PAPRa

An Open-source Powered Respirator in Response to the COVID-19 Pandemic

COVID-19
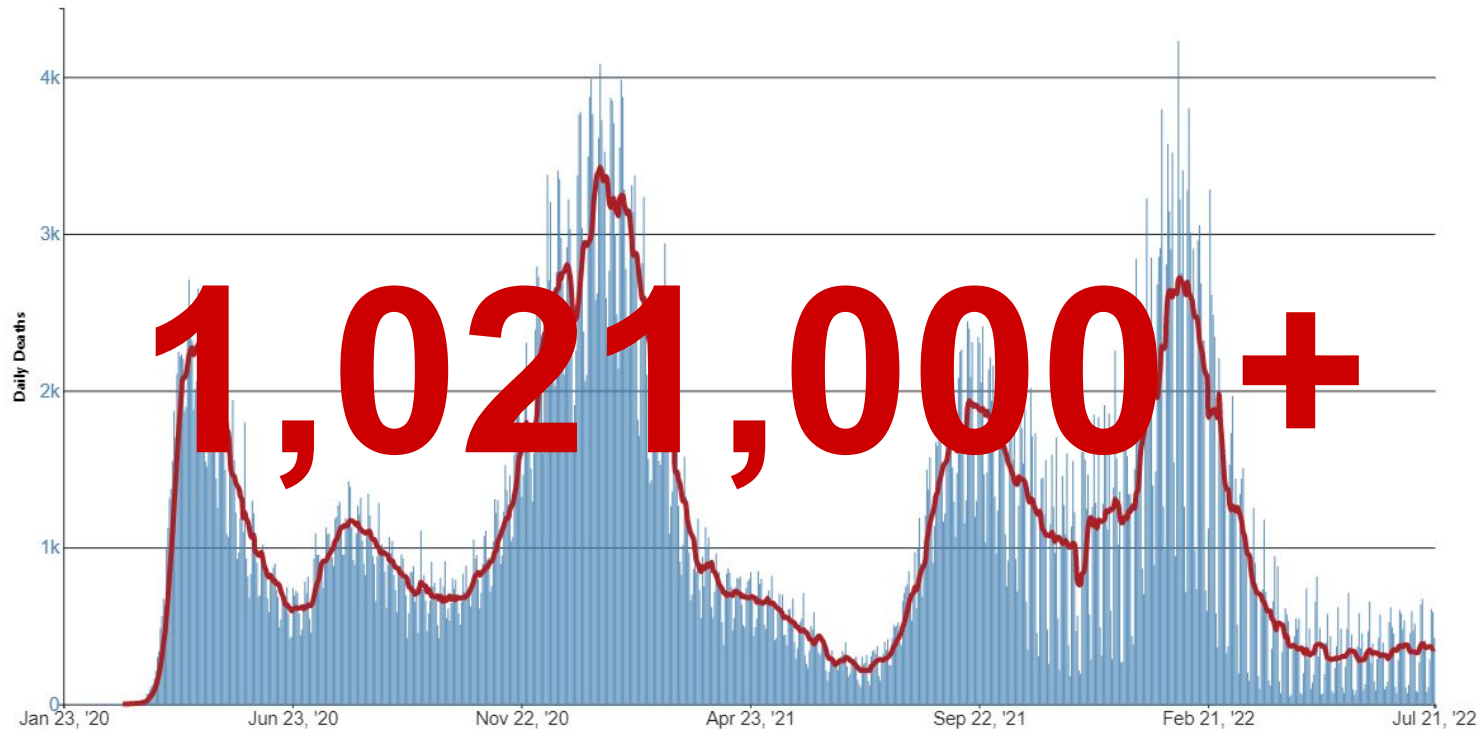
Coronavirus Disease 2019

Virus: SARS-CoV-2

Why it spread so far?

- People are infectious days before symptoms appear.
- Novel virus with no treatments existing.
- Unknown exact spread mechanism.

COVID-19 Deaths in US

Daily Trends in Number of COVID-19 Deaths in The United States Reported to CDC

1,021,000 +

Actual Guidelines from the CDC

In settings where facemasks are not available, HCP might use homemade masks (e.g., bandana, scarf) for care of patients with COVID-19 as a last resort.

-Centers for Disease Control and Prevention

Timeline of Action at Keck Medical Center of USC

3/22/2020   Joe Savoie, Director of Imaging Services, tests 3D printed mask

3/23/2020   Prototype printed overnight

3/24/2020   Meeting with Infection Prevention

3/25/2020   Fit test with Respiratory Support
- Asked Facebook to for people with 3D printers

3/26/2020   Connect groups in LA on getting masks made

- CRASH Space - https://blog.crashspace.org/
- Sunweaver Creative
- Trojan Family
  - Iovine and Young Academy
  - USC School of Architecture
  - USC School of Engineering

3D Printed PPE

Community 3D Printing

PAPR Life Force

April 2020, Karen Solomon reached out to Daniel Stemen, Manager of Respiratory Services at KMC, about things to do to help with PPE shortage.

May 2020, PAPR Life Force group was formed as a group of like minded individuals working to develop a PAPR unit for healthcare and public use.

August 2020, initial prototype created using Amazon sourced products which were not rationed.

September 2020, PAPR Life Force effectively dissolved and the project was brought to Tetra Bio Distributed.

Design Goals

- Provide at least N95 levels of protection
- Provide comfort to the wearer through an 8 hour shift
- Easy-swap battery change mid-shift capability
- Lightweight (under 1kg)
- ~~In 2020, using non COVID rationed components~~
- Attachable to a belt/backpack/carrying system
- Easy to don and doff
- 100% open source where possible
- Designed for distributed manufacturing (3D printable)
- Splash resistant

Early Prototype

- Never worked
- Fan was outside of the sealed box
- Useful in testing 3D printability of components and as the genesis of design

Oct 2020 Iteration

- Inhalation and exhalation through the filter, ditched because CO_2 rebreathing was significant (and dangerous)
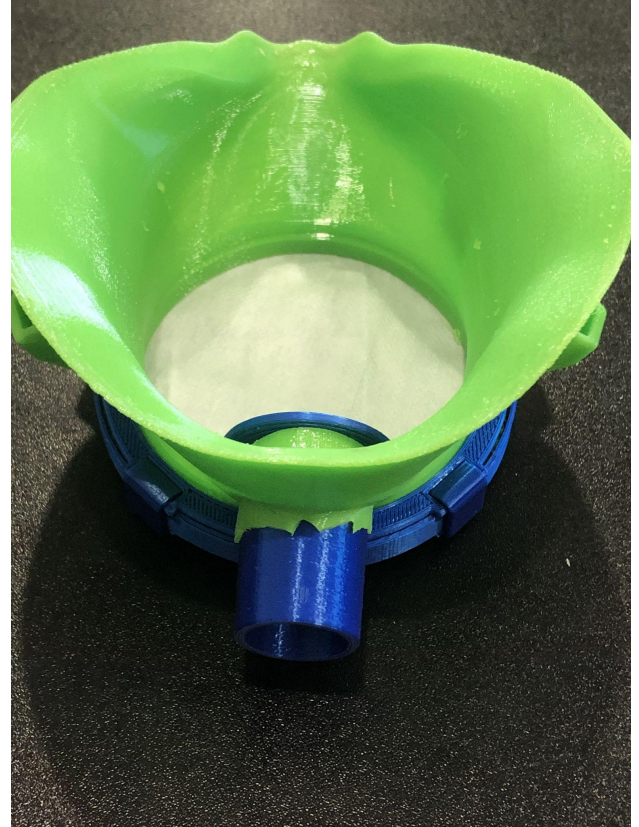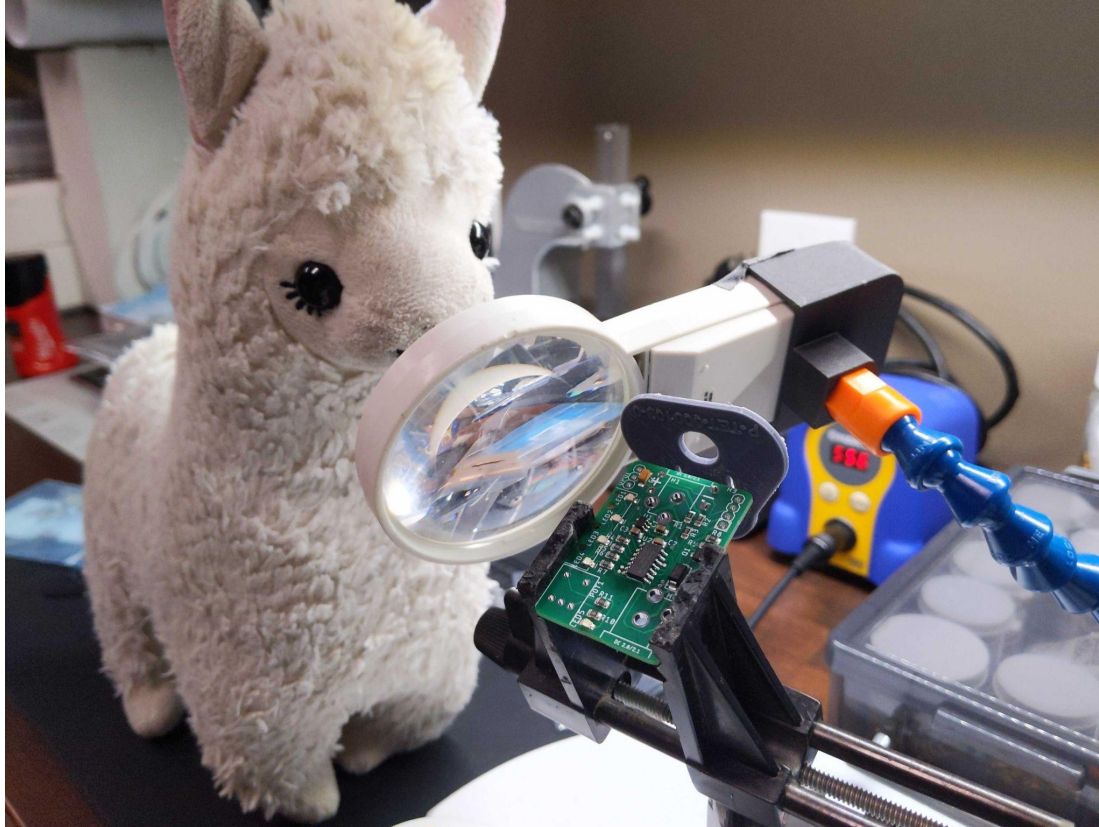- Electrical parts were assembled from Amazon parts
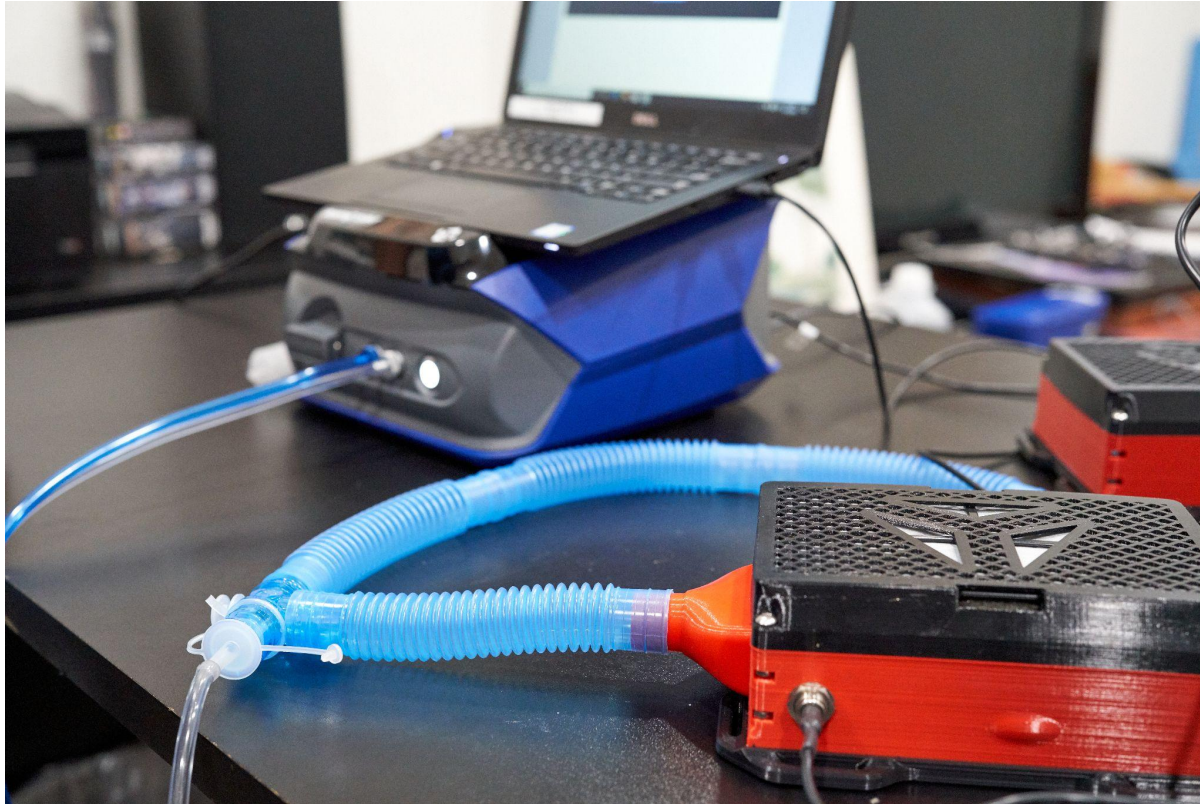
Jan 9 2021 Iteration

- New mask to prevent rebreathing
- Began exploring printing in flexibles
- Starting to design for assembly

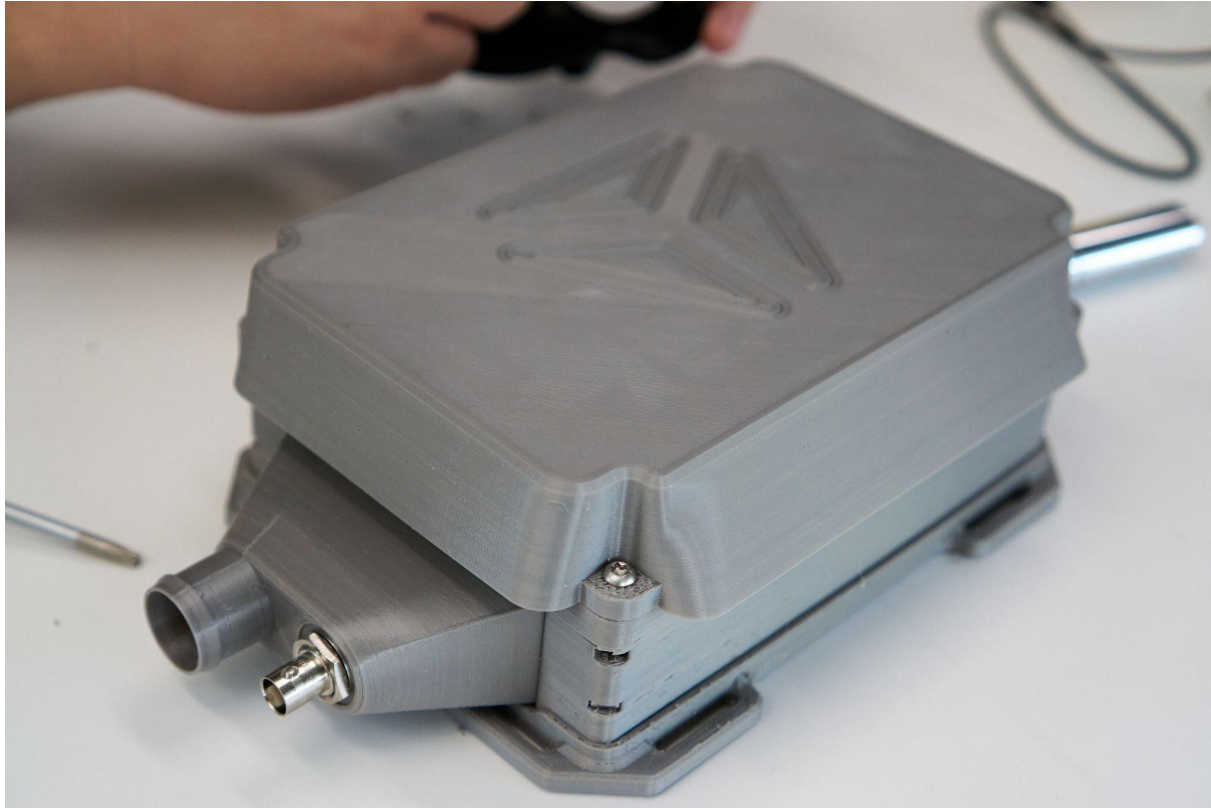# Jan 31 2021 Iteration– Board Changes and Bad Masks

March 2021– Quantitative Testing and Connectors

- Started testing with a TSI PortaCount to validate N95 performance
- Experimented with a proprietary connector board (would not recommend)

April 2021 Iteration

- Moved all fan box inputs and outputs to one side
- Experimenting with some moisture protection
- Major redesign of the controller housing
- BNC connectors

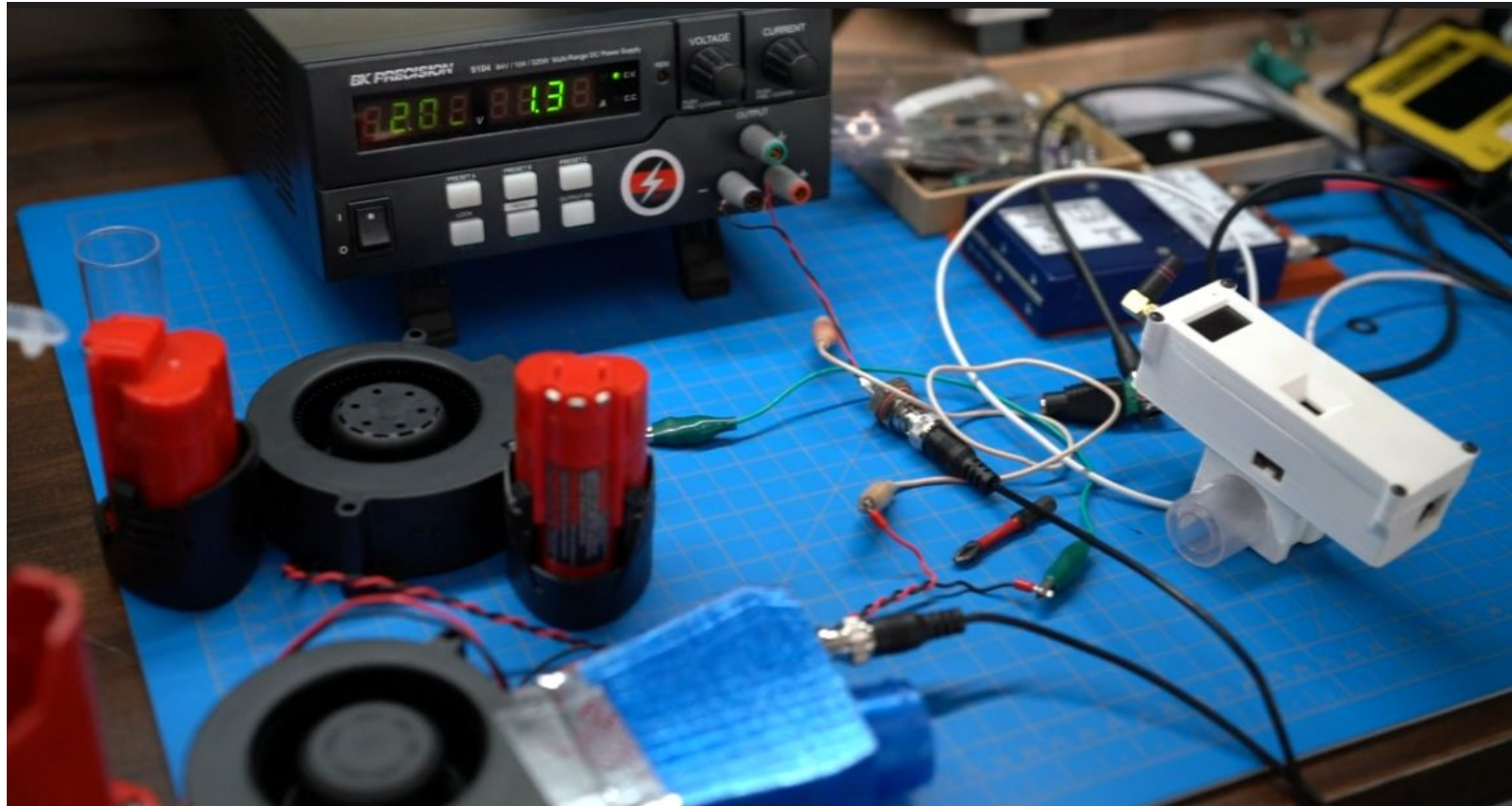# May 2021 Iteration – Now with a weather guard!

Aug 2021 Iteration

- 3D printed clips provided clamping pressure for filter (went back to screws)

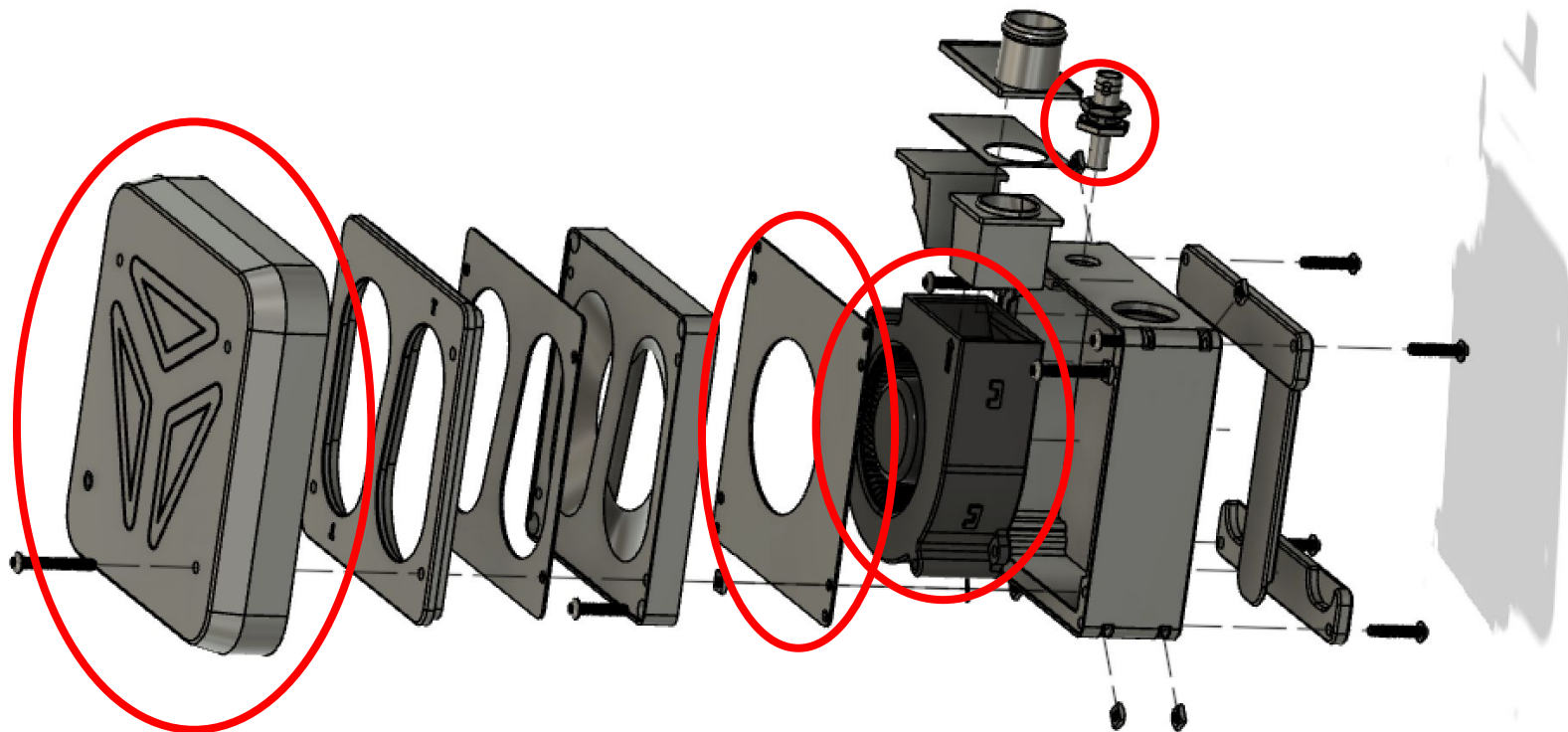# Oct 2021– Testing flow and battery life

Feb 2022– Now livestreaming! (https://twitch.tv/tetrabiodistributed)

June 2022– Also on Youtube!
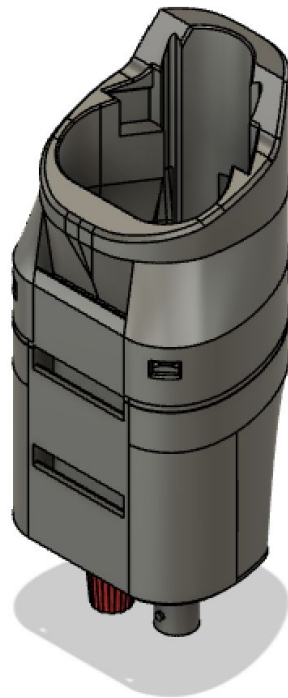(https://www.youtube.com/channel/UCSiY0Y9G6xLsiJXyrbaWW8w)
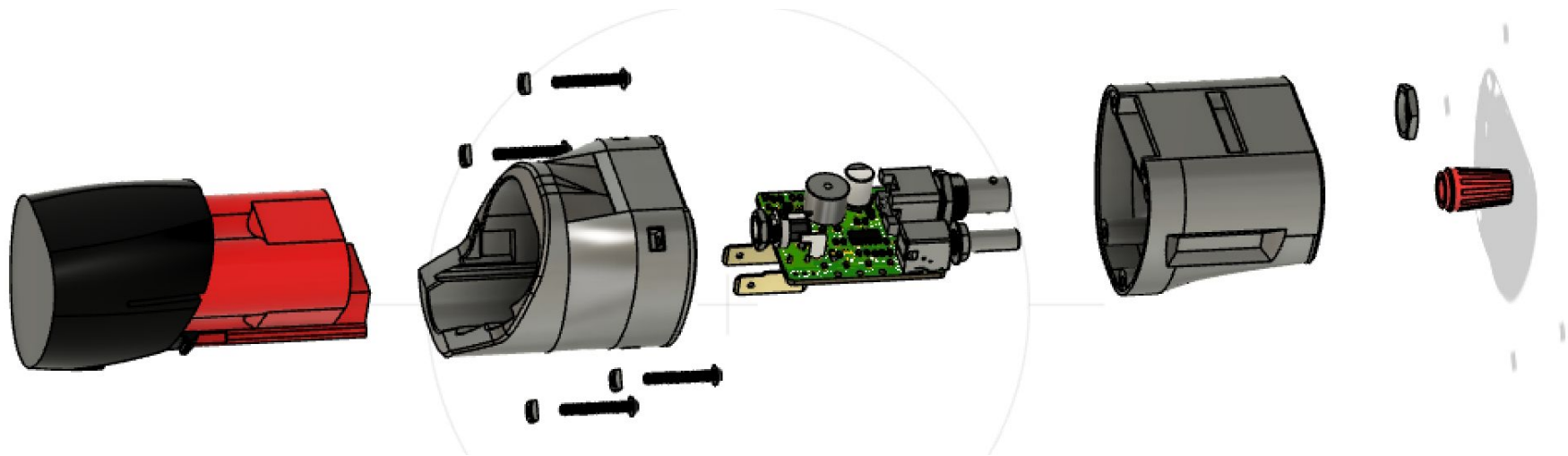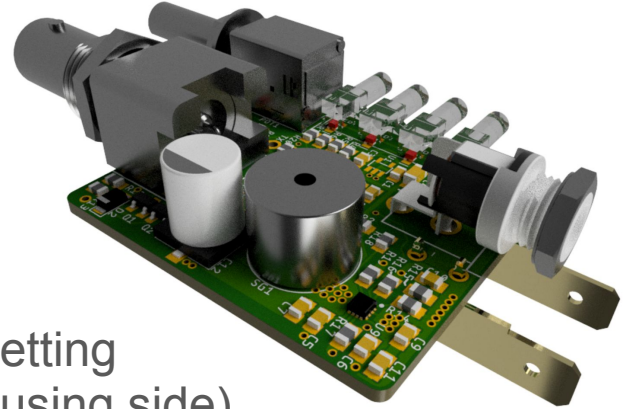
Fan Box Schematics
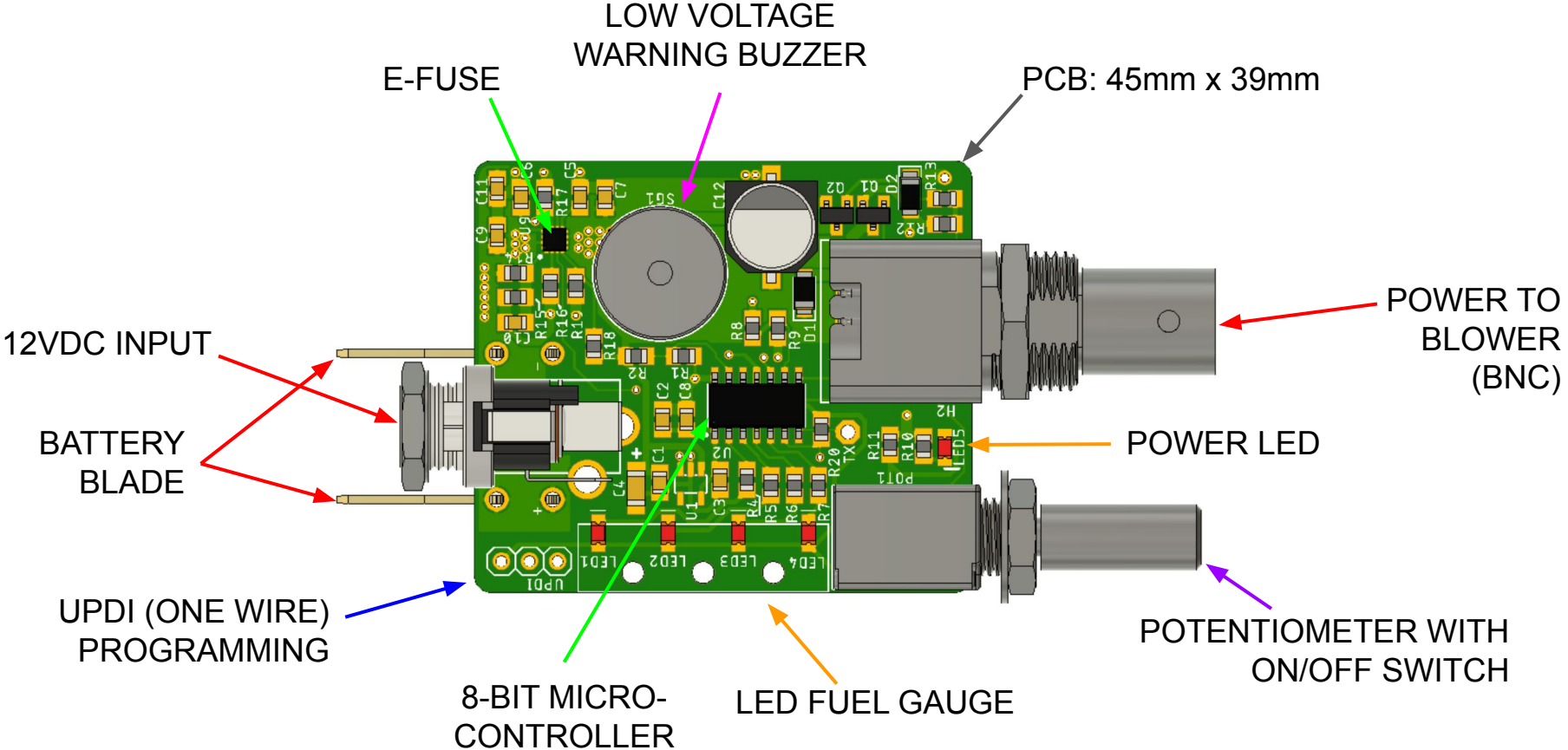
Power Supply

Controller Schematic

PAPRA PCB

Features:

- Blade connectors for Milwaukee M12 battery
- Potentiometer with switch for turn on and fan setting
- Battery fuel gauge with 4 LEDs (lightpipe to housing side)
- Low battery/voltage buzzer
- 20kHz PWM frequency for low noise
- DC Power jack input when not using battery, 2A/14V max
- Fully protected power input against reverse polarity, undervoltage, overvoltage, over-current and over-temperature.
- Low-cost ATtiny404 microcontroller ($0.51 each @ 100 piece quantity)
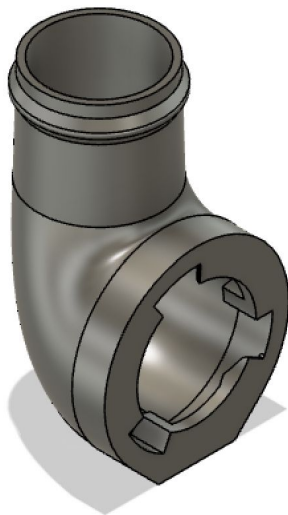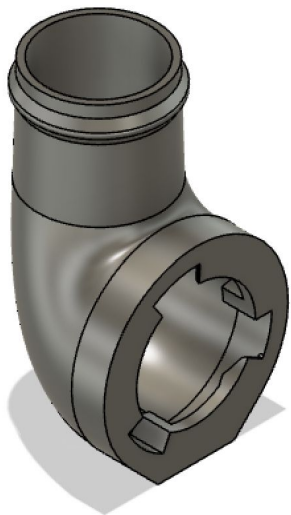- PCB BOM cost ~$13 @ 100 pc qty

PAPRA PCB

LOW VOLTAGE
WARNING BUZZER

E-FUSE

PCB: 45mm x 39mm

POWER TO
BLOWER
(BNC)

12VDC INPUT

BATTERY
BLADE

POWER LED

UPDI (ONE WIRE)
PROGRAMMING

POTENTIOMETER WITH
ON/OFF SWITCH

8-BIT MICRO-
CONTROLLER

LED FUEL GAUGE

3M Half-Face Respirator Adapters

3M Half-Face Respirator Adapters

The Team

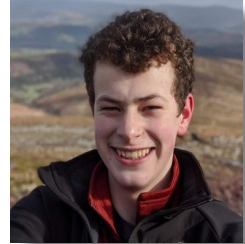Mark Roden, PhD   Daniel Stemen, MSRS   Darryl Hwang, PhD   Patrick Campbell, MSME

Sean Marquez   Burhan Qaddoumi   Jamie Waters   Kevin Butler, MBA

Next Steps

- Have solutions for other problems than COVID (Firefighting? Construction?)
- Solve the proprietary mask issue
- Publish our current iterations (N100/P100)
- Kickstarter, with $2 million dollar stretch goal as NIOSH certification?

Call To Action

- Help with marketing/getting the word out
- Help with mask design so we're not using a proprietary solution
- Help with building– make sure we're not the only ones who can build it
- Help with instructions