COVID-19 Task Force: Aerosols and Ventilation

Linden Schrage

Abstract:

Growing bodies of research indicate that SARS-CoV-2 is transmitted through aerosols and that the spread of these particles can be effectively reduced through the use of air filtration and ventilation. Our research applies these findings to a residential collegiate setting.

A preliminary study was conducted to investigate the aerosol removal efficacy of HEPA purifiers in thirteen different on-campus Harvard College dormitory bedrooms and common rooms in nine different dormitories. These initial experiments revealed that the use of HEPA filters in dorm rooms was effective in reducing the amount of aerosol spread. Expanding on these results, the different filtration systems were examined in thirteen different Harvard settings under varying conditions with the ultimate goals of exploring how larger, more varied rooms handle aerosols over time and determining which spaces are safer for occupancy.

Motivation and Goal:

Recent scholarship has implicated aerosols as one transmission path for the spread of the Covid-19 virus and has established air filtration and ventilation as an essential mitigation technique. However, little research has examined air filtration in a residential collegiate setting and, in particular, the use and efficacy of these purifiers at Harvard College. Informal reports from the students enrolled this semester on campus at Harvard College reported a high level of desire for additional opportunities to safely interact with other students for both social and academic reasons. It was expressed that the lack of safe and supported opportunities for social interaction was driving students to participate in unregulated and unsafe social settings. This behavior could be reduced if a set of safer options was presented to students, especially as the previous option of outside interaction has been eliminated as the weather grows colder.

To address this concern, a series of measurements of particulate dispersal and air handling were conducted across the college campus to analyze the behavior of a subset of available rooms, and to preliminarily determine what characteristics may make for a safe room to reopen for use by students on campus in the spring semester. Rooms were selected based on student desire for access, varied geometry and configuration, accessibility for measurement, and overall usefulness to the residential educational experience.

Data Collection and Methods

The TS1 Model 8026 Particle Generator and the Model 9303 Aerotrak Particle Counter were used to conduct aerosol handling measurements in various locations. The particle generator aerosolized a NaCl solution and then deposited those particles into the air to build up the particle room concentration, while the particle counter used a laser and an isokinetic inlet to measure the particle density of the given space. These generated particles served as a proxy for particles naturally created by people from activities such as talking. A standard procedure was used in every room. The counter was placed 6 feet away from the generator along the longest dimension of the room. The generator was set to maximum strength and the counter had these settings: 96 cycle count, 5 second hold time, and 20 second sample time. The only experiments that deviated from this standard were the second Field Hockey trial and the Farnsworth reading room where the cycle count was 40 and sample time was 60 seconds due to limited storage space on the particle counter. All experiments ran for 40 minutes. After 20 minutes into the measurement, the generator was turned off and, when applicable, the HEPA filter was turned on for the remaining 20 minutes. Honeywell HEPA filters were set to the “germ” setting and Dyson HEPA filters were set to setting 5. The HEPA filters were placed in locations considered normal for that particular room, such as against the wall near the outlet, to simulate where the HEPA filter may be placed if

that room were in use. A total of 25 rooms with diverse geometries were tested, such as locker rooms, library study rooms, common areas, gyms, and classrooms. People were not to enter or exit the rooms during testing, so the student stayed inside the room throughout the experiment so they could be present to turn the generator off after 20 minutes.

Overall Data

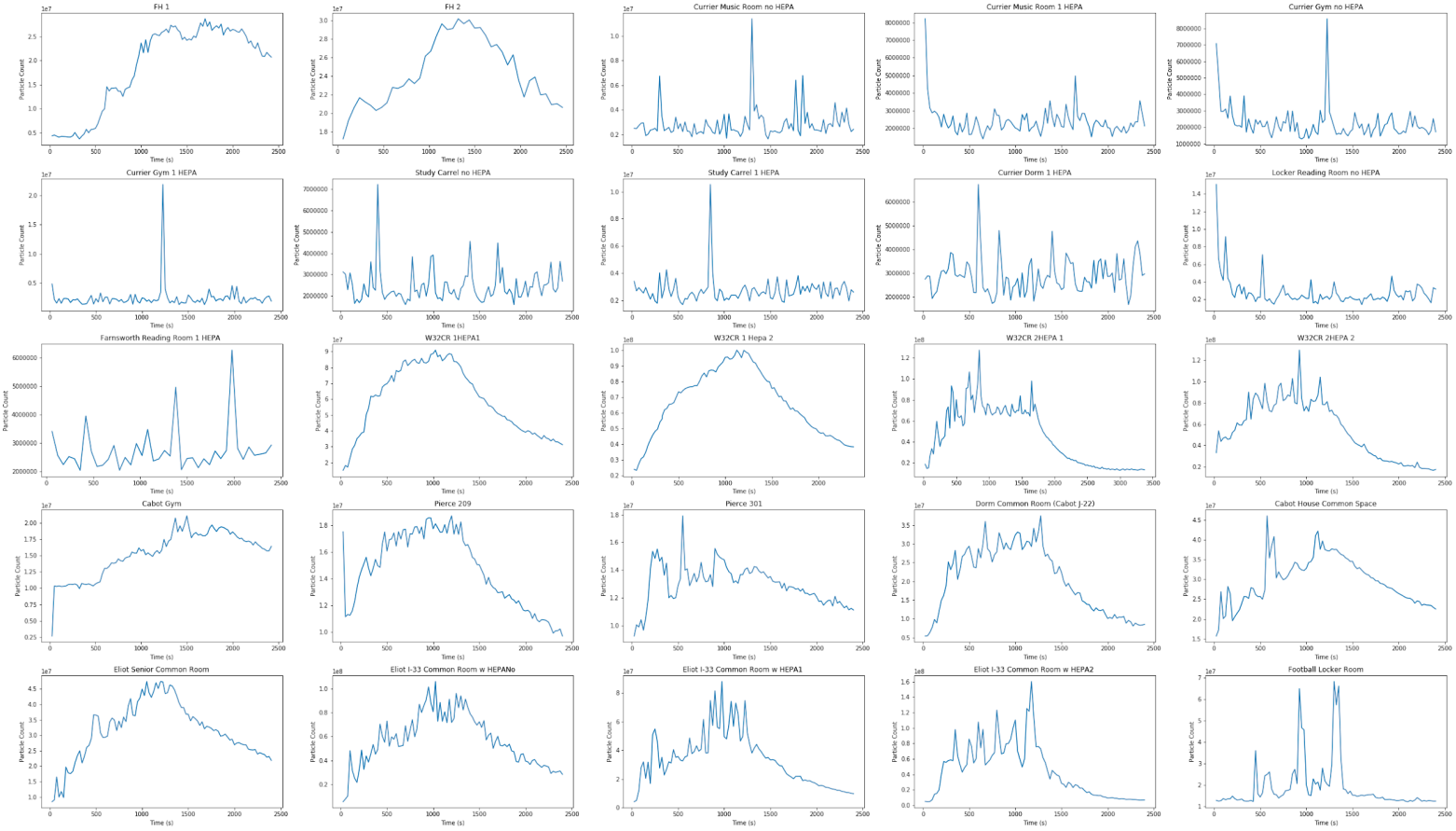

Figure 1: All data plots from particulate experiments.

Twenty five trials were conducted in thirteen rooms across the Harvard campus. A list of tested sites is provided in the appendices, and is labeled on the plots above. These sites were selected to represent a wide variety of room types and sizes in the spaces accessible for testing. Consideration was also made to analyze spaces that are most valuable to the student educational

experience in college, with spaces such as library rooms, locker rooms, and practice rooms explored as possible candidates for reopening. Classrooms were tested as possible candidates for group study spaces due to lack of in-person classes in those spaces.

Analysis

Twenty five data plots were generated from the data gathered from spaces across campus. After analyzing the curves of each graph, certain trends were observed. Generally, larger spaces such as the Currier gym and Football locker room did not show a clear rise and fall of particle count, whereas smaller spaces such as classrooms or dorm common rooms did. This difference is depicted Figure 2 below. A likely explanation for this different behavior based on room size is that the particle generator was unable to generate sufficient particles to saturate the space's larger volume of air. Larger rooms also often have higher levels of air handling, further reducing both the rate of increase and total level of airborne particulates seen. This has positive implications for the safety of larger rooms, especially with increased ventilation and other interventions such as masks, as it reduces the overall risk of virus transmission by lowering the likelihood of receiving a critical dose of viral particles through air transmission.

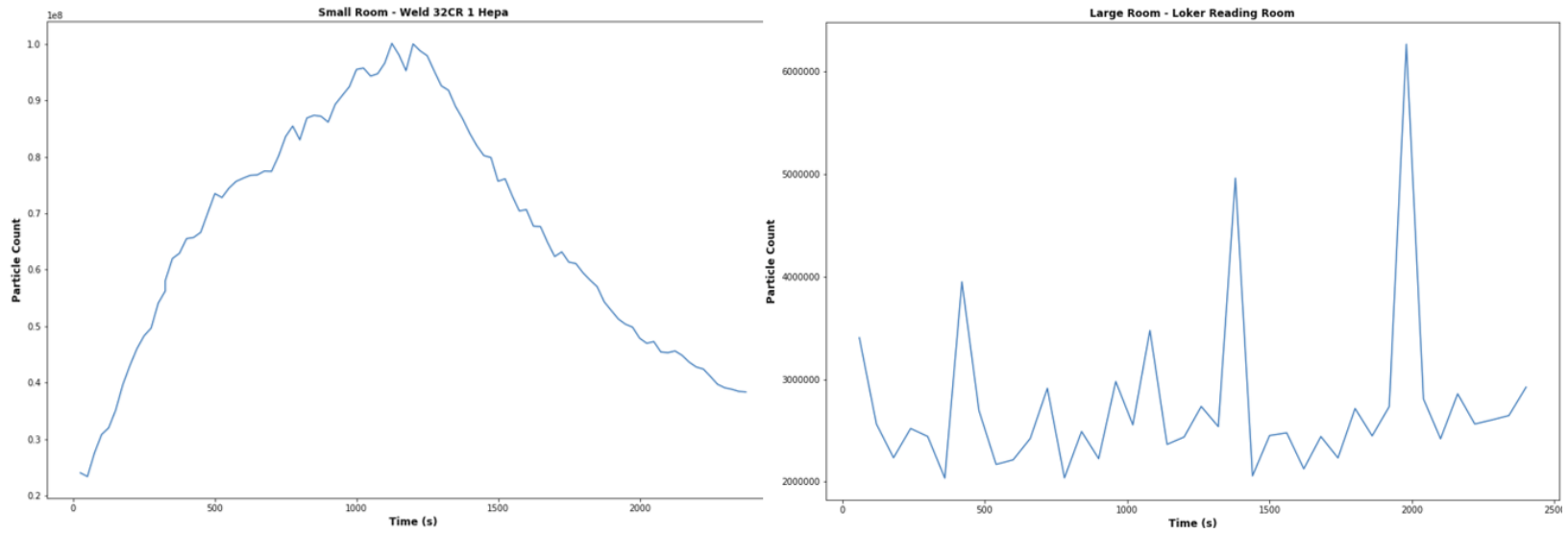

Figure 2. Comparison of Particulate Levels vs Time in a Small and Large Room

Another trend observed was the amount of ventilation (ie. open windows, natural building ventilation) having a significant impact on the peak of aerosol concentration and the rate of exponential decay after the particle generator is turned off, which is shown between the measurements for Pierce 209 and Pierce 301 in Figure 3. Pierce 301 is significantly larger in overall volume than Pierce 209, and on the testing date had several more windows open to increase ventilation. In Pierce 209 a clear build up and threshold of particulate levels can be seen, whereas in Pierce 301 it is much less significant. Surprisingly, Pierce 301 had a slower rate of particulate removal despite having significantly more ventilation available. Additionally the overall level of particles observed in both is similar, however the lower impact of the particle generator on 301 is clear. Thus it may be surmised that the base level of particles is not coming from the generator itself, but from the outside air or other sources.

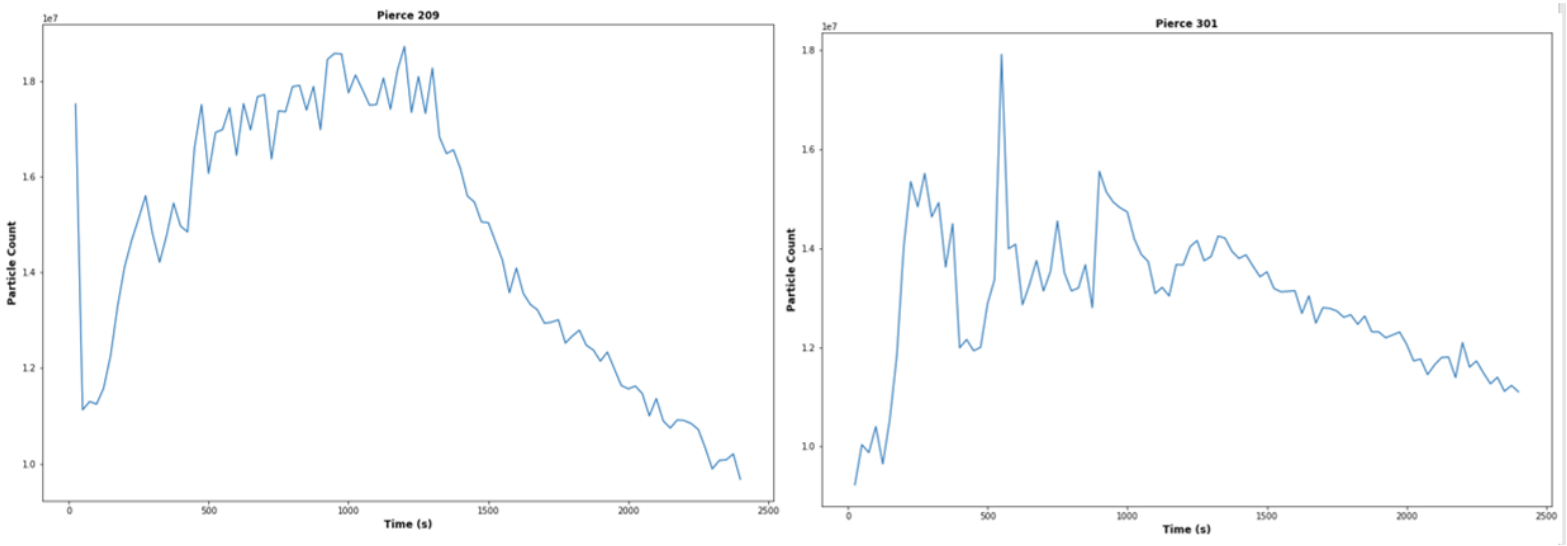

Figure 3. Pierce 209 and Pierce 301 Particulate Count vs Time

There were some unexpected spikes in particulate count reported in some rooms, which could be due to the person quickly approaching the particle counter or accidentally standing in front of the counter's laser when turning the generator off. The spikes may also be due to gusts of wind in rooms with open windows or gusty air conditioning units. These spikes are particularly clear in the larger rooms such as the Currier Gym in Figure 4 below, but were also seen in smaller rooms with active ventilation such as the Music Practice Room discussessed in the following paragraph. These spikes were observed in the data collected from 9 total experiments across 5 rooms, and were recorded on separate particle counters of identical make, model, and settings by different operators.

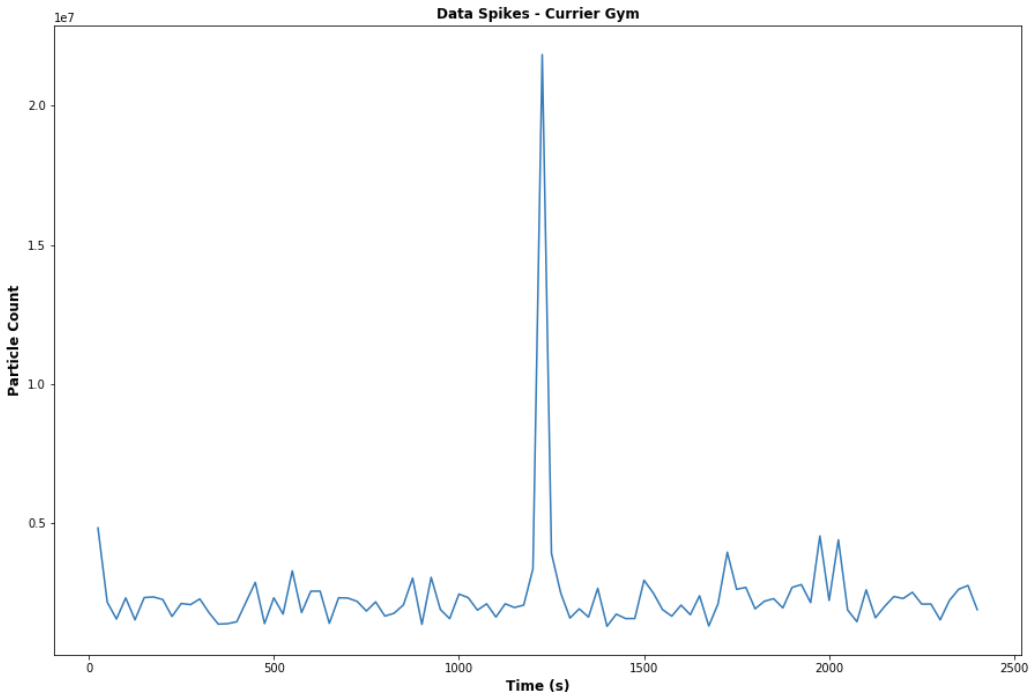

Figure 4. Spikes in Particulate Data Collected.

Another unexpected finding was the measurements conducted in the Currier Gilbert Music Room. Despite its small size, the room was unable to build up a significant particle concentration like other small rooms did, as shown in Figure 6. This room was uniquely padded with soundproofing material, so the particles could have stuck to this material and subsequently prevented an increase in aerosol concentration that would normally be anticipated for a room of this size. Additionally, as depicted in Figure 5 below, the room had an air vent that was active during the measurement time.

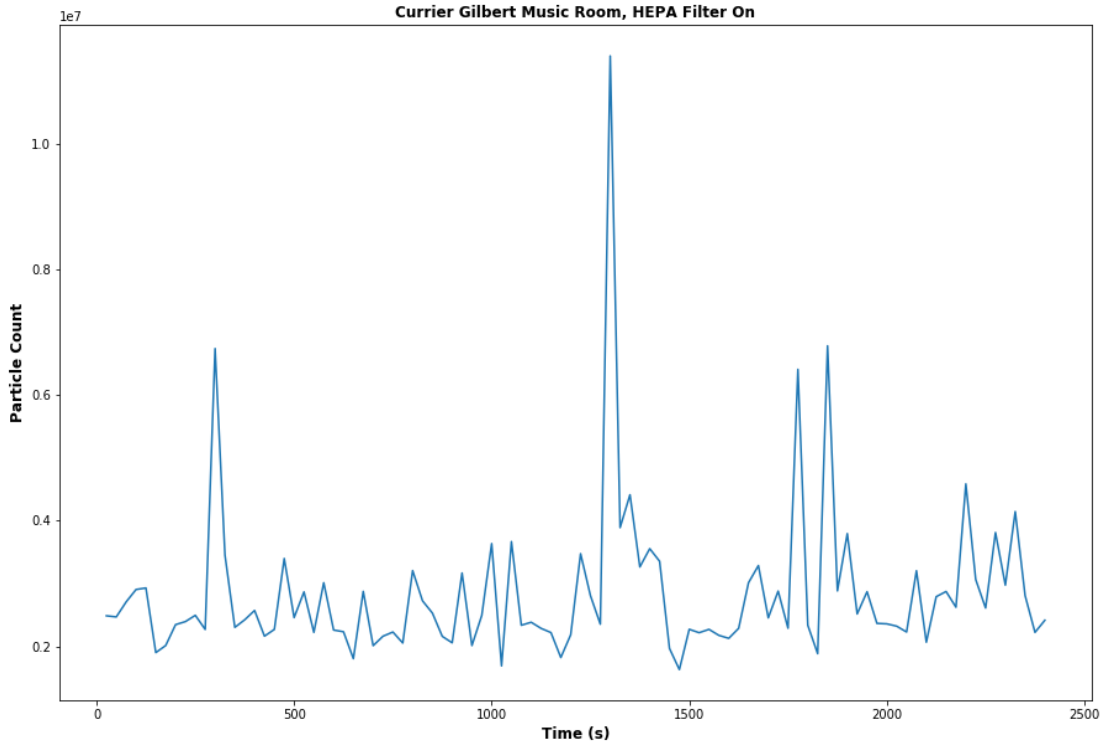

Figure 6. Particle Trend in Currier Gilbert Music Room

Recommendations:

When considering its reopening plan, we recommend Harvard opens larger rooms first, to help ensure the safety of the students. In addition to the size of the room, increasing the ventilation within the room by opening windows, doors, or placing HEPA filters in rooms would decrease the risk of aerosolized particle transmission. We do not recommend that these be the only precautions taken, but in conjunction with mask wearing and social distancing, increasing room ventilation would increase the safety of students. With this preliminary data, it appears that padded walls limit the spread of aerosolized particles as seen in the inability to increase particle concentration in the music room despite its small volume. This could be an addition to some smaller rooms to account for the minimal ventilation. We also recommend the University continue its testing and monitoring of aerosol spread throughout the campus.