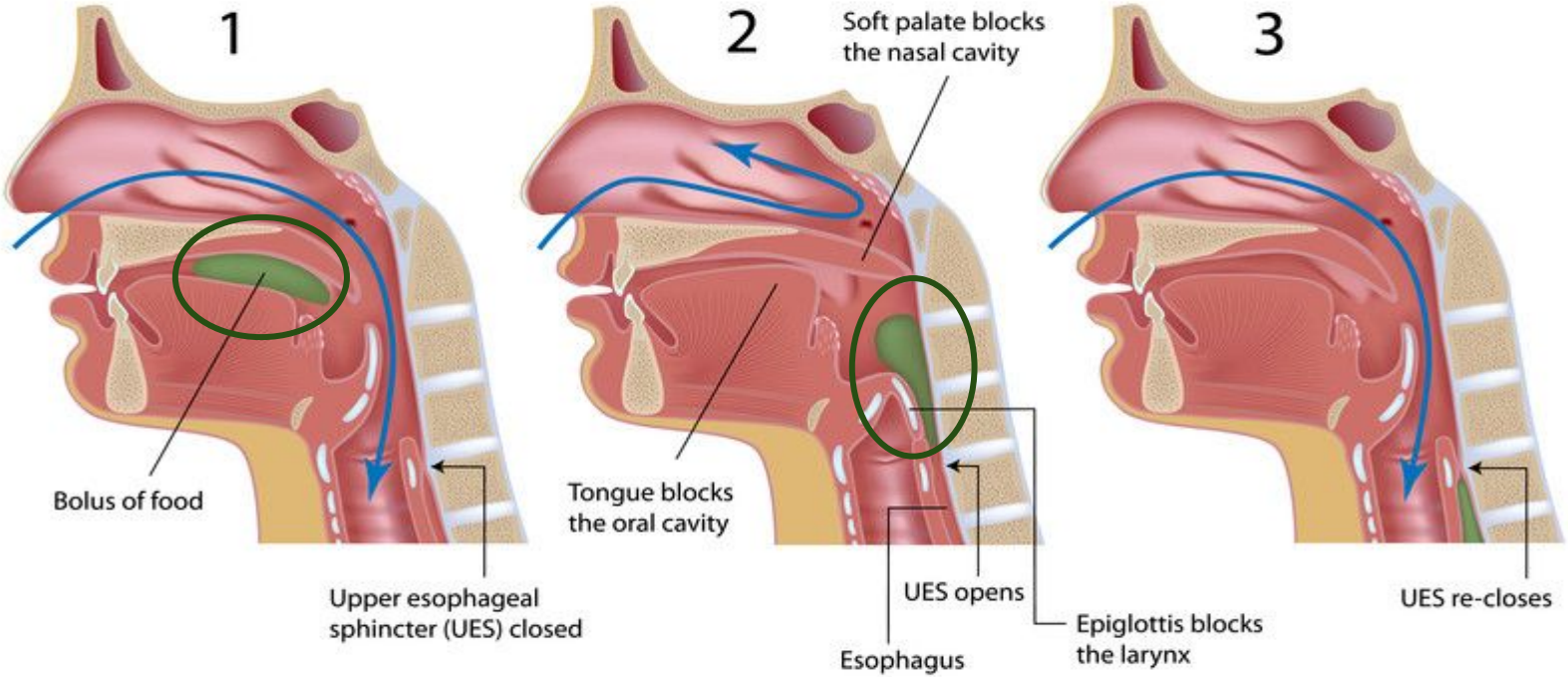
P3 Presentation

PillPals: Angia C., Miles M., Kent Y., Spencer Z.

The Normal Swallow Reflex[1]



Oral stage

Pharyngeal stage

Esophageal stage

Ailment: Presbyphagia - The “Aged Swallow”

- *The characteristic changes of the swallowing process of older adults that result from the normal aging process.*[2]
  - Reduced muscle strength.[2]
  - Decrease in the size of the opening of the esophagus.[2]
  - More dilated esophagus.[2]
- These changes make it **difficult to swallow a pill**:
  - Pill gets **stuck on the tongue**, leading to **gagging.**[3]
  - Pill gets **stuck in the throat or esophagus**, leading to **discomfort.**[2]

Target Users

Primary Users

- 65 years or older
- Limited neck motion[4]
- Routinely takes multiple pills (~5)[5]
- Low-moderate income (less than $30,000/year)[6]

Secondary Users

- Caretakers
- Nurse
- Family member

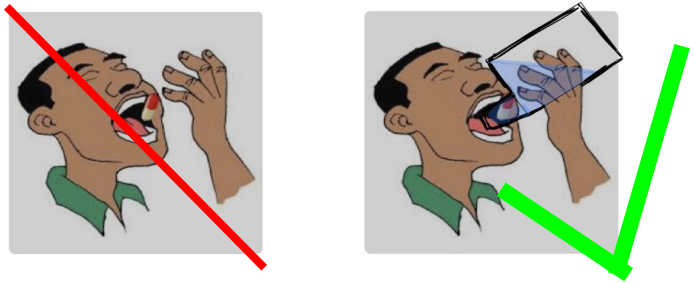
Problem Thesis

*People **65 years of age or older** with **presbyphagia** in the **U.S.**[7] of **low to moderate income**[6] seek an **intuitive** pill swallowing aid for routine ingestion of **multiple**[5] solid oral medications to ensure effective disease management.*

Assumptions:

- User has difficulty swallowing pills.
- A pill swallowing aid will encourage the user to take their medication and ensure effective disease management.
- User is able to lift and drink from a disposable plastic water bottle.

Our Solution



User’s problem:

- Pill getting **stuck on the tongue**, leading to **gagging**
- Pill getting **stuck in the throat or esophagus**, leading to **discomfort**

Our solution will be a pill swallowing cup that will:

- **Release pill and water simultaneously** from the cup.
  - Prevents stimulation of sensory receptors involved in the **gag reflex.**
- Produce a **greater flow**,
  - Allows for smoother passage into and down the esophagus to **reduce sensation and discomfort** (less muscle force required).
- Allow the user to take multiple pills.

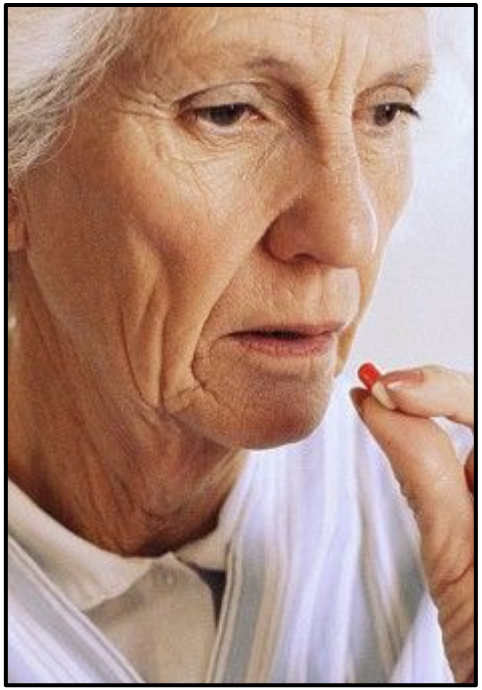
Value of our solution

Elderly are prone to:

- Modifying their medication[8]
  - **Overdose or underdose.**
- Skipping, delaying, or discontinuing doses[9]
  - **Ineffective disease management.**

Who we are helping:

- Of the 47.8 million people aged 65 or older in the United States[10], **16 million** of them have **difficulty swallowing**[3].



Design Inputs

Objective	**Constraint**
1. Minimizes sensation of the pill.	Likert scale rating (1 = felt pill completely, 5 = did not feel pill at all) is higher than OralFlo's.
2. Be able to be used for multiple pills.	Minimizes sensation at volumes up to 600mL (113ml[11] x 5pills[5]).
3. Does not cause neck discomfort.	Pill falls out before the cup reaches an angle of 50[12] degrees above the horizontal.
4. Our device will be easy to lift by weighing about the same as a standard disposable water bottle	Weighs less than 500g[13].
5. Will be intuitive to use	User can intuit how to use on the first try.

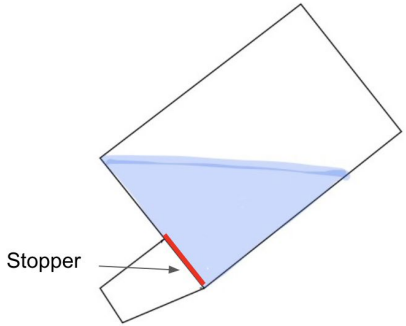
Insights from P2

Final P2 Prototype Weaknesses:

- Slow tilting, causing premature water flow
  - Leads to water accumulation in mouth
- Learning curve
  - Tilt cup quickly, then coordinate pill drop

New concept: **water stopper**

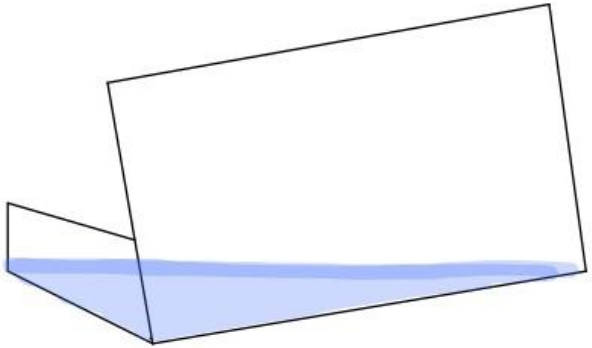
- **simultaneous delivery of pill and water** into mouth
- **greater flow rate** of water to carry pill into the mouth



Engineering Method

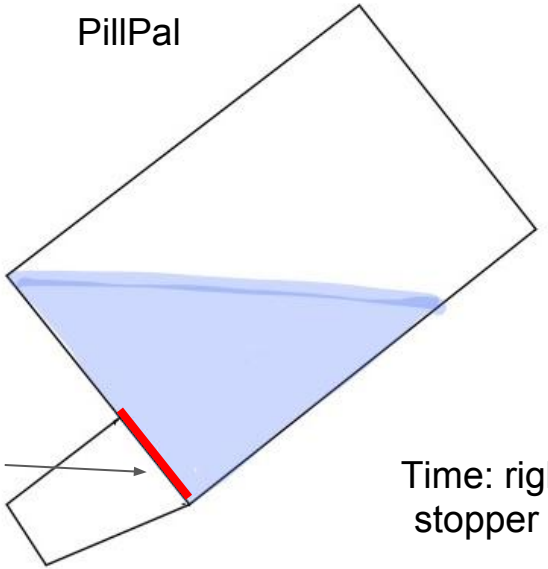
Problem: What will be the flow rate **right before water flows** into the mouth for the Oralflo and for the PillPal?

Oralflo



Time: right before water flows out the spout

PillPal

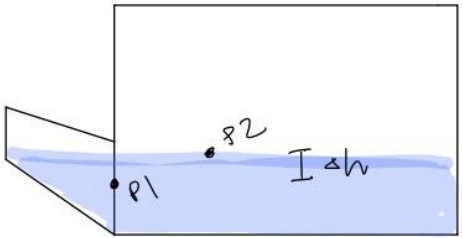


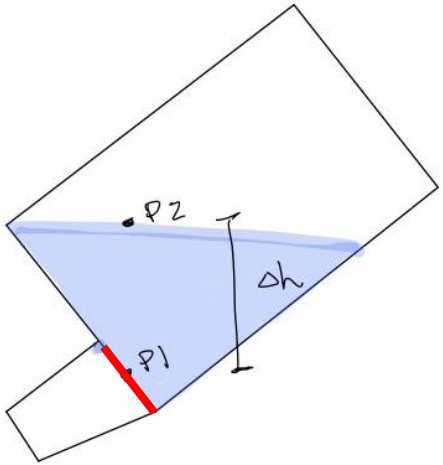
Time: right before the stopper is removed.

Engineering Method - Cont’d

Assumptions

- Cup oriented before water pours out ($v_1 = 0$)
- Steady State
- Incompressible Fluid
- Lossless
- Along Streamline
- Gauge Pressure
- Long Cylindrical Pipe





Engineering Method

Principle: Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho_1 v_1^2 + \rho_1 g h_1 = P_2 + \frac{1}{2}\rho_2 v_2^2 + \rho_2 g h_2$$

Principle: Poiseuille Flow

$$Q = \frac{\pi R^4}{8\eta L}\Delta P$$

Engineering Method - Cont'd

(No flow)

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

0 0 0 0

(No flow) h = 0 Gauge Pressure

$$P_1 = \rho g h_2$$

$$Q = \frac{\pi R^4}{8\eta L}\Delta P \longrightarrow Q = \frac{\pi R^4}{8\eta L}\rho g h_2$$

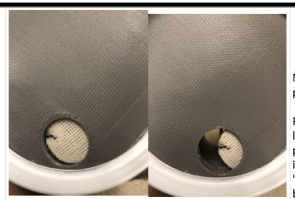
(Poiseuille Flow)

Measured Values

Oralflo: ~5.38 mL/sec

PillPal: ~16.54 mL/sec

P3 DEEM

6	design a structure that blocks water before pill is released and stop blocking after pill is released	Target: team will build a plate that can slide and is connected to the sliding platform in pill compartment. It covers the spout when the platform is at one end and opens the spout when platform slides to the other end. Test plan:fill in 150 ml of water. Block the spout and point the cup down for 5 seconds. Measure amout of water leaked		Material: pla, copper, acrylic, hot glue, plastic lid Procedure: 3D print the spout, compartment, lid. laser cut the acrylic into shape of sliding plate and a circular block whose diameter is 1mm larger than the spout. turn a copper wir "L" shape then glue it to holes on platform/ block to connect them. Use hot glue to connect	leak in 5 seconds: 51ml	the blocking mechanism is working, amount of water coming out is significantly less than without blockage. However, the circular shape is hard to match cover the entire spout due to manufacture error. try other design of blockage to see if it would be better
7	design a water blockage that uses the same mechanism but can block more water	Target: team will try differenty size/ shapes of water blockage and test which one can better block water Test plan:fill in 150 ml of water. Block the spout and point the cup down for 5 seconds. Measure amout of water leaked		Material: pla, copper, acrylic, hot glue, plastic li Procedure: 3D print the spout, compartment, li laser cut the acrylic into shape of sliding plate and a square block of 21*25 mm^2 turn a copper wire into "L" shape then glue it to holes on platform/block to connect them. Use hot glue to connect and seal	leak in 5 seconds: 29ml	The 21*25 square blocks enough water to be functional After user testing, we find that this design has good performance regarding of pill swallowing. However, tit's hard for elderly to intuitively understand how to use it, and at full capacity it becomes hard for erderly to hold modify the cup so it fits elderly population better
8	design the appearance of cup so it's more intuitive for elderly to understand how to use it	Target: team will change the shape of pill compartment and add signs on the cup to help user understand how to use it Test plan: give user our new design and observe if they can operate without instruction		Material: pla, copper, acrylic, hot glue, plastic lid Procedure: change CAD of pill compartment into postbox shape. Repeat how we make prototype 18 Lasercut acrylic boards into shapes of pill and arrow, paint them with acrylic paint	One user understand without instruction All understand and operate correctly after instruction	The elderly can understand how to use them after instruction based on stereotype of how people take medicine, an instruction in user manual is required
9	design a structure that prevents pill from falling into cup	Target: team will creat a grid at the end of spout to hold the pill and prevent it from falling Test plan: put pills of 2mm*2mm*1mm into the spout, see if it falls out		Material: pla, prototype 19, superglue Procedure: CAD out a grid and glue it to the end of spout	No pill falls out	This prevents pill from going into the cup

Testing Protocol

Sample population: 8 test subjects over 65 years old with pill swallowing difficulties

To test intuition:

- Handed Oralflo and asked to intuit.
- Handed Pill Pal and asked to intuit.

To test minimizing sensation:

- Asked them to provide a likert scale rating for how much they felt the pill (1 = felt pill completely, with discomfort, 5 = did not feel pill at all)

To test volume:

- Tested Pill Pal at two volumes (150 mL and 600mL)

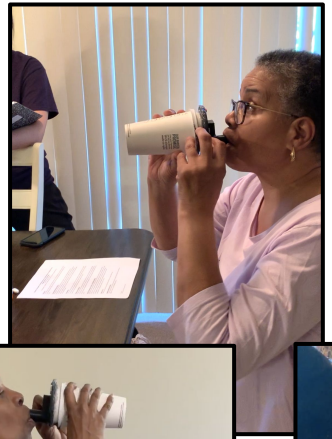
To test angle:

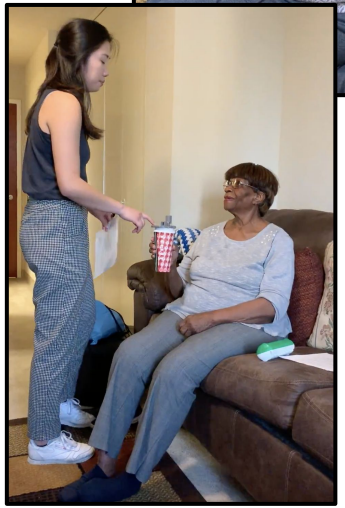
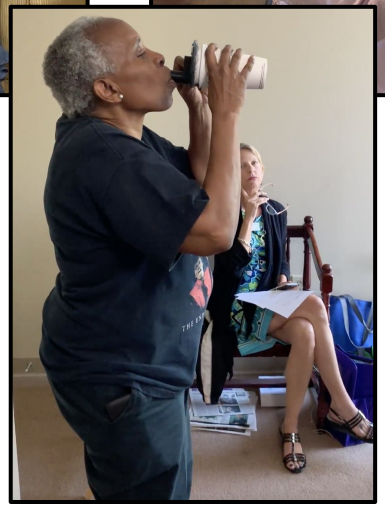
- Measured angle of head tilt from video.

Key Assumptions:

- Takes 113mL[11] of water per pill
- Takes pills smaller than 20 mm
- User will use the device at home.

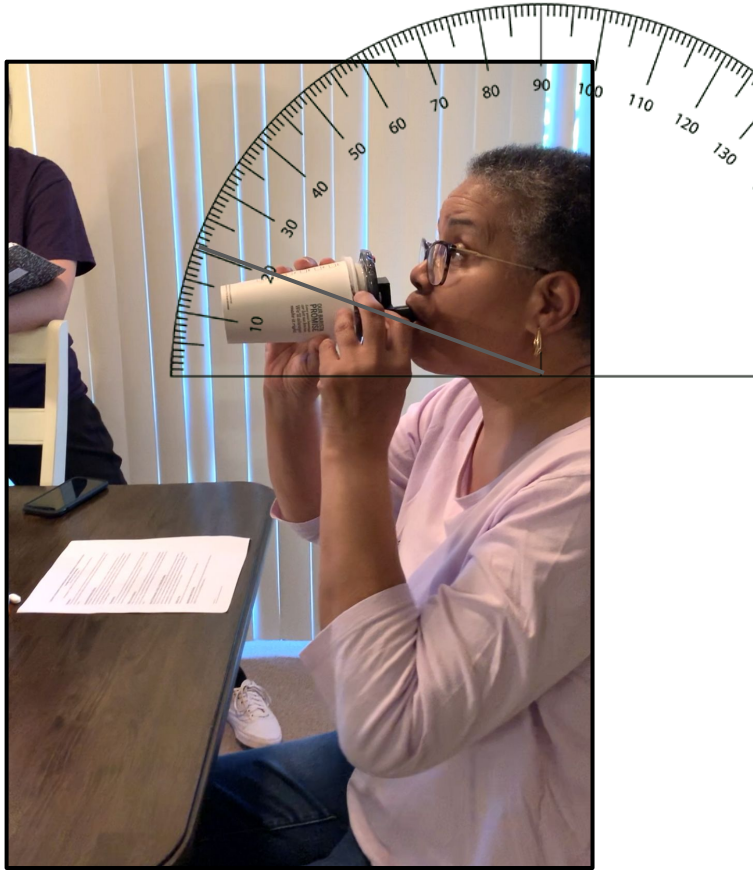
User Testing Documentation

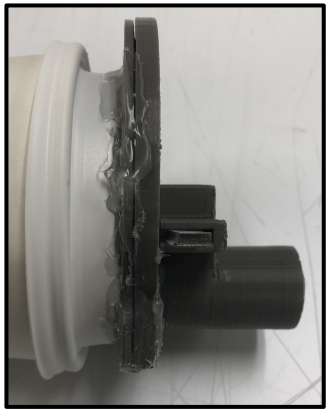
Quantitative Results

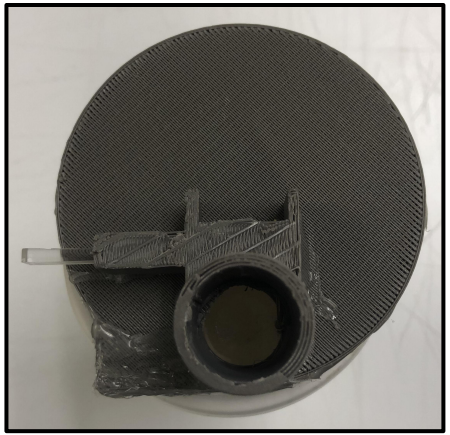
	PillPal	Oralflo
Sensation	4	3
Tilt Angle	~20 degrees	~20 degrees
Volume of Water Swallowed	20-46ml	20-74ml



P3 Testing Feedback - Iteration 1

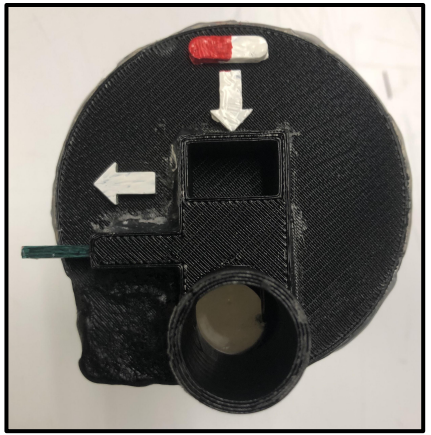
PROS:	CONS:
Successfully delivers the pill before 50 degrees of tilting.	Unintuitive ● Where does the pill go? ● When do I pull?
Better swallowing performance due to sudden and strong water flow.	Too heavy at max water volume
Does not require refilling for 5 pills	Difficult to see transparent components





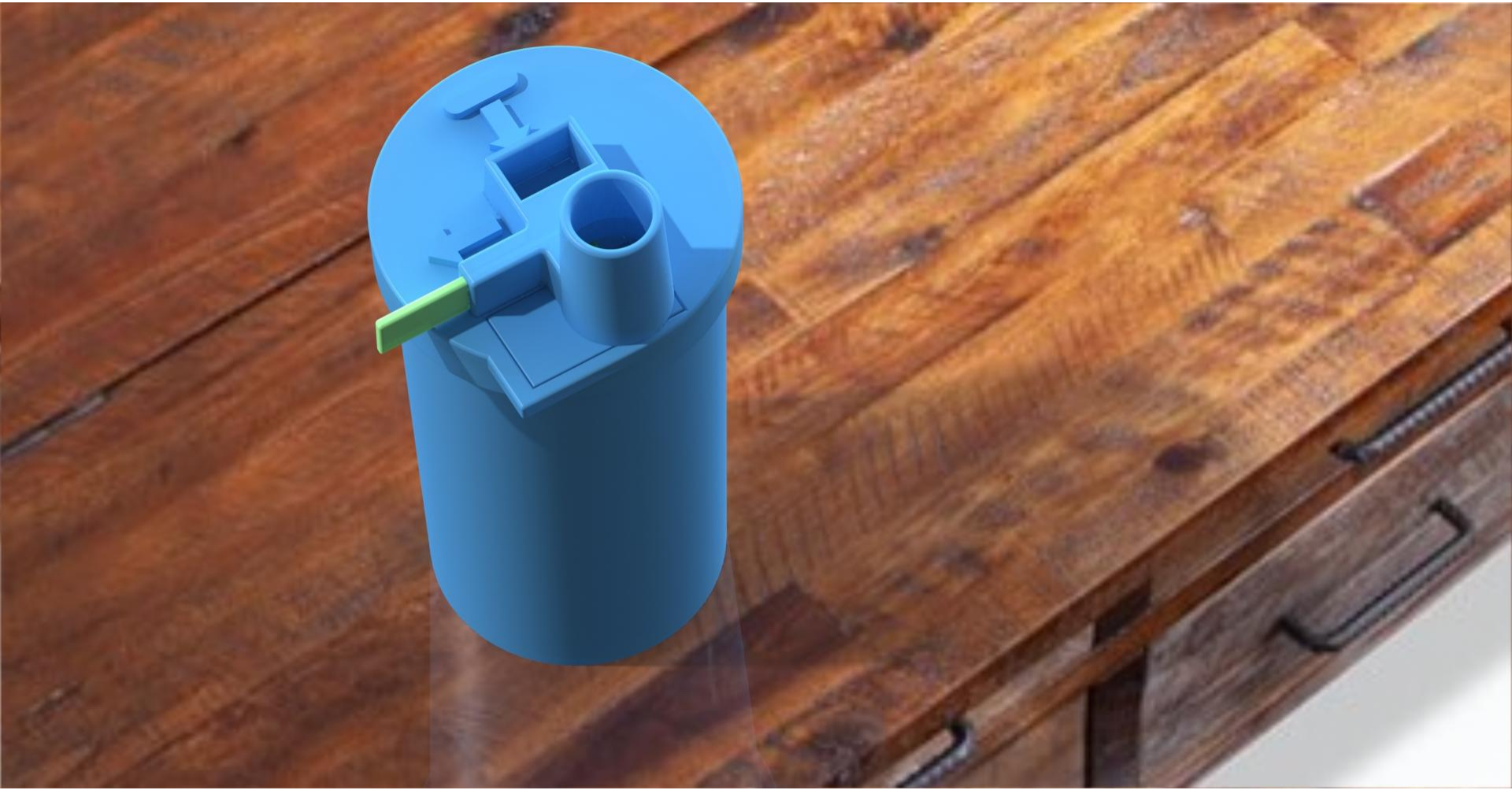
P3 Testing Feedback - Iteration 2

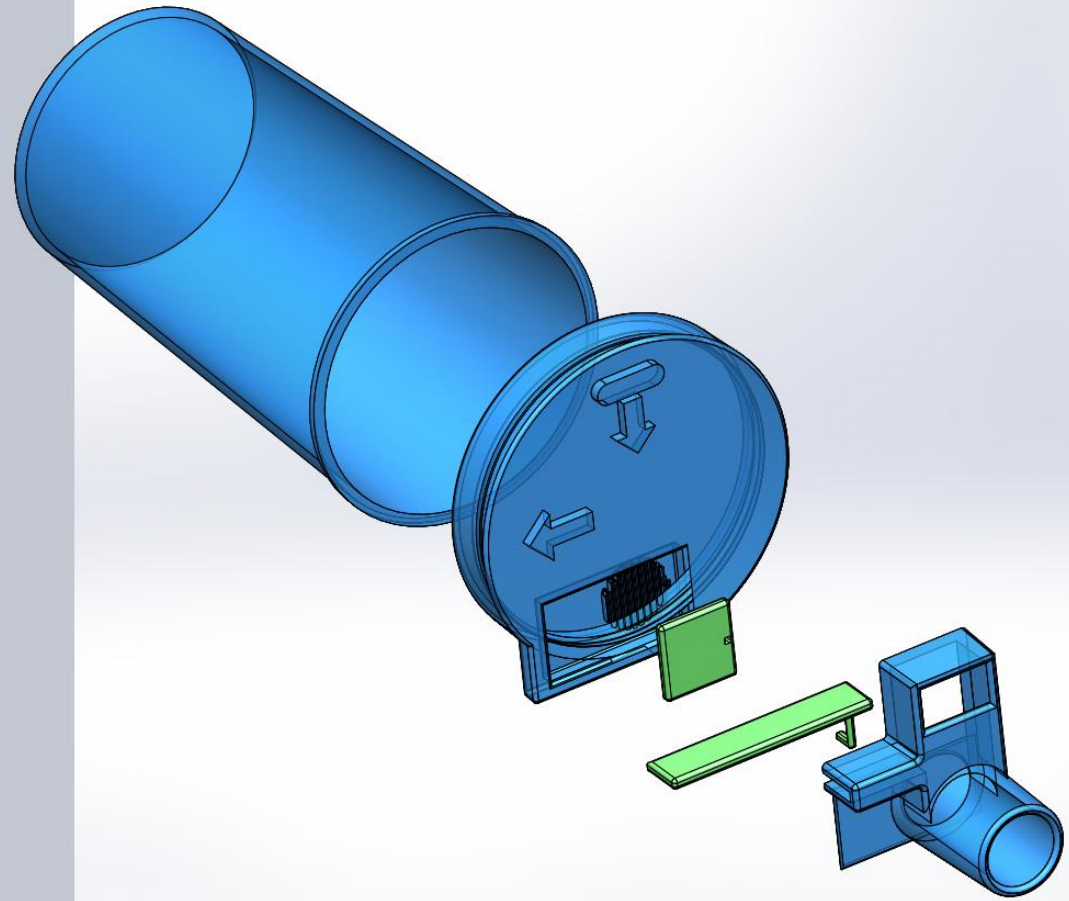
PROS:	CONS:
Design helps with intuitive setup **(Arrows, symbols, shape of compartment)**	Pill falls into cup when slider is prematurely pulled
Slider is more obvious **(Green)**	
Good size **(600mL to 300 mL cup)**	



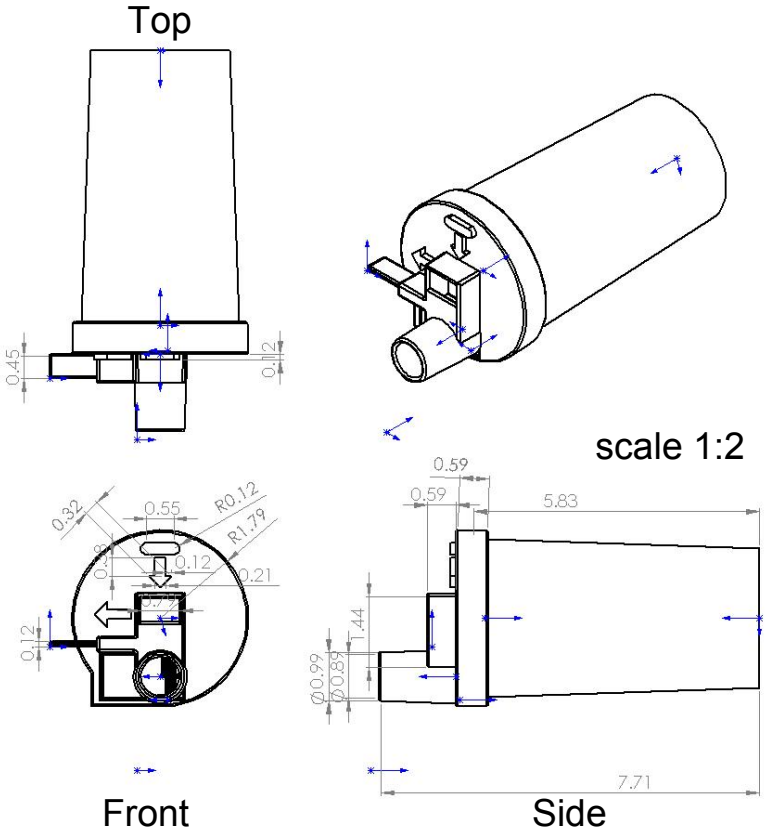
P3 Final Iteration

Final “Works-Like” / “Looks-Like” Model

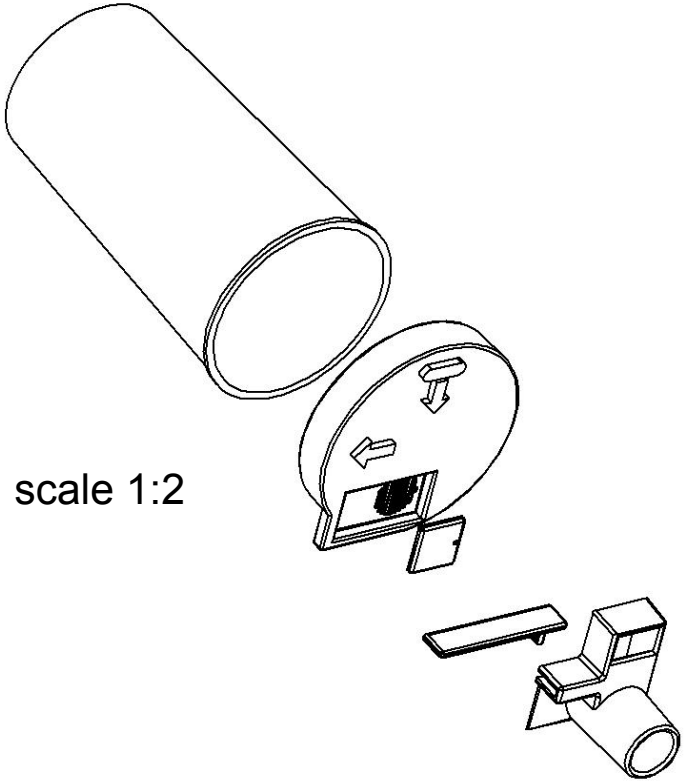




Assembly 4-views



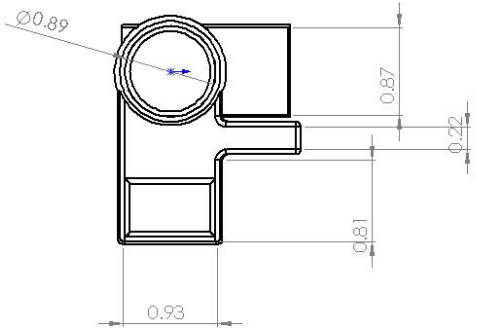
Assembly Exploded

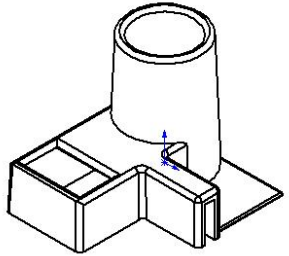


scale 1:2

Spout

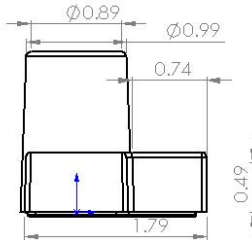
Top



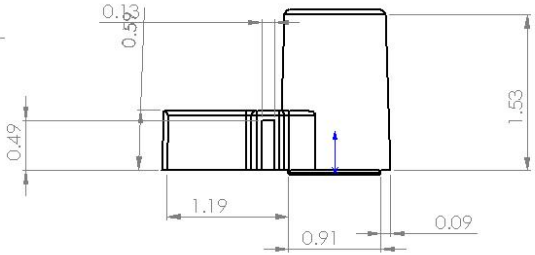


SCALE 1:1

Front



Side



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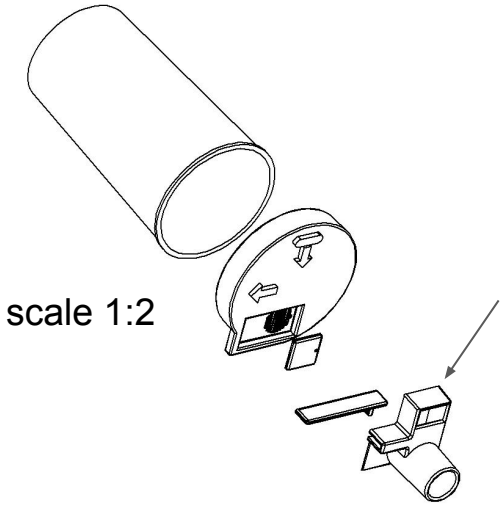
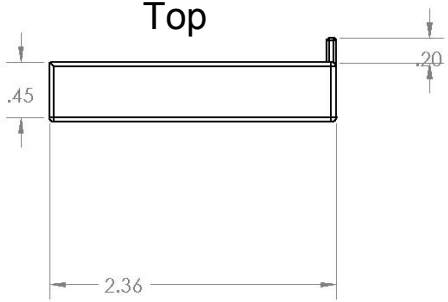
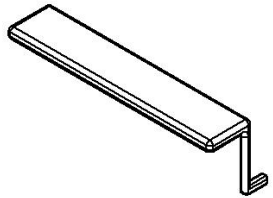


Slider

Top





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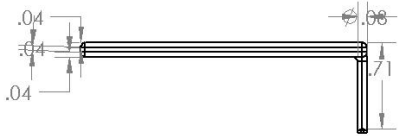

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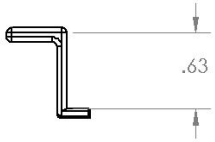

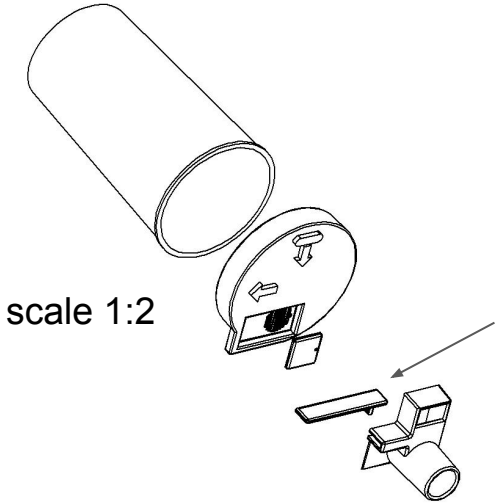

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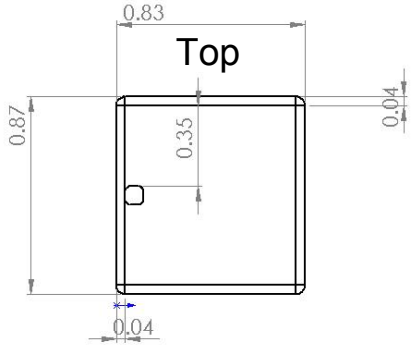
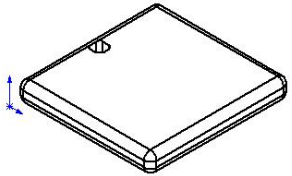
Water Stopper

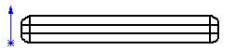


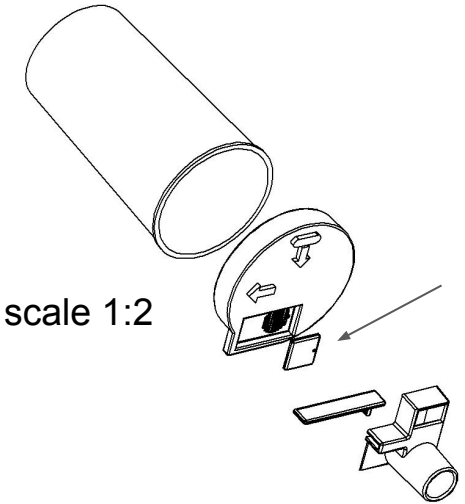


SCALE 2 : 1

Front

Side





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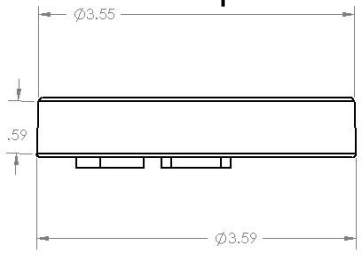
Lid Base

Top



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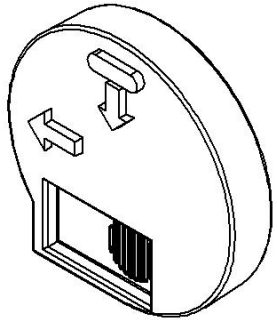
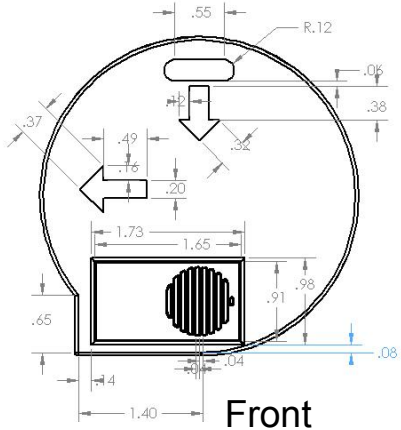
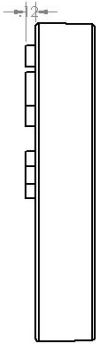
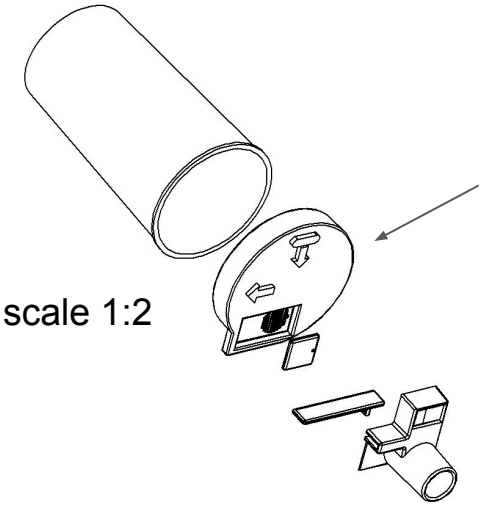




Front



Side



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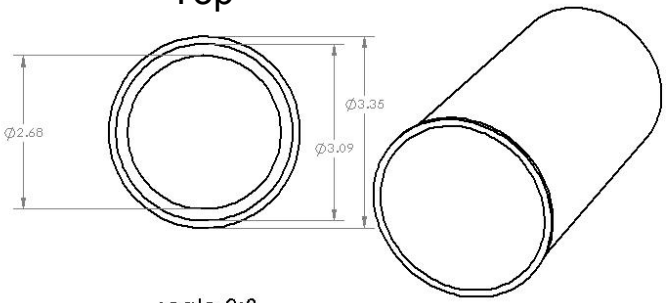
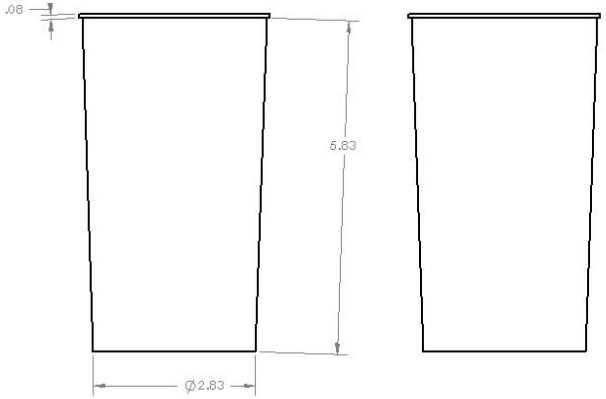
Cup

Top

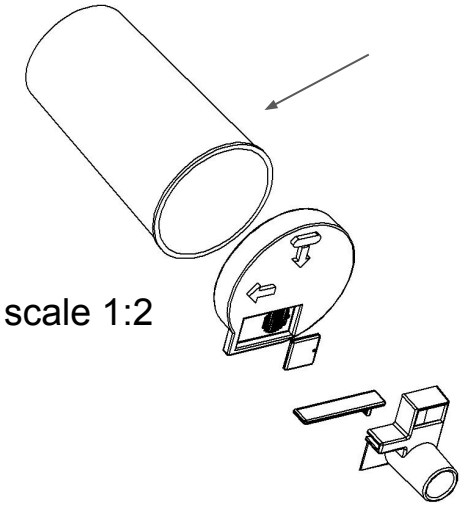


scale 2:3



Front

Side



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Design Documentation - Component Matrix

Part	Quantity	Supplier / Catalog #	Material	Manufacturing Process	Estimated Cost (700k units)	Estimated Cost (10k units)
Cup	1	N/A	Polyethylene Terephthalate (PET)	Injection Molding	$746,442	$31,975
Lid Base	1	N/A	Polyethylene Terephthalate	Injection Molding	$193,645	$8,186
Spout	1	N/A	Polyethylene Terephthalate	Injection Molding	$245,136	$15,583
Water Stopper	1	N/A	Polyethylene Terephthalate	Injection Molding	$96,005	$17,137
Slider	1	N/A	Polyethylene Terephthalate	Injection Molding	$48,002	$8,568

Manufacturing Breakdown

		Cup	Lid Base	Spout	Stopper	Slider	Total
	Materials	$617,649	$51,708	$71,849	$46,482	$23,241	$810,929
	Production	$64,301	$56,955	$78,027	$25,275	$12,638	$237,196
	Tooling	$64,491	$84,952	$95,259	$25,275	$10,124	$280,101
	Total	$746,441	$193,615	$245,135	$97,032	$46,003	**$1,328,226**
700,000 units	Per unit	$1.0663	$0.2766	$0.3502	$0.1386	$0.0657	**$1.8975**
	Materials	$10,338	$127	$5,169	$2,055	$1,028	$18,717
	Production	$3,376	$915	$1,688	$2,798	$1,399	$10,176
	Tooling	$18,261	$7,145	$9,131	$10,229	$5,115	$49,881
	Total	$31,975	$8,187	$15,988	$15,082	$7,541	**$78,773**
10,000 units	Per unit	$3.1975	$0.8187	$1.5988	$1.5082	$0.7541	**$7.8773**

Estimated Cost

Target Market:

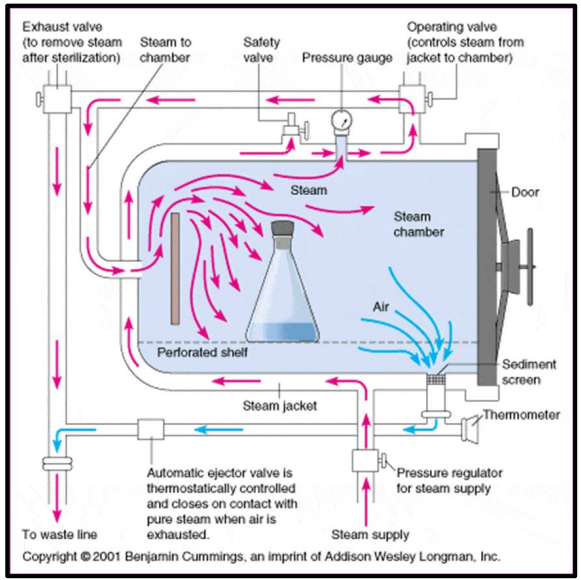
1. low-moderate income elderly with presbyphagia - 6.4 million
2. assisted living homes

Cost to make:

- 10,000 units (safe startup range)
  - $78,773 (x 1.09^{14} packaging) = **$88,779**
  - **$8.8779** per unit
- 700,000 units (~10% of market)
  - $1,328,226 (x 1.09 packaging) = **$1,448,861**
  - **$2.0698** per unit

Design Documentation

- Sterilization Method: Steam/Heat
- Packaging: Standard cardboard packaging box



Design Documentation

- Environmental Impact
  - Pros
    - Reusable
  - Cons
    - Plastic waste is harmful to the environment
    - Pollution from production

Design Documentation

- Business sustainability
  - Increase in elderly population
    - 48 million to 88 million by 2050[15]
  - Versatility as a normal cup
  - Cheap if mass produced
    - 700,000 units vs 10,000 units

Pillpal vs Oralflo

PillPal	Oralflo
Helps swallow better due to faster flow rate	Weak flow rate
Can take at least 5 pills without refilling water	At most two pills
Can be used as a normal cup	Too small to be used as a normal cup
Hard, steady wall	Thin wall
Appearance close to normal cup	Childish “sippy cup”

Results and Conclusion

User:

- Elderly
- Low-moderate income

User's Problem:

- Pill swallowing difficulties caused by presbyphagia
- Takes multiple pills

Our Solution:

- A cup that will release pill and water simultaneously and with greater flow to prevent gagging and discomfort.
- Allows user to take up to 5 pills.
- Has obvious visual cues.

Price: $15

- 10k units: net profit = $6 per unit sold
- 700k units: net profit = $12 per unit sold

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Appendix

Interview Footage

P3 DEEM - Entry 1

6	design a structure that blocks water before pill is released and stop blocking after pill is released	Target: team will build a plate that can slide and is connected to the sliding platform in pill compartment. It covers the spout when the platform is at one end and opens the spout when platform slides to the other end. Test plan:fill in 150 ml of water. Block the spout and point the cup down for 5 seconds. Measure amout of water leaked		Material: pla, copper, acrylic, hot glue, plastic lid Procedure: 3D print the spout, compartment, lid. laser cut the acrylic into shape of sliding plate and a circular block whose diameter is 1mm larger than the spout. turn a copper wir "L" shape then glue it to holes on platform/ block to connect them. Use hot glue to connect
			leak in 5 seconds: 51ml	the blocking mechanism is working, amount of water coming out is significantly less than without blockage. However, the circular shape is hard to match cover the entire spout due to manufacture error. try other design of blockage to see if it would be better

P3 DEEM - Entry 2

7	design a water blockage that uses the same mechanism but can block more water	Target: team will try differenty size/ shapes of water blockage and test which one can better block water Test plan:fill in 150 ml of water. Block the spout and point the cup down for 5 seconds. Measure amout of water leaked		

Material: pla, copper, acrylic, hot glue, plastic li Procedure: 3D print the spout, compartment, li laser cut the acrylic into shape of sliding plate and a square block of 21*25 mm^2 turn a copper wire into "L" shape then glue it to holes on platform/block to connect them. Use hot glue to connect and seal	leak in 5 seconds: 29ml	The 21*25 square blocks enough water to be functional After user testing, we find that this design has good performance regarding of pill swallowing. However, tit's hard for elderly to intuitively understand how to use it, and at full capacity it becomes hard for erderly to hold modify the cup so it fits elderly population better	

P3 DEEM - Entry 3

8	design the appearance of cup so it's more intuitive for elderly to understand how to use it	Target: team will change the shape of pill compartment and add signs on the cup to help user understand how to use it Test plan: give user our new design and observe if they can operate without instruction	
		Material: pla, copper, acrylic, hot glue, plastic lid Procedure: change CAD of pill compartment into postbox shape. Repeat how we make prototype 1& Lasercut acrylic boards into shapes of pill and arrow, paint them with acrylic paint	One user understand without instruction All understand and operate correctly after instruction	The elderly can understand how to use them after instruction based on stereotype of how people take medicine, an instruction in user manual is required

P3 DEEM - Entry 4

9	design a structure that prevents pill from falling into cup	Target: team will creat a grid at the end of spout to hold the pill and prevent it from falling Test plan: put pills of 2mm*2mm*1mm into the spout, see if it falls out			
		Material: pla, prototype 19, superglue Procedure: CAD out a grid and glue it to the end of spout	No pill falls out	This prevents pill from going into the cup	

Moving Forward after Tuesday Interviews

- Better appearance
- More colors
- Clear user manual
- Make more intuitive