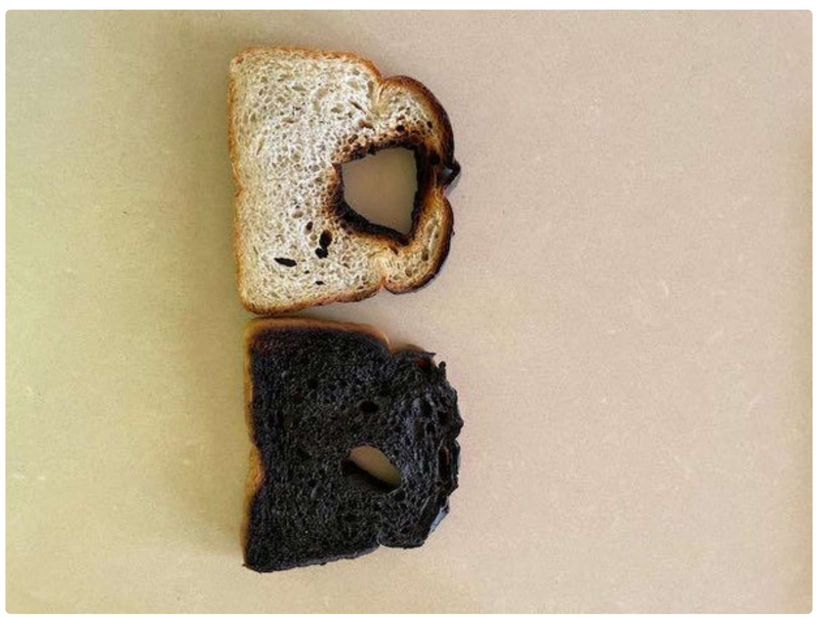
Toast Test--Simulated Testing of Indoor Spaces for COVID Spread

by rabbitcreek

COVID is spread by micro droplets that hang in the air for hours. Statistically it does not appear to be spread by surfaces so a lot of the rules that we use for keeping safe are unlikely to help--breath barriers, obsessive washing of everything. Incredible real life examples of how it is spread are now obvious in retrospect: an airplane packed with 400 spreaders of virus, not respecting distancing, half the time with their masks off, no breath barriers between seats--no one gets COVID. Why? Airplanes change out their air once every three minutes and 75% of it is from outside. You should be so lucky with your teammates for a beer after a game at the corner bar....Well now you can be with the Toast Test. It is a simple reproducible way of evaluating the factors that make for a safe COVID environment.

Much scientific study has gone into modeling of indoor environments for the spread of virus particles. The algorithms used are very complex and rely on an untold number of assumptions. In-Vivo virus distribution experiments have also been done with a variety of closed environments but they rely on extensive testing methods and are dangerous if using live virus. What is needed is a test that mimics the movement of viral aerosols, is easy to track, reproducible, and responds to the same forces that we know decrease virus transmission risk: diluting air movement, HEPA filtration and ventilation.

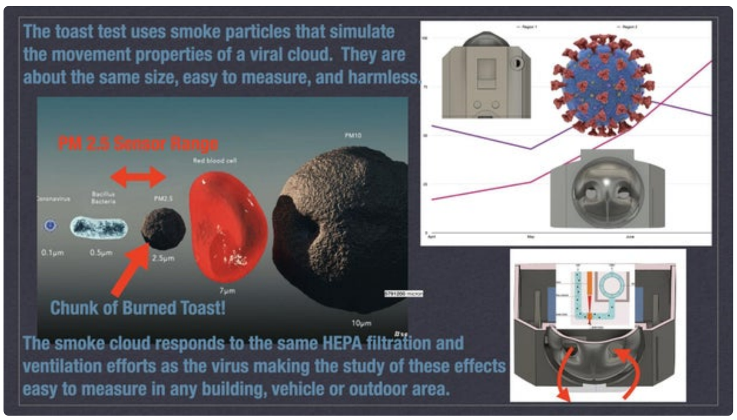
The Toast Test has nothing to do with the great news that Toast of London is now signed up for a new season. Rather it is an easily built, battery operated, unit that uses the virus simulating effects of a toaster smoke plume to follow the potential for COVID safety in inside environments.



Step 1: The Theory

Much recent work supports the concept that these coronaviruses behave like other respiratory viruses tending to spread in particles that are below 2.5 microns in size. Hacked particles from coughing that behave like missiles and hit the ground or evaporate quickly are eliminated by their large physical size do not predominate. A super spreader with a normal speaking voice can manufacture a floating cloud of 6000 particles in about 10 minutes. Symptomatic cough spreaders produce the chunks that do not go deeply into your lungs like the small floaters that dive toward your alveoli. It's rare these days to see a symptomatic cougher out in public.

Smoke particles from Burning Toast are about 2.5 microns in size. They are used frequently for the testing of the efficiency of HEPA filtration systems. (Wirecutter does their annual test of HEPPA filtration by lighting 4 matches for their smoke to fill a test room.) They behave like any particle in this size range--hanging for hours and blown about by fans, filters and out open window. The great thing about them and the basis of the toast test is that very cheap and accurate sensors exist for following their level and enable you to accurately count them without resorting to massive computer simulations or risking peoples lives by assaying live viruses.



Step 2: Gather Your Materials

The Toast Tester is a very simple build requiring only a PM2.5 sensor, Lipo battery, ESP32 microcontroller and power boost. The sensor I choose was nice as it displays values above 1000--many do not. Most of these PM2.5 sensors have been well studied for their accuracy and are good. All the components were carefully chosen for the bespoke case design printed in PLA.

1. PM2.5 Air Quality Sensor and Breadboard Adapter Kit - PMS5003 Adafruit $40

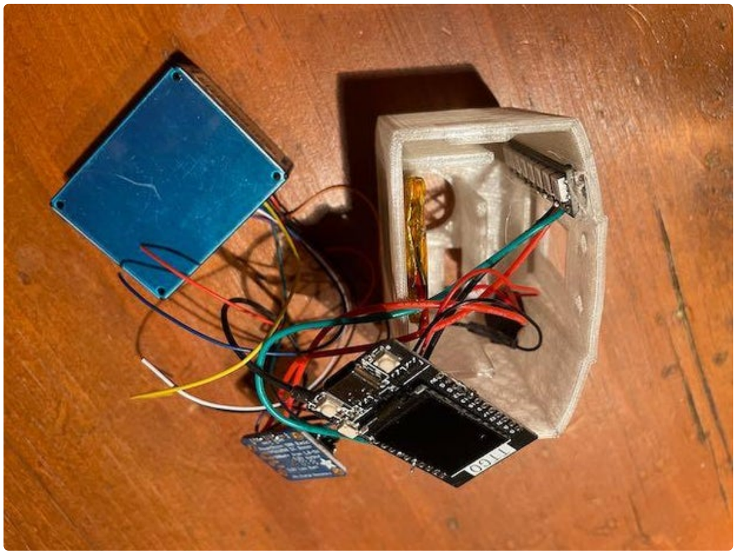
2. Lipo Battery 700 mah $4

3. TTGO T-Display ESP32 CP2104 WiFi bluetooth Module 1.14 Inch LCD Development Board $11

4. PowerBoost 1000 Charger - Rechargeable 5V Lipo USB Boost @ 1A - 1000C Adafruit $18 --but you can use generic for much cheaper

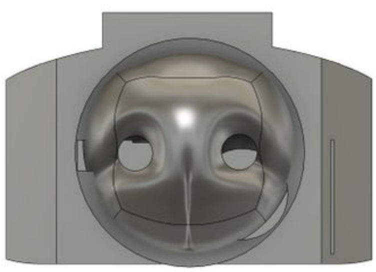
5. NeoPixel Stick - 8 x 5050 RGB LED with Integrated Drivers $6 Adafruit

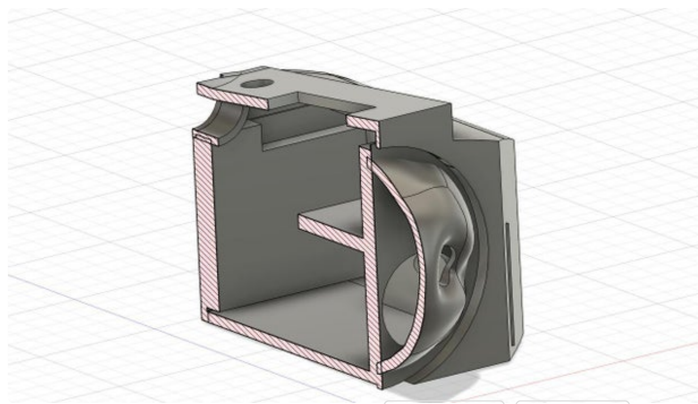
6. On-Off Power Button / Pushbutton Toggle Switch Adafruit $2



Step 3: 3D Printing

The body of the Toast Tester was made in three parts. All are printed in PLA without support. The back case is designed to snap into position. The front dog nose is glued on with superglue. Make sure you align up the nostrils with the input and output holes for the sensor as it samples the air through these holes.





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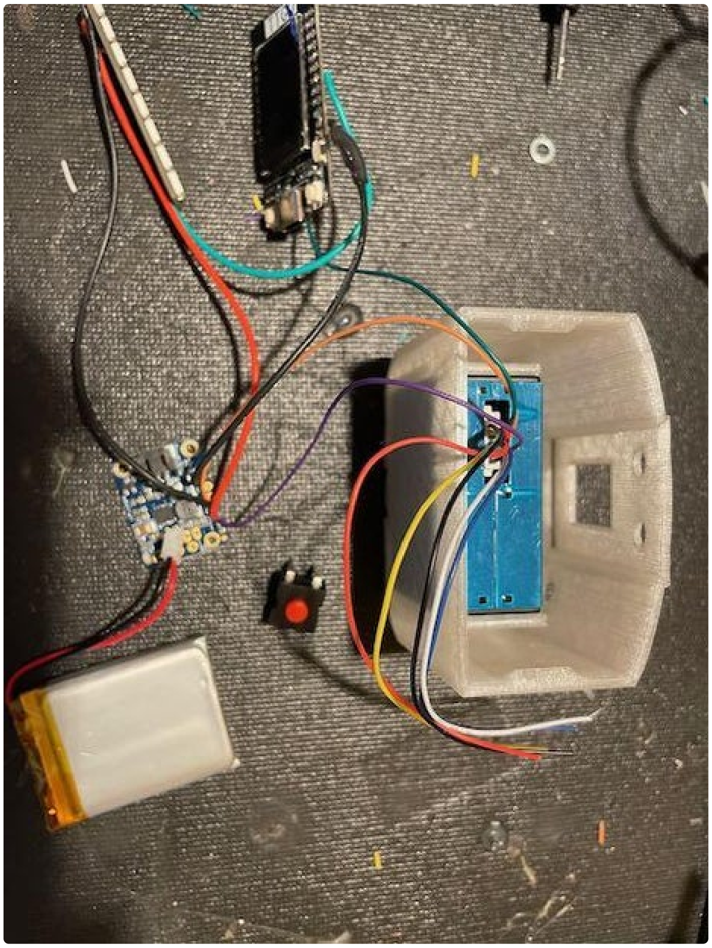
Step 4: Wiring It

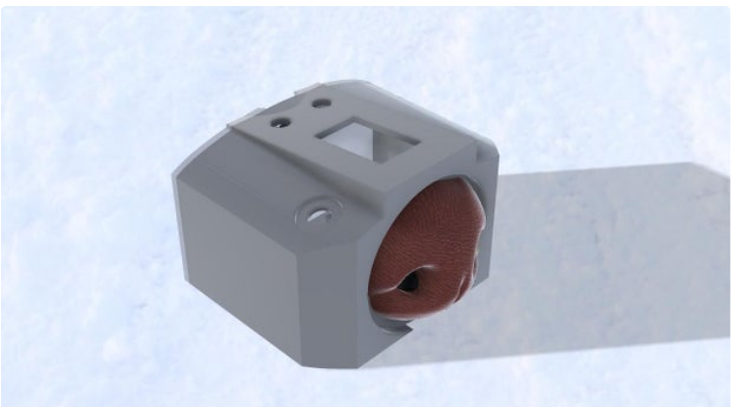
The wiring for this device is fairly easy. The sensor has RX, TX power and ground and when it comes from Adafruit there is a breakout board for the wiring that you can use--or you can cut it off if you examine where the wires are from. You do not need the Rx lead connected only the Tx because it is using serial communications and you don't really need to talk to the unit. Connect the Tx out from the sensor to pin 13 on the TTGo. Connect Gnd and power to the boost unit as you need 5 volts to run the sensor but the logic is 3 volts. Also power the Neopixel strip from the boost unit as this requires 5 volts too. The Lipo battery is connected through the ON/OFF switch to the TTGo board as it also supplies charging to the battery when plugged in at the back of the unit. The data line for the Neopixels comes from pin 33 on the TTGo. The buttons on the TTGo are internally connected as well as the color screen so that is it for the wiring.



Step 5: Program It

At the heart of the software is the program and library from Adafruit for examining the data from the PM25AQI sensor library. It reads a serial data stream with lots of information in the particle breakdown from the sensor as soon as power is applied. The software additions are the Blynk library and timers for uploading the data to a Blynk app, tuning the Neopixel array for the level of PM2.5 and the large number of computations for the built-in output screen on the TTGo.

In the setup the program initializes the serial and the serial1 ports and sets the input pin from the sensor. The Blynk timer is initialized for 5 seconds for reporting intervals to the internet through the WiFi connection. Make sure you input your credentials for your network and Password. You also have to set up a Blynk account with authentication code for Blynk to grab the data. The screen is initialized and the serial port is checked for its connection to the sensor. The logo for the Toast Test is set up on the home screen. The Neopixel group is initialized to off. In the main section of the program the PM2.5 level is checked repeatedly until it rises above 1000. This starts the test and the timers in the program to determine how fast and at what rate the level of particles rise and fall. All of this information is put out on a series of bar graphs and the data is sent off over Wifi to the Blynk app for graphing.

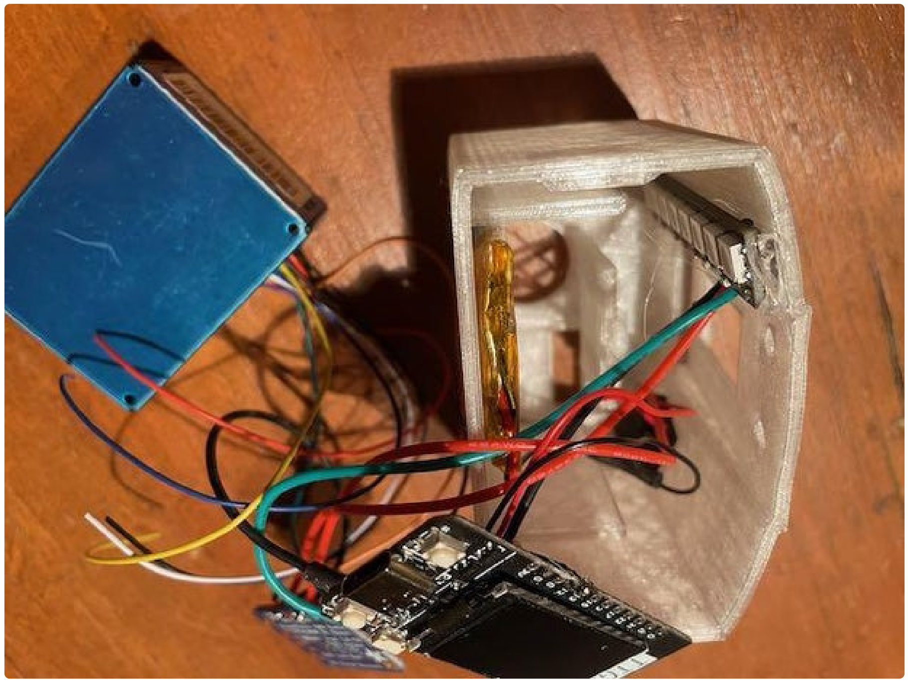


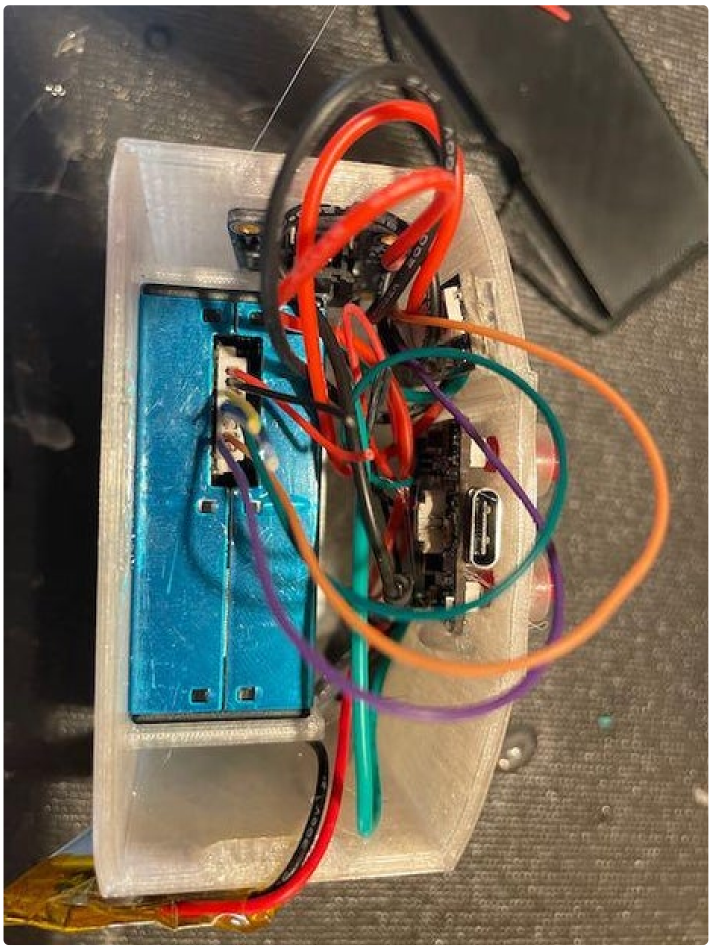
Download

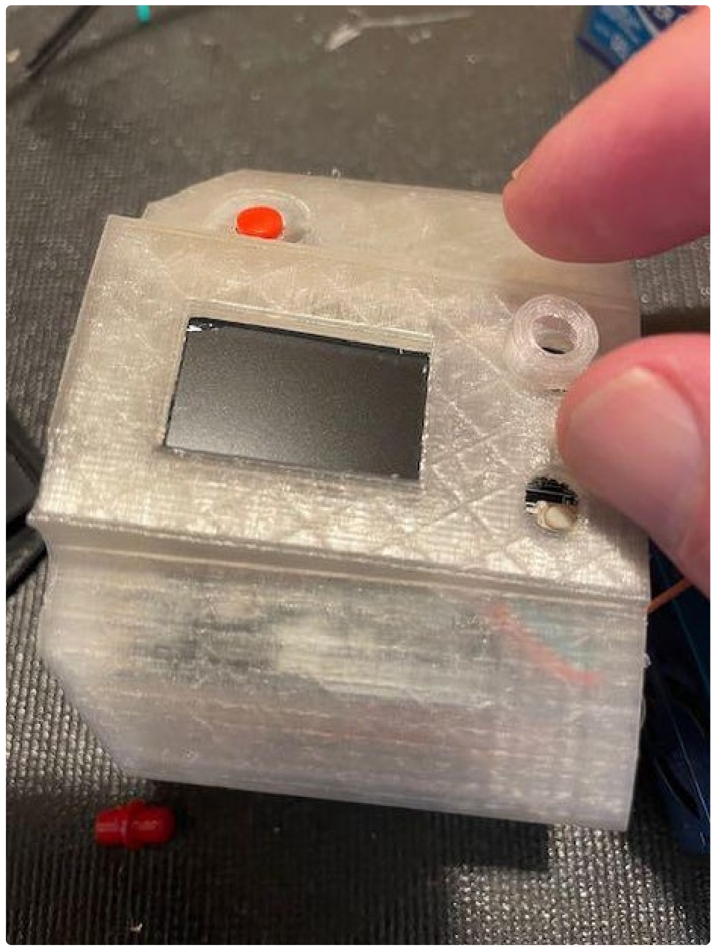
https://www.instructables.com/ORIG/FWV/OI5H/KNLR56E4/FWVOI5HKNLR56E4.ino

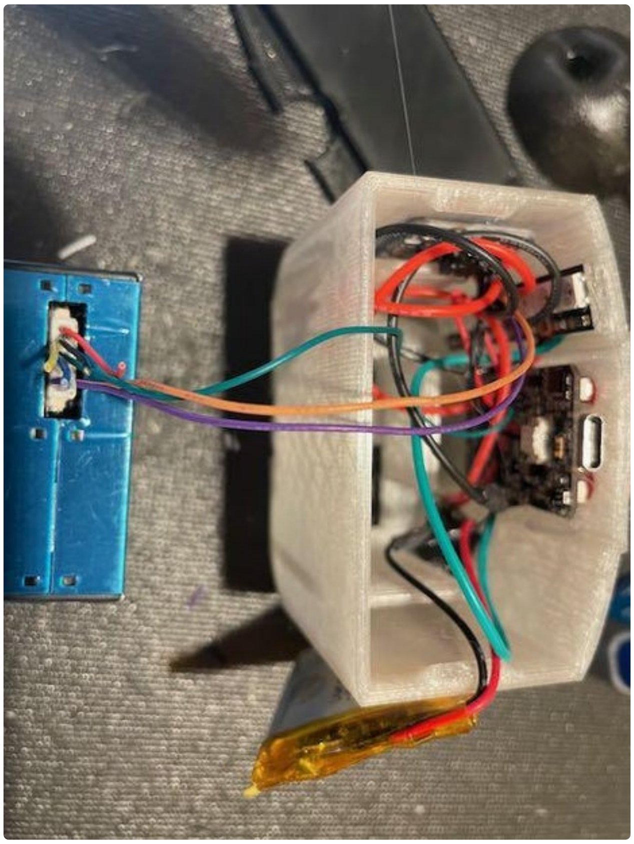
Step 6: Build It

The unit is very easy to build after wiring it. The first to go in is the Neopixel strip which is E6000 glued to the roof of the unit with the Neopixels pointing inward. The base unit has been 3D printed to house the TTGo unit in just the correct position to place the screen and the buttons in the correct position. Add some glue near the antenna base to hold the computer unit in a solid position. The boost unit is glued to the side of the base unit as shown in the photos. The separate buttons and their collars are superglued to the case as shown. The on/off switch is mounted in its hole and superglued in. Finally the battery and the large sensor are fitted into position. The sensor input and output holes are fixed to their respective openings in the case. The back cover clicks into position allowing for the charging opening at the top. The last step is gluing in the dog nose with E6000.







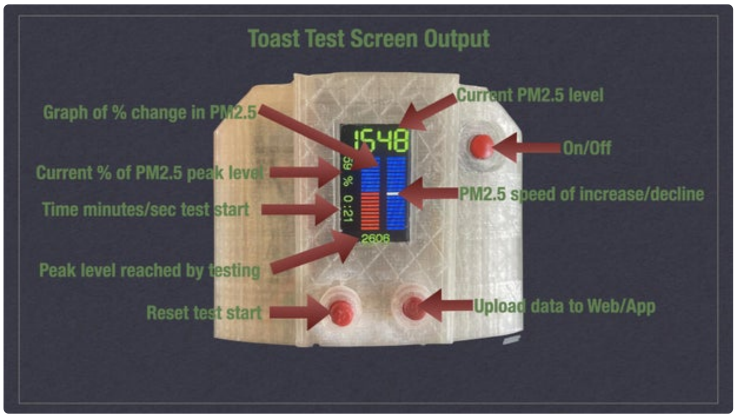


Step 7: The Toast Test

The Toast Test is very simple to run. The enclosed space for assessment of COVID risk is checked to maximize the the ability to clear aerosols. Windows are opened, fans activated, HEPA filtration on maximum. A standard toaster has two pieces of bread inserted into one slot to maximize toast thickness. All fire alarms in the test volume are overridden, sealed off or removed. Place the toast tester adjacent to the toaster. The toast tester unit is activated and the "Toast Test" toaster logo appears. The "insert toast" logo appears. The toaster is turned to maximum and the toast is depressed. When thin trails of smoke appear out of the toaster watch the screen and when the bar graphs appear the Toast Test is initiated and the toaster can be turned off. This means that the sensor has detected levels over 1000 ug/M3 and will initiate timer and data transmission. The lower button on the left resets the unit in case another test need to be done.

The output screen provides information on the test as it proceeds. The upper number is the current PM2.5 level. The right bar graph indicates if the level is rising or falling and how fast by the color and how far off the neutral point the level is. The bar graph on the left indicates % change in level from the initial high mark. The small number at the bottom is the maximum level of PM2.5 reached during the start of the test. The numbers to the left are the % of high in the current reading and the time in minutes and seconds since the start of the test. The test ends when there is a 80% reduction in the PM2.5 level.

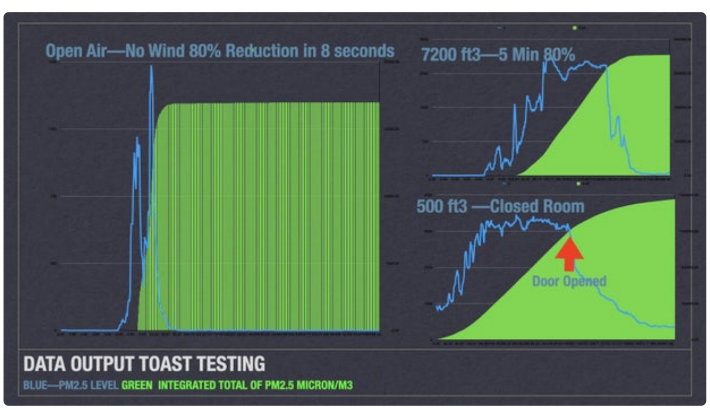
https://youtu.be/3uy6ISAVOBU

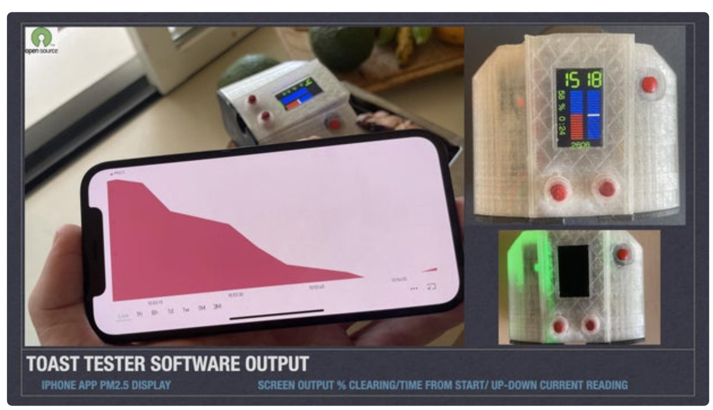


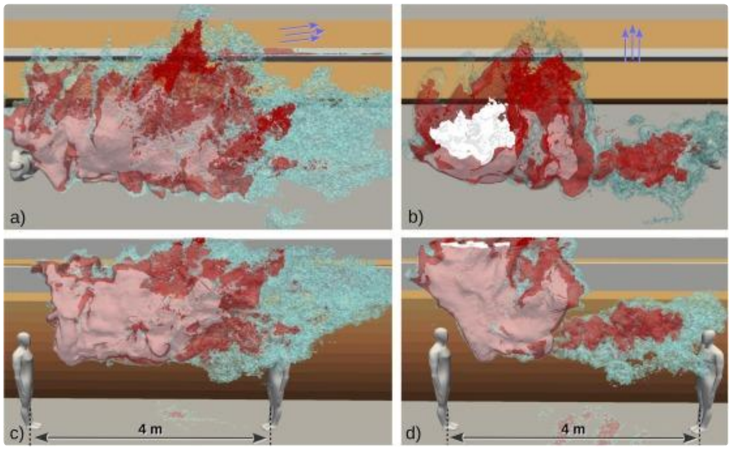
Step 8: The Output

I have done limited testing with the Toast Tester over the last month. Three representative graphs from the data are presented above. The blue is the level of PM2.5 in ug/M3 over time and the light green is the integral (or sum) of the level over time. It becomes obvious when testing in open air why the incidence of human to human transmission outside is nonexistent. The graph on the left is a Toast Test on a still day outside. The Toast Tester rises to a test initiating maximum and then falls 80% within 8 seconds. There is basically no retention of virus in a cloud like formation outdoors. The bottom right graph is Toast Testing within a 500 ft3 room. After initiating a high test level the level plateaus out and remains unchanged for 15 minutes until a door is opened whereby the level immediately falls. This demonstrates the ability of the test to recognize and document stagnation where the virus cloud will stay perpetually. The third graph--upper right demonstrates the test in a 7500 ft3 room with open windows and ceiling fans. The initial high level gradually diminishes to 20% within 5 minutes. This would characterize a "normal" test where levels of transition from high to low can be characterized by the time it takes the test to normalize. My initial experience with HEPA filtration with the Toast Test indicated that with home units placed on high you got slow but steady decline that was completely overshadowed by opening one window.

The EPA in their judging of a competition for indoor HEPA filtration units considers diminishment of 80% of a PM2.5 cloud to be significant so we used this benchmark in our Toast Test. Toast Test units are easily networked together using Bluetooth or Wifi to add additional 3D modeling capabilities to show how the infectious cloud dissipates within an enclosure. The Toast Test attempts to answer the question--how safe am I in this enclosed space if a source of infectious virus enters the room.



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