Transit Airflow Verification Studies

TCRP Insight Event – Air Quality in Transit Buses

Nathan Edwards

nedwards@mitre.org

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MITRE | SOLVING PROBLEMS FOR A SAFER WORLD

Airborne Risk & Airflow Studies

Verification & quantitative measurement describe how systems actually perform

Some research on spread of infection (not airflow)

Some research on theoretical airflow models and/or simulation

Many guidelines based on best practices (but have not been verified)

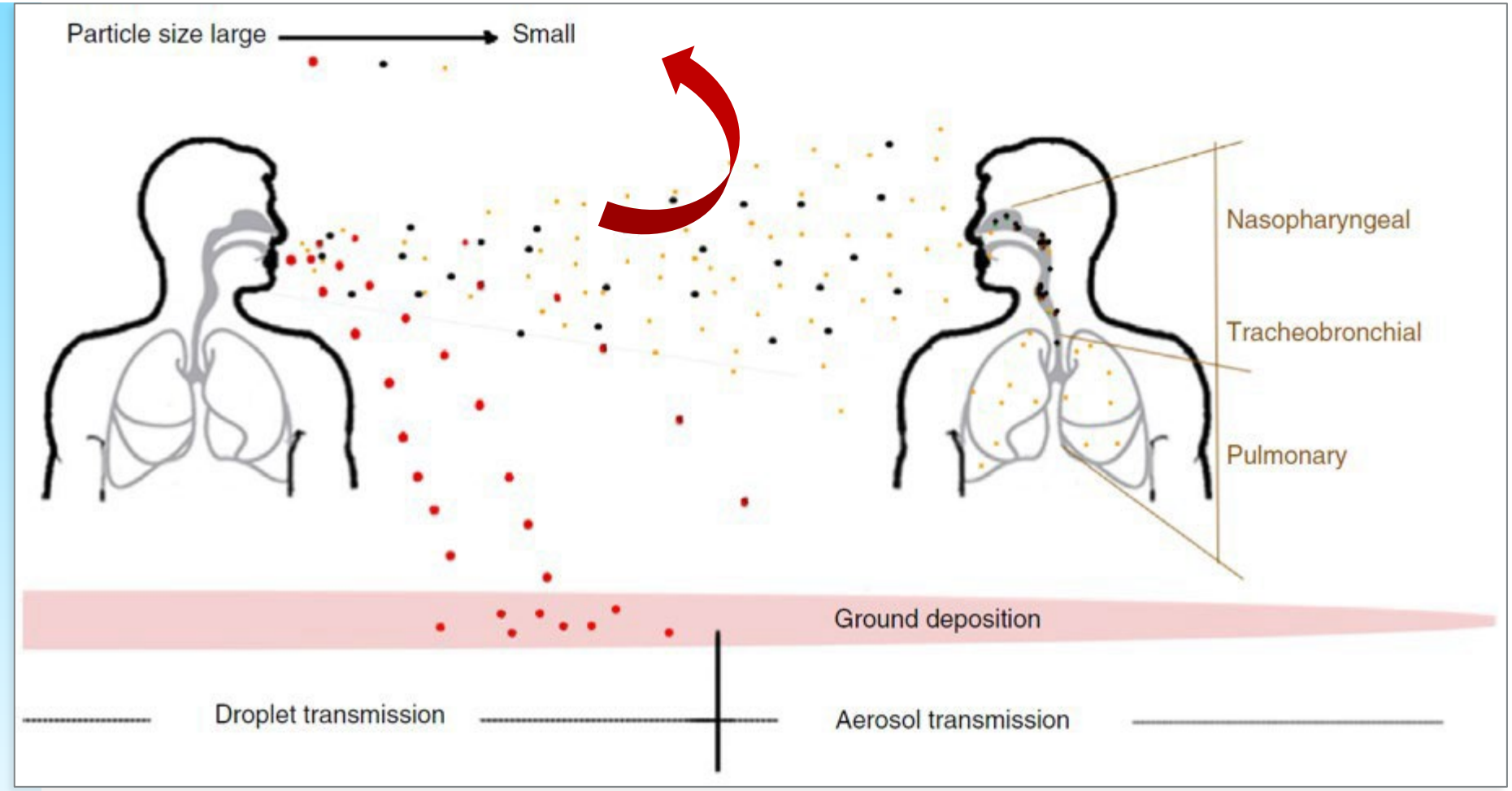
Only a few have conducted field studies

Framing the Problem: Airborne Transmission & Misnomers

Social Distancing only **applies to droplets**

Debate on **aerosol transmission**

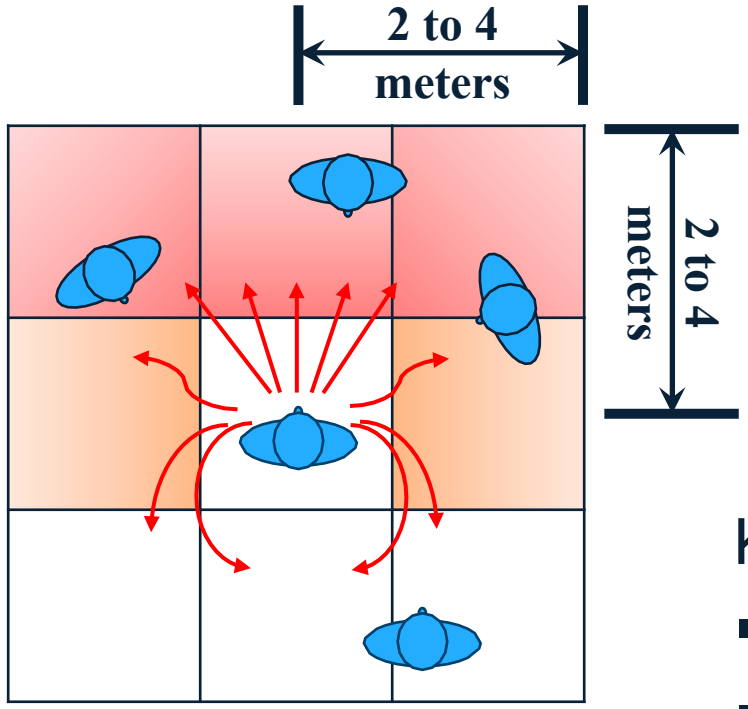
How do we disrupt the **chain of transmission?**



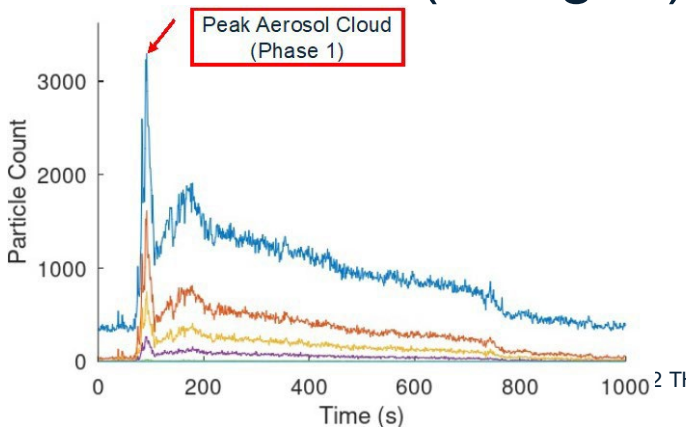
Pan M, Lednicky JA, Wu C-Y. Collection, particle sizing and detection of airborne viruses. Journal of Applied Microbiology. 2019;127:1596–611.

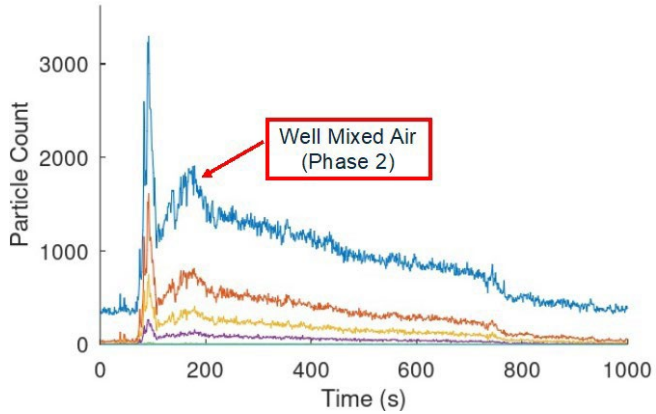
N. Edwards (MITRE)

Aerosol Model for Close Contact & Nearby



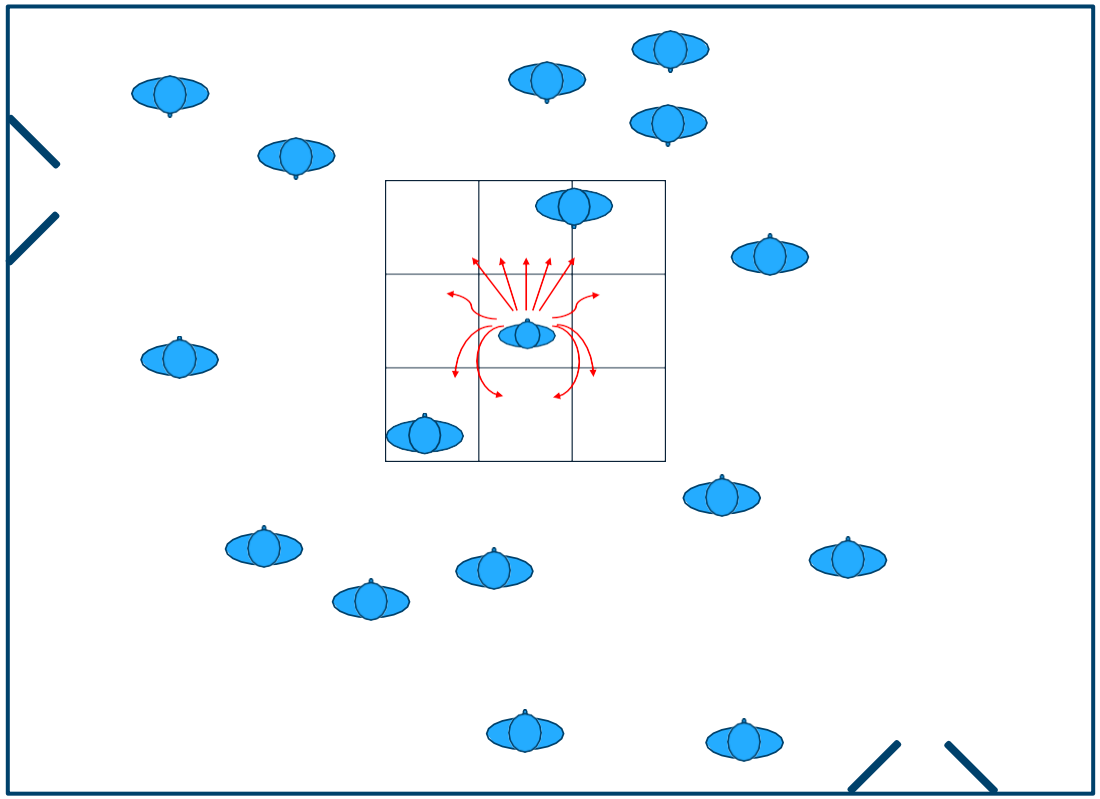
Close Contact (3x3 grid)





Key Factors:

- Air volume
- Population density
- Airflow & ventilation
- Masks
- Air filtration



Nearby
(within same room or airflow)

Low Floor Buses, “Dust Intrusion”, Leading Edge Suction

Image from FTA-2021-0011-0037_attachment_1.pdf

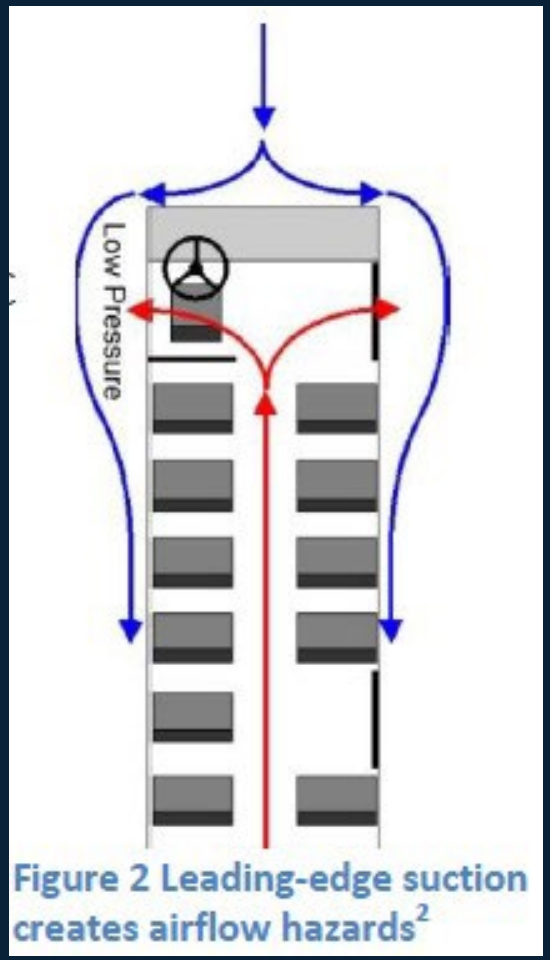
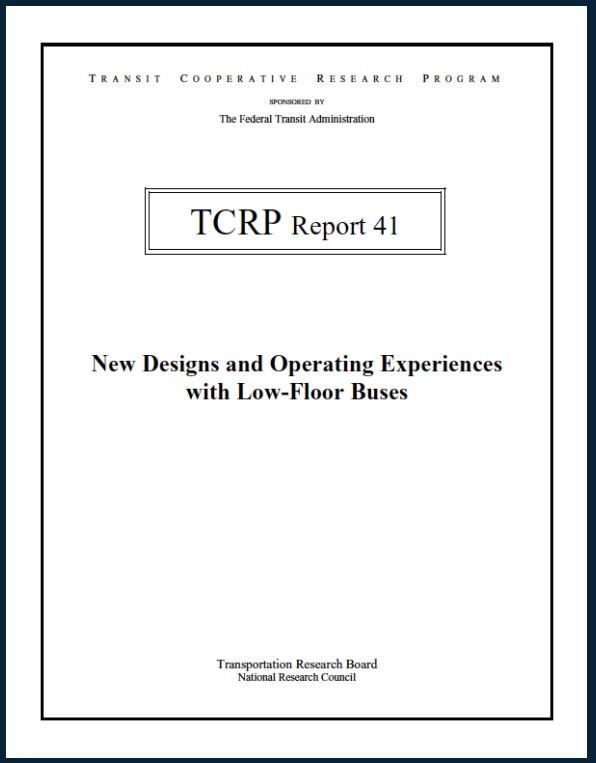


Figure 2 Leading-edge suction creates airflow hazards[2]

- Operators noted dust and exhaust fumes of new bus designs
- 1998 test – smoke bomb placed in upper right corner of rear mounted AC (external)
- No intrusion at slow speeds
- 20 mph - smoke passed through the rear bulkhead and migrated forward to driver area
- System-level bus design matters for clean air


TRANSIT COOPERATIVE RESEARCH PROGRAM

SPONSORED BY

The Federal Transit Administration

TCRP Report 41

New Designs and Operating Experiences with Low-Floor Buses

Transportation Research Board
National Research Council

King, Rolland D. *New Designs and Operating Experiences with Low-Floor Buses*. TRB’s Transit Cooperative Research Program (TCRP); 1998. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1071

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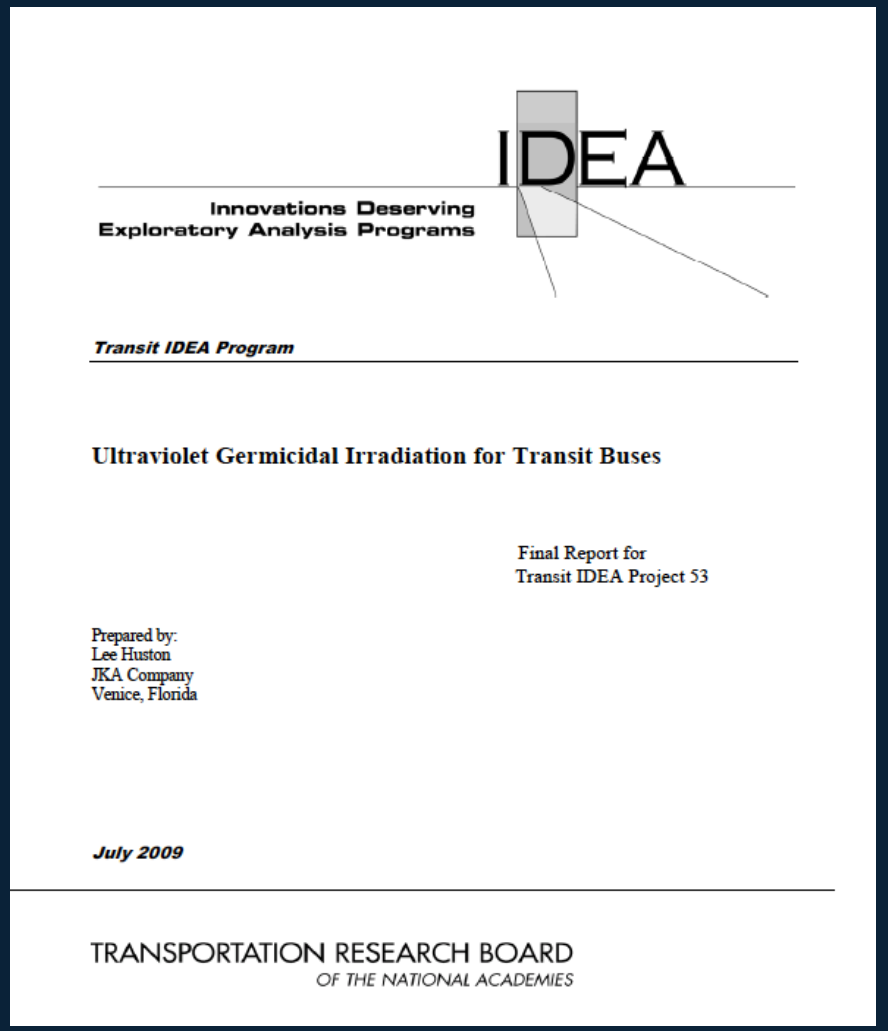
TCRP J-04/IDEA 53: Ultraviolet Germicidal Irradiation for Transit Buses (2009)

- Airflow studies to determine effectiveness of UVGI
- 14 buses tested
- Airflow tests at 9 locations within HVAC
- Biofilms buildup reduced airflow
- Clogging of evaporator with cheap air filters
- UVGI improved airflow 31%, 24%, 23% on respective bus series
- Air filters are critical part of HVAC system


IDEA
Innovations Deserving Exploratory Analysis Programs

Transit IDEA Program

Ultraviolet Germicidal Irradiation for Transit Buses

Final Report for
Transit IDEA Project 53

Prepared by:
Lee Huston
JKA Company
Venice, Florida

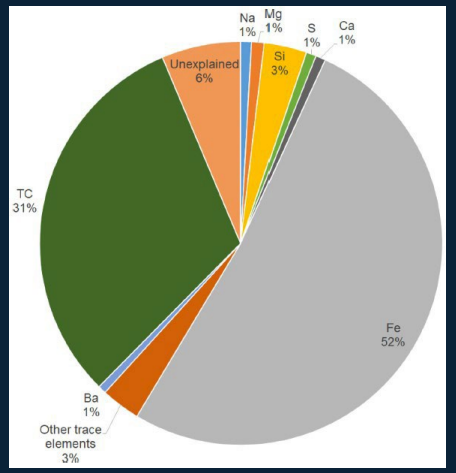
July 2009

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Huston L. *TCRP Transit IDEA J-04/IDEA 53: Ultraviolet Germicidal Irradiation for Transit Buses*. National Academies Transportation Research Board; 2009. Accessed December 29, 2020. https://www.trbtss.org/?p=2131

PM2.5 Concentration & Composition in Subway Systems in the Northeastern United States (2015 and 2019 data)

- PM2.5 particle data at 4 metro subway systems in Boston, NYC/NJ, Philadelphia, and Washington DC
- 292 locations and 337 samples:
    - Underground, Above ground, On-train, Ambient
- Analyzed particle types at 13 underground subway stations in Boston, NYC/NJ, and Washington DC
- Underground stations 10 to 37 times worse than above ground (mean to mean).
- On-train significantly reduced PM2.5 exposure, 37% up to 87% reductions (mean to mean)



Luglio David G., Katsigeorgis Maria, Hess Jade, et al. PM2.5 Concentration and Composition in Subway Systems in the Northeastern United States. *Environmental Health Perspectives*. 129(2):027001. Feb 2021. doi:10.1289/EHP7202

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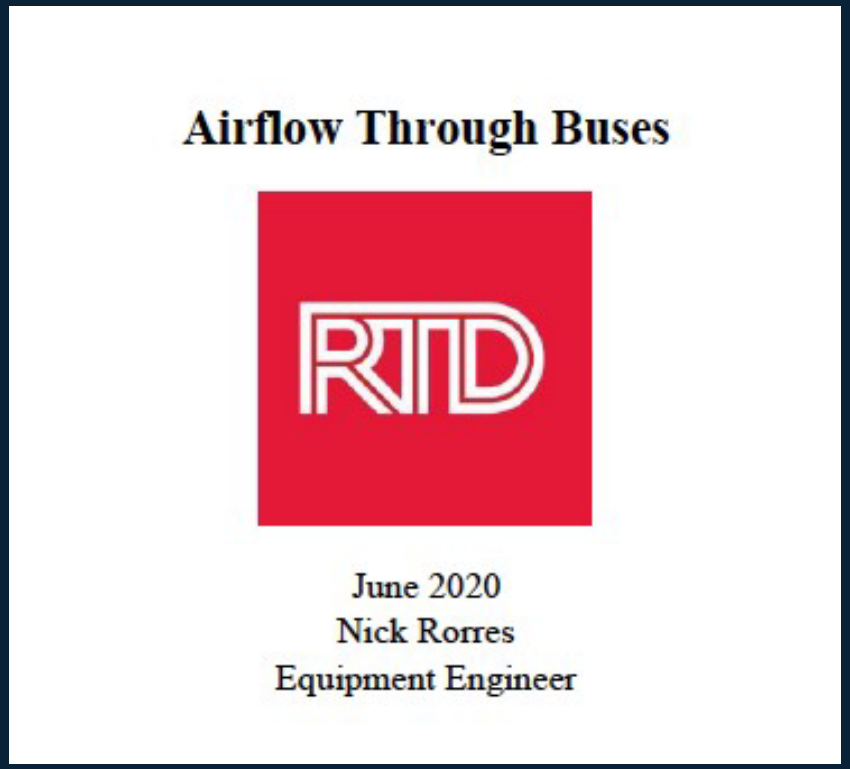
RTD Airflow Through Buses

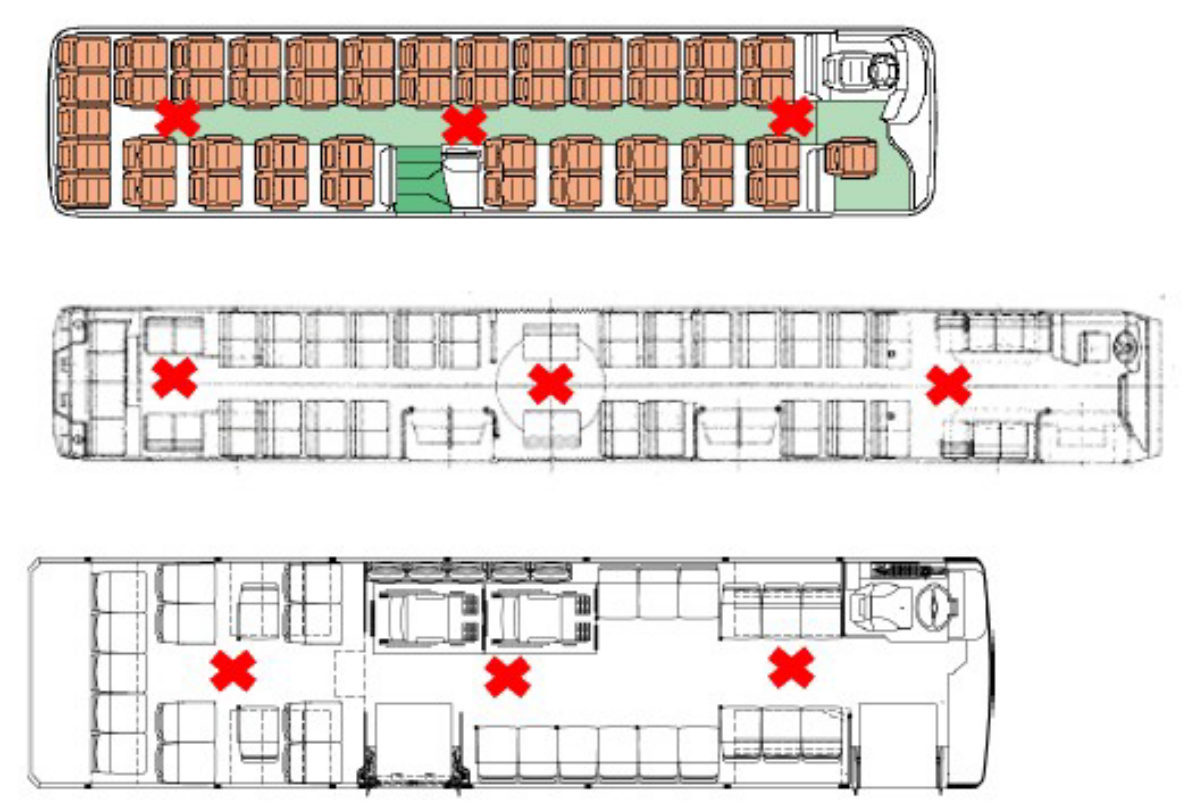
- Intercity, transit and articulated bus
- Each driven at 15, 30, 50 mph East & West
- Windows closed, hatches only open, front windows, all windows & hatches
- Measurement at approx. 5 foot above floor
- Averaged airflows from 3 sensors

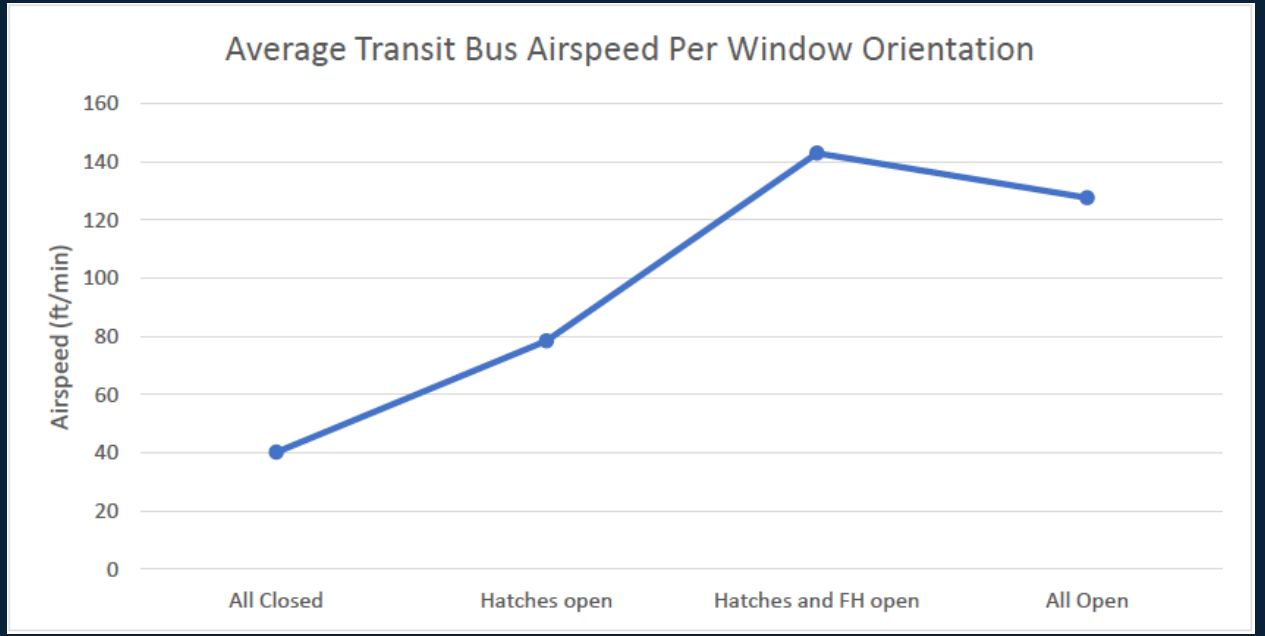


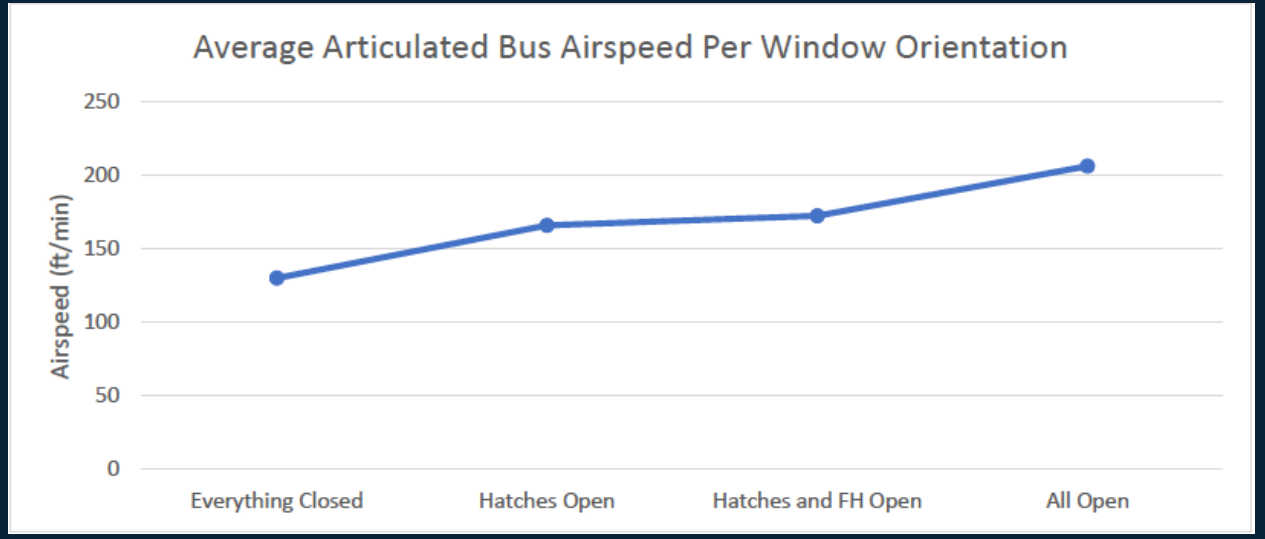
RTD. Is the air moving on RTD's buses? Yes – perhaps more than you think. RTD - Denver. Published October 29, 2020. Accessed December 14, 2020. https://www.rtd-denver.com/news-stop/news/air-moving-through-rtd-buses

Rorres N. *Airflow Through Buses*. Regional Transportation District (RTD); 2020. https://www.rtd-denver.com/sites/default/files/files/2020-10/Airflow%20Through%20Buses.pdf

RTD Airflow Through Buses

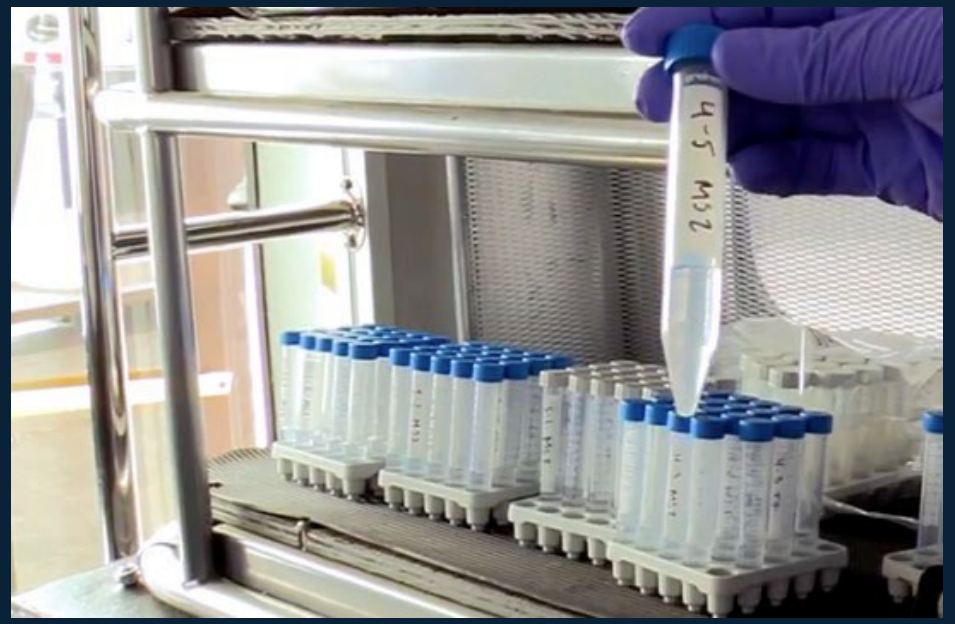






Fresno State Univ – Transportation Institute

- Three different bacteriophages, Phi6, MS2 and T7 released into air (spray)
- Collection plates throughout
- Mitigation tests on 5 buses:
  - Photocatalytic oxidation inserts:
  - UV-C light
  - Positive pressure environment
  - Copper tape and fabric
- Also tested with colored smoke, steam, CFD



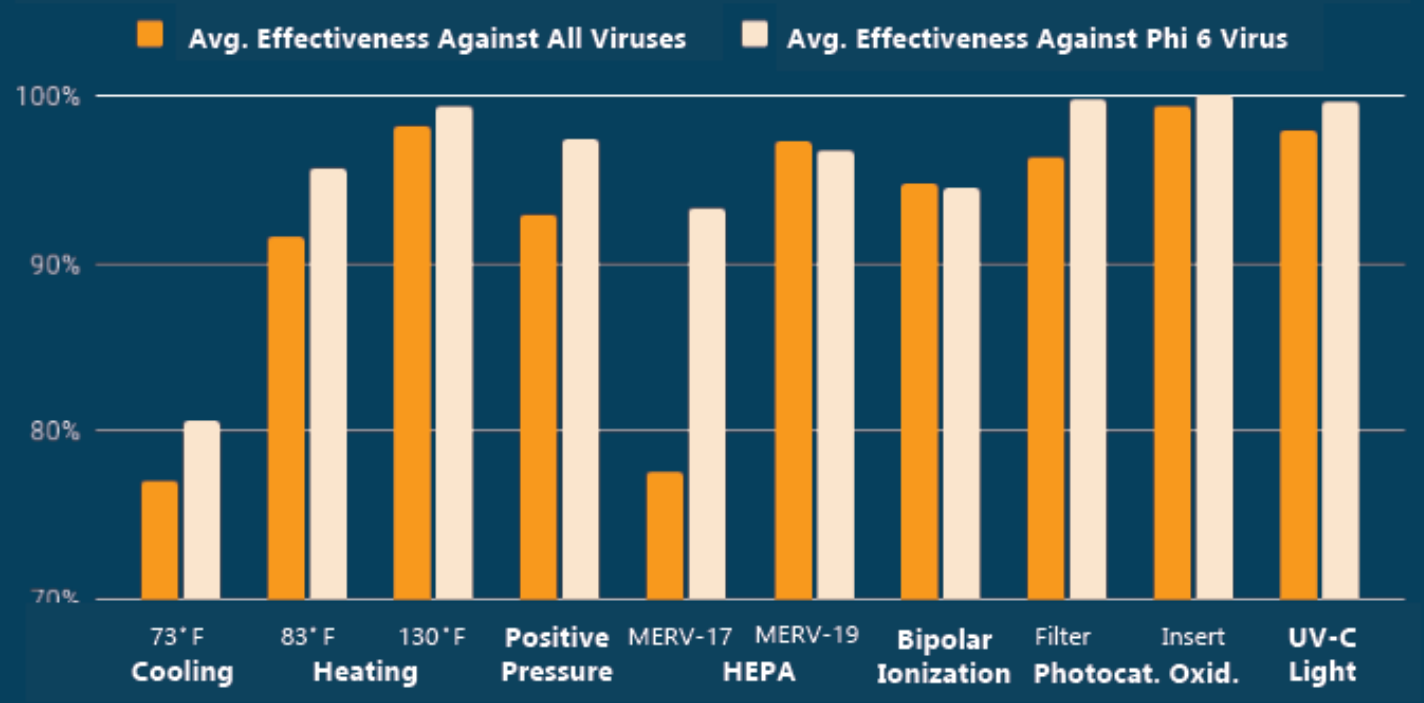
A Tawfik. Transportation Institute releases promising findings of COVID-19 public transit study – Fresno State News. *Fresno State News*. http://www.fresnostatenews.com/2020/10/28/transportation-institute-releases-promising-findings-of-covid-19-public-transit-study/ Published October 28, 2020.

Fresno State Univ – Transportation Institute

Fresno State Univ – Transportation Institute

Virus Mitigation Results

from Air



from Surfaces

Positive pressure mitigated all viruses on surfaces by 100%.

Copper foil tape and fabrics with high-percentage of copper mitigated the Phi6 virus by 99.7%. Results were inconclusive with the other two viruses.

Notes: Transit could be safer in winter, since higher HVAC heating temperatures alone mitigate large percentages of the viruses.

These findings could equally be applicable to any confined space with HVAC, such as offices, classrooms, court houses, shops, restaurants, etc.

66-Seat School Bus and 35-Foot Low-floor Transit Bus

84 test runs
over 2 weeks

78.3 million points
of real-time data collected

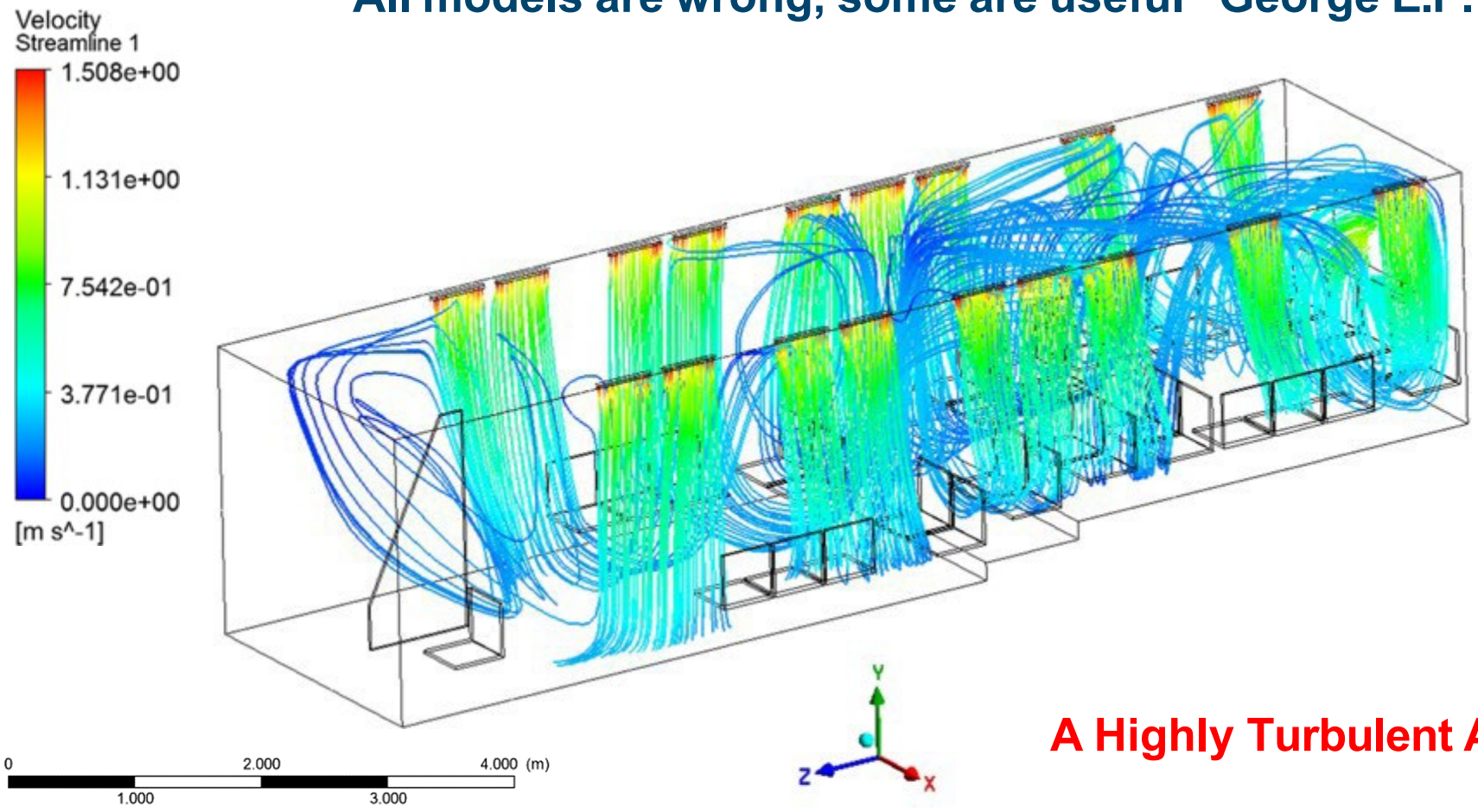
124.73 miles
of "bus-in-motion" testing

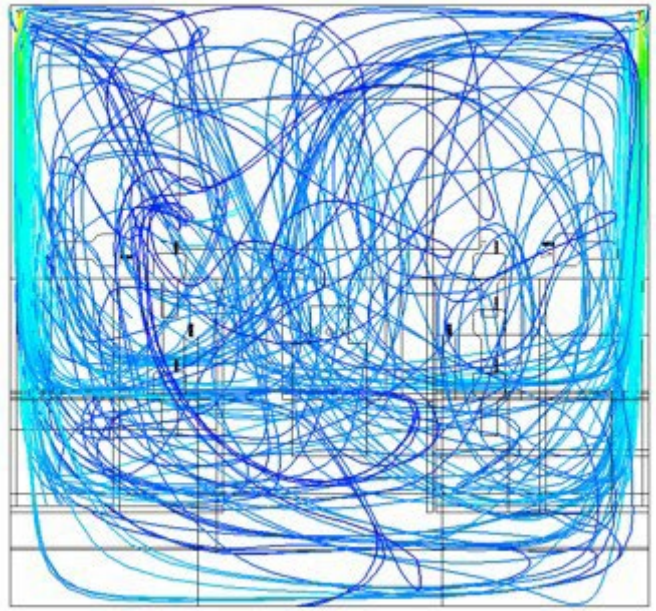
https://www.mitre.org/news/press-releases/face-masks-open-windows-on-buses-reduce-potentially-infectious-particles

Edwards NJ, Widrick R, Wilmes J, et al. **Reducing COVID-19 Airborne Transmission Risks on Public Transportation Buses: An Empirical Study on Aerosol Dispersion and Control**. *Aerosol Science and Technology*. 2021;55(12):1378-1397. doi:10.1080/02786826.2021.1966376

CFD Modeling used to Inform Sensor Positions

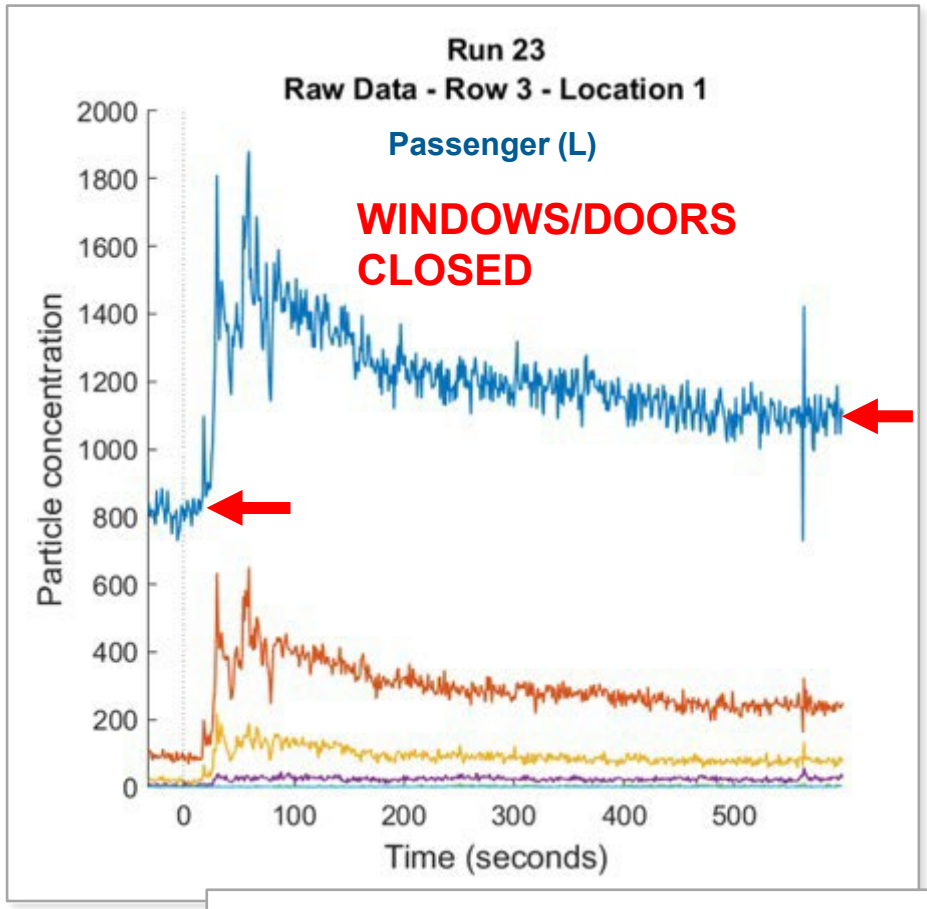
“All models are wrong, some are useful” George E.P. Box, 1976

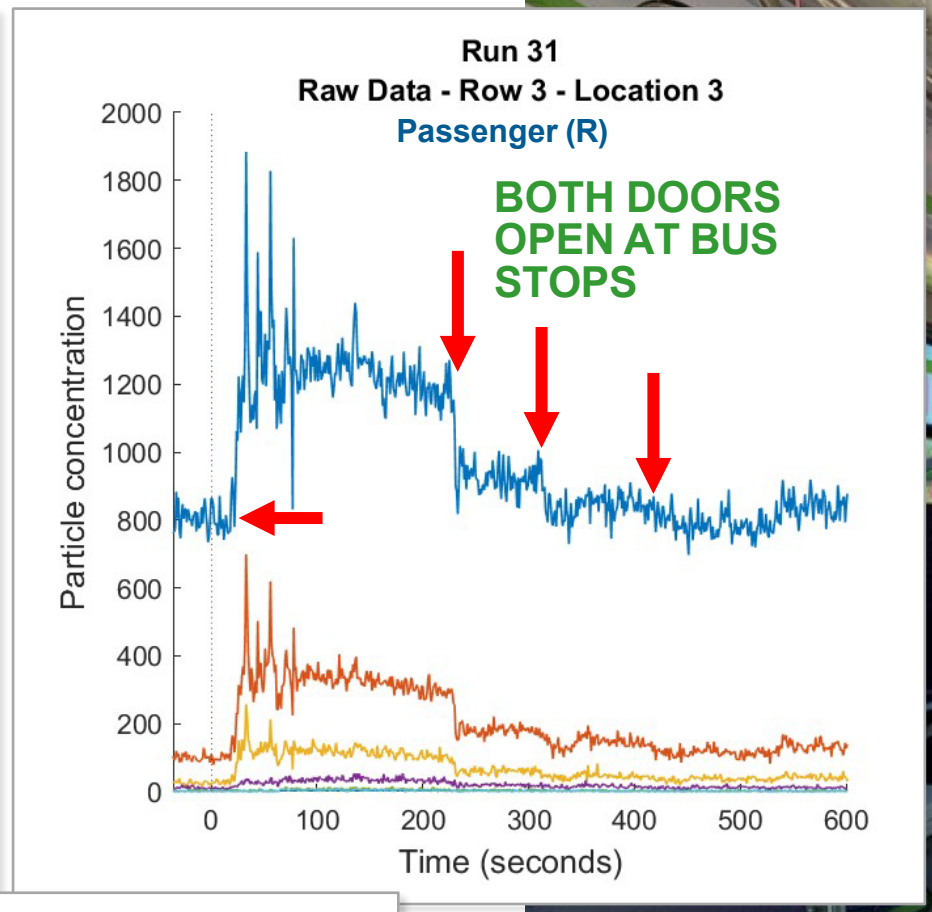




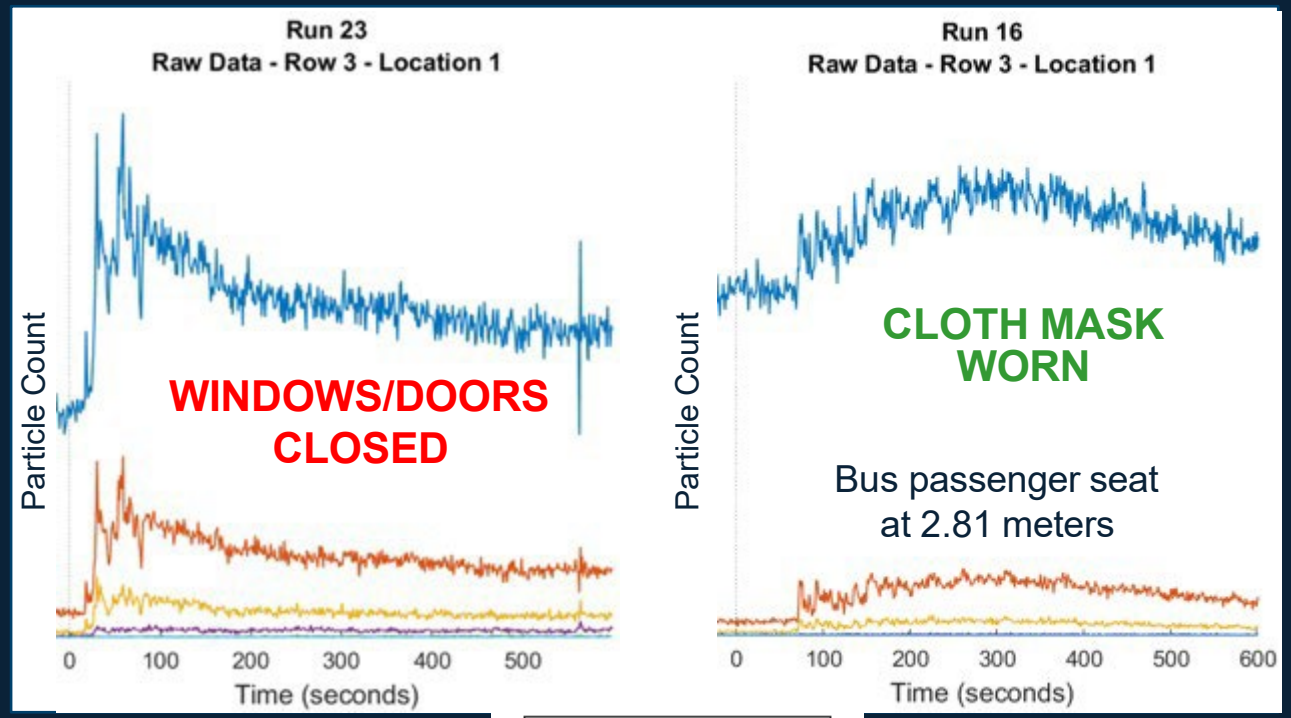
A Highly Turbulent Air Environment

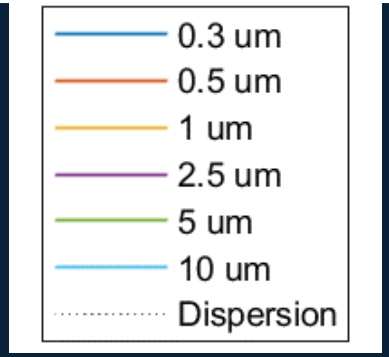
Aerosol Dispersion Analysis





Quality of Masks, Time and Virion Transmission (~Infection Probability Risk based on Exposure)





Masks decrease emissions, distance and exposure

Est. VIRION COUNT		Mask for Protection					
		None	Procedure Mask	Cloth (mixed)	Surgical (medical)	Cloth + Procedure	N95
Mask for Exhalation Control	None	22500	13928	13707	6413	5135	338
	Procedure Mask	13928	8621	8485	3969	3178	209
	Cloth (mixed)	13707	8485	8350	3906	3128	206
	Surgical (med)	6413	3969	3906	1828	1463	96
	Cloth + Procedure	5135	3178	3128	1463	1172	77
	N95	338	209	206	96	77	5

15 Minutes at 6 ft , 50% air exchange

- Think like an aerosol → ventilate
- Use time, distance, shielding
- Don't let your guard down

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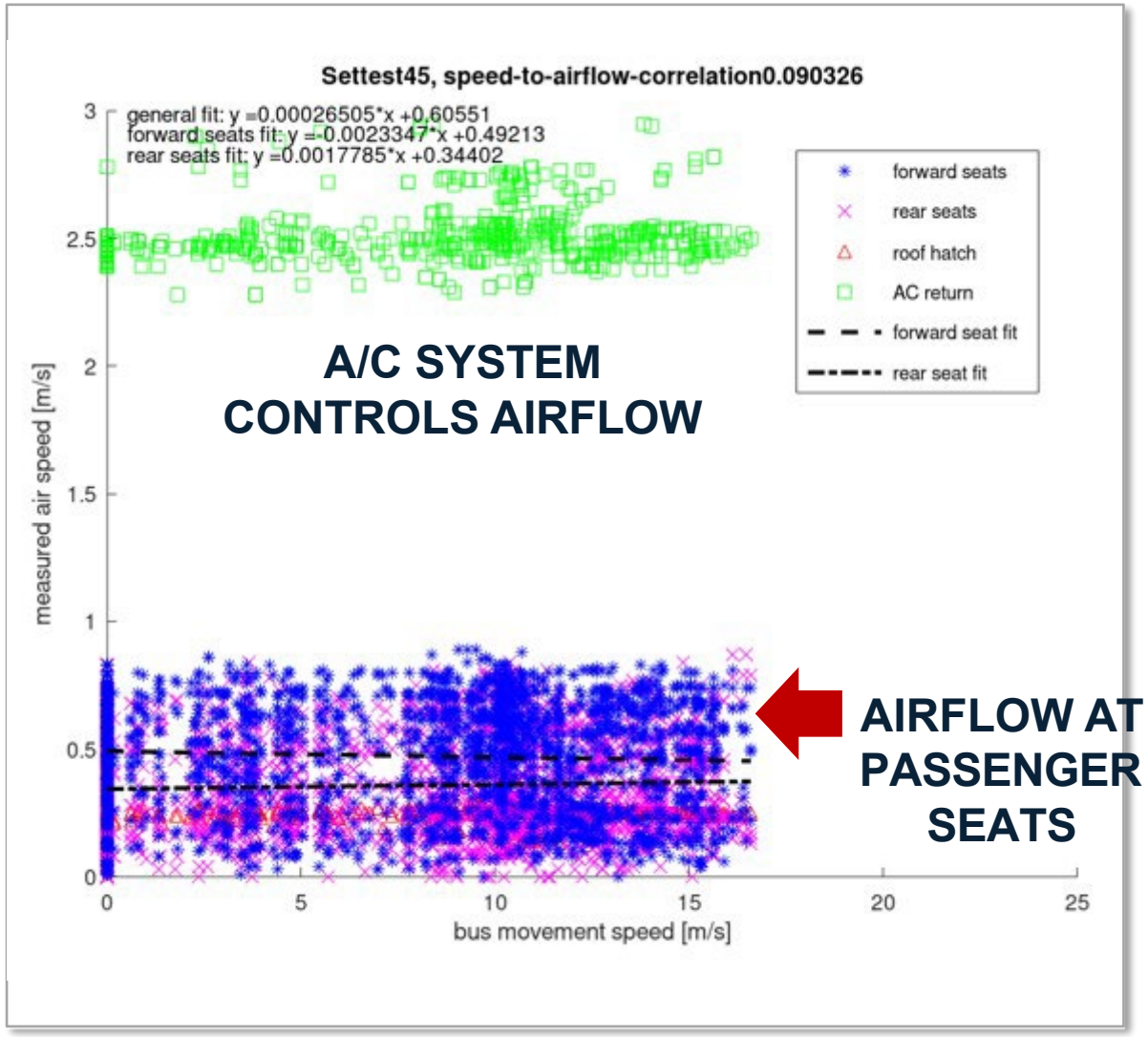
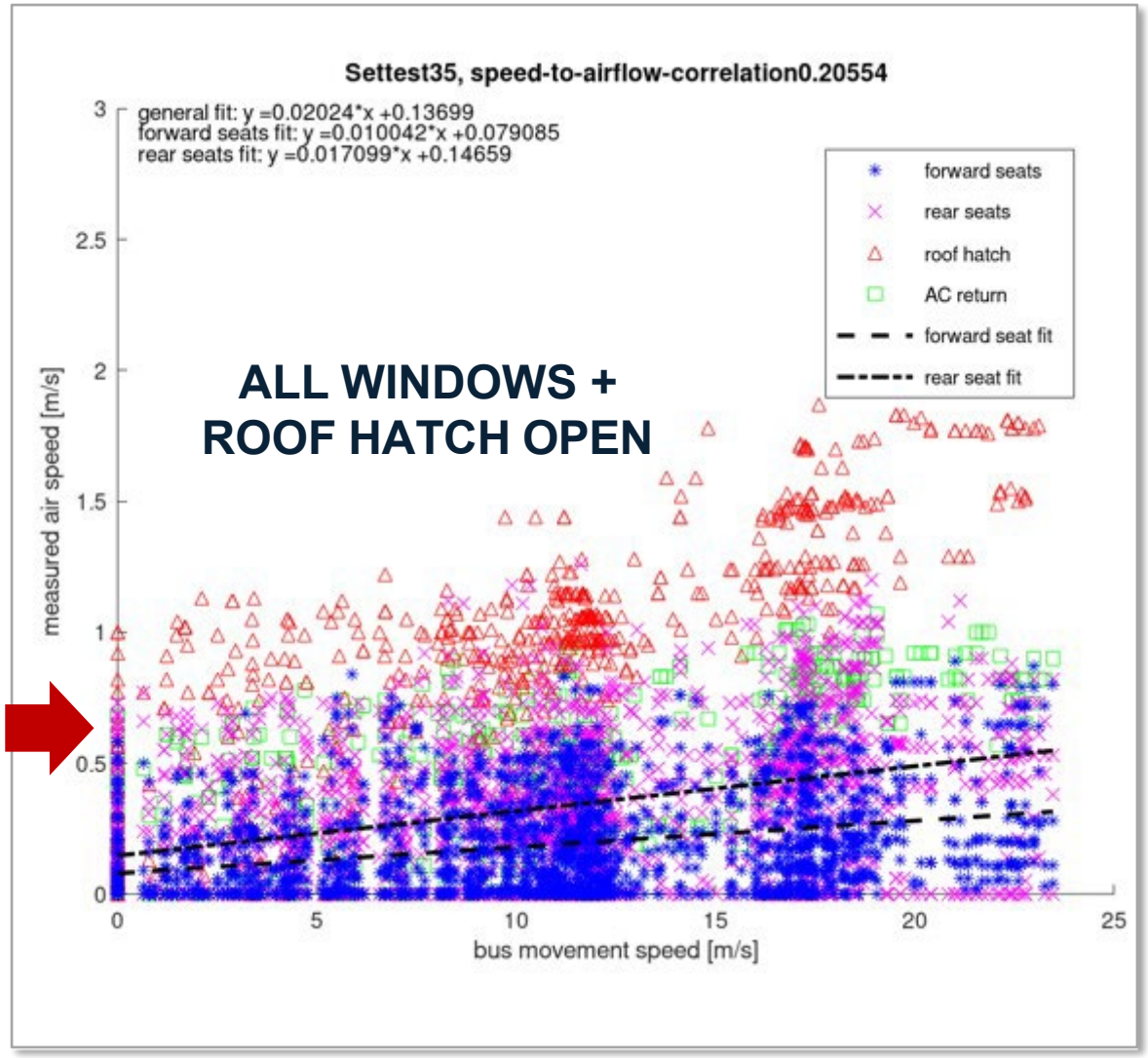
Airflow to Bus Speed Correlation

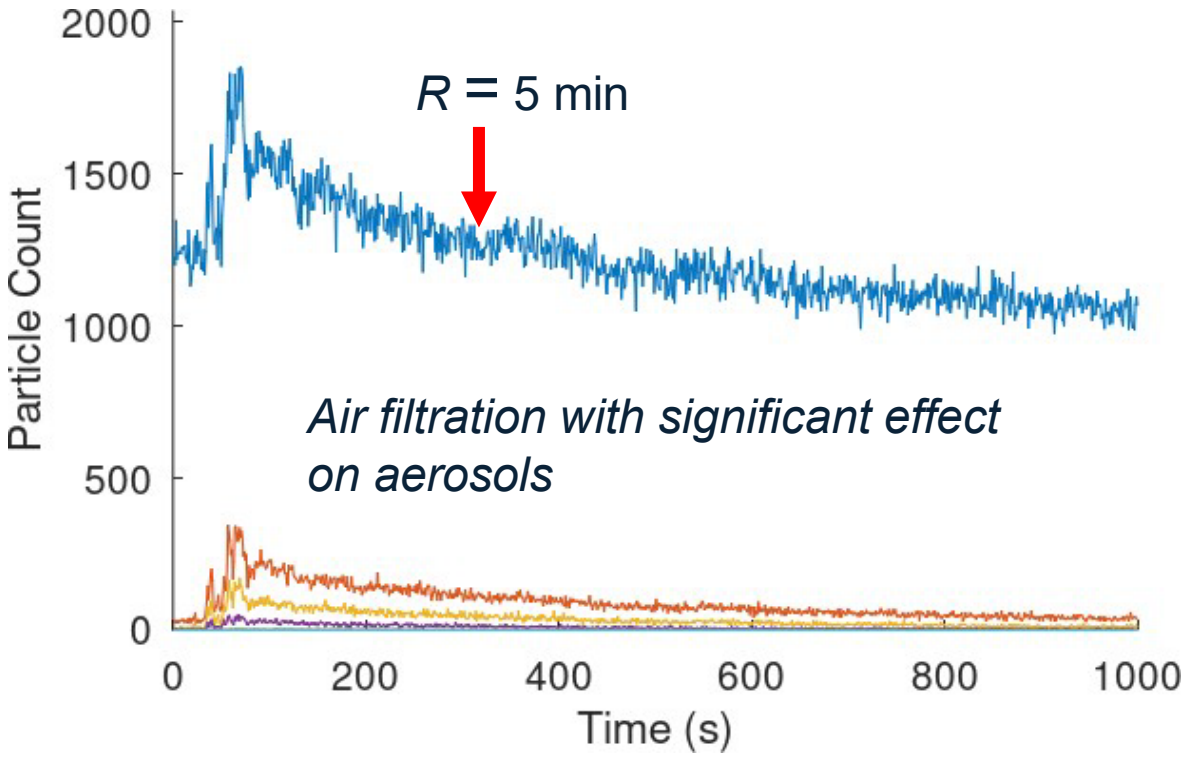


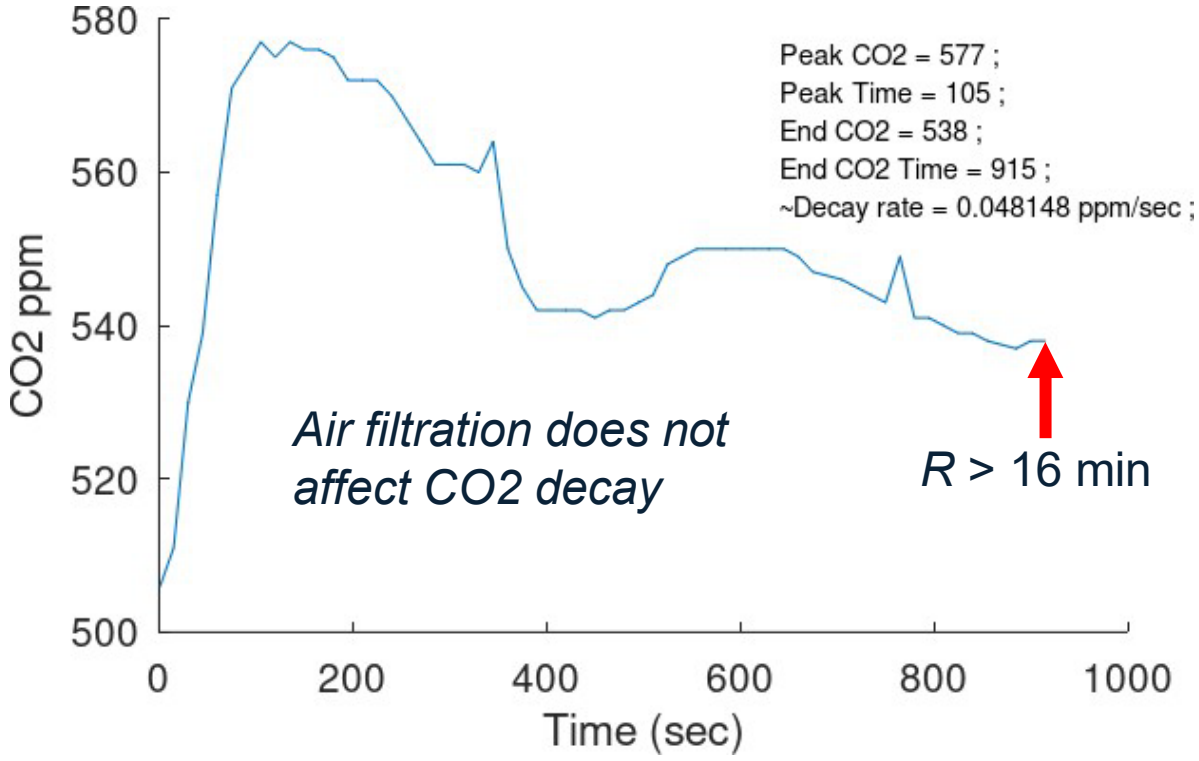
AIRFLOW AT PASSENGER SEATS



Misnomers on CO2 Decay: Compare to Aerosols

Portable Air Filter
ON – Speed 2





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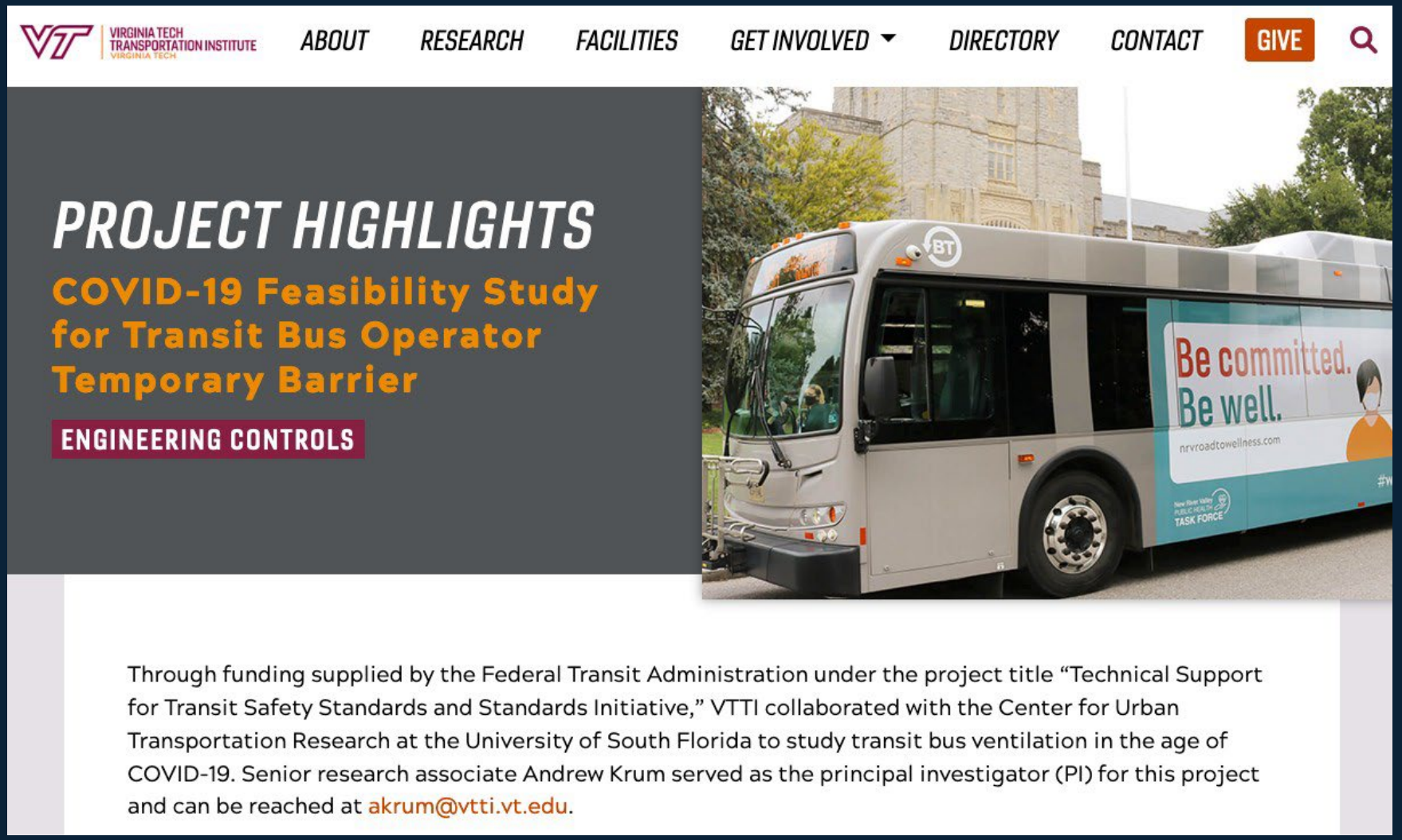
Continuing Research: DHS and NYC

https://www.dhs.gov/science-and-technology/news/2021/02/16/feature-article-nyc-initiatives-safeguarding-nation-s-public-transit-systems

Continuing Research: Virginia Tech Transportation Institute



https://www.vtti.vt.edu/projects/bus-barriers.html

Summary

- Verification Testing can show results that are different than best practices or simulation
- Positive movement toward engineered design of HVAC and air quality
- More science and engineering opportunities for transit systems
- Real-time monitoring is valuable considering urban and micro-weather