

# OpenPAPR

Open-source ecosystem for a modular  
Powered Air-Purified Respirator (PAPR)

<https://github.com/OpenPAPR>

OpenPAPR Team



April 2, 2020

# Motivation



*“True PAPRs are in short supply nationally.”*  
– Dr. Robinowitz, UCSF Anesthesiologist

**#6 This Is An Anesthesiologist, Dr. John Henao, Who Is Running Out Of Ppe (Personal Protective Equipment) At His Hospital**



"He, like most of us, are currently working under the assumption that most people are Covid19 positive and asymptomatic, but in order to save our dwindling supplies of PPE, are only using them for known cases of Covid19. In order to safely intubate all patients he had to jerry rig his own gear. He put on a CO2 sampling nasal cannula. He then put on a regular old plastic bag on over his head with a seal (you can see he taped it tightly around his neck). He ran the oxygen at 10 L/min. He sampled his CO2 to monitor. He did this for 10 min (long enough to intubate a patient). THIS is what we have to do because we have no PPE. I am horrified. I cannot even begin to know if this is safe and cannot recommend it. But, sure, we'll be safe with bandanas, scarves, and homemade cloth masks. (That, folks, is sarcasm). For my friends who are fellow physicians, please be safe, and for those of you who are not, please call or tweet or write your elected officials to demand that we are given adequate equipment in order to treat you safely"

Source: <https://www.theguardian.com/world/2020/mar/24/coronavirus-medical-staff-beg-for-masks-social-media>

Source: <https://twitter.com/thedelports/status/1241049353562640384>

# Inception ~ Mar. 21, 2020



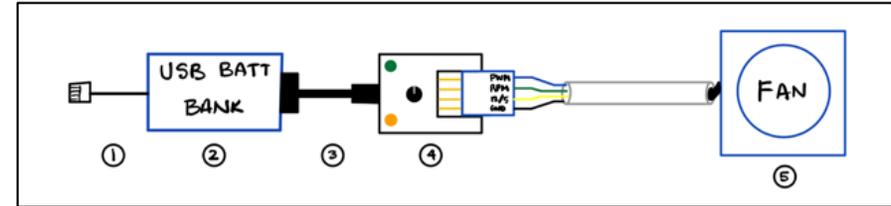
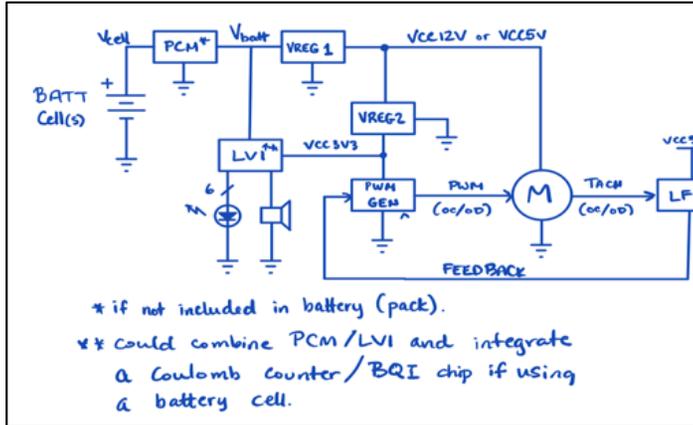
**From:** [eeecs-profs-request@lists.eecs.berkeley.edu](mailto:eeecs-profs-request@lists.eecs.berkeley.edu) <[eeecs-profs-request@lists.eecs.berkeley.edu](mailto:eeecs-profs-request@lists.eecs.berkeley.edu)> **On Behalf Of** Stuart RUSSELL  
**Sent:** Saturday, March 21, 2020 3:57 PM  
**To:** [adi@eeecs.berkeley.edu](mailto:adi@eeecs.berkeley.edu)  
**Cc:** Niloufar Salehi <[nsalehi@berkeley.edu](mailto:nsalehi@berkeley.edu)>; Rikky Muller <[rikky@berkeley.edu](mailto:rikky@berkeley.edu)>; Michel Maharbiz <[maharbiz@berkeley.edu](mailto:maharbiz@berkeley.edu)>; Nicholas Weaver <[nweaver@icsi.berkeley.edu](mailto:nweaver@icsi.berkeley.edu)>; Shafi Goldwasser <[shafi.goldwasser@gmail.com](mailto:shafi.goldwasser@gmail.com)>; EECS Faculty <[eeecs-profs@eeecs.berkeley.edu](mailto:eeecs-profs@eeecs.berkeley.edu)>  
**Subject:** Re: [urgent] Personal Protection Equipment and UCSF

Here's a suggested solution from a friend who has some practical engineering experience. He has talked it over with a manufacturer and it seems practical, but he needs a bit of electrical help. If someone has **a good hands-on student who can help right now**, please have them contact Lakin directly.

Thanks  
Stuart

How it all started: with an email to faculty for “a bit of electrical help”... “This is quite a simple circuit, so we likely **just need** couple hours of help to design it”

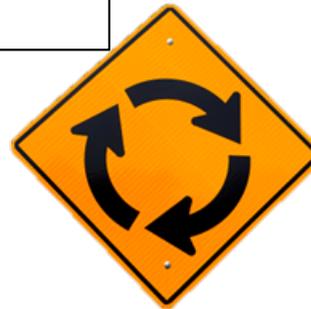
# EECS Faculty Focus on the Electronics ~ Mar. 22, 2020



*Oh, no! Amazon won't deliver until Apr 21!*

*Time for a more custom solution*

*And it was going to take **a lot** more than 1-2 hours!*



*And we realized the mechanicals weren't working!*



4.2.4 Breathing Rate Verification of Low, Moderate, and/or High work rates

4.2.4.1 The manufacturer shall specify the highest work rate from Table 1 for the intended use of the PAPR system. The PAPR must maintain pressure above ambient in the face area and/or the hood area around the neck during the manufacturer's minimum battery life time while breathing at each of the rates desired while properly mounted on a headform.

**Table 1: NIOSH Approved Work Rates**

Work Rate	Minute Volume	Tidal Volume and Respirations
Low	25 Lpm	1.30 liters @ 19.2 respirations per minute
Moderate	40 Lpm	1.67 liters @ 24 respirations per minute
High	57 Lpm	1.95 liters @ 29.1 respirations per minute

4.2.4.1.1 Air pressure shall be measured in the area of the nose and mouth, inside the respiratory inlet covering of the completely assembled PAPR on a headform.

4.2.4.1.2 A breathing machine shall be used to meet the work rates as described in Table 1.

4.2.4.2 Pressure shall remain above ambient at all times during testing. Static pressure relative to external pressure may not exceed 2" of water column height for any PAPR during testing.

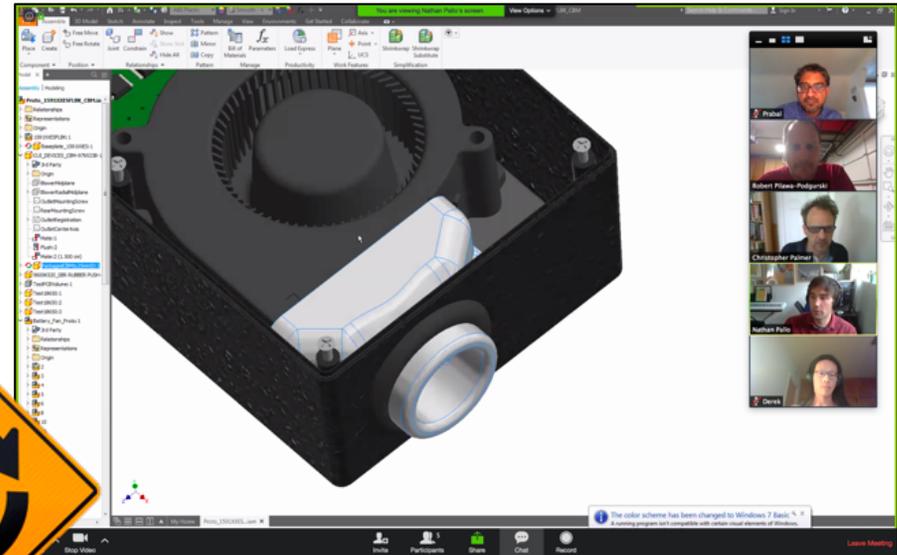
# Collaboration in the Time of Coronavirus ~ Mar. 23+, 2020



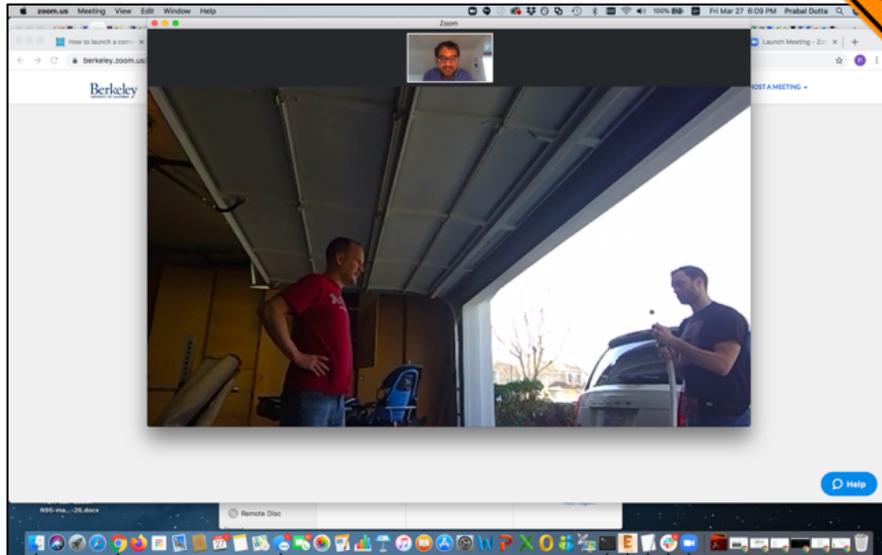
**From:** [eeecs-profs-request@lists.eecs.berkeley.edu](mailto:eeecs-profs-request@lists.eecs.berkeley.edu) <[eeecs-profs-request@lists.eecs.berkeley.edu](mailto:eeecs-profs-request@lists.eecs.berkeley.edu)> **On Behalf Of** Stuart RUSSELL  
**Sent:** Saturday, March 21, 2020 3:57 PM  
**To:** [adj@eecs.berkeley.edu](mailto:adj@eecs.berkeley.edu)  
**Cc:** Niloufar Salehi <[nsalehi@berkeley.edu](mailto:nsalehi@berkeley.edu)>; Rikky Muller <[rikky@berkeley.edu](mailto:rikky@berkeley.edu)>; Michel Maharbiz <[maharbiz@berkeley.edu](mailto:maharbiz@berkeley.edu)>; Nicholas Weaver <[nweaver@icsi.berkeley.edu](mailto:nweaver@icsi.berkeley.edu)>; Shafi Goldwasser <[shafi.goldwasser@gmail.com](mailto:shafi.goldwasser@gmail.com)>; EECS Faculty <[eeecs-profs@eecs.berkeley.edu](mailto:eeecs-profs@eecs.berkeley.edu)>  
**Subject:** Re: [urgent] Personal Protection Equipment and UCSF

Here's a suggested solution from a friend who has some practical engineering experience. He has talked it over with a manufacturer and it seems practical, but he needs a bit of electrical help. If someone has a good hands-on student who can help right now, please have them contact Lakin directly.  
 Thanks  
 Stuart

How it all started: with an email to faculty



Discussing CAD design details over Zoom (and getting the grad students involved!)



Doing handoffs at a socially safe distance

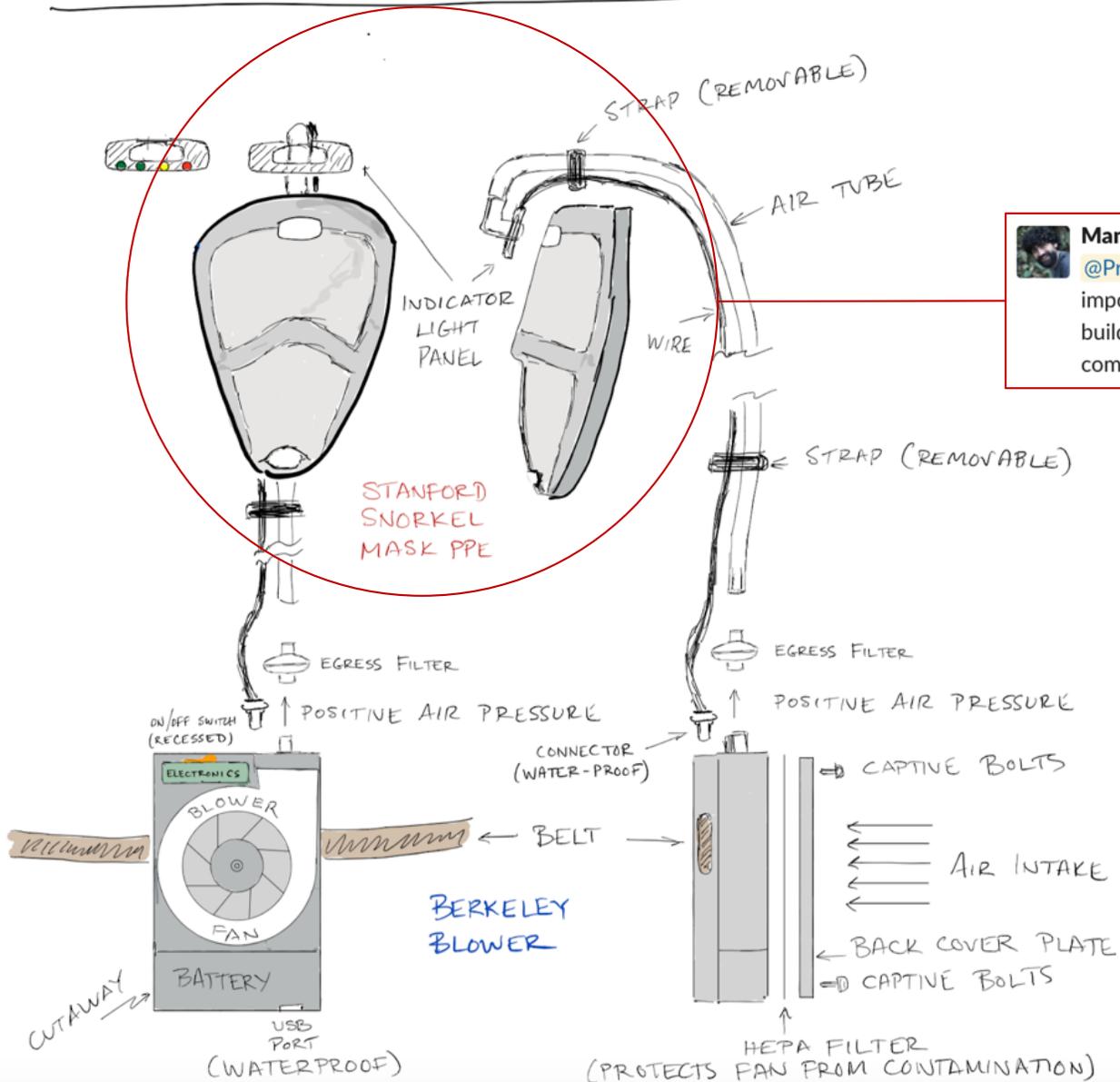
DATE	SALESORDER NUMBER	PURCHASE ORDER NUMBER	CART NAME	STATUS
3/26/2020	63604143			Completed
3/26/2020	63602208			Completed
3/25/2020	63588186			Completed
3/25/2020	63587679			Completed
3/24/2020	63570885			Completed
3/24/2020	63570834			Completed
3/23/2020	63553285			Completed

FedEx overnight orders shipping every night

# Expand the Scope (and the Blower Fan) ~ Mar 25, 2020



## MODULAR PPE CONCEPT



Manu Prakash 10:34 PM

@Prabal Dutta Let's connect - I think the modularity is very important and we have someone in our team that was already building the computer fan blower option for different use cases. Let's combine that effort. What's your email contact?

# Growing Sense of Urgency from UCSF Doctors



*“PAPRs and respirators are hard to find these days for obvious reasons.”*

*“Supplies are short for PAPRs in hospitals, and the surge is not here yet... How’s the progress? Anything I can do to help?”*

*“I actually have a small grant that’s unrestricted. Send me the receipt and I’ll help out.”*

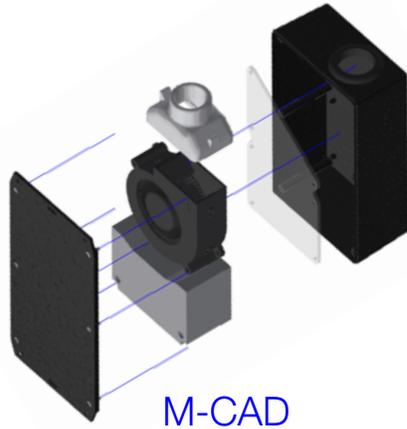
# Vision: An Ecosystem of Open/3DP Components\*



# Connecting the "Dots"...to a First Prototype

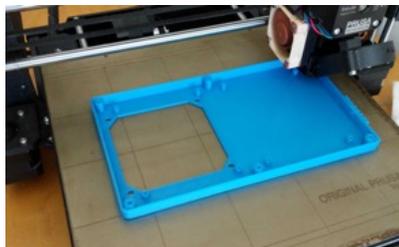


# CAD → Fully Working Prototype ~ April 1, 2020 [no joke!]



Condition	Display
POWER OFF	●●●●●●
Battery Level: 75-100% Airflow Normal	●●●●●●
Battery Level: 50-75% Airflow Normal	●●●●●●
Battery Level: 25-50% Airflow Normal	●●●●●●
Battery Level: 0-25% Airflow Normal	●●●●●●
Battery Level: 75-100% Airflow Low	●●●●●●
Battery Level: 50-75% Airflow Low	●●●●●●
Battery Level: 25-50% Airflow Low	●●●●●●
Battery Level: 0-25% Airflow Low	●●●●●●

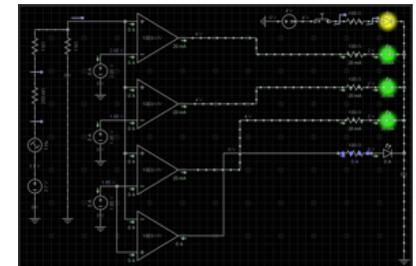
Status UI



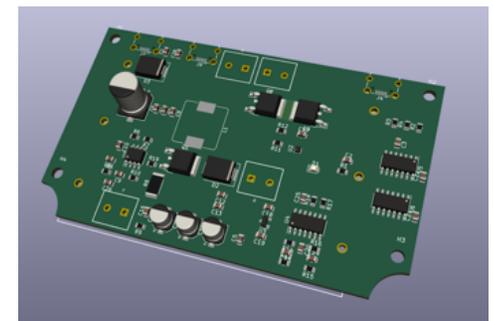
3DP Parts



Berkeley Blower



E-SIM



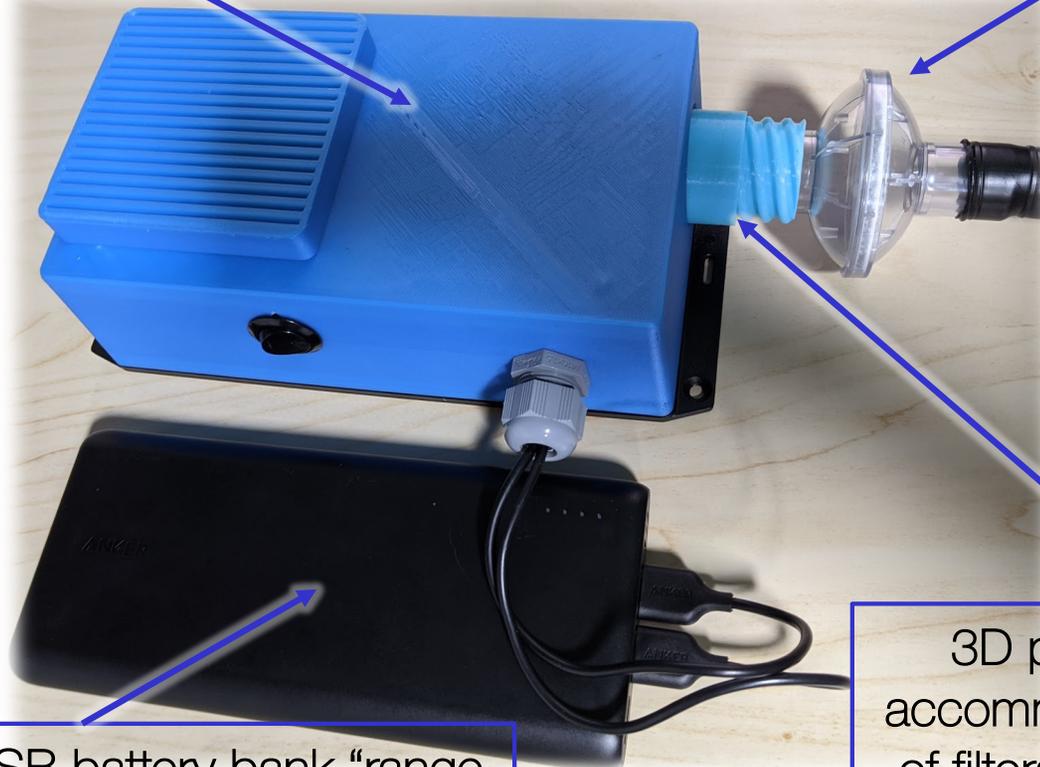
E-CAD

# OpenPAPR – Rev 1 ~ April 1, 2020



Easy-to-sanitize enclosure, containing on-board lithium-ion battery, electronics, and blower fan. All components selected to be widely available commercially

\$1.50 medical in-line viral filter, 99.999% efficient



Off-the-shelf USB battery bank “range extender”, enabling 4-5 additional hours of run-time and easy charging

3D printed adapter, to accommodate a wide range of filters and hoses. Library of open-source parts available on project website

# OpenPAPR – User Demo ~ April 1, 2020



Only consumable can be a \$0.10 polyethylene bag that is widely available. Continuous airflow and positive pressure makes it comfortable and safe to wear. Airflow tested to match commercial medical-grade PAPRs.

# From a Sense of Urgency to a Call to Action



*“PAPRs and respirators are hard to find these days for obvious reasons.”*

*“Supplies are short for PAPRs in hospitals, and the surge is not here yet... How’s the progress? Anything I can do to help?”*

*“I actually have a small grant that’s unrestricted. Send me the receipt and I’ll help out.”*

*“All I can say is amazing work.”*

*“I’ll back you out of my savings account if necessary.”*

*“Should I have our leadership speak with your leadership about permitting you to focus on this potentially life saving work?”*

# OpenPAPR Team



## @ UC Berkeley

Derek Chou  
Prabal Dutta  
Nathan Pallo  
Chris Palmer  
Robert Pilawa-Podgurski

## @ UCSF

Dr. David Robinowitz  
Dr. Jeffrey Sall  
Dr. Stephen Weston

## @ Home

Brooke Dagnan  
Stephanie Lie  
Lakin Moser  
Brooke Pilawa-Podgurski

# Roadmap & Needs



- Mechanical engineering assistance
- Laboratory testing for fit & function
- Documentation and user manuals
- Compliance and safety “verification”
- Legal guidance on emergency liability
- Manufacturing contracts to scale up
- Logistical support for distribution
- Financial resources for production

# Additional Reading



- American Society of Anesthesiologists: Update on the Use of Personal Protective Equipment by Anesthesia Professionals ([link](#))
  - Airway procedures are high risk for exposure to aerosols – which are not filtered by standard surgical mask.
  - ASA recommends n95 respirators or PAPRs for all anesthetic cases and for airway procedures.
  - N95 Respirators are under a world wide shortage, therefore, PAPRs are in very high demand.
- Physicians, and those Performing Aerosol Generating Procedures (AGPs) Are at Higher Risk both of COVID-19 and Worse Outcomes ([link](#))
- What is an air-purifying respirator? (<https://www.cdc.gov/niosh/docs/2018-176/default.html>)
- General Cautions and Limitations for Powered Air Purifying Respirators (<https://wwwn.cdc.gov/NIOSH-CEL/Limitations/Papr>)
- Dire Need for PPE (<https://www.sfgate.com/coronavirus/article/Home-Depot-Halts-Sales-of-N95-Masks-Amid-15173652.php>)
- Bay Area Situation (<https://www.sfchronicle.com/bayarea/article/Coronavirus-Nurses-are-wearing-trash-bags-at-one-15172777.php>)
- National Stockpile Nearly Depleted ([link](#))
- Governments Calling for Help with PPE Manufacture ([link](#))