Project Stop the Drop(let)s

Version 4.3 - 3 April 2020

If you've received this as a PDF, please check back at the following link for updates
https://docs.google.com/document/d/15oz2ZGF7SyJ6eaZBFzyJwBzTsjb-8n2Xxgecx2yLAnA/edit?usp=sharing

Update:

NY Times Article and Material Filtering Capability.

- https://www.nytimes.com/article/coronavirus-homemade-mask-material-DIY-face-mask-ppe.html?action=click&module=Spotlight&pgtype=Homepage

The CDC is now recommending the use of Cloth Face Coverings to help slow the spread of the virus. I like the use of the term face coverings, as it helps separate these from confusion with surgical masks or respirators that comes with the term face masks. I'll also give them credit for the incredibly simple face covering demo in the embedded youtube video. It will be seen if this guidance takes off and what social pressure there is to embrace this. I definitely endorse the use of face coverings given the constraints the CDC is making about this being reducing spread and not providing protection to an individual.

- https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover.html
- https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/diy-cloth-face-coverings.html

Finally, if it hasn't been discussed already one of the reasons we need to provide excellent protection to healthcare workers interacting with Covid-19 patients is that in other respiratory viral infections the significance of the illness is related to the viral exposure that someone experiences. It's not been proven for SARS-CoV-2 yet, but it appears the only safe assumption to make. Here are two articles and a study on the issue.

- https://www.nytimes.com/2020/04/01/opinion/coronavirus-viral-dose.html
- https://www.newscientist.com/article/2238819-does-a-high-viral-load-or-infectious-dose-make-covid-19-worse/
- https://www.ncbi.nlm.nih.gov/pubmed/25416753

What Is This

The goal of this project is to develop a DIY Respirator design that maximizes ease of home manufacture, reusability, fit and effectiveness against SARS-CoV-2. We are calling this a DIY Respirator as it has a face seal, although the filter media used is still to be determined as more data is gathered. Face Masks do not provide a face seal and while they may capture some large droplets they are ineffective against small particulates.

Currently many countries are not embracing the use of Respirators or Face Masks by the general public, unlike in a number of other countries that have had better success

controlling this pandemic. The COVID-19 pandemic appears to be primarily spread by airborne droplets, yet in western countries individuals are currently being told to social distance and to wash their hands. While social distancing is a control mechanism that can obviously be effective, people still need to come in close proximity for essential activities and the closure of non-essential businesses cannot go on until a vaccine is available. Smear transfer (from hands and to your face) is not believed to be the primary means of transmission for SARS-Cov-2, yet it is the primary thing we are telling the public to protect themselves against. Currently individuals are only told to wear a face mask if they are exhibiting symptoms, despite the fact that it's known that infected individuals may not show any symptoms and can spread the virus.

Since we get asked this a lot, we do not believe that the CDC has been misleading us about what we should do. The US Government just doesn't currently have better tools to give to the public to prevent airborne transmission (other than social distancing). There are not enough N95 respirators available for the public and even if they could hand them out the vast majority of people would not use them in an effective manner. N95 respirators are also a temporary use disposable product and ramping up production to supply the entire country is not feasible.

Most importantly, it's vital that the general public not deplete the limited respirator and surgical mask resources for healthcare workers. There are already significant shortages for healthcare workers and they will likely run out of certified respirators before the end of this pandemic. Medical personnel and emergency responders are having to make difficult decisions about taking additional risk to extend the use of N95 respirators. If this project can find an effective filter media, it may prove to be an essential tool for them as well.

This DIY Respirator design is public domain and a work in progress all constructive feedback and help is welcome. **At this point we need the community's help finding and testing filter media for this application.** We have no ownership of this idea and my only request is that you actively educate others on the limitations of this design, giving people a false sense of protection to engage in risky behavior is counter-productive. We hope that people making their own respirator teaches them the importance of it's fit and function and helps ensure they will use it correctly. We also believe that this respirator specifically targeted against this virus can be lighter and more comfortable to wear for extended periods than more general purpose respirators.

Current Design Status

It appears that we've solved the face seal issue, by cutting a nitrile glove in half you can use it as an effective seal. Now all we need to do is find the most effective filter material that you can still breathe through and is safe. The use of high MERV and HEPA filters is a tempting choice, but we definitely need feedback from experts on the use of these

filters. We are concerned that some of these commercial filters appear to use synthetic fibers and it's unclear if shedding is a safety risk if you start cutting them up. Additionally are there other sources of filter materials available that are better suited to this application.

This design is definitely not ready for broad public release as of yet, we need to verify we aren't giving people bad info. I'm also wondering if the filter material is safe to attach to your face for extended periods, do we need to worry about the inhalation of stray fibers? We will also need to prove that this is safe and effective and figure out how to communicate with a wider audience.

We hope that we can find an effective enough filter media that this design can be used in an emergency by medical staff and emergency responders against SARS-CoV-2, before they run out of certified N95 respirators.

Finally, we have no idea if this project will result in success, but we hope you agree that it's worth trying. If you see critical faults or issues that we are not addressing please let us know. We will happily end this effort and document what the shortcoming was, if needed.

Potential Filter Media

- Industrial or Home Air Filters (HEPA or MERV 12-16)
    - There is a wide range of materials and filter levels, which is acceptable for this unique application is not clear.
    - MERV 12-16 are where home filters start to become effective at ultrafine particles, but we are unsure if they can shed particles or how they function in this unique application. Safety of the user is a concern.
    - HEPA and MERV 16 filters are on paper equivalent to N95 filter media, but I have no idea if they have a low enough pressure drop for a person to breathe comfortably through.
- Polypropylene Melt-Blown
    - Actual N95 Grade material in rolls or sheets, if the limiting production issue is the N95 mask molding/assembly. A warning that there are an increasing amount of fraudulent N95 masks on the market and I assume that sourcing forged N95 raw material is a similar concern. Here are two articles talking about the material shortage
    - Here are two good articles about how they ended up with this shortage.
        - https://www.wired.com/story/decades-offshoring-led-mask-shortage-pandemic
        - https://www.npr.org/sections/goatsandsoda/2020/03/16/814929294/covid-19-has-caused-a-shortage-of-face-masks-but-theyre-surprisingly-hard-to-mak

    - There are other grades and applications for this material that might be an acceptable alternative for example.
        - https://www.kcprofessional.com/workplacesolutions/non-wovens/filtration-media
    - Chemical wipes and Oil absorbent pads that don't absorb water, which are used in oil spill kits or chemical wipes.
        - Kimtech wipes number 33570 and possibly others https://www.kcprofessional.com/en-us/products/wipers/specialty-wipers/33570
        - https://meltblowntechnologies.com/products/absorbents/oil-only-absorbents/
- Polyurethane Foam
    - This is a common foam used in many applications, such as memory foam. There are some applications in ULPA filters, but we don't know if there are other filter applications that might be effective here.
- Vacuum Cleaner Bags
    - There was some vacuum cleaner bag material tested in one of the reports listed in the references and it was determined to be the most effective, but also difficult to breathe through.
    - We have also tried the material from a shopvac HEPA filter cartridge and it was extremely difficult to draw any air through. This shopvac filter appeared to have a coating that was likely the issue and could have been attributed to the shopvac need to deal with liquids.
- There have to be other options as well. Nonwoven Fabrics is a fascinating industry that is invisible to almost all of us, yet essential to our everyday lives. We hope that this request reaches someone with expertise in this area.
- Limited Medical Supplies
    - We are starting to build a list of possible filter materials that are only available in hospitals. If you are working on this problem for a hospital contact us for access.
- Final Materials Note. Just increasing the thickness of a filter material is not very effective at decreasing ultrafine particles, as the pressure drop for low performing materials becomes unacceptable.
    - An example would be a woven material that only captures 2% of ultrafine particles. Doubling this material might increase this effectiveness to 4%, but the pressure drop also doubles. You still have a poor filter that is now hard to breathe through.
    - Instead the critical factors appear to be the size and density of the strands that make up the filter, see the reference documents for more on how this

works. When we talk about amazing advances from nanomaterials, this is one of those applications.

Reference Material

- CDC Article on the Design of N95 Respirators and Surgical Masks https://blogs.cdc.gov/niosh-science-blog/2009/10/14/n95/
- Project BREATHE a Government report on respirator design considerations https://www.cdc.gov/niosh/npptl/hospresptoolkit/pdfs/ProjectBREATHE-final-report-508.pdf
- 3M Respiratory Biohazard Protection Reference https://multimedia.3m.com/mws/media/409903O/respiratory-protection-against-biohazards.pdf
- Respiratory Source Control Using Surgical Masks With Nanofiber Media - Study testing effectiveness different respirators and surgical masks on a mannequin https://www.researchgate.net/publication/261745047_Respiratory_Source_Control_Using_Surgical_Masks_With_Nanofiber_Media
- Influenza Virus Aerosols in the Air and Their Infectiousness (is there similar data for coronavirus?) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4147198/
- Effectiveness of cough etiquette maneuvers in disrupting the chain of transmission of infectious respiratory diseases https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3846148/
- Ineffectiveness of common materials against sub-micron or ultrafine particles
    - https://www.researchgate.net/publication/258525804_Testing_the_Efficacy_of_Homemade_Masks_Would_They_Protect_in_an_Influenza_Pandemic
    - https://academic.oup.com/annweh/article/54/7/789/202744
- Study on the ineffectiveness of cloth masks for healthcare workers against viral respiratory infections
    - https://bmjopen.bmj.com/content/5/4/e006577
- Good article on the problem with homemade masks and another article about why we should be wearing at least some sort of mask
    - https://www.cnet.com/how-to/homemade-face-masks-why-they-may-not-protect-you-from-coronavirus/
    - https://www.nytimes.com/2020/03/27/health/us-coronavirus-face-masks.html?action=click&auth=login-email&login=email&module=Top%20Stories&pgtype=Homepage
- See the public comments file that is a bit of a mess, but feel free to add your own comments as well

https://docs.google.com/document/d/1Yigxy2kRAJLSnM5iankBeX8lZe2nq-eeDsgs4Fw8q4U/edit?usp=sharing

Design Objectives

- The goal of this DIY respirator is to provide the best face seal possible from household materials and tools. While comfort is also important and hopefully the ability to create a custom fit will allow you to achieve this, building several different plastic frames is encouraged to help get the best fit.
- It is also designed to allow the use of different filter materials (based on the best material available) and allow the replacement of that filter material as often as required.
- This design is a framework only for the larger community to identify improvements and the best possible filter material.
- Provide better protection than no mask or face masks with gaps around the nose area, while avoiding overwhelming public demand for limited resources required for healthcare workers.

WARNING

The efficacy of this design is based upon good fitment (no leakage of air around the faceseal) and dependent upon the filtration capability of the filter material, which is not something that can be casually assessed. This effort is not making any recommendation on acceptable filter materials, because one has not been identified or tested as of yet.

Official Government Certified Respirators and Filters are the only products that can be guaranteed effective with appropriate training, certification and annual fitcheck testing.

Materials

- Any Large HDPE Plastic Container (Recyclable Plastic Number 2) such as the common one gallon jug (milk or water)
- 2-3 paperclips or other stiff wire (in the worst case scenario you might need to use a coat hanger to ensure the proper fit)
- 2 rubber bands or some elastic material. Note elastic is far superior, you might be able to scavenge some from a worn out mask, clothing or other products. Small bungee cords are another possibility.
- 3-4 feet of string (if you can't get enough elastic)
- One Nitrile Glove
- Filter Material (Still in development. If you are trying this before an acceptable filter is identified, we would recommend using cotton fabric which are not

effective filters against virus particles but give you a sense of the final design possibility)
- Blank paper, scissors, pen and tape

Tools

- Cutting Board
- Sharp Knife, Utility Blade or Scissors
- Recommended - Needle Nose Pliers
- Hole punch (optional)

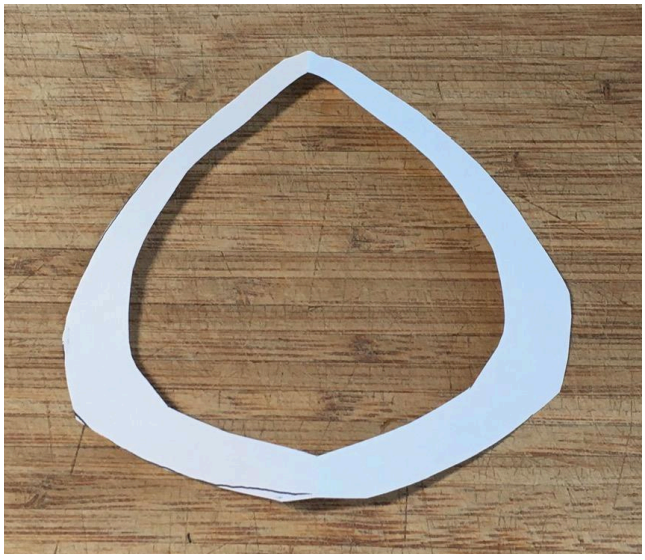
Time Required

- 30 Minutes (or less with practice)
- No sewing required

Directions

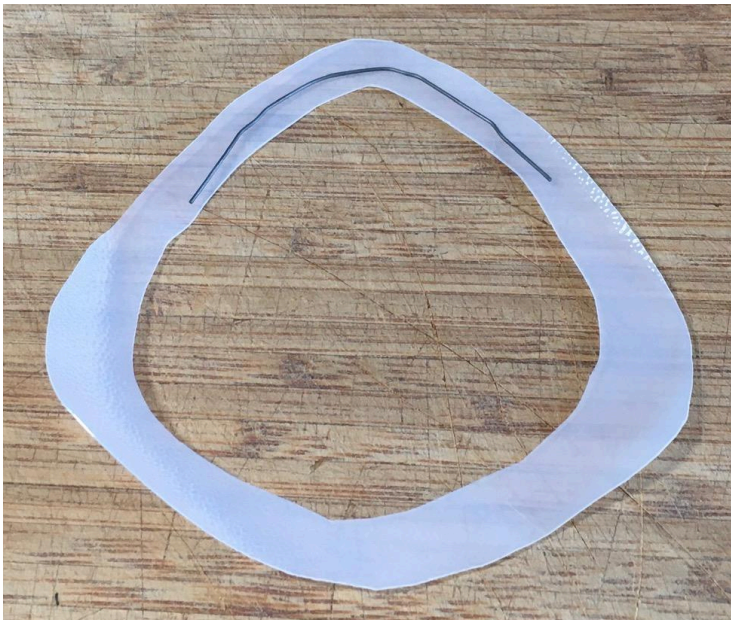
1. Find an empty plastic bottle made of HDPE (Plastic Number 2) with relatively flat surfaces that are at least 4” x 4”. A gallon milk jug is ideal and can be used to make 4-6 masks (filter frames). Other plastics may work for this as well (please provide comments on your experience), but HDPE is extremely common for this size bottle. If the container you have is a thicker plastic a hairdryer or other heat source can be used to carefully heat and reshape the plastic to provide a better fit.
2. Using a knife carefully cut the bottle into relatively flat panels, by cutting out the sides at the corners. Discard (or recycle) the top and bottom of the container. Thoroughly clean these plastic panels with soap and water.

3. Use a piece of blank paper to cut out a pattern and test the fit against your face. Note that you should also test the fit with some of your potential filter material over your face. The filter material will cause you to have to oversize the mask slightly.

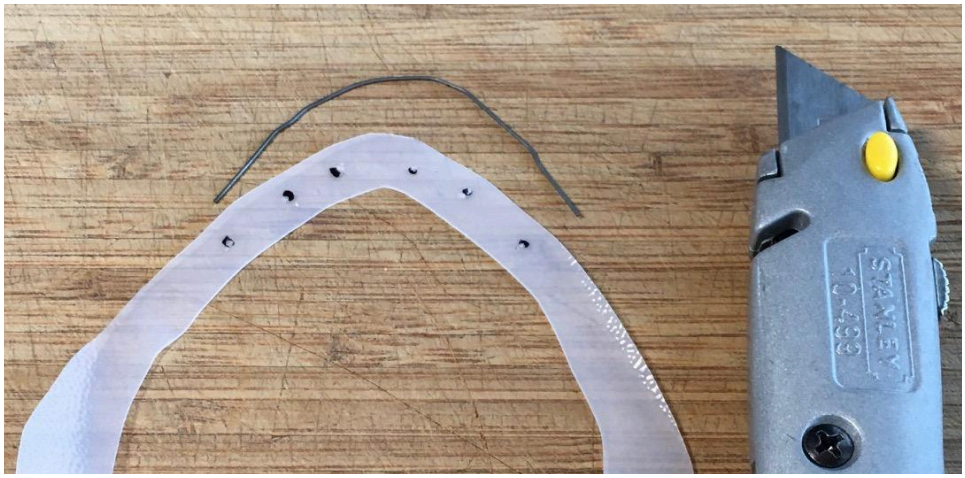



4. Tape the shape onto the plastic, cut out both the inside and outside of the mask ensuring that there are no sharp edges.

5. Straighten a paperclip and slightly curve it so that it sits over the bridge of the plastic.

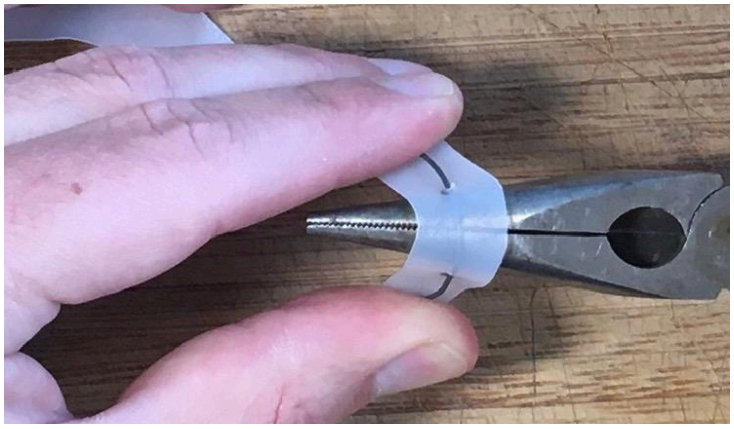


6. Using the point of the knife poke 6 holes in the center of the plastic along the nose bridge along the length of the paperclip. Don't make these holes too large as you want a tight fit for the next step. In the photo below a sharpie has been used to mark the location of the 6 holes.



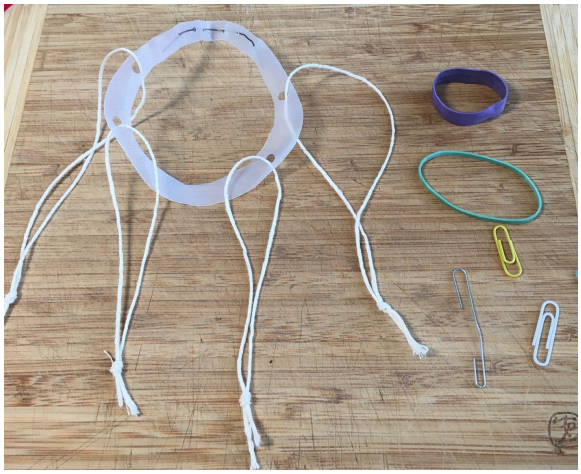
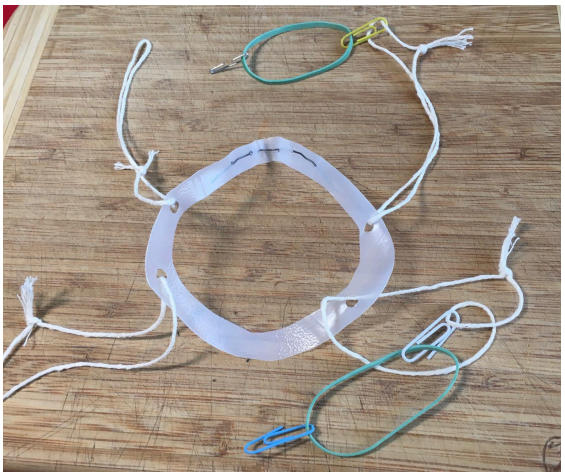
7. Thread the paperclip through the holes, use the needle nose pliers to pull or push the paperclip through the plastic. Start and end the paperclip threading, so that the ends of the paperclip are on what will become the outside of the mask (away from your face). That is, begin and end threading from the outside of the mask.

8. Using the closed pliers (or something else similar in diameter as the bridge of your nose) start to bend the paperclip to the shape of your nose and cheeks. Do this slowly checking the fit on your face and avoid bending the paperclip too much to avoid breaking it.



9. Create four small holes in the plastic (two on each side, above and below the mouth location), so that you can thread in strings. The holes can be made with the knife, or a hole punch if you have it.

10. Based on the size of your head and the rubber bands that you have available determine the right length for the strings so that the rubber bands will provide a tight fit. One strap should go above your ear and the other should go below. Use the remaining paperclips to create a loop between the sting and the rubber band. Note that elastic is a far superior option here and you can likely scavenge some from an old used up face mask or some other piece of clothing or bag that you already have. Small Bungee cords might also work.

11. Ensure a proper fit for the plastic against your skin and practice attaching the string and adjusting as needed. Holding the plastic on your nose with one hand and using the other to put the top strap on first before the lower strap is a useful technique to develop. Also note that the filter material will add some bulk to your face, particularly at the nose.
12. Now let's make a sealing surface to your skin. Take the nitrile glove and cut the fingers off and just the tip of the thumb. Now cut up the thumb side of the glove and between the fingers, so that you can open the glove into a single sheet. Note that nitrile will easily tear from the end of a partial cut, avoid excess cut ends and if you get them near where the seal will be try to carefully tear them out by pulling on the nitrile and guiding the tear out the material. Note other flexible and thin materials may work for this as well, please provide comments on your experience with any other materials (e.g. silicone, latex, cellophane, plastic bag, etc).

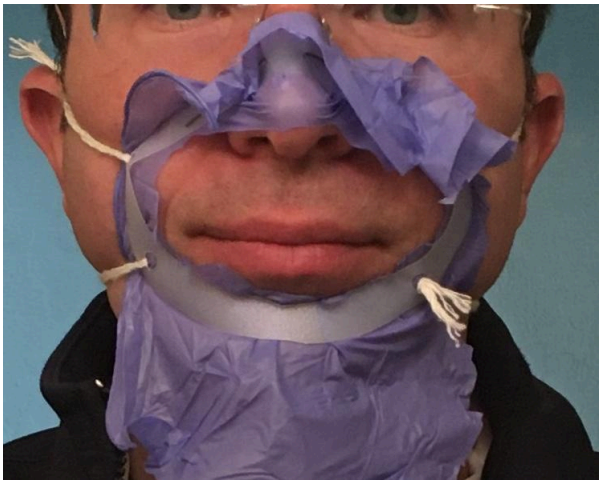

WARNING

DO NOT SUFFOCATE ON THE GLOVE IN THE FOLLOWING STEPS, JUST PULL IT OFF OF YOUR FACE IF BREATHING BECOMES DIFFICULT. BE CAREFUL NOT TO INHALE ANY FRAGMENTS OF THE GLOVE AS WELL.

13. Hold this opened glove to your face so that it covers everywhere that the seal will be needed, then identify where on the nitrile the center of your mouth/nose will be. Remove the nitrile from your face and carefully cut an X in the center location about the size of a quarter. We will use this X-cut to perform an informal seal check on the mask.

14. Place the glove back over your nose and secure the plastic frame over top of that. You will be able to breathe out of the X-cut and can check the seal by holding the X closed with your fingers and both breathing in and out (negative and positive pressure checks). Try to optimize the fit to pass this test, the positive test will cause the mask to push out eventually, but it shouldn't be too easy. Note that facial hair will interfere with a successful seal, so beards are an issue (you've now learned why beards are not allowed in the military or many industries where the use of respirators are required).
    Do this check several times with your head rotated at different angles and with your mouth in different positions to simulate talking with the mask on. Try taking off the plastic frame and glove and putting them back on performing this seal check again, as after the next step you won't be able to do the seal check again with this glove (remember we are in a pandemic don't waste a glove if possible) and you'll need to be able to achieve this seal again after removing the frame. Spend time checking this and adjusting the plastic frame, remember this design will only be as effective as this seal.
    Remember to keep breathing and make sure to laugh at how you currently look.

15. Once you are satisfied with the seal and you are still wearing this thing, you can carefully start tearing the nitrile away from the mouth opening starting from the ends of the X-cut. Only tear away enough nitrile to uncover your mouth and nose, don't tear all the way to the seal and ensure that all sharp cuts have been removed from the nitrile, so those points won't start to tear later.

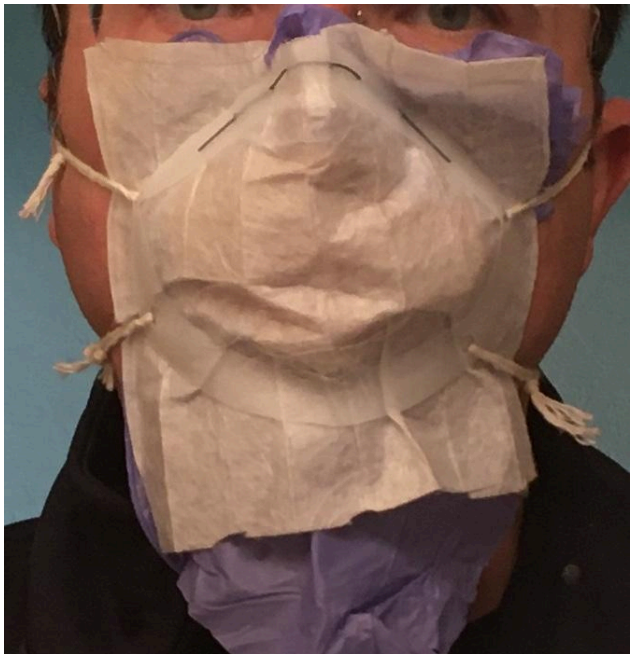


WARNING

THE USE OF AN INAPPROPRIATE FILTER MATERIAL CAN POTENTIALLY RESULT IN PERSONAL HARM. FILTERS CAN BE MADE OF EXTREMELY SMALL FIBERS THAT INHALING CAN RESULT IN LUNG DAMAGE.

16. Take the plastic frame off and reinstall it with the filter material that you've selected, creating as much of a pocket as you can to maximize the filter surface area that you will breathe through. If the nitrile glove doesn't stay on your face well enough during this process, you might consider a small amount of petroleum jelly or maybe chapstick to help it stick to your skin better (please comment on

your experience with this process).
Try to avoid folds in the filter material, as these could be entry points for unfiltered air. This filter media selection continues to need improvement and we will likely need a sandwich of materials. Eventually we can generate some templates for trimming the filter material and glove to make this look slightly less ridiculous.
We are still in trial mode!



17. Someone will also need to come up with guidelines for how long to use the filter material for and how to sterilize it and the plastic frame between uses. I've also been given the suggestion that a slightly more complex version of this filter frame would allow you to capture both the sealing surface and the filter media individually, so that you could remove just the filter material while leaving the majority of the frame with the sealing surface in place. While this would be a vast improvement to the design it would require a more complexity that was outside the scope of this initial project.
Additionally better instructions for donning and doffing this thing are required, as you should assume the exterior of the frame and mask are contaminated after wearing, remember this is not just another surface like your clothing it's where you've been sucking air through while wearing so that any virus you encounter will be trapped there. Respirators are complex devices that are not simple to use, air and the smallest particles will always take the path of least resistance through any gaps around the filter. One valid critique of this design is that people aren't good at properly using respirators, but we believe that under the present circumstances with the proper training and social pressure that they will pay

attention now. The good news is that other than for medical workers and emergency responders an improvised design for this pandemic might not have to be as good as the N95. The vast majority of virus particles expelled appear to be contained in droplets that are easier to protect against while airborne, but we are still learning about the SARS-CoV-2 virus.

Public Domain

This project has been influenced by a number of people that we can't thank enough for helping us understand the problem at hand, but the following two key innovations appear to be original creations of this project (on 21 and 25 March 2020 respectively) and if these are in fact original creations they are Public Domain and free to use by all interested manufacturers and open for anyone to build for themselves. If there are any existing patents on these designs we are unaware of them as both of these are original ideas spurred on by the Covid-19 pandemic. If this design does already exist then why is what appears to be a useful design not available in the marketplace. We are not familiar with the full details of public domain or creative commons licensing, but if someone is willing to research and help formally document this, please contact us. Any potential manufacturer is responsible for verifying these assertions on their own, ensuring the safety of their product and taking all legal responsibility.

- A flexible or moldable filter frame reinforced by a flexible piece of metal, which is designed to be custom fit by the user to their face over the mouth and nose. This filter frame is reusable and is held to the face with straps and captures a disposable filter to the users face. Similarly a user's face could be scanned or molded and a custom filter frame manufactured specifically for that individual.
- A flexible seal (such as silicone, nitrile or latex) that sits on the user's face and forms a sealing surface when captured under a disposable filter and the filter frame described above. This seal could initially have a small opening in the center to allow the user to perform positive and negative pressure checks by holding this opening closed. After completion of these pressure checks the user could remove this excess seal material near the mouth/nostrils and reinstall the filter frame over the sealing surface and a disposable filter. Similarly a custom and reusable seal could be made unique to that individual user's face, which combined with the custom manufactured filter frame described above could be verified to provide a seal with formal fit check testing.

Feedback

Please submit any quantifiable data or feedback to the following email

- stopthedroplets@gmail.com

If you have more information on filter media or testing resources, your help is greatly appreciated. We believe the filter media selection and testing are the most important part of this project, so the more work that occurs on this the better.
Finally, if this design is not feasible for some reason, we are completely willing to document this issue and withdraw this project from consideration. The obvious flaw in this proposal is the lack of an acceptable filter media, so resolving this issue is the current priority.

Conclusion

This respirator design is being proposed as an alternative and a potential improvement over the existing N95, providing a reusable frame and straps that provide a better fit to the user's face.
Another significant improvement over the N95 is the introduction of a flexible material against the face to create a sealing surface that can be fit checked.
Further, this design enables for the simplified manufacture of the disposable filter material as well as the diversification of different filter materials that can be appropriately certified for their specific application. A disposable mask seal custom to this application could also be produced and distributed with the disposable filters (improving on the repurposed nitrile glove).
Additionally, this design allows for a fabric cover to be attached over the filter frame, which can both protect the filter material and also allow for custom designs and logos. People have recently told me that face masks aren't socially acceptable in western countries, this is no longer acceptable and we need to develop strategies to overcome this stigma if we are to beat this virus.
Finally, we never would have contemplated this design or the shortcomings of the current N95 if not for the pressing need that we saw as a result of the ongoing Covid-19 Pandemic. We hope that this design can actually make a positive impact on the resolution of this crisis. Most importantly we want to encourage the support of basic scientific research and government/research organizations that openly publish their findings (the CDC, NIH and the NHS in particular). If this design proves to be useful, it is only because of our society's collective knowledge, which we need to continue to develop in the future.

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