Curated list of available Models for rapid prototyping against Covid-19

Included items: face shields and masks, ventilator parts and arm door openers.

Date: 16.04.2020

Author:

Christian Damiani
Medizinische Sensor- und Gerätetechnik (https://www.th-luebeck.de/msgt/)
Technische Hochschule Lübeck
Mönkhofer weg 239
Lübeck
Germany

Disclaimer: all models presented here have been made by third parties and are not validated or tested for use in medical settings. Please refer to the linked sources for more information. I assume no responsibility or liability for damage to equipment or persons as a result of their use. This is not a scientific review but just a summary of the most useful DIY Models which appeared during the last weeks motivated by the shortage of supplies because of the corona virus. This document can be freely distributed as long as it is left unchanged and this disclaimer is included.

Introduction: I evaluated more than 50 models from different sources on the internet, out of which 11 made it to the final list. When possible, only models which have been tested by the community and are being actively used in Corona-settings were included. A couple of alternative designs offering useful features have been also included. I tried to keep the list as short and objective as possible. The models are continuously evolving, so I suggest you keep an eye on updates before printing. DIY Models which do not require 3d printers were not included in this document. They are faster to make and possibly suitable in many cases, but most of them cannot be reused.

Safety and Regulations: Except for a couple of face shields and masks which got a sort of "express" clearance in USA and a few other countries, most of the models shown here have not been validated to be use in medical settings and should only be considered for use in an emergency. In particular, the use of DIY ventilator and CPAP parts is critical and can be life-threatening. These components should only be considered for use in a desperate situation after proper evaluation of the risks by Medical doctor and Technicians.

Cleaning and sterilization: all models should be properly washed AND sterilized/disinfected after manufacturing or before reuse. Washing with soap water can be sufficient to remove dirt (and can kill Corona-Virus), but there are no validated guidelines for disinfection of the parts. Prusa put together a list of possible methods for some FDM materials: https://help.prusa3d.com/en/article/prusa-face-shield-disinfection_125457. Also effervescent tablets for dental prosthesis could be useful (apparently compatible with PET).

A list of effective disinfection methods to reuse n95 disposable masks is given in this document: https://stanfordmedicine.app.box.com/v/covid19-PPE-1-1 Please take into account that not all methods described are compatible with FDM or SLA materials. Below is a material compatibility list for the most common FDM printing filaments and sterilization agents:

Best Practices for Sanitizing 3D Printed Medical Supplies (FDM)

	Ammonia	Chlorine bleach	Ethyl Alcohol	Formaldehyde	Hydrogen Peroxide	Iodophores	Isopropyl alcohol	Paracetic acid	Phenolics	Autoclave	Dry Heat	Ethylene Oxyde (EtO)	Gamma Irradiation	Electron Beam	UV-C
ABS	Red	Yellow	Green	White	Green	Yellow	White	Yellow	White	Red	Yellow	Green	Green	Green	Red
PLA	Red	Green	Green	White	Green	Green	White	Yellow	White	Red	Red	Green	Green	Green	Red
Vinyl	Red	Green	Green	Green	Green	Green	White	Green	White	Red	Red	Green	Green	Green	Yellow
PET	Green	Green	White	Green	Green	Green	Green	Yellow	White	Yellow	Yellow	Green	Green	Green	Yellow
TPU	Red	Green	Red	White	Red	Green	Green	Red	White	Red	Red	Green	Yellow	Yellow	Green
Nylon 6	Green	Red	Green	Green	Red	Green	Green	Red	White	Green	Yellow	Green	Green	Green	Green
PPE	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Red	Green
HIPS	Green	Red	Green	Green	Green	Green	Green	Green	Red	Red	Yellow	Green	Green	Red	Green
PEI	Red	White	Green	Green	Green	White	White	Green	Green	Green	Yellow	Green	Green	Green	Green

Legend: Green = Best option | Yellow = Proceed with caution | Red = Do not use | White = No Information

OSCMS

Models License: the models presented here were released under semi-restrictive licenses which allow non-commercial applications. Please refer to the sources linked for more information.

Face shields:

1. Prusa Shield

Source: https://www.prusa3d.com/covid19/

Comments: developed and tested by Prusa. 12.000 Shield already donated in the Czech republic. Sterilization guidelines available. Continuous updates. Multipart Print file available. The transparent shield needs manually-punched holes and must be thick enough to guarantee stability. Elastic band required. About 1:20 Min print time per shield frame.

2. HannocH Model remix by Emmendez

Source: https://www.thingiverse.com/thing:4240364
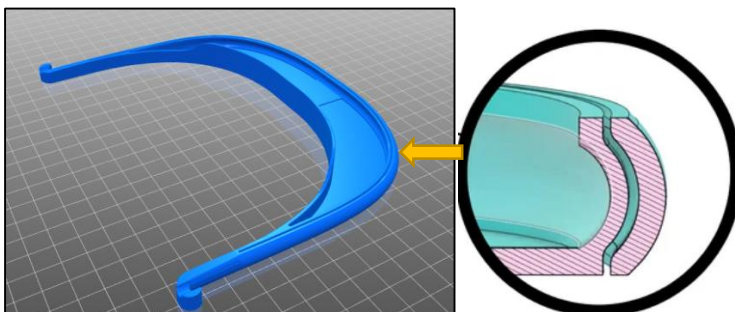
Comment: Simpler and lighter design than the Prusa Shield. Also easier to assemble. Require thinner transparent sheets. Maybe not as robust. Based on the originals design by HannochH (https://www.thingiverse.com/thing:4233193 and https://www.thingiverse.com/thing:4230817). Holes replaced by hooks for more comfort. Two different frame sizes available. Tested in hospital setting (according to authors).

3. HannocH Model remix by Justindepew

Source: https://www.thingiverse.com/thing:4247673
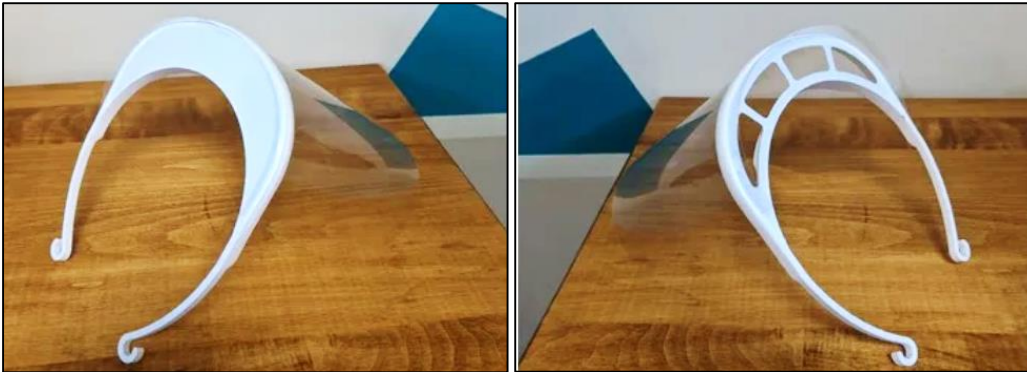
Comment: also based on the originals design by HannochH. Holes replaced by hooks for more comfort. Could be used without rubber band thanks to bent geometry (but I think that fitting and comfort might be a problem here). Versions with and without vents are available.

4. Design by atomic labs (https://limbs.earth)
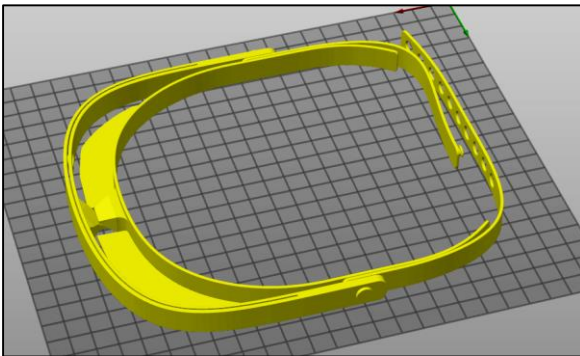
Source: https://drive.google.com/open?id=1WfYDaZphVwvkxP_kfksOl9UCsBBJZ8l8

Comments: integrated adjustable straps, so no need for rubber bands. No need for punched foil. But much longer print times.

Face masks:

General comments:

- Here is a link to a very interesting document from the Stanford AIM Lab on how to sanitize N95 disposable Masks for reusing them: https://stanfordmedicine.app.box.com/v/covid19-PPE-1-1.
- Regarding filter materials, according to this publication by Davies et al: DOI: 10.1017/dmp.2013.43 , cotton Pillow cases, cotton T-shirts (cotton pads could also be an alternative) and Tea towels could be used as replacement filter materials for face masks. Be careful, there are many hints on the internet regarding alternative filter materials (like HEPA filters) but none consider breathability. Another interesting summary of filter materials properties can be found in this article (no peer reviewed pub available yet): https://www.nytimes.com/article/coronavirus-homemade-mask-material-DIY-face-mask-ppe.html
- Of course, if you have access to FFP1/2 or N95 filters you should use them!. But avoid FFP3, N99 or N100 as they have reduced breathability and are not really suitable for medical settings.

- I discarded mask models with:
  - printed straps. I consider using elastic rubber bands a better and faster option.
  - round filters, as they are difficult to cut manually.
  - ridiculously small filter openings (difficult to breath).
  - Unnecessarily high material waste and print time
  - More than two single parts
  - And also some which were too weird to be used in public…
- Hint: PLA masks can be partially reshaped if submerged into hot water to improve fit and confort.

Only two models survived!:

1. 3dLine v3 at opensourcemask.com
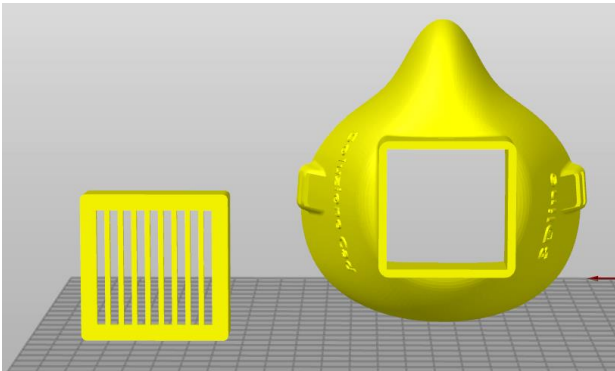
   Source: https://www.opensourcemask.com/en/download-file/14-3dline-v3-italy.html
   Comment: only two parts, simple to assemble (just squeeze filter material between the cap and the mask), no support required. The filter can be replaced without taking out the mask. Printing efficiency (e.g. overnight) could be increased by stapling several copies of the mask and adding minimal support material in-between. Possible: no hook for easy strap attachment. Filter cover somewhat small (decreased breathability).

2. Modified 3dLine v3 by Felix Harden at our University
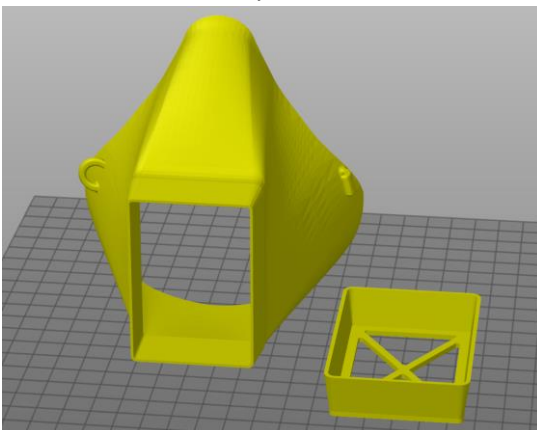
   Source: https://www.thingiverse.com/thing:4285985
   *Comment*: logo erased for faster print times and easier cleaning. Hook on one side for faster strap attachment. Larger Filter opening to improve breathability. Improved geometry for more comfort. Simplified cover grid.

Ventilator Masks and Manifolds:

General comments:

- These are critical components for life-supporting systems and their application in an extreme emergency must be carefully assessed by the medical personnel in advance. To put it in simple words: if a four-fold ventilator splitter fails or negatively affects the functionality of the system, four people can die. Without the splitter, potentially at least one of those would have survived. Please read this document before going on: https://www.asahq.org/about-asa/newsroom/news-releases/2020/03/joint-statement-on-multiple-patients-per-ventilator

- Be especially careful regarding print quality, materials and robustness. There are no guidelines or validated methods in this regard yet.
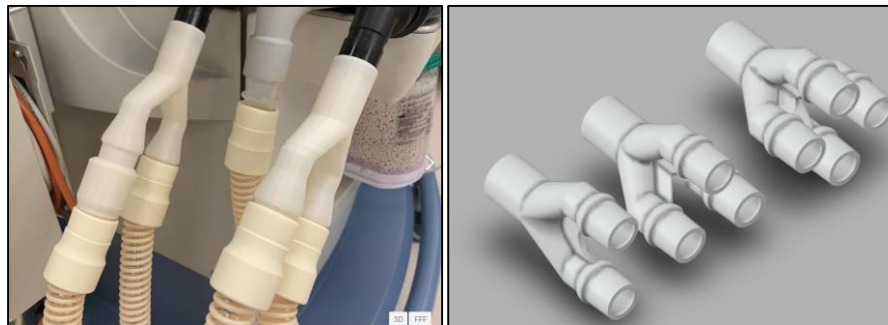
1. Ventilator Manifold Maine (by Dan Abbot using Formlabs printer):
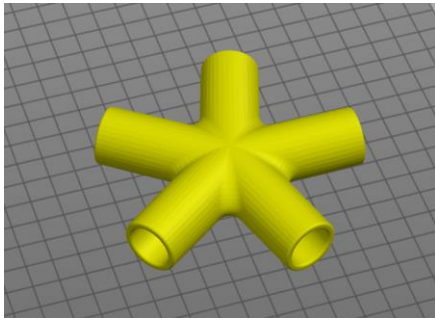
   Source: https://www.youtube.com/watch?v=MQofbS19-Io&feature=youtu.be

   Comments: device tested, but not on humans. Links to file download in the video description.

2. Prusa comunity ventilator splitters

   Source:
   - https://www.prusaprinters.org/prints/25808-3d-printed-circuit-splitter-and-flow-restriction-d
   - https://www.prusaprinters.org/prints/27803-ventilator-circuit-splitters-reinforced-thicker-wa

   Comments: these are from the community and not from Prusa itself. Not tested on patients. Just Design prototypes.

3. Respirator valves:
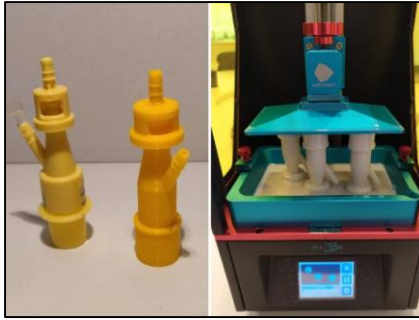
Source: https://grabcad.com/library/3d-printing-respirator-valves-covid-19-1
Comment: these are apparently being used in Italy (according to some media)

4. "Decathlon" mask adapted for C-PAP

Source: https://www.isinnova.it/easy-covid19-eng/
Comment: again, this are apparently being used in Italy as a replacements for C-PAP masks in sub-intensive therapy.

Arm door openers (to avoid using your hands when opening doors):

1. Materialise model

Source: https://www.materialise.com/en/hands-free-door-opener/technical-information
Comments: different models for different handles. Require screws.

2. CIM UPC model

Source: https://www.youmagine.com/designs/arm-door-opener-covid-19

Comment: One "universal" model. Can be mounted with cable ties. No need for screws.

Cons: may be not suitable for some handles.