensure reliability of the cane whilst in operation.

Effectiveness of this approach in design to satisfy the design constraint can be measured on simplicity of operation of all three major subsystems together. Collapsing and re-extending the cane will demonstrate its overall usability level in a practical manner. The primary contributor to that will satisfy the usability constraint is the telescoping mechanism subsystem. To further improve the chances of success, the team continues to refine the design of the operation of the telescoping system. In section following such, the initial iterative concept design revised from Prototype 1.

The measure of effectiveness for this design constraint is a focus of Prototype 2. Simulations are conducted in CAD of the telescoping mechanism's ability to retract and extend without abruptions in its path. This ensures tolerances within the chosen components operate as intended. Building upon this, a small-scale model of the telescoping mechanism along with the structural shaft segments were 3D printed to confirm the tolerances in the design in the physical world. This will be explored below in Prototype 2.

3.1.2 DFX Factor 2

Design for Reliability

Designing for reliability means ensuring client confidence in the product throughout the use phase of its life cycle. More specifically when applied to this project of a collapsible walking cane, the user must trust the cane to always support the user's body weight, in all conditions, and never malfunction. Reliability has been a major consideration when designing this product.

Reliability has been effectively implemented into the design of the cane in multiple ways. First the material choice. The outside of the cane will be fully aluminum rods, ensuring it can hold heavy weight, and not rust from year-round use. The final prototype is planned to have a threaded tip, with multiple attachable ends, to keep grip on all surfaces. To prevent accidents when using the cane, the button on the cane can not be pushed in, to collapse the cane unless it is held upside down. This ensures the cane only folds when intentionally.

Reliability can be tested using force element analysis on prototype 2. Using FEA the canes durability under stress will be tested. The cane will undergo accelerated stress testing, again using the CAD simulation. The goal is for the cane to be able to fold and unfold 10,000 times in its lifetime, to match up to industry leaders.

3.2 Prototype 2

The goal surrounding Prototype 2 is to provide a high fidelity, full CAD model that includes the telescoping mechanism within the structural system, as well as the handle subsystem which enables control of the subsequent subsystems. Additionally, with the telescoping mechanism in place, the collapsibility of the mechanism can be tested via simulation. For a physical representation, the team has opted towards 3D printing a small-scale model of the telescoping system, ensuring the operation of the rods providing support and collapsibility operates as intended.

For Prototype 2, the prototype can be separated into three separated entities:

1. Handle Subsystem
2. Telescoping Subsystem
3. 3D Printed Telescoping Mechanism
4. Full CAD Model incorporating all three major subsystems

Each entity will be discussed in its respective sections below.

3.2.1 Feedback + Results + Design Update

The team has received some feedback after the initial prototype design from the TA, the professor, and other students. The professor told the team that they were doing a great job and to keep doing what they are doing. The feedback received from peers from the initial design was that it was a little convoluted and difficult to understand, so the team improved the design to make it more understandable. Taking all that feedback into consideration, the team decided to modify the design for prototype 2. The sketch of the updated telescoping mechanism of the cane can be seen in the figure below:

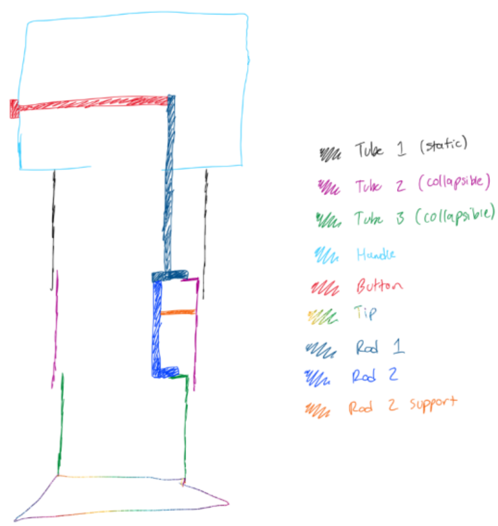


Figure 7: Telescoping Mechanism Update

Figure 7 provides an updated approach to the operation of the telescoping mechanism, aiming to improve simplicity and reliability in the design. This new design will also be more lightweight, stronger, and easier to manufacture in comparison with the initial design. The new approach for this subsystem is implemented in the design of Prototype 2.

3.2.2 Untested Critical Product Assumption

For this prototype, the team has a couple of critical product assumptions to test, namely the collapsibility of the telescoping mechanism and the tolerances between the prototype pieces.

<u>Collapsibility of the telescoping mechanism:</u> The different sections of the cane should be able to collapse and extend without any failure or unwanted collapsing and extension. The team is assuming that the cane will extend without locking or getting stuck, and that it will not collapse upon any sort of pressure application to the tip. The team is also assuming that the cane will extend and collapse easily (when wanted) without too much friction.

Material Tolerances: This prototype was 3D printed and therefore will not be fitted perfectly. When 3D printing pieces that fit together, it's important to reduce the diameter of the female piece by a fraction of a millimetre to ensure low friction. The amount of diameter reduction depends on the printer that is being used since every 3D printer is different. Cheaper printers require adding a higher tolerance (bigger gap between fitted pieces) because they are not as accurate and never output a print that has the exact same specifications as the input CAD file. More expensive printers, such as the one used for this prototype, are better, but still require a tolerance, albeit much less.

3.2.2.1 Assessing Critical Product Assumption

Table 5: Prototype 2 Critical Product Assumption Tests

Test No.	Reason for Prototype	Evaluation Criteria/Determine Measurables	Level of Prototype	Kind of Prototype	Metrics	Test Description	Analysis Method
	Communication, Performance Measurement, Risk Management, Learning/Understanding	*What are you testing with your concept (target measurable attributes)?*	*HiFi/LoFi Focused, HiFi/LoFi Comprehensive*	*Visual, Analytical, Physical*	*What metrics will you test?*	*What specifically will you test*	*Specifically, how will you test, include things like duration, sequence of test, equipment, etc.*
1	Performance Measurement	Collapsibility of Telescoping Mechanism	LoFi Focused	Physical	-Smooth Collapsibility -No unwanted collapsing under load	-Extend and collapse cane multiple times to check for smooth movement -Apply force to the tip to ensure that the cane does not unintentionally collapse.	Manually test the extension and collapsing (500 cycles). In between each cycle, apply 170 lbs force to the tip.
2	Performance Measurement	Collapsibility of Telescoping Mechanism	LoFi Focused	Physical	-Just enough friction to still allow smooth extension and collapsing of the cane	- Measure the force required to extend and collapse the cane and ensure that it is within a reasonable range (about 5 lbs).	-Measure the force to extend the cane using a hand-held luggage scale. -Measure the force to collapse the cane using a scale (the force should be low enough that the team can use a kitchen scale)
3	Risk Management	Material Tolerances	HiFi Focused	Analytical, Physical	-Fit between 3D printed pieces -Friction	-Print multiple pieces with different tolerances to find the best measurements to use.	-Find the best fitted pieces with maximum friction to ensure that they do no fall apart.

3.2.3 Prototype 2 Concept Design

3.2.3.1 Handle Subsystem

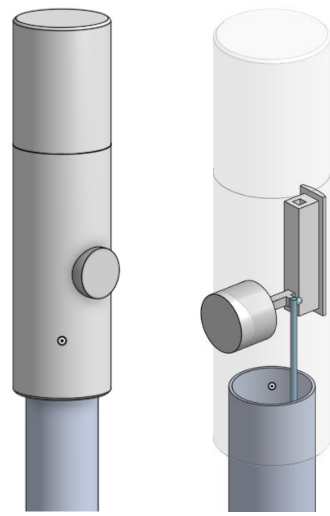


Figure 8: Handle Subsystem

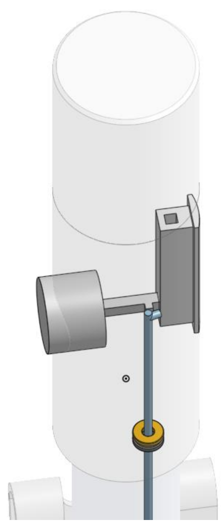


Figure 9: Safety Disengagement Mechanism

In the comprehensive CAD model, the handle subsystem is created to our initial design concept and is ready for further iterative development if needed. The handle consists of a two-piece handle, where the top portion can be removed in case of troubleshooting needs when considering the safety lock mechanism of the telescoping system. The integration of the telescoping system with the handle is also completed. Here lies the disengagement button that allows for collapsibility of the telescoping system. Engagement of the button will cause the rods within the structure to rotate, thus moving its rod supports off the designated positions within the structural segments, which allows the structural segments to collapse upon each other. For preventing accidental collapsing, the safety locking mechanism is included. Referring to Figure 9, the Safety Disengagement Mechanism works with a weighted metal sphere in the boxed section that prevents the engagement of the button while the cane remains upright. The weighted components ensures that the button can only be operated strictly while the cane is in an upside-down position.

3.2.3.2 Telescoping System

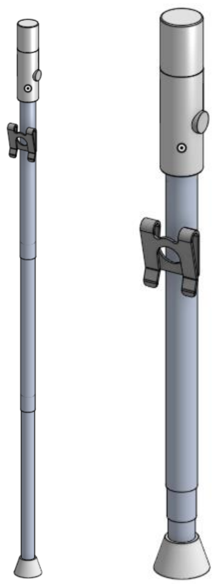


Figure 10: Extended & Collapsed Simulation

Figure 11: Telescoping Mechanism in Depth

The incorporated telescoping system operates on the premise of rotating rods that lie upon ridges etched into the structural segments to provide support, as highlighted in the updated design concept seen in Figure 7. Missing from the complete CAD model is the ridges that provide the structural support where the telescoping rods lie its load-bearing support. As the goal for this prototype is designated as completing the telescoping mechanism and ensure its functionality, the ridges to provide support for the structure will be added subsequently.

3.2.3.3 Physical Telescoping Mechanism Model

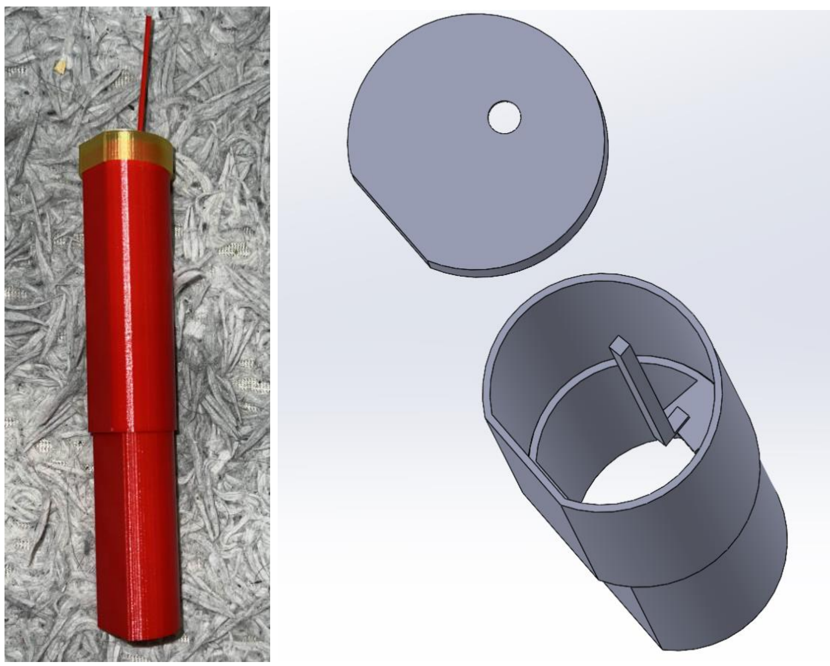


Figure 12: 3D Printed Telescoping Mechanism

The 3D printed telescoping mechanism aims to provide physical evidence and demonstration of the operation of the rotating telescoping rods in practice. With this physical model, the ridges for structural support of the telescoping rods are present to show how the rotation of the rod off the ridge allows the collapsibility of the structural segments.

3.2.4 Prototype 2 Testing and Evaluation

Prototype 2 is split into two parts: the full CAD model and the physical print of the telescoping mechanism.

The CAD model is a comprehensive, analytical, high-fidelity prototype. The goal for this prototype is to finalize the design for the cane and to test the functionality of the telescoping mechanism. As seen in Figures 8 and 9, the cane handle design is finished. This was the last subsystem of the design that had to be finished. Also, as seen in Figure 10, the collapsible mechanism works as intended with the steel rods inside.

The second part of Prototype 2 is a focused, physical, medium-fidelity prototype. This physical model focuses on the telescopic mechanism’s functionality and how the rods inside interact with the shell. The model functions as expected and provides the team insight into how to design for manufacturing when it comes to making the final product.

A tabulated model of the goals for Prototype 2 can be found in Table 6.

Table 6: Prototype 2 Test Metrics

Target	Goal	Expectation	Outcome
Handle Subsystem	Complete CAD	Comprehensive model	Complete
Telescoping Subsystem	Complete CAD and test CAD collapsibility	Comprehensive model	Complete
CAD Model of Product	Integrate the three major subsystems	Comprehensive model	*Missing ridges in structural segments for the telescoping rods to support on
Telescoping Proof of Concept	Test the telescoping system functionality via 3D print model	Proof of concept of rod rotation on ridges	Expectation met.

In conclusion, the team will aim to bring the high-fidelity CAD model to a full-scale, operational prototype for Design Day. We plan for most of the full-scale prototype to use purchased materials, such as an aluminum shell and steel rods for the body of the cane. This is a simpler option compared to manufacturing our own components, even if we would have more control over sizing with that method. The team will plan the next three weeks in anticipation of design day, ensuring we meet our set targets.

3.3 Project plan update

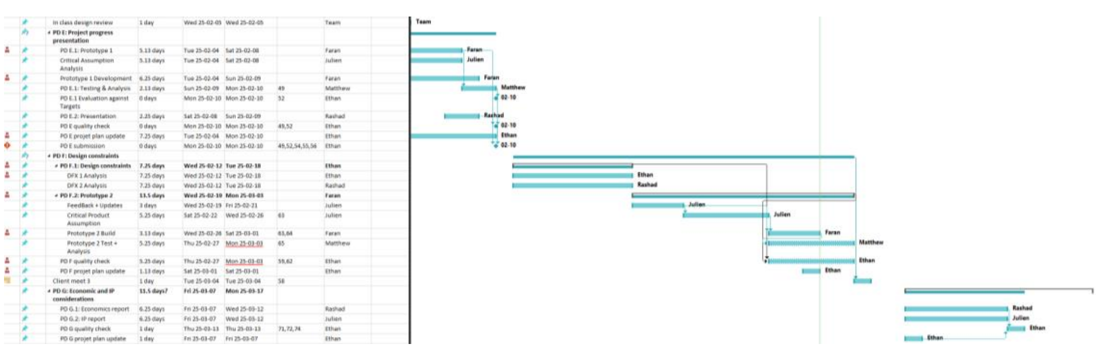


Figure 13: Gantt Chart Update PD F & G

4 Economic and IP Considerations

4.1 Economics report

4.1.1 Costing & Classification

Table 7: Costs & Classification related to Production

Expense	**Cost ($)**	**Type**	**Direct or indirect**	**Fixed or variable**	**Justification** **(Further Justified in 4.1.4.1)**
Materials	20,000	Material	Direct	Variable	Materials are direct for usage, though variable dependent on demand. A starting point of $20,000 is selected for production of 570 canes.
Salaries	20,000	Labor	Direct	Fixed	Salaries are classified as a direct cost, which is fixed. It can become semi-variable with modifications to the workforce.
Rent	0	Expense	Indirect	Fixed	Rent is a fixed, indirect cost. It is not associated with production. Remains a fixed cost on an annual basis typically. The team will operate out the founder’s garage.
Equipment	7,000	Expense	Indirect	Fixed	Equipment is estimated at a total cost of $7,000, and justification will be provided. It is an indirect cost apart from direct product. It is a fixed cost.
Marketing	1,000	Expense	Indirect	Fixed	Targeting advertising will be an indirect cost unrelated to product, and a fixed annual cost.
Electricity	1,000	Expense	Indirect	Semi-variable	Electricity is directly proportional to production of goods. Increased use of equipment to create goods will increase electricity use.
Overhead	1,000	Expense	Indirect	Fixed	Overhead costs remain indirect and fixed. These will include costs such as insurance, property taxes, licensing/subscriptions/permits.

4.1.2 3 Year Income Statement

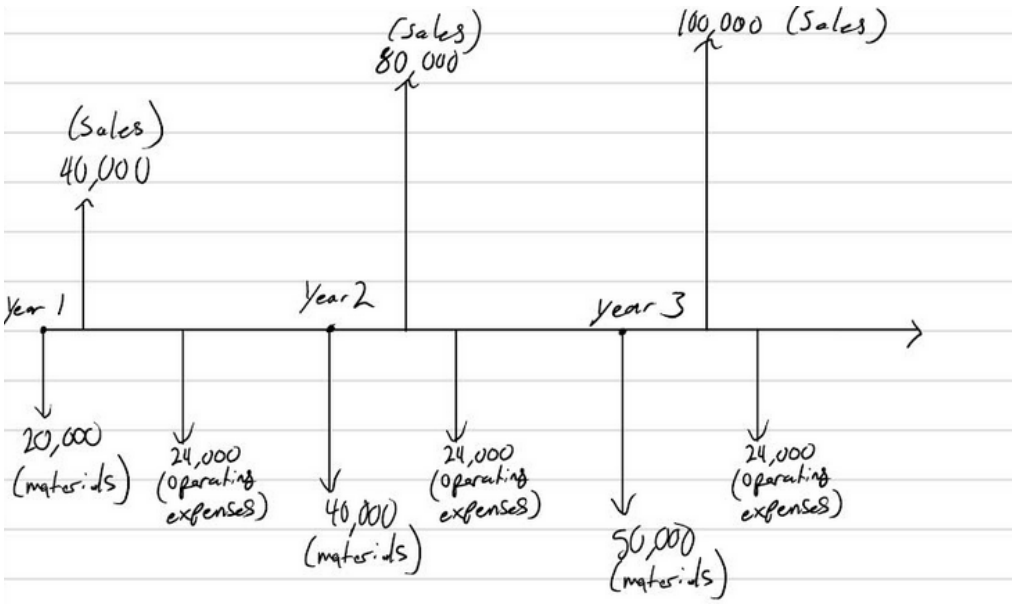
Table 8: 3 Year Income Statement

Classification	Name	Amount ($)
Revenue	Sales (Year 1)	40,000
	Sales (Year 2)	80,000
	Sales (Year 3)	100,000
	Total	**220,000**
Cost of production	Materials (Year 1)	20,000
	Materials (Year 2)	40,000
	Materials (Year 3)	50,000
	Overhead/ Maintenance	3,000
	Total	**73,000**
Operating Expenses **(3 Years)**	Rent	0
	Electricity	3,000
	Depreciation	2,000
	Salaries	60,000
	Equipment	7,000
	Total	**72,000**
Net Income	Revenue – Production - Expenses	**75,000**

*The unit cost of the product is classified as $35.

With a market price of $70, selling 285 canes will yield $40,000 in revenue. Subsequent years will increase production, thus increasing total material costs.

4.1.3 NPV Break Even Analysis



$$NPV = \sum \frac{\text{net income per year}}{(1+\text{interest})^{\text{year}}}$$

$$= \frac{-4{,}000}{(1+0.08)^1} + \frac{16{,}000}{(1+0.08)^2} + \frac{26{,}000}{(1+0.08)^3}$$

$$= \$30{,}357$$

Assumptions:

- Unit Cost is \$35 for the product. Products are sold at a price of \$70.
- An annual interest rate of 8%, compounded annually.
- Fixed costs per year are \$24,000.

Our annual cash in is 70 times units sold (x) and cash out is a fixed \$24,000 and 35x. Net income is 35x – \$24,000. For breakeven, set NPV to 0.

$$\text{Cash in} = 70x \qquad \text{Cash out} = 35x + 24{,}000$$

$$\text{net income} = 35x - 24{,}000$$

$$NPV = 0 = \sum \frac{\text{net income}}{(1+\text{interest})^{\text{year}}}$$

$$0 = 35x - 24{,}000 + \frac{35x - 24{,}000}{(1+0.08)^2} + \frac{35x - 24{,}000}{(1+0.08)^3}$$

Solving for x numerically provides 267 canes sold per annum to breakeven.

In conclusion, via NPV analysis, 267 canes must be sold per year to breakeven on income versus expenses. The business will become profitable with sales being greater than 267 canes.

4.1.4 Justification of Economics Report

4.1.4.1 Costing and Classification

For Costing and Classification, the selected costs will be broken down with references:
An initial startup for production and manufacturing of the SnapCane will involve the following costs.

Materials:

Initial costing for materials will be based on purchasing raw materials to construct the product. With aluminium tubing with varying sizes being cost averaged at $8, the subsequent costing for structural tubing for a unit will be estimated at $24 [3] [4]. In terms of the rotating steel rods for the telescoping subsystem, the averaged cost will be $6 [5]. The remaining portion of the handle system and tip can be cost averaged as $2 of PLA 3D printing filament, $1.50 for a bearing to allow rotation of the internal rods, and $0.50 for a spring for release mechanism for the button, providing an additional $4 per unit [6] [7] [8]. In pure material costs, this results in $34. This will be rounded to $35.

For a unit cost of $35 in materials, the initial startup will aim to build 570 canes in the first year. This will result in a total material cost of $20,000 per annum.

Salaries:

In terms of salaries, the initial startup phase will be $20,000 total for the team of 5. The team will take a small salary to minimize the total cost value of the startup phase which incurs fixed initial one-time costs. Upon further success and sales of product, the team will be able to augment salary with increased profits and completion of debt payback. The team focuses on company spirit to mitigate the feeling of being underpaid.

Rent:

In terms of rent, a cost of $20000 will be used to represent the rental of a small warehouse situated in a lower cost of living. As the average rental price in the city of Ottawa is listed as $2000 a month, incurring a per annum cost of $24000 [9]. Due to these high expenditures, the team will operate out of the founder's garage. The team will incur no monthly cost in the spirit of building the company and will solely pay for the utilities used.

Equipment:

In terms of equipment, the following would be needed to manufacture the product. Initially, a welding machine is required to connect the three subsystems together in a strong manner. This will result in a $2000 cost incursion. For smaller fabrications, a 3D printer is required [10]. This cost can be placed at roughly $1000 [11]. Miscellaneous items such as an angle grinder, quality control tools such as calipers and force rigidity test mechanisms, and various assembly tools will be needed. These costs can be estimated to be roughly $4000. Granting a total of $7000 [12] [13] [14]. Though, based on requirement, additional tools may be necessary.

Marketing:

The most cost-effective method of marketing can be found through social media marketing. Through a social media marketing agency, exposure for the product can be increased for a reasonable cost. The team has placed a $1000 budget per annum for this resource [15].

Electricity:

The average small business operation in Ontario has a per annum electricity bill of roughly $1000 [16]. For the purposes of our business and its use of high-powered tools to constantly manufacture product, the team has allocated $1000 for electricity per annum.

Overhead:

Miscellaneous overhead can be represented by additional costs incurred by items such as business insurance premiums, industry-specific licensing, and/or certifications the business must undergo to render it fully operational. The team has allocated $1000 per annum

4.1.4.2 3 Year Income Statement

For the 3 Year Income Statement, the following assumptions were made.

- All produced goods are sold.
- The budget allocated for variable expenses remain consistent for the purposes of the income statement. In reality, the cost will increase with production, though, as for electricity per example, the cost incursion will not be too significant.
- The materials allocated per annum will increase as production methods become more efficient, allowing for a reduction in overhead to offset increases in variable expenses, as well as increased revenue from an increased sale in product year by year.

4.2 Intellectual property report

4.2.1 Intellectual Properties related to the Design

The team was able to find two very similar products to prototype. The first is titled Hinged Walking Cane, invented by Joseph Ritter, Megan Gilligan, Gregory J. Foster, and Robert W. Sheldon. The patent was filed with the Canadian Intellectual Property Office in 2018. A drawing of the design can be found below:

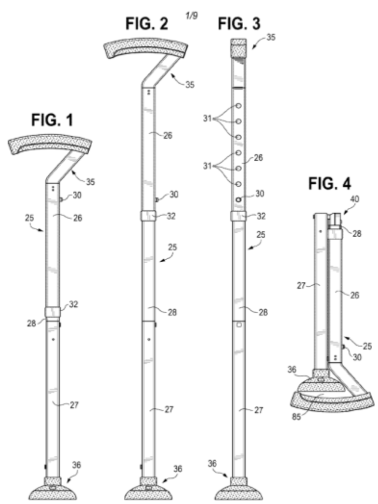


Figure 14: Patent drawing of the Hinged Walking Cane from CA 3083351 (Ritter et al., 2018). [1]

Referring to Figure 14, it is seen the cane is hinged on one side, allowing it to twist in the middle off-axis and then fold in half. It’s similar to the team’s product in that it can collapse but this cane does not use a telescopic mechanism to do so.

The second patent is a design that was filed in 1920 with the United States Patent and Trademark Office by Frank Kutwicz. It is titled Collapsible cane. A drawing of the design can be seen in the figure below:

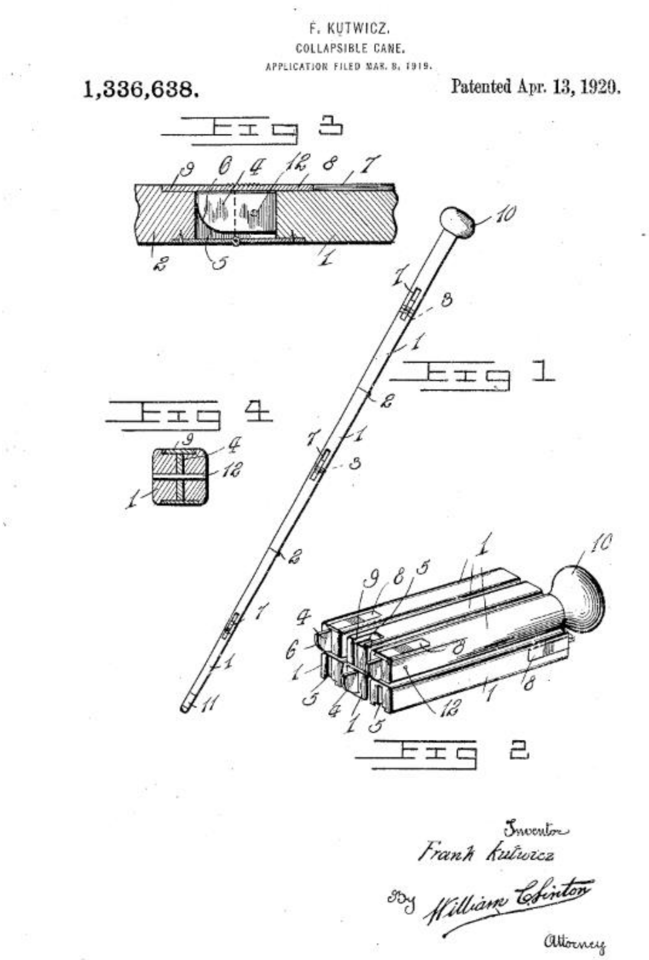


Figure 15: Patent drawing of the Collapsible Cane from US1336638A (Kutwicz, 1920). [2]

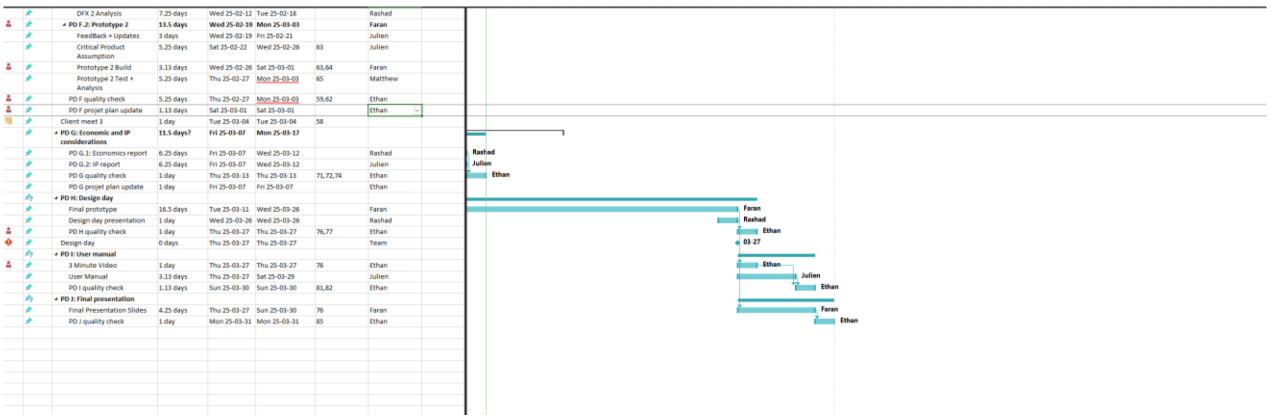
This is similar to the team's product in that it can collapse, but just like the previous patent it does not use a telescopic mechanism to do so. The team was originally thinking of doing something similar to this, in such that it collapses into a rectangular shape that can be clipped on to a belt, but afterwards decided against moving forward with that idea in favor of a telescopic system.

4.2.1.1 Importance of the Intellectual Properties

In a general sense, the team must ensure that their design is unique and does not overlap with any existing patents to avoid any legal issues and disputes with the inventors of overlapping designs. Looking at both the intellectual property patents shown in Figure 14 and 15, the collapsing mechanisms are not similar at all to the team's design and therefore don't have the potential of causing any legal problems for the team down the line. However, if the team wanted to hypothetically copy the design in Figure 15, they could do so because the patent was filed over 100 years ago and is no longer under protection.

In conclusion, at this stage, the team is in a very good position to move on to the next deliverable. The development of the cane design is progressing, and the team should be ready to present at design day in a couple of weeks.

4.3 Project plan update



DFX 2 Analysis	7.25 days	Wed 25-02-12	Tue 25-02-18		Rashad
PD F.2: Prototype 2	**13.5 days**	**Wed 25-02-19**	**Mon 25-03-03**		**Faran**
FeedBack + Updates	3 days	Wed 25-02-19	Fri 25-02-21		Julien
Critical Product Assumption	5.25 days	Sat 25-02-22	Wed 25-02-26	63	Julien
Prototype 2 Build	3.13 days	Wed 25-02-26	Sat 25-03-01	63,64	Faran
Prototype 2 Test + Analysis	5.25 days	Thu 25-02-27	Mon 25-03-03	65	Matthew
PD F quality check	5.25 days	Thu 25-02-27	Mon 25-03-03	59,62	Ethan
PD F projet plan update	1.13 days	Sat 25-03-01	Sat 25-03-01		Ethan
Client meet 3	1 day	Tue 25-03-04	Tue 25-03-04	58	
PD G: Economic and IP considerations	**11.5 days?**	**Fri 25-03-07**	**Mon 25-03-17**		
PD G.1: Economics report	6.25 days	Fri 25-03-07	Wed 25-03-12		Rashad
PD G.2: IP report	6.25 days	Fri 25-03-07	Wed 25-03-12		Julien
PD G quality check	1 day	Thu 25-03-13	Thu 25-03-13	71,72,74	Ethan
PD G projet plan update	1 day	Fri 25-03-07	Fri 25-03-07		Ethan
PD H: Design day					
Final prototype	16.5 days	Tue 25-03-11	Wed 25-03-26		Faran
Design day presentation	1 day	Wed 25-03-26	Wed 25-03-26		Rashad
PD H quality check	1 day	Thu 25-03-27	Thu 25-03-27	76,77	Ethan
Design day	0 days	Thu 25-03-27	Thu 25-03-27		Team
PD I: User manual					
3 Minute Video	1 day	Thu 25-03-27	Thu 25-03-27	76	Ethan
User Manual	3.13 days	Thu 25-03-27	Sat 25-03-29		Julien
PD I quality check	1.13 days	Sun 25-03-30	Sun 25-03-30	81,82	Ethan
PD J: Final presentation					
Final Presentation Slides	4.25 days	Thu 25-03-27	Sun 25-03-30	76	Faran
PD J quality check	1 day	Mon 25-03-31	Mon 25-03-31	85	Ethan

Figure 16: Gantt Chart for PD G, H, I J

5 Design Day Pitch and Final Prototype Evaluation

A lot of companies treat accessibility like it's a luxury. But for millions of people, something as simple as folding a cane can be a real challenge. Whether you're carrying groceries, trying to open a door, or just moving around, accessibility should make things easier, not harder. That's where the SnapCane comes in.

For many, mobility aids are essential for independence, but they often come with unnecessary complications. Traditional canes take up a lot of space and become a burden when they're not in use. Even folding canes need two hands to operate, and when you fold them, where do you even put them? The SnapCane changes all of that.

The client we designed the cane around required something light weight, while keeping its strength. The upright 'walking stick' esque grip also was designed with the client in mind, ensuring a natural, and more comfortable grip. A big focus of ours has been simplicity, the intuitive design of the SnapCane ensures it can fold and unfold with ease.

(Demo while talking) To use it, hold the cane out and press the button, and the cane unfolds easily instantly. No need to use both hands or struggle with complicated mechanisms. When you're done, just flip it over, press the button again, and it folds back up.

We've made sure SnapCane isn't just about folding, it's about making everyday life easier. The SnapCane is easy to use, takes up less space, and is easier to store than every other cane on the market. The SnapCane will keep you moving without extra effort.

We're excited to bring this to the world, and we hope you'll be a part of it. Stay tuned for our launch, and thanks for checking out SnapCane.

6 Video and User Manual

6.1 Video pitch

https://youtu.be/OHEskLnmNAg

6.2 User manual

See separate document for the user manual.

SnapCaneUserManual.docx

7 Conclusions

In summary, many lessons were learned from this overall experience with designing the prototype from initial phases to completion. A key insight that can be derived is found to be the importance of prototyping with multiple iterations. In specific, the telescoping mechanism in the design proved to be the most complex component, as well as most critical component in the project. With the final prototype being implemented with the conceptual design of the telescoping mechanism, unforeseen issues regarding the initial design were found and unable to be fixed prior to the final due date. With more prototyping in between, the design flaws could have been identified early on and could have resulted in the design concept to be changed. This could have provided the prototype with a better chance of success. Due to a difficult time constraint, the team initially didn't see it feasible to construct multiple physical prototypes, though more thought could have been utilized to forgo this obstacle.

Implications regarding the final project state solely lie in the functionality of the second rod of the telescoping system, as well as full implementation of the handle subsystem. The team focused primarily on the telescoping system and opted to forego the construction of other pieces of the prototype in efforts to have a functioning prototype. A design concept flaw resulted in the second telescoping rod getting stuck upon support by the first rod, which prevented the cane's collapse when fully extended. It is notable that the first rod functions as intended, providing load bearing support, and the ability to collapse and retract the structural tubes.

Next steps include modifications to the connecting pieces between the first and seconds rods. A gearing system can be used to engage the second rod, thus preventing the second rod from over-rotating and getting stuck in a position past the first rod, as previously discussed. The design files for the handle have already been created and simply need to be 3D-printed and attached to the top of the cane for the completion of the handle subsystem.

In conclusion, unforeseen obstacles have been encountered in the final phases of manufacturing that could have been detected with deeper prototyping. This serves as a crucial lesson for the students in Group F1.4 the importance of prototyping and proof of concept for complex mechanisms.

8 Bibliography

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