3D-PRINTED NEONATAL ASPIRATOR FOR VOA

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BACKGROUND OF NEONATAL ASPIRATORS

- Motivation:
  - 25% of global neonatal deaths are associated with asphyxia. [1]
  - 1 million newborns die due to asphyxia per year, according to WHO. [2]
- Two primary purposes of neonatal aspirators:
  - **Deep suction:** to remove amniotic fluid or meconium in a newborn's airway (mouth and nostrils) during birth or a tracheostomy. [3,4] (hospital)
  - **Shallow suction:** to clear mucus near the opening of a newborn's nose by nursing mothers. (home)
- Assumption:
  - design an aspirator device that serves both purposes.

BACKGROUND: PUMPS AND WALL SUCTION

- Electrical pumps and wall suction
  - High-resource settings have "wall suction", to which a single-use mucus catheter is connected. Flow is controlled by using thumb over hole.
  - Can exist in low-resource settings too, but more costly ($780 [1])
  - Not practical for home use
  - Used for both purposes
- Manual pump, foot operated
  - Cheaper than electrical pump, but moving parts need maintenance.
  - Can be as cheap as $12, for just the pump. Suction/catheter supplies cost extra.
  - Used for both purposes.

Manual and electric aspirator pumps [5]

BACKGROUND: HAND OPERATED SUCTION

- Bulb Suction & Laerdal *($0.50 - $3.00 USD)*
  - Used for shallow suctioning near opening of newborn's nose and mouth.
  - Common in high and low-resource settings.
  - May be reused up to several hundred times, if sterilized [2]
  - Drawbacks:
    - Hand bulb suction has limited suction strength and requires repetitive operation (squeeze, release, discharge fluid, repeat).
    - While not designed for deep catheter suctioning, can be modified by cutting off tip and inserting catheter suction. [3]

BACKGROUND: MOUTH OPERATED SUCTION

- DeLee Suction Trap *($2.00 - $9.00 USD)*
  - Used for deep suctioning [4] or shallow suctioning [6].
  - Compatible with mouth or pump suction.
  - Markings indicate fluid level (typically 20 ml).
  - Reusable when sanitized; catheter tube disposable, reusable up to 24 hrs [8]
  - Drawbacks:
    - If trap fills up, fluid could enter provider's mouth.
    - For shallow suction, must dispose of or clean flexible tube (more difficult).

- Nose Frida *($15.00 USD)* [7]
  - Used for shallow suctioning
  - Placed on nostril, not in it.
  - Single, reusable tubing (unlike DeLee).
  - Non-invasive
  - Drawbacks:
    - In-line suctioning requires disposable filter
    - Not compatible with deep catheter suctioning

DESIGN REQUIREMENTS

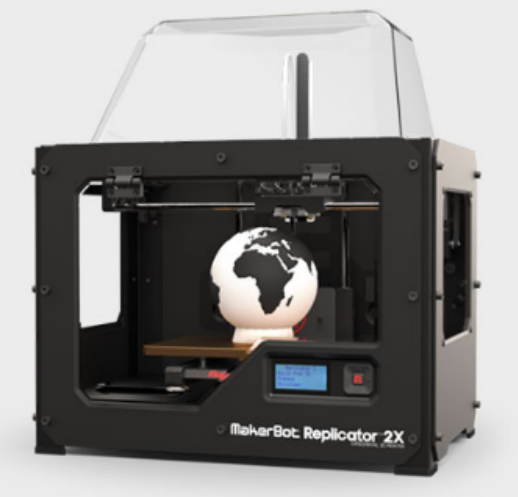
- Musts:
  - Multi-purpose:
    - useful for deep catheter suction (hospital users, trach tubes) **and**
    - shallow suction (hospital or nursing mothers)
  - At least 20 ml volume for deep suctioning of amniotic fluid
  - Operate without electricity
  - Re-usable and durable
  - Minimize disposable parts (decreases operating cost)
  - Easy to clean with boiling water or by hand with soap and water
  - Mucus and fluid must not be able to enter provider's suction tube
  - Compatible with 3D printers at VOA
  - Comparable in cost to existing technologies
  - Ergonomic

DESIGN REQUIREMENTS

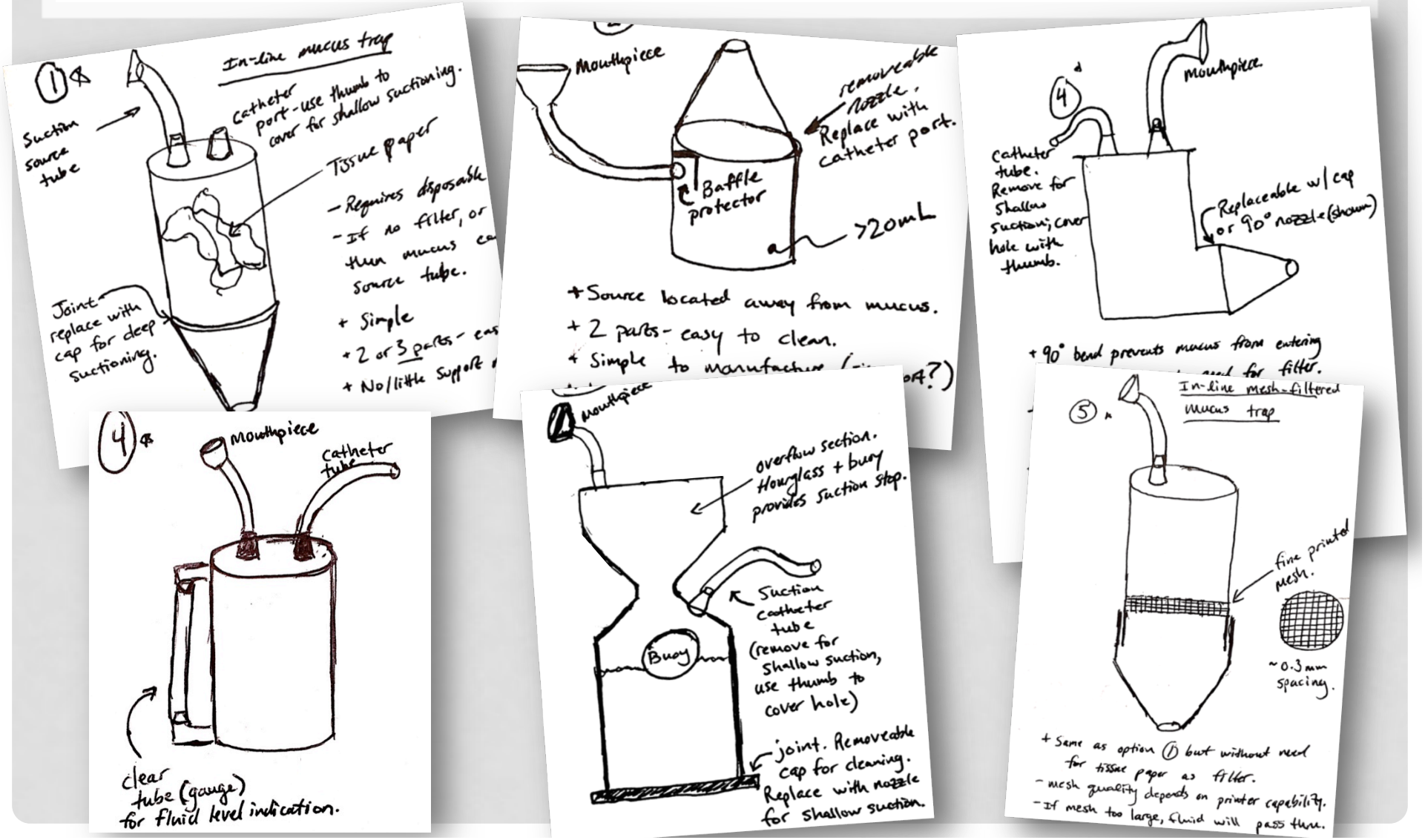
- Shoulds:
  - Simple to manufacture
  - Should be compatible with electric/manual pumps, wall suction.
  - Indicate fluid level
  - Minimize moving parts for extended life

3D-PRINTER CAPABILITIES AT VOA

- 3D Printers:
  - Makerbot, Retr3D eWaste, Ultimaker
- Nozzle sizes: 0.3 and 0.4 mm
- Material availability:
  - ABS, PLA, FLEX
- Material of choice:
  - **ABS**, for its *durability and cost* ($48 USD per kg)
  - FLEX was **not** chosen because it is flexible at temperatures around 60 C; it could melt in a car on a hot day. *Also it is 2x more expensive than ABS or PLA.*
- Assumptions:
  - Clear materials are not available.
  - Plastic medical grade tubing and suction catheters are available in-country.



MY IDEATION PROCESS: SKETCHES OF VARIOUS DESIGN IDEAS



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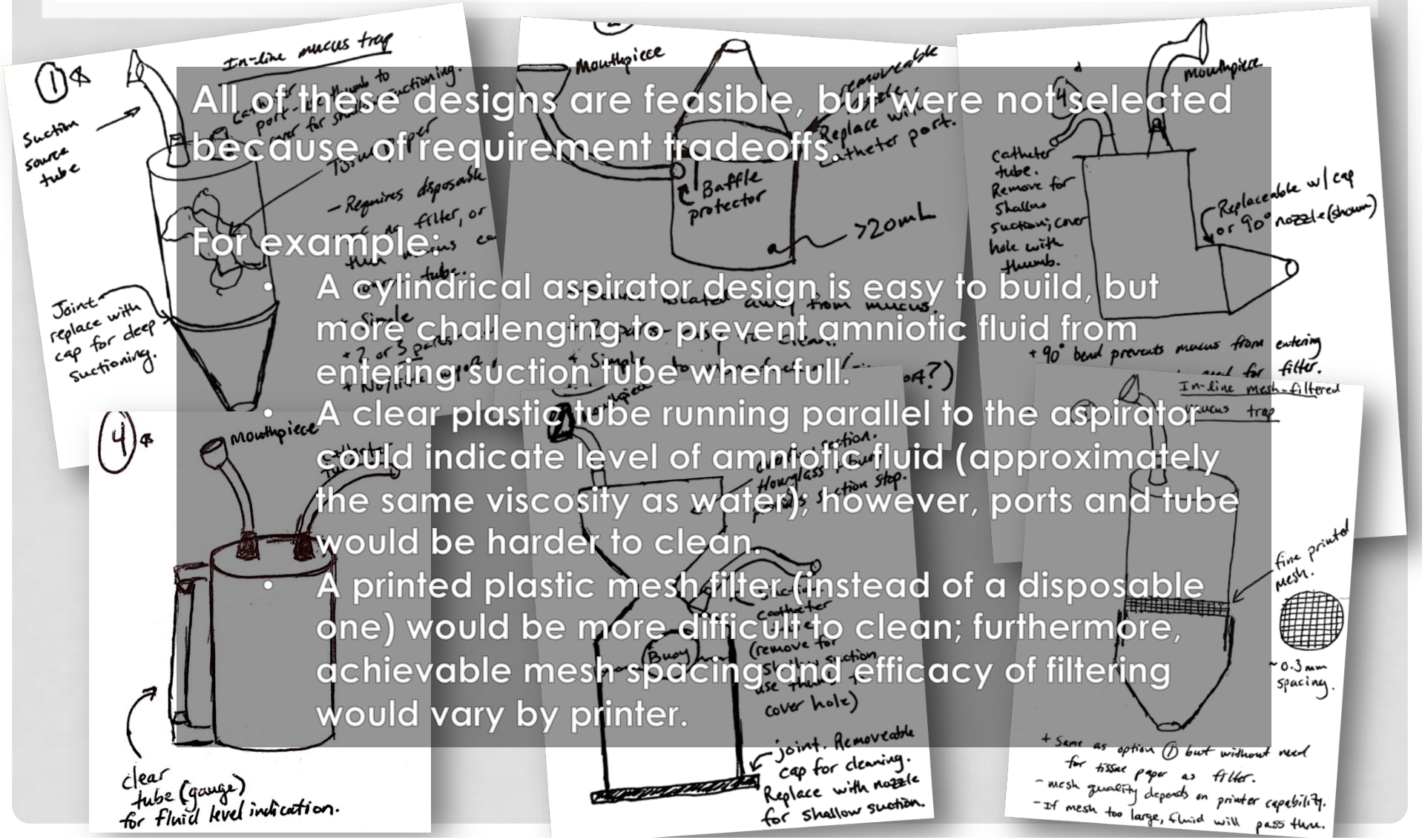


All of these designs are feasible, but were not selected because of requirement tradeoffs.

For example:

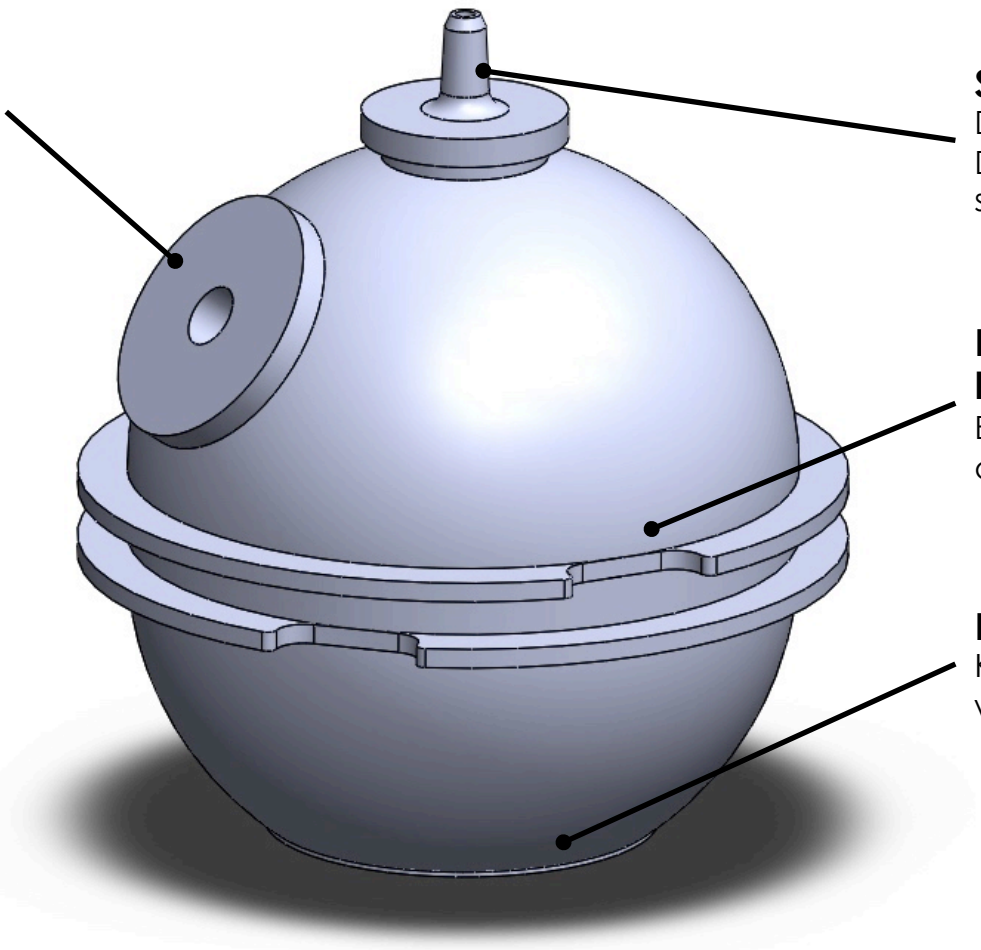
- A cylindrical aspirator design is easy to build, but more challenging to prevent amniotic fluid from entering suction tube when full.
- A clear plastic tube running parallel to the aspirator could indicate level of amniotic fluid (approximately the same viscosity as water); however, ports and tube would be harder to clean.
- A printed plastic mesh filter (instead of a disposable one) would be more difficult to clean; furthermore, achievable mesh spacing and efficacy of filtering would vary by printer.

FINAL DESIGN – DEEP ASPIRATION

Interchangeable catheter/nozzle port
Allows for deep or shallow aspiration. Catheter port hole can be sized appropriately.

Catheter tube directed away from suction port
Fluid falls to bottom, away from suction port.

No disposable parts or filters
Except for deep insertion catheter tube.



Suction port
Designed to fit 5mm Inner Diameter tubing; can be sized appropriately.

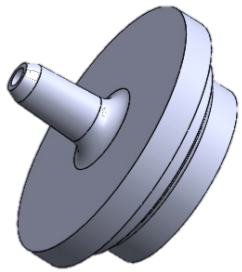
Ergonomic spherical body with side tabs
Easy to handle, assemble, and disassemble.

Flat bottom
Keeps aspirator upright when not used

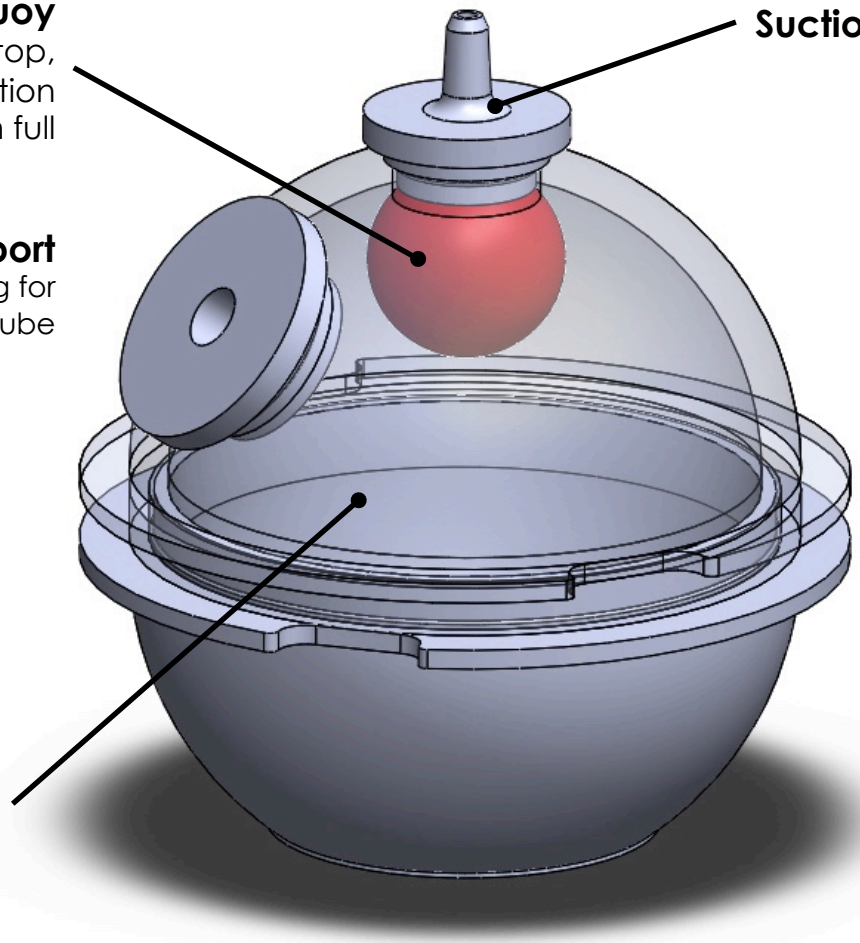
FINAL DESIGN – INTERNAL VIEW

3D printed hollow buoy
Naturally floats to top, blocking fluid into suction tube when full

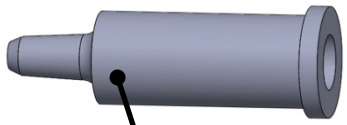
Catheter port
can have a hole or a fitting for a catheter tube



Large 60 ml internal volume
Unlikely to be filled. Buoy may be optional.



Suction port



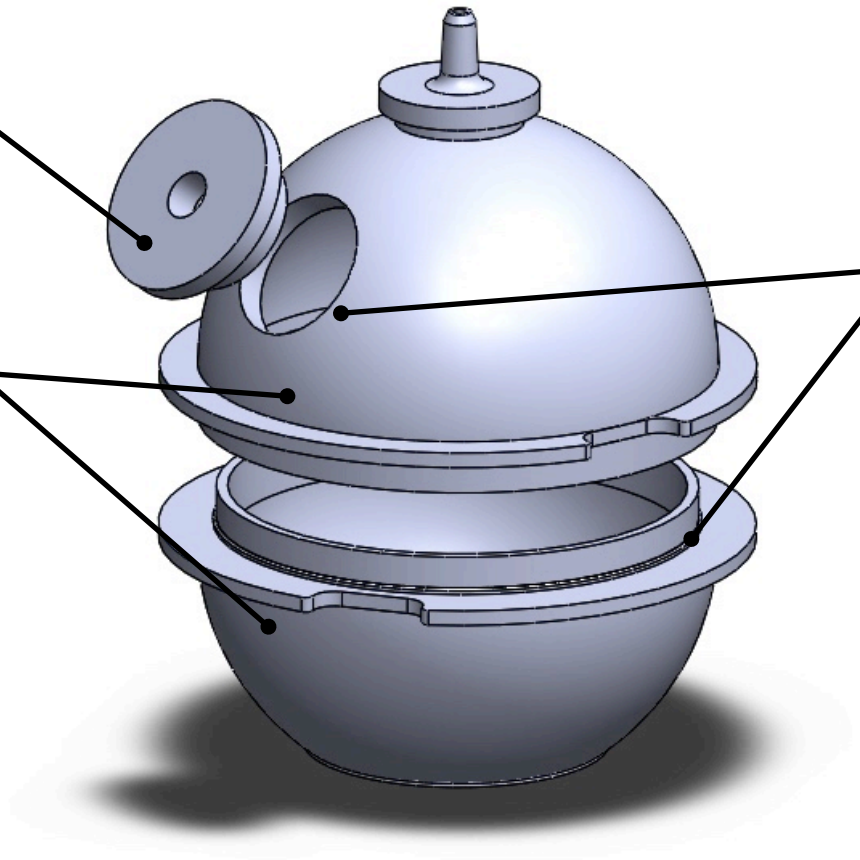
Mouthpiece
Buy or print reusable barbed fitting to be compatible with wall suction (see below)

FINAL DESIGN – ASSEMBLY/DISASSEMBLY

Catheter port
Can be replaced with nozzle for shallow suction

Bowl shaped halves
Easy to clean by hand with soap and water or in boiling water

Simple to manufacture
Each part is printed separately with minimal support material

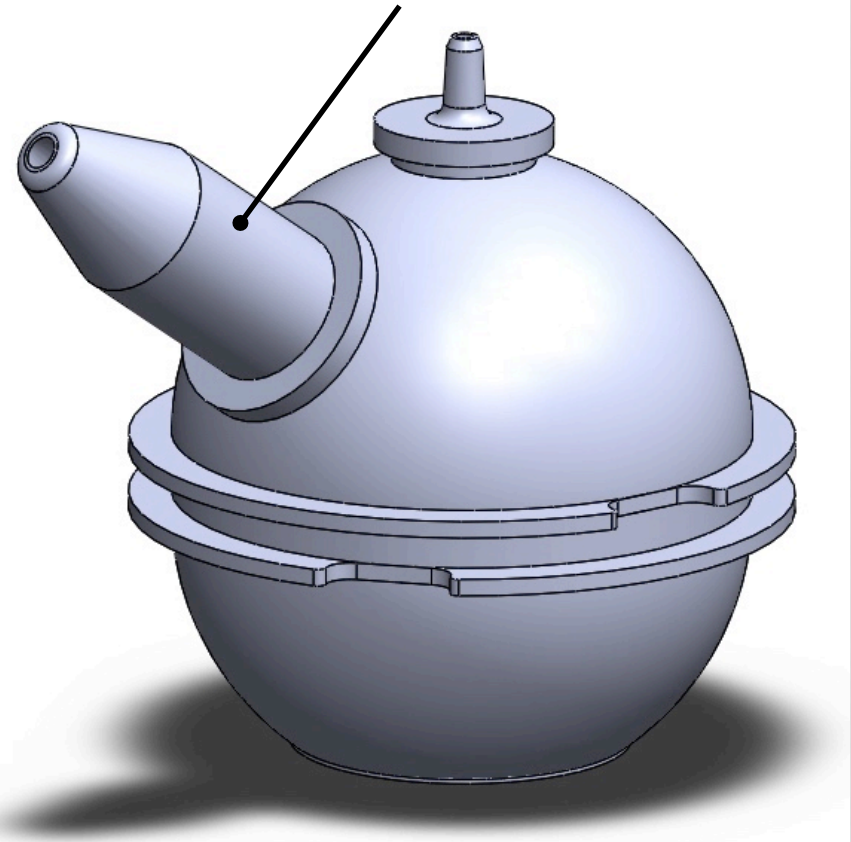


Snap fits
All parts conveniently snap into place

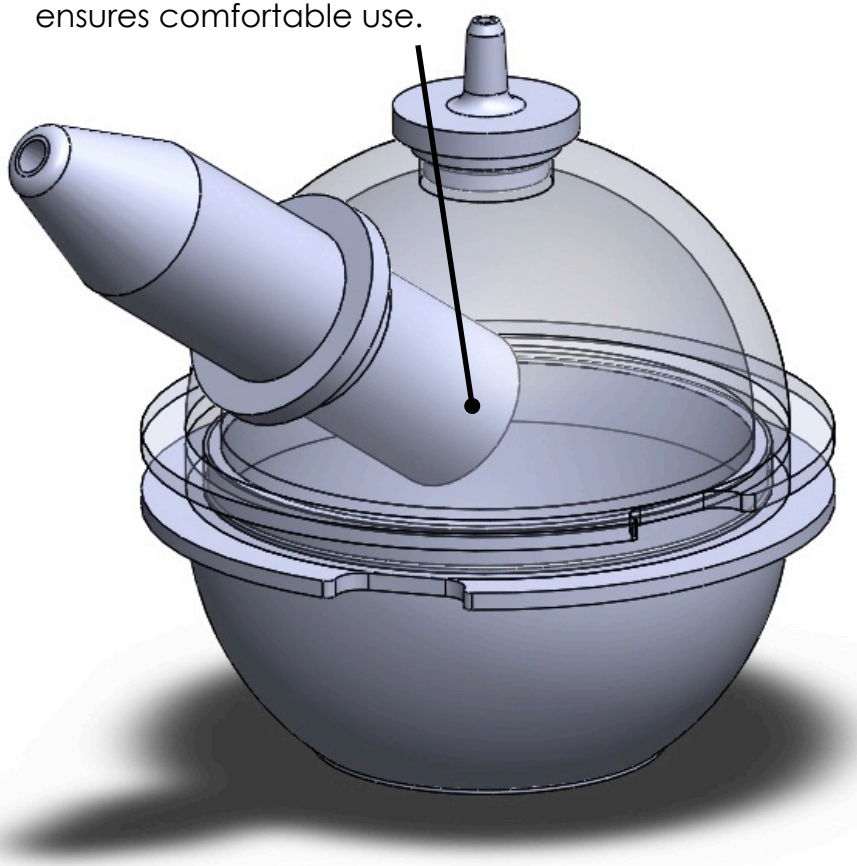
Estimated material cost: $2.60 USD
Mass of material printed is 0.055 kg x $48/kg.

FINAL DESIGN – SHALLOW ASPIRATION

Non-intrusive nozzle for shallow suction
Placed on nostril to create seal.
Replaces the catheter port.



Nozzle oriented away from suction port, and angled for ergonomics
Prevents mucus from entering suction port. Angle ensures comfortable use.



NOTES

- Design files included:
  - Solidworks
  - STEP
  - STL
- Two versions of the spheres are included.
  - One is a friction fit
  - Second is a snap fit
  - Printing the two will help determine which design is better
- The size of the ports can be adjusted to fit available plastic tubing.

REFERENCES

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2. http://www.who.int/medical_devices/innovation/new_emerging_tech_38.pdf
3. http://www.tracheostomy.com/care/suction.htm
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