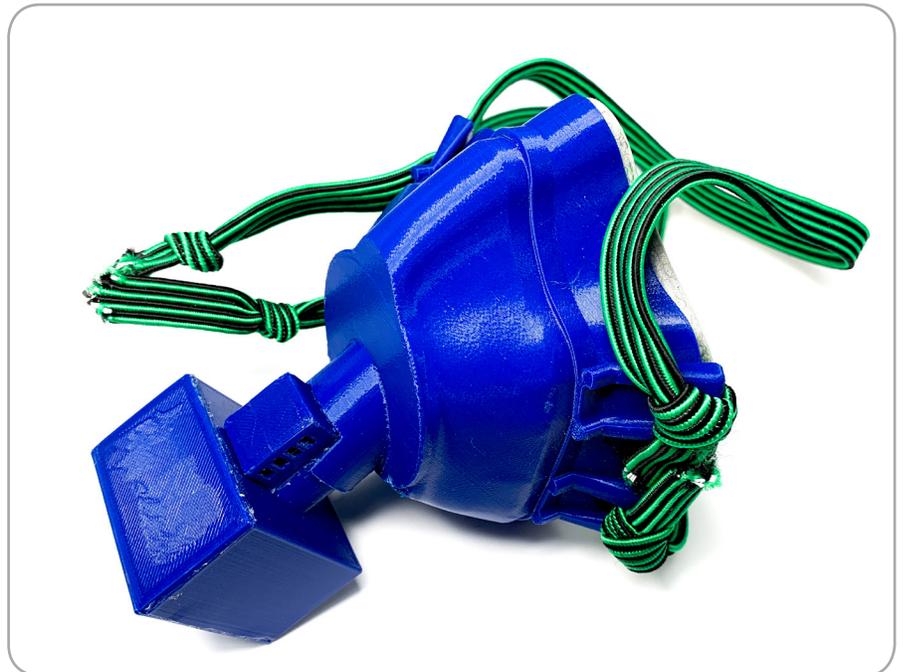


# S.A.F.E. CARTRIDGE SYSTEM

## Project Guide



Introduction

Assembly

Fit and Use

# INTRODUCTION

The **Self-Assembly Filter for Emergencies (S.A.F.E.) Cartridge System** is a HEPA filter cartridge system designed to fit onto masks to provide protection from airborne particles and viruses. Utilizing simple 3D printing and materials that are readily available in hardware stores, the S.A.F.E. Cartridge can be easily made at home.

The goal of the S.A.F.E. Cartridge System is to help increase the availability of personal protective equipment during viral outbreaks, like COVID-19. The HEPA filter inside the S.A.F.E. Cartridge System filters particulates at 0.3 microns with 99% efficiency, compared to the 95% efficiency of N95 masks.

The S.A.F.E. Cartridge System was designed to be used with either a 3D printed mask with a foam seal or with hospital masks with a port, like the disposable AeroEclipse Aerosol Mask made by Monaghan Medical Corporation. This is a disposable device and you should immediately disposed of if damaged in any way during use.

Proper filtration requires proper mask seal. If there is any kind of leakage around the mask and face, unfiltered air will enter the mask. Taking time to ensure that the mask and S.A.F.E. Cartridge assembly is properly fitted to the user's face with a proper seal is essential in getting full filtration. Mask fit should be tested through normal hospital testing procedures.

The S.A.F.E. Cartridge System aims to provide extreme filtration of air for personal protective equipment in an easy-to-make, plug-and-go package.

## The MUSC Design Task Force

The S.A.F.E. Cartridge System was created through a collaborative effort between designers, engineers, and physicians at the Medical University of South Carolina. This interdisciplinary design team came together to act as a design task force to specifically address the design engineering problems during the COVID-19 pandemic in 2020. The design team members continually strive to innovate in their respective departments, from the MUSC College of Dental Medicine to the Human Centered Design Program in the MUSC Department of Surgery.



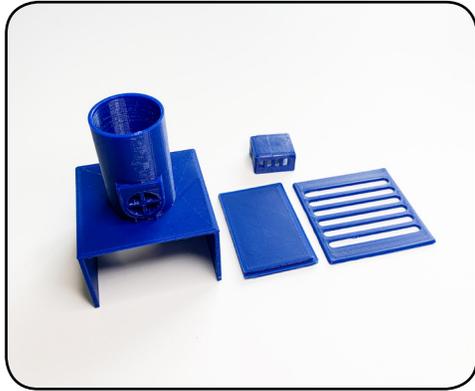
### WARNING

**Proper filtration REQUIRES proper mask seal!**

Use care when assembling and using the S.A.F.E. Cartridge System in order to prevent leakages during use. Before using the S.A.F.E. Cartridge System in an environment that requires protective gear, check for proper air flow and sealing.

Some steps in the assembly process will require the use of hot glue, super glue, and sharp knives. Handle with care.

# KEY COMPONENTS



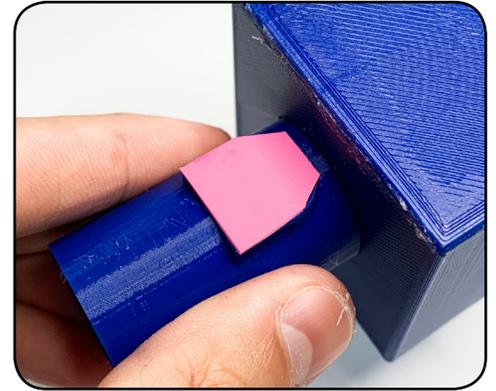
## S.A.F.E. Cartridge pieces

3D printed  
Max layer height of 0.15mm  
Four components total



## HEPA Filter

Made from a Filtrete True HEPA Filter (#1150096) which can be found in local hardware stores



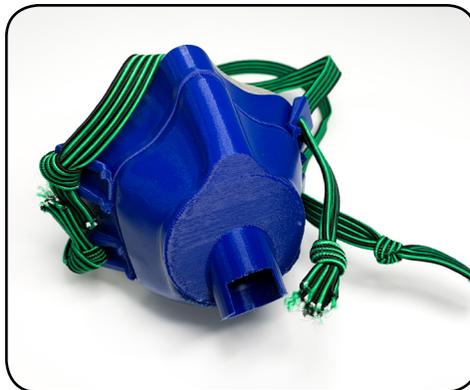
## Valve Membrane

Can be made from rubber kitchen gloves or rubber sheet



## Hospital Mask

Disposable AeroEclipse Aresol Mask Assembly  
made by Monaghan Medical



## Printed Mask

3D printed  
Max layer height of 0.3mm  
Use nylon strapping to tie around face during use



## Foam Gasket

Foam neoprene window sealer can be used to create a complete seal between mask and face during use

- Both the hospital mask and 3D-printed mask are compatible with the S.A.F.E. Cartridge System and can be used interchangeably as needed.

# REQUIRED MATERIALS AND TOOLS

## MATERIALS

### S.A.F.E. Cartridge Materials

- 3D-printed S.A.F.E. Cartridge parts
- Filtrete True HEPA Filter (#1150096)
- Lightweight cloth (optional)
- Thin rubber sheet or rubber kitchen gloves

### Hospital Mask Materials

- Disposable AeroEclipse Mask by Monaghan Medical Corporation
- 1/4 inch neoprene window seal foam by MD Building Products
- 1/8 inch nylon paracord
- Strong adhesive tape

### 3D-Printed Mask Materials

- 3D-printed mask
- 1/4 inch neoprene window seal foam by MD Building Products
- 1/2 inch flat bungee cord by HDX

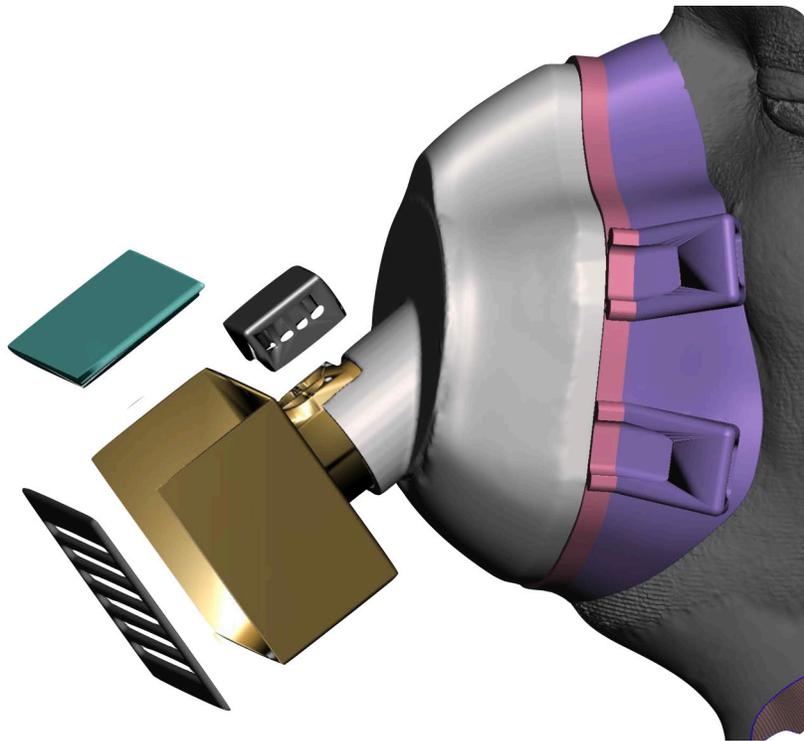
## TOOLS

### Required Tools

- 3D printer (FDM printer)
- Hot glue gun and hot glue sticks
- Sharp blade or hobby knife
- Super glue
- Scissors
- Ruler

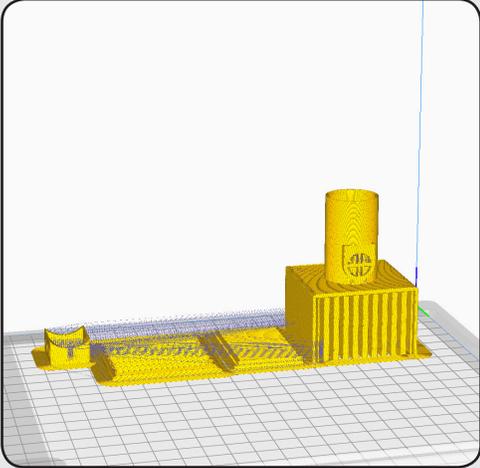
# 3D Printing Guide

## Preparing for Assembly



3D Rendering of the S.A.F.E. Cartridge System Prototype

# 3D PRINTING GUIDE



## S.A.F.E. Cartridge Components

Material: ABS, PETG, or PLA

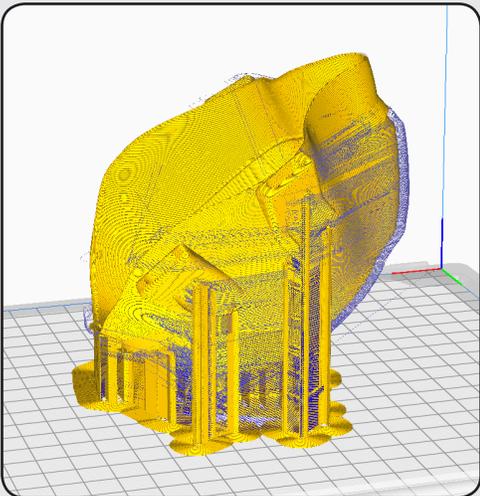
Max Layer Height: 0.15mm

Infill Density: 15%

Support: Everywhere

Support Density: 15%

Refer to image for ideal print orientation.



## 3D-Printed Mask

Material: ABS, PETG, or PLA

Max Layer Height: 0.3mm

Infill Density: 15%

Support: Everywhere

Support Density: 15%

Refer to image for ideal print orientation. The port opening for the mask should be flat with the build plate.

# S.A.F.E. Cartridge Assembly

## Assembly Guide

# ASSEMBLY GUIDE | 3D PRINT PREPARATION



## 1. Identify components

The S.A.F.E. Cartridge consists of four 3D-printed components: Cartridge, Lid, Valve Protector, and Shield. 3D-printed parts need to be prepped and cleaned before assembly. Due to differences in 3D printers, some of these preparation steps may not be necessary depending on your machine settings.



## 2. Trim components

Separate your components from any brims or bedplate adhesion artifacts. Using a sharp blade or hobby knife, make sure that each edge of the prototype is clean and without artifact.



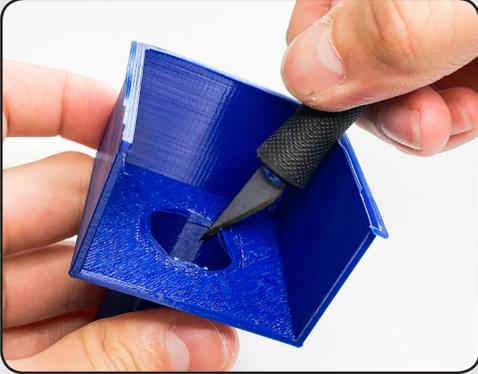
## 3. Remove support from cartridge

Using pliers or flush cutters, carefully remove any support material from within the cartridge.



## 4. Remove support from valve

Using pliers or flush cutters, carefully remove any support material from the valve opening at the top of the cartridge. The four holes should be unobstructed.



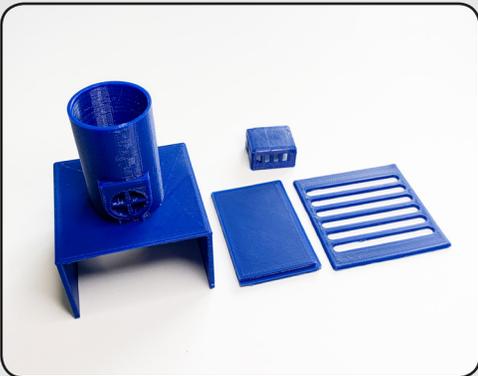
## 5. Clean openings

Clean up any hole edges in the cartridge using a sharp blade, making sure to remove any small artifacts or excess filament.



## 6. Remove support from valve protector

Using pliers or flush cutters, carefully remove any support material from the valve protector.



## 7. Set aside for assembly

The 3D-printed components are now ready for assembly.

# ASSEMBLY GUIDE | FILTER PREPARATION



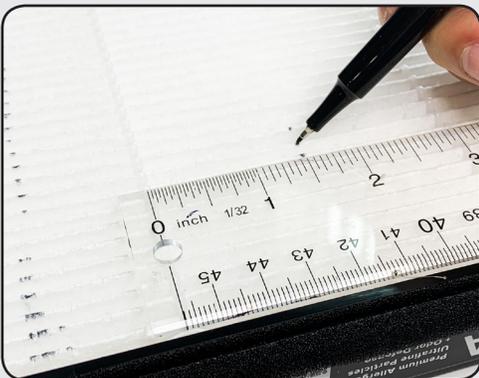
## 1. Open filter

Open the Filtrete True HEPA filter cartridge and remove the black carbon material from the back of the filter.



## 2. Mark first filter line

Locate one of the structural white glue bands on the HEPA filter and mark the filter **1 inch** from the structural glue. Mark every pleat of the filter from one end to the other end of the filter frame.



## 3. Mark second filter line

On the other side of the structural white glue band, measure **1.5 inches** and mark. Mark every pleat of the filter from one end to the other end of the filter frame.



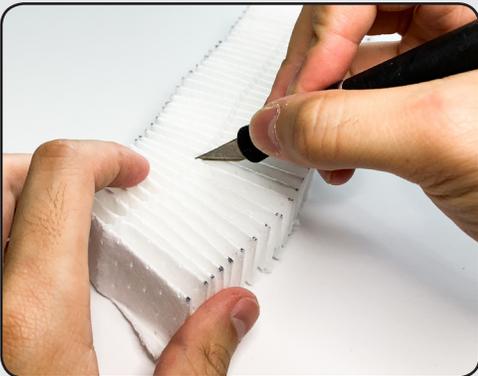
## 4. Cut filter edges

Using scissors, cut the filter along the markings that were just made in **Steps 2 and 3**. Make sure your cut is perpendicular to the folded edge of the filter to ensure a straight edge. Do not cut more than three folds of material at a time to reduce the chance of cutting at an angle.



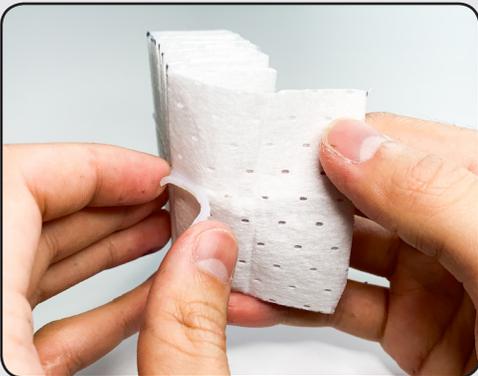
## 5. Cut filter from frame

Using a sharp blade or scissors, cut through the ends of the filter, removing the entire row of filter folds from the frame. Make sure all filter cuts are straight and level.



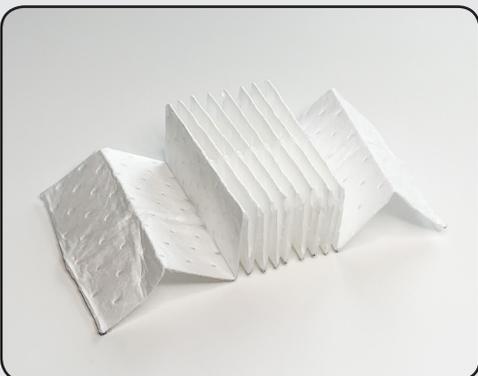
## 6. Split filter into sets of 10 folds

Count **10 folded peaks** and cut the filter into a smaller piece. Multiple filter sets can be made out of one filter row.



## 7. Remove support glue

Carefully peel back the supportive glue from the **first 2 folds** of the filter on both sides. Cut the peeled support glue away from the filter and discard. If a tear appears in the filter, discard the filter as any tear may cause a leak. Fibers from removal are normal and will not impact the filter's use.



## 8. Set aside for assembly

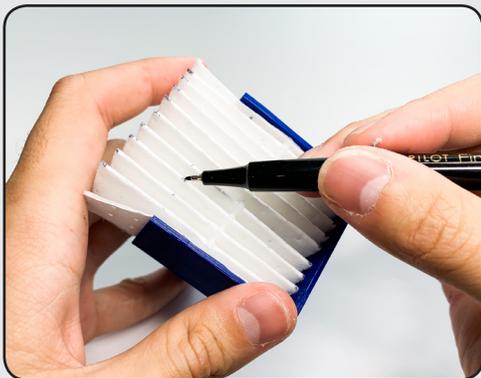
The filter piece is now ready for assembly. Refer to the picture on the left to confirm proper splitting of support glue and filter fold count.

# ASSEMBLY GUIDE | CARTRIDGE ASSEMBLY



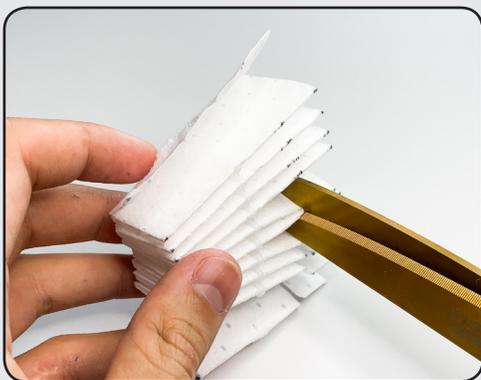
## 1. Align the filter in the cartridge

Slide the filter into the cartridge, with the right and left ends of the filter facing the front of the cartridge as shown.



## 2. Mark the filter

Apply slight pressure on the top of the filter to hold in place and mark across the filter at the level of the cartridge walls.



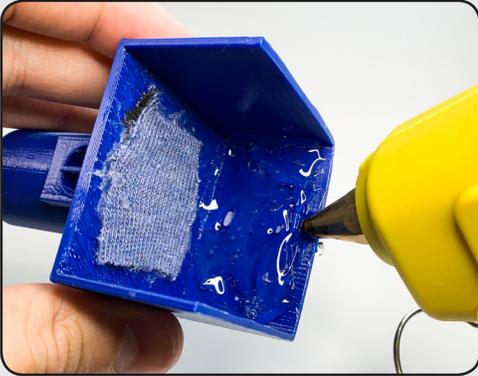
## 3. Cut the filter to size

Remove the filter and carefully cut along the mark made in **Step 2**. Make sure that the cut is straight and is level across the entire filter.



## 4. Attach port fabric (optional)

Apply hot glue around the cartridge port hole and adhere a small square of lightweight fabric over the hole. **Read Steps 5-9 before proceeding as the following sequence will require rapid work.**



## 5. Flood cartridge with glue

Flood the bottom of the cartridge with hot glue, ensuring that the entire bottom surface is completely covered with hot glue.

**CAUTION:** *The hot glue will rapidly heat up the plastic and can burn if not applied carefully. Exercise caution and be aware of hot areas during Steps 6-9.*



## 6. Glue filter into cartridge

Quickly insert the filter down into the cartridge, making sure the right and left ends of the filter are facing the front of the cartridge. Apply light pressure to ensure that the filter is secured in place. Hold until dry. An optional gentle burst of compressed air over the area can accelerate the cooling of the hot glue.



## 7. Glue and seal edges of filter

Apply a solid line of glue along the entire length of each edge of the cartridge and adhere the filter edges to the cartridge wall. Make sure that there is a solid line of glue from the bottom corner to the very top of the cartridge to prevent leaks during use.



## 8. Flood lid with glue

Pick up the lid and carefully flood the bottom surface of the lid with hot glue



## 9. Apply lid

Quickly press the lid into the top of the cartridge. Hold firmly into place and allow glue to flow onto and around the filter. The filter will bend slightly under the pressure of the lid by design to ensure full filter adhesion.



## 10. Glue shield onto cartridge

Glue the cartridge shield into place by applying hot glue to the front edge of the cartridge and applying the shield.



## 11. Trim extra glue (optional)

Using a sharp blade, carefully trim the excess glue that may have leaked out of the cartridge.

*This is an aesthetic step and will not impact filter functionality during use.*



## 12. Prepare rubber material

Trim the rubber to fit over the cartridge valve or use the rubber template to cut out the valve membrane. Copies of the rubber template can be found on [Page 17](#).

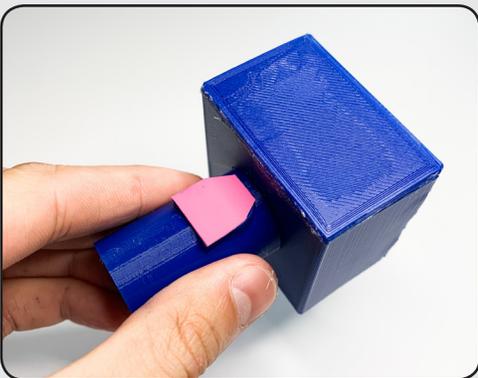
*The valve membrane should not protrude past the valve surface but should completely cover the valve holes.*



### 13. Glue valve membrane

Using super glue, carefully apply glue **ONLY to the flat edge** of the valve. Adhere the rubber valve membrane over the valve opening.

**CAUTION:** Superglue adheres to skin instantly. Exercise caution when gluing.



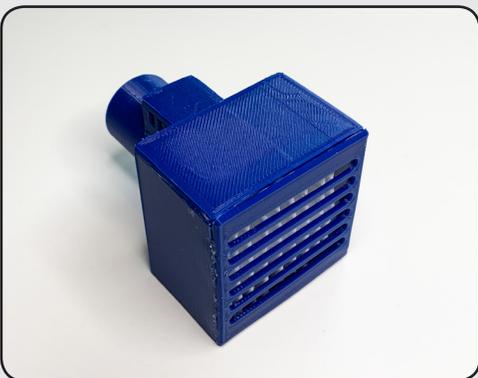
### 14. Check valve membrane

The valve membrane should only be adhered on one edge and should sit flat over the valve holes when left untouched as seen in the photo on the left.



### 15. Glue valve protector into place

Attach the valve protector over the valve using hot glue. Carefully trim excess hot glue away from the outside using a sharp blade.



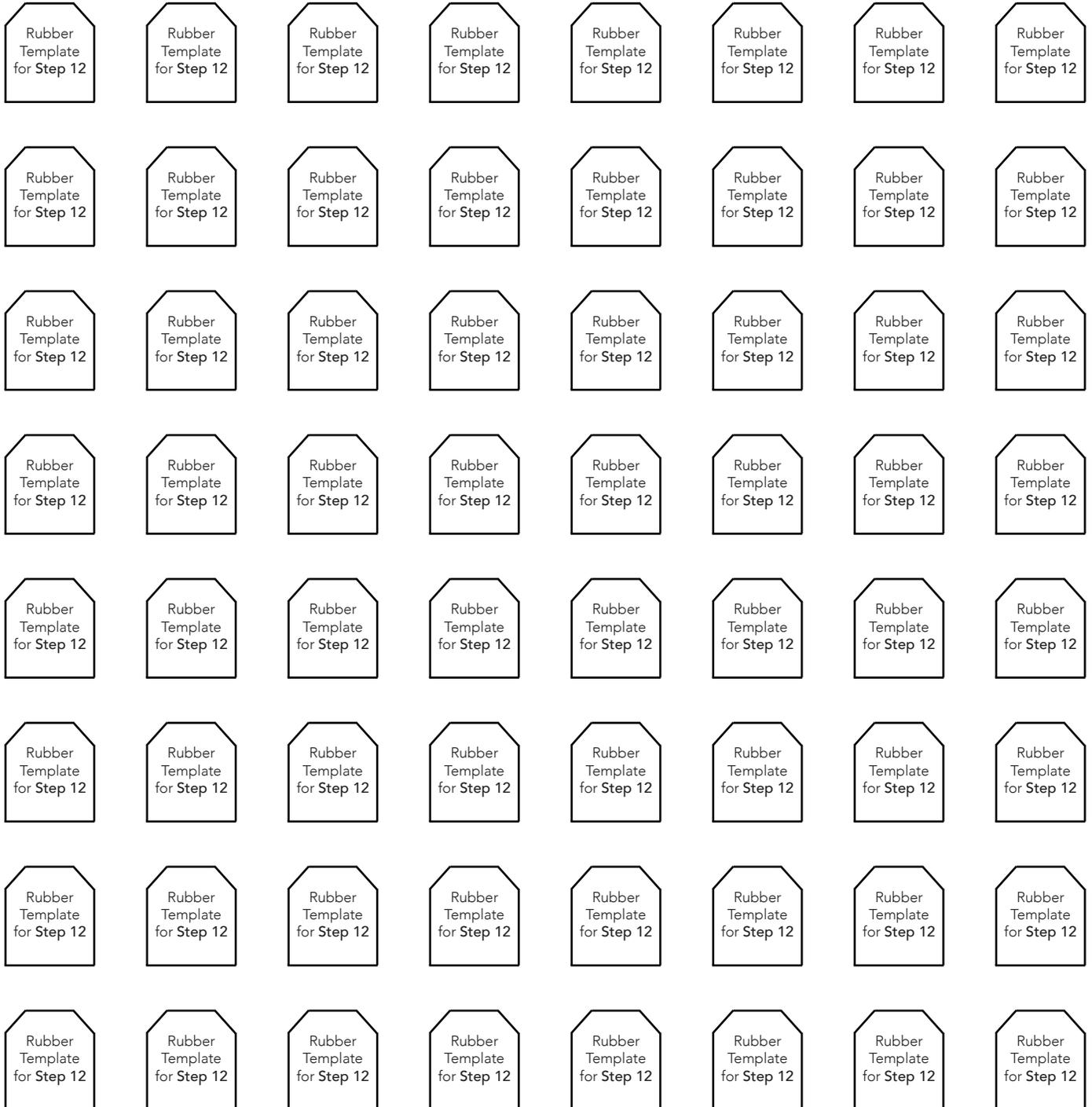
### 16. Assembly complete

The S.A.F.E. Cartridge is complete and ready for use with your mask system.



# ASSEMBLY GUIDE | RUBBER TEMPLATE

Cut out one of the rubber templates below for use in **Step 12** of the Assembly Guide | Cartridge Assembly to size the rubber valve membrane.

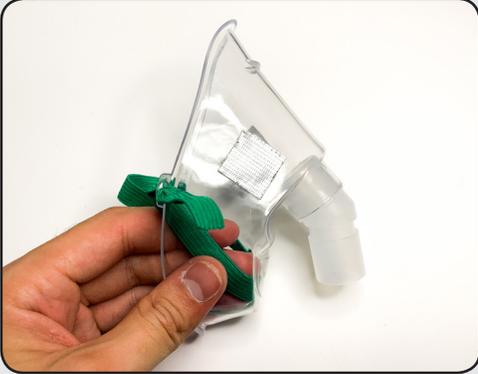




# Mask Assembly

Preparing the Hospital Mask

# MASK ASSEMBLY | HOSPITAL MASK



## 1. Plug existing mask holes

Plug the existing vent holes in the disposable AeroEclipse Aerosol Mask using a piece of strong adhesive tape, ensuring complete blockage of the holes.



## 2. Prepare foam gasket

Cut a length of neoprene window sealer foam 20 inches long. Carefully cut a slit that is 0.25 inches (1/4 in) deep along one edge of the foam. The foam should be long enough to go around the edge of the mask.



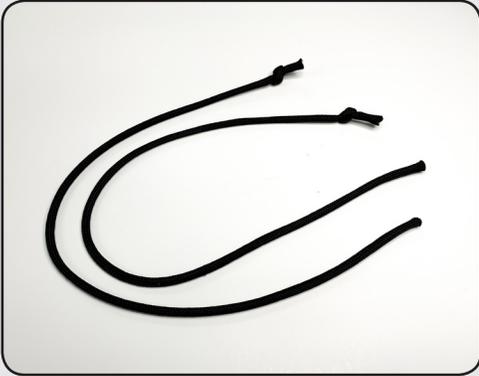
## 3. Attach foam gasket

Use super glue to carefully attach the foam around the perimeter of the mask, inserting the mask edges into the slit cut in the previous step.



## 4. Seal the loose ends of the gasket

Trim any extra overlapping foam material. Use a layer of hot glue to join the ends of the foam strip together to create a tight seam.



## 5. Cut a new strap

Cut the 1/8 inch paracord to **40 inches**. Cut the paracord in half and tie a single knot on one end of each piece.



## 6. Attach the new strap

Use a strong adhesive tape to adhere one of the strap pieces into place by applying the tape across the paracord in front of the knot. Repeat on the other side of the mask for the second paracord piece and then cut the existing elastic strap in half.



## 7. Attach S.A.F.E. Cartridge

Attach the S.A.F.E. Cartridge System securely onto the end of the mask port, making sure the valve is facing upwards. Use tape to secure the cartridge if there is a loose fit to ensure an airtight seal. Some light sanding of the mask port may be required depending on your printer tolerances.



## 8. The mask is now ready for use

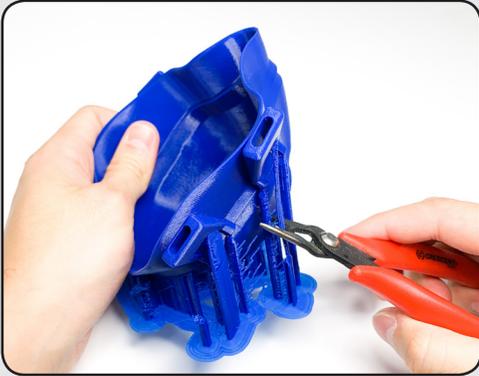
To use, press the mask against the user's face. Tie the top strap around the back of the head. Tie the bottom strap around the base of the head. Tighten both to ensure that the mask will not lift or move off of the face.



# Mask Assembly

Preparing the 3D-Printed Mask

# MASK ASSEMBLY | 3D-PRINTED MASK



## 1. Clean the 3D print

Using pliers and flush cutters, carefully remove any support material from the 3D-printed mask.



## 2. Cut the foam gasket

Cut a length of neoprene window sealer foam **20 inches** long. The foam should be long enough to go around the inside edge of the mask.



## 3. Attach foam gasket

Use super glue to carefully attach the foam around the perimeter of the mask, making sure that there is at least **0.125 inch (1/8 in)** of foam past the edge of the mask.



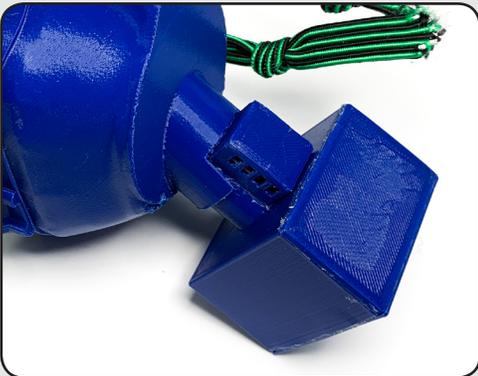
## 4. Seal the loose ends of the gasket

Trim any extra overlapping foam material. Use a layer of hot glue to join the ends of the foam strip together to create a tight seam.



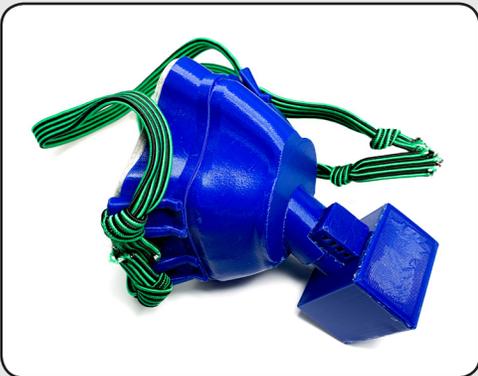
## 5. Cut a new strap

Cut two flat bungee cords to **30 inches** in length and insert both strap ends into the mask strap holders. Tie one end of each strap to the mask itself using a knot. Tie a knot into each of the free ends of the strap. You should be able to pull the free end forward to tighten the mask.



## 6. Attach S.A.F.E. Cartridge to mask

Attach the S.A.F.E. Cartridge System securely onto the end of the mask port, making sure the valve is facing upwards. Use tape to secure the cartridge if there is a loose fit to ensure an airtight seal. Some light sanding of the mask port may be required depending on your printer tolerances.



## 7. The mask is now ready for use

To use, press the mask against the user's face. Pull the straps over the user's head and tighten by pulling on the free strap ends on the front of the mask.



# Wearing the Mask

How to Fit, Wear, and Clean the Mask

# WEARING THE MASK | HOSPITAL MASK



## 1. Tie top strap

Put mask over mouth and nose. Securely tie the top straps behind the back of your head.



## 2. Tie bottom strap

Pull the bottom strap behind the base of the head and tie securely. Make sure the mask is seated securely on your face.



## 3. Test the mask seal

Test the mask seal by plugging the S.A.F.E. Cartridge with your palm and inhaling. A vacuum should be drawn inside the mask. If there is a leak, adjust the mask using the straps. *A complete seal is required for proper S.A.F.E. Cartridge System functionality. Test seal before use.*



## WARNING

Proper filtration **REQUIRES** proper mask seal!

Before using the S.A.F.E. Cartridge System in an environment that requires protective equipment, check for proper air flow and sealing. These masks may be tested for fit and functionality using standard N95 testing procedures for the clinical setting.

# WEARING THE MASK | 3D-PRINTED MASK



## 1. Put mask on

Put mask over mouth and nose. Pull the two straps over your head with the bottom strap going to the base of your head and the top strap over your ears.



## 2. Pull straps forward to tighten

Pull the free ends of each strap forward to tighten. Make sure the mask is seated securely on your face. Tie loose ends of the mask in place if necessary to hold in place.



## 3. Test the mask seal

Test the mask seal by plugging the S.A.F.E. Cartridge with your palm and inhaling. A vacuum should be drawn inside the mask. If there is a leak, adjust the mask using the straps. ***A complete seal is required for proper S.A.F.E. Cartridge System functionality. Test seal before use.***



## WARNING

Proper filtration **REQUIRES** proper mask seal!

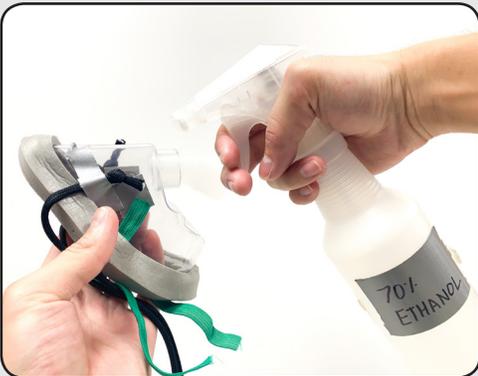
Before using the S.A.F.E. Cartridge System in an environment that requires protective equipment, check for proper air flow and sealing. These masks may be tested for fit and functionality using standard N95 testing procedures for the clinical setting.

# CLEANING THE MASK | APPLIES TO BOTH MODELS



## 1. Remove S.A.F.E. Cartridge

Carefully pull the S.A.F.E. Cartridge out of mask and throw away. It is recommended to dispose of the S.A.F.E. Cartridge after each day of use. Do NOT use a wet agent to sterilize the S.A.F.E. Cartridge.



## 2. Sterilize mask and straps

Using 70% isopropyl or ethanol, spray the entire surface of the mask, both inside and outside surfaces.

This cleaning method can be used for both models of masks as shown. Let the mask dry completely before using again.





# CHANGING WHAT'S POSSIBLE

The S.A.F.E. Cartridge System has been through several iterations since its conception at the Medical University of South Carolina. The S.A.F.E. Cartridge System and masks were tested by a certified technician for fit and filtration efficacy utilizing the same test procedure and compound as used in standard N95 fit tests.

The prototypes were deemed effective.

The S.A.F.E. Cartridge System is currently being reviewed by the FDA.

## The innovators behind the S.A.F.E. Cartridge System

The S.A.F.E. Cartridge System was designed and invented by the following innovators who were a part of an interdisciplinary design task force at the Medical University of South Carolina.

Joshua Kim, MS

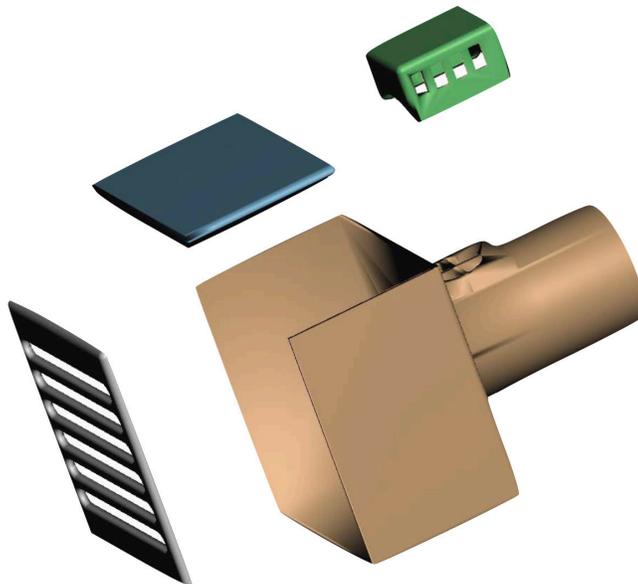
John Yost

Dr. Walter Renne, DMD

Dr. Christian Brenes, DMD

Dr. Michael Yost, PhD

Dr. David Mahvi, MD



3D Rendering of the S.A.F.E. Cartridges Prototype

# S.A.F.E. CARTRIDGE SYSTEM HUMANITARIAN USE LICENSE

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