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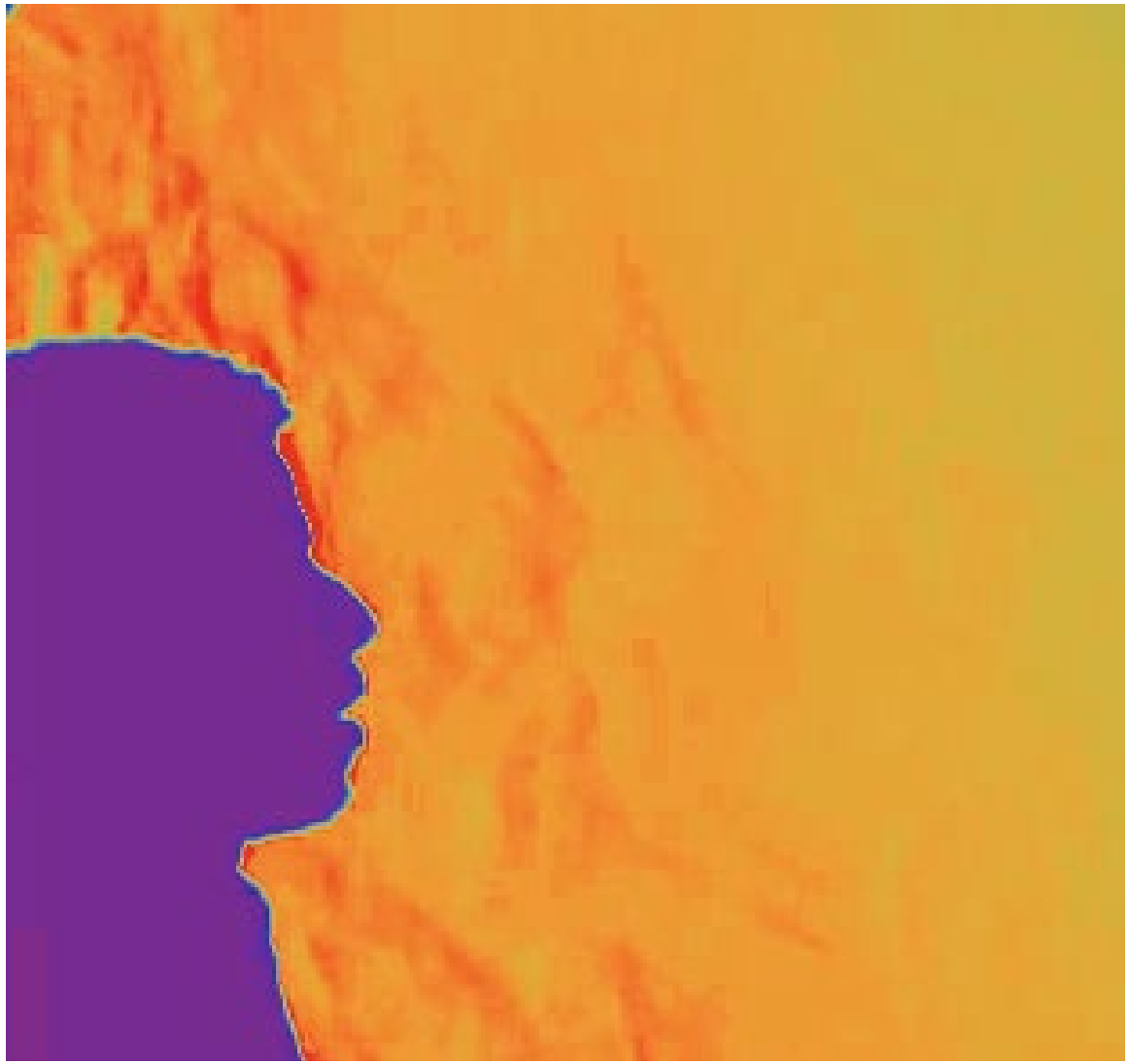
We shape a better world

The use of CFD modelling to support pandemic-resilient design in the built environment

International Workshop on Resilient Hospital Design

Brunel University

22nd July 2021



Schlieren videos of breathing and coughing, from Bauhaus-Universität Weimar https://vimeo.com/399120258 (Colorized by Arup)

Transmission

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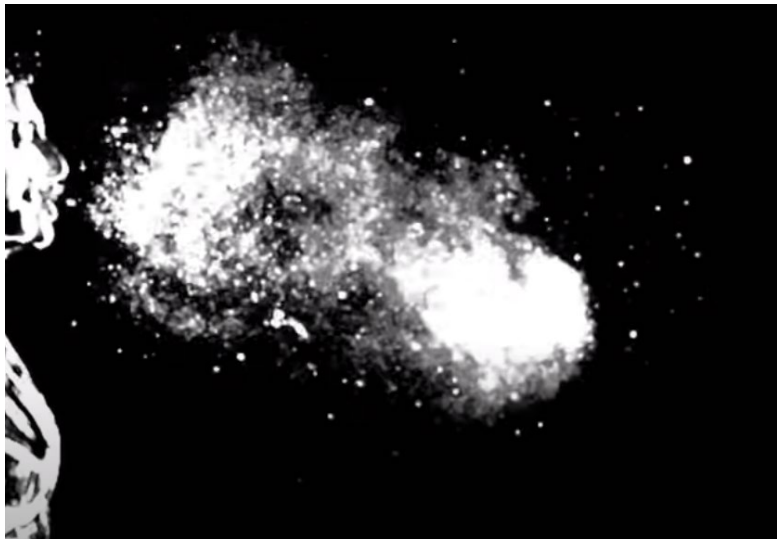
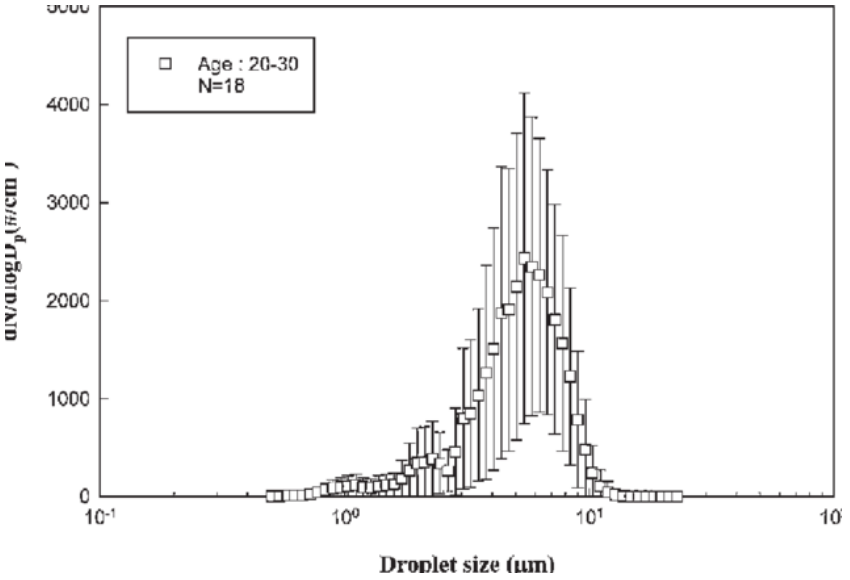
- SARS-CoV-2 is spread from person to person, mainly through close contact. It is transported in respiratory droplets from breathing, talking, coughing, etc.
- Key risk is close contact with an infected person.
- Small (<~10micron) aerosolised droplets present risk of airborne transmission at greater distances
- Evidence for short-range airborne transmission has been identified in offices, conference rooms, restaurants and air-conditioned buses, choir rehearsals, quarantine hotels, etc.



Still from "Coughs and sneezes travel farther than you think", MIT https://www.youtube.com/watch?v=9qqHOKUXY5U



From "The Size and Concentration of Droplets Generated by Coughing in Human Subjects" Yang et al, 2007

Transmission

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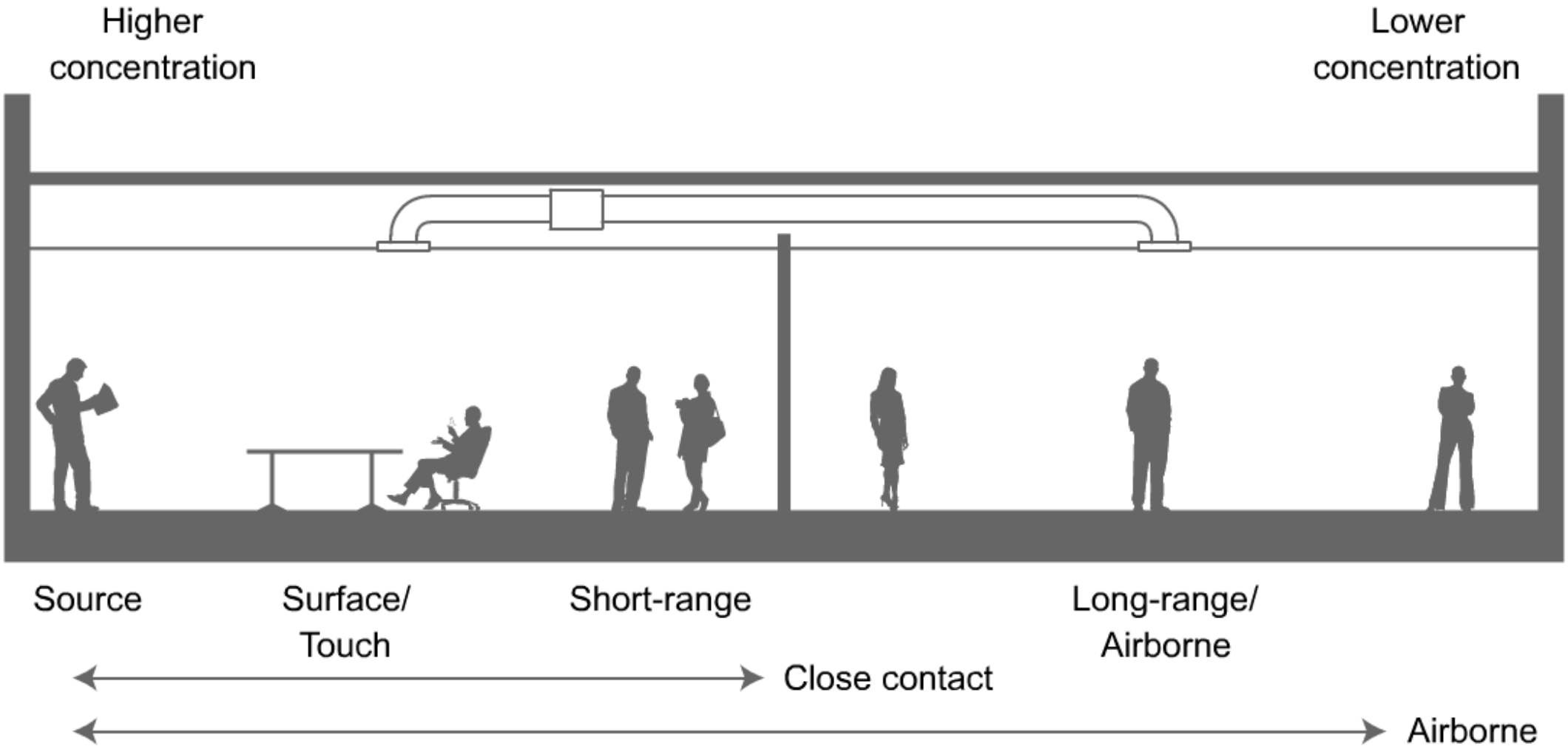

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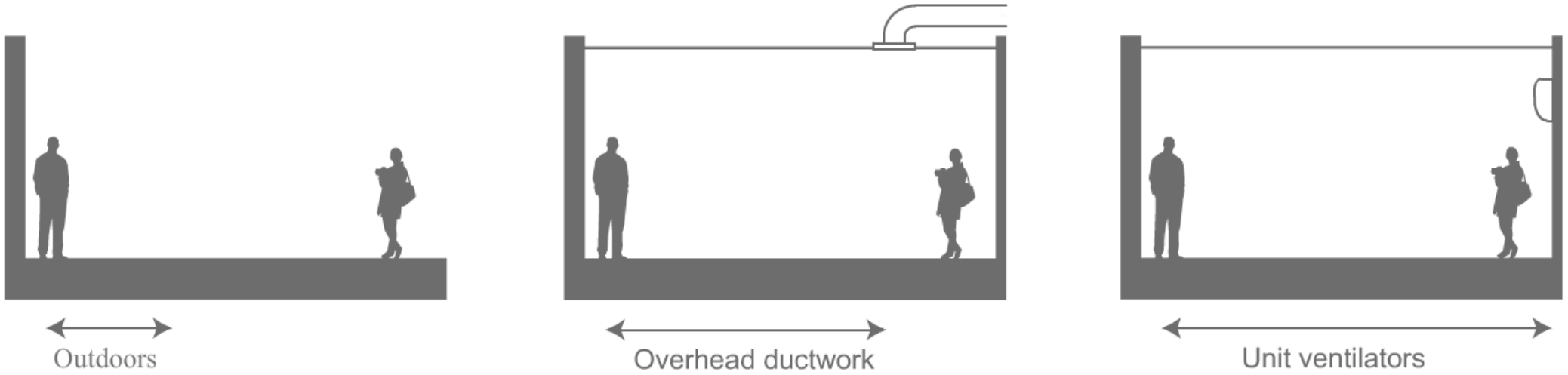
Short-Range isn’t a fixed number



Pre-existing Capability

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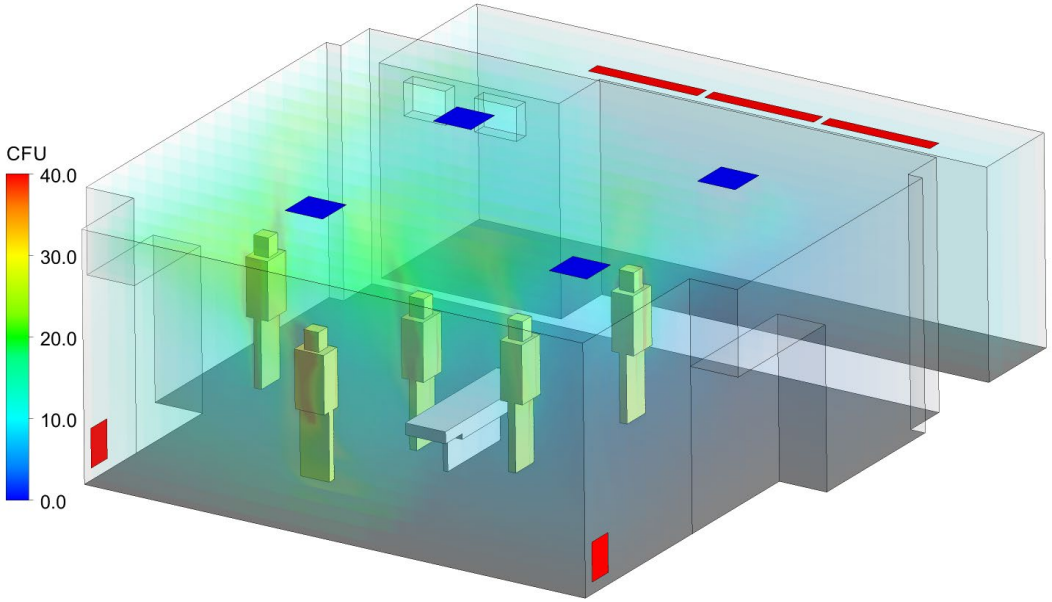

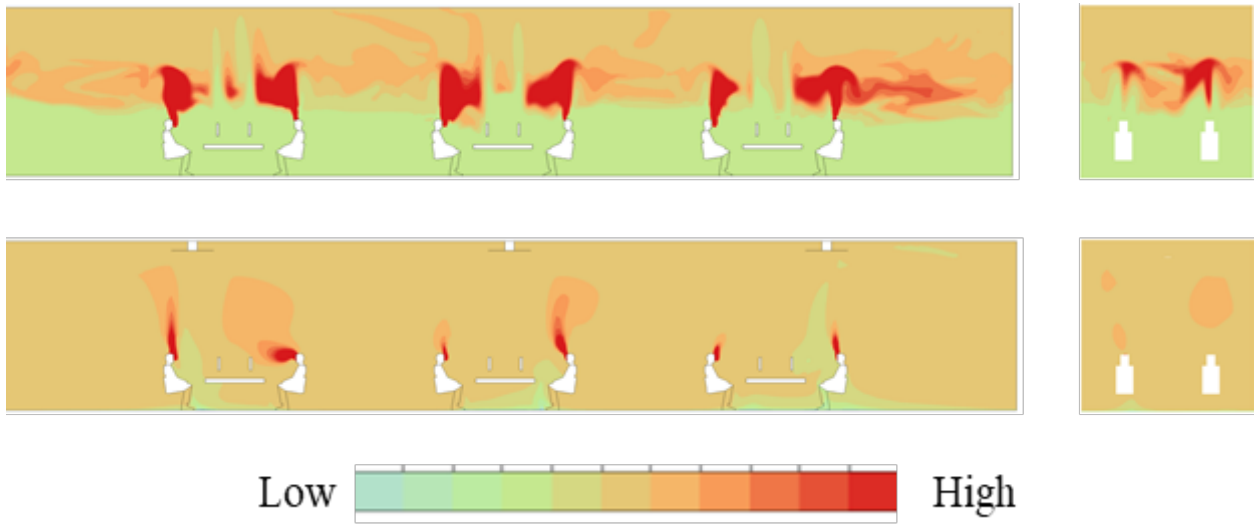

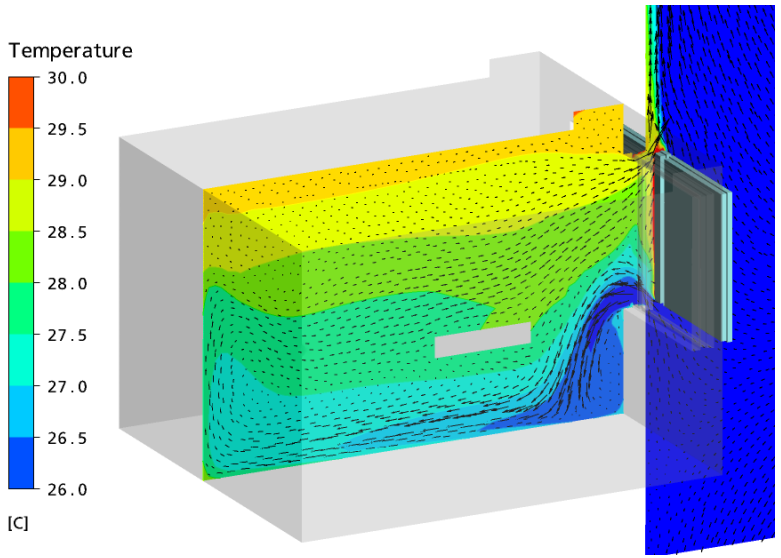

Partitions

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Arup, San Francisco

Alex Welsh for The New York Times “The Pandemic May Mean the End of the Open-Floor Office” May 4, 2020.

Partitions

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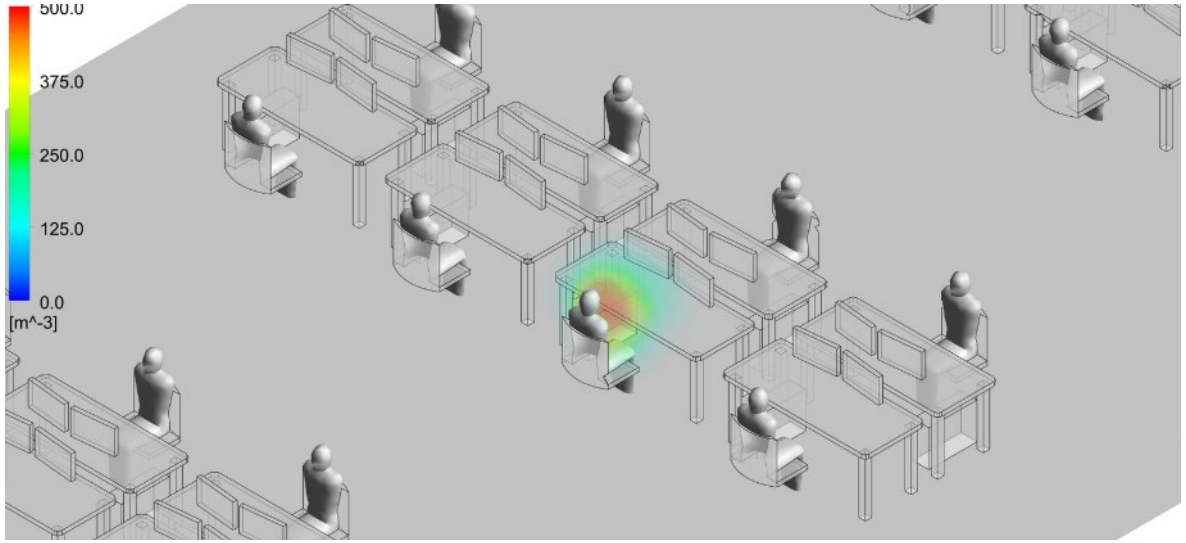

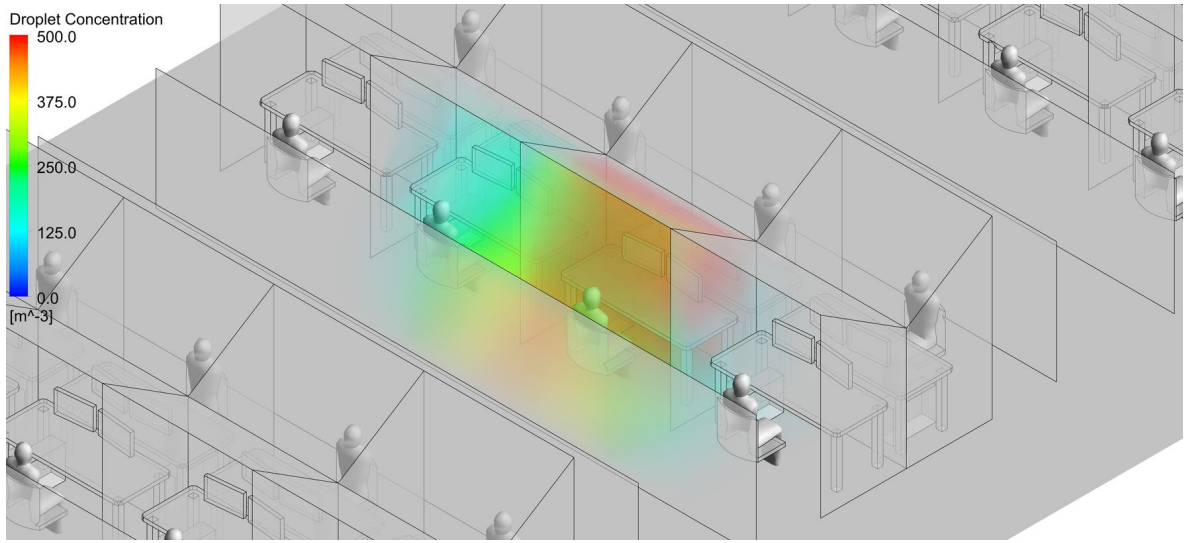

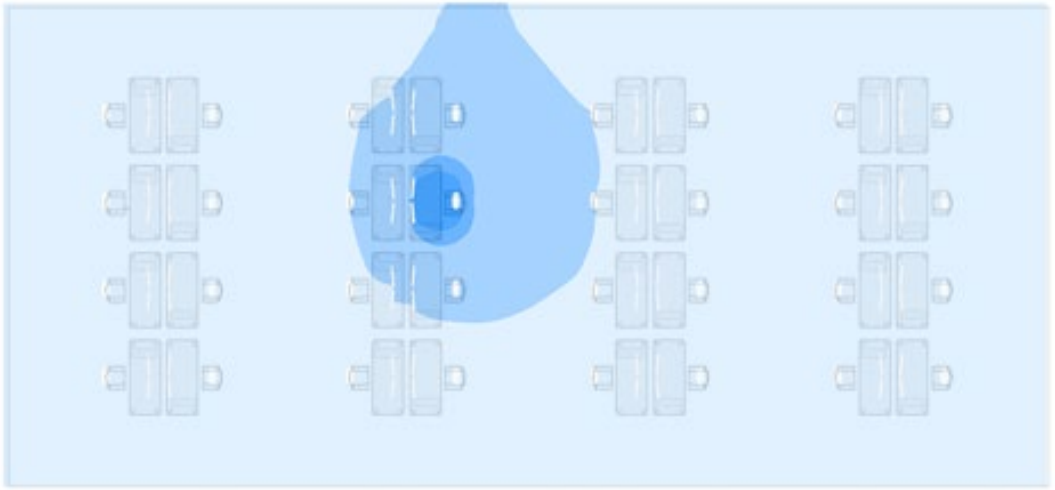

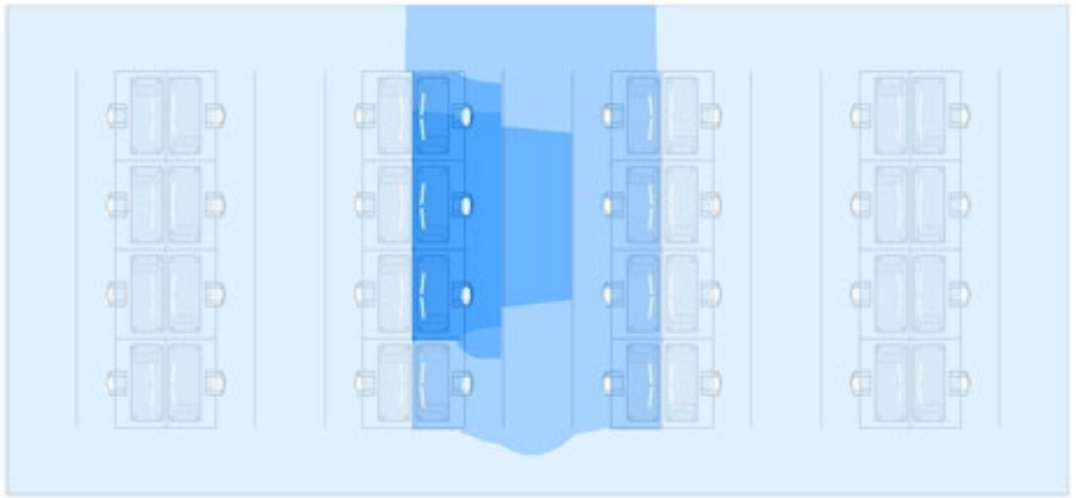

AGP Treatment Shield

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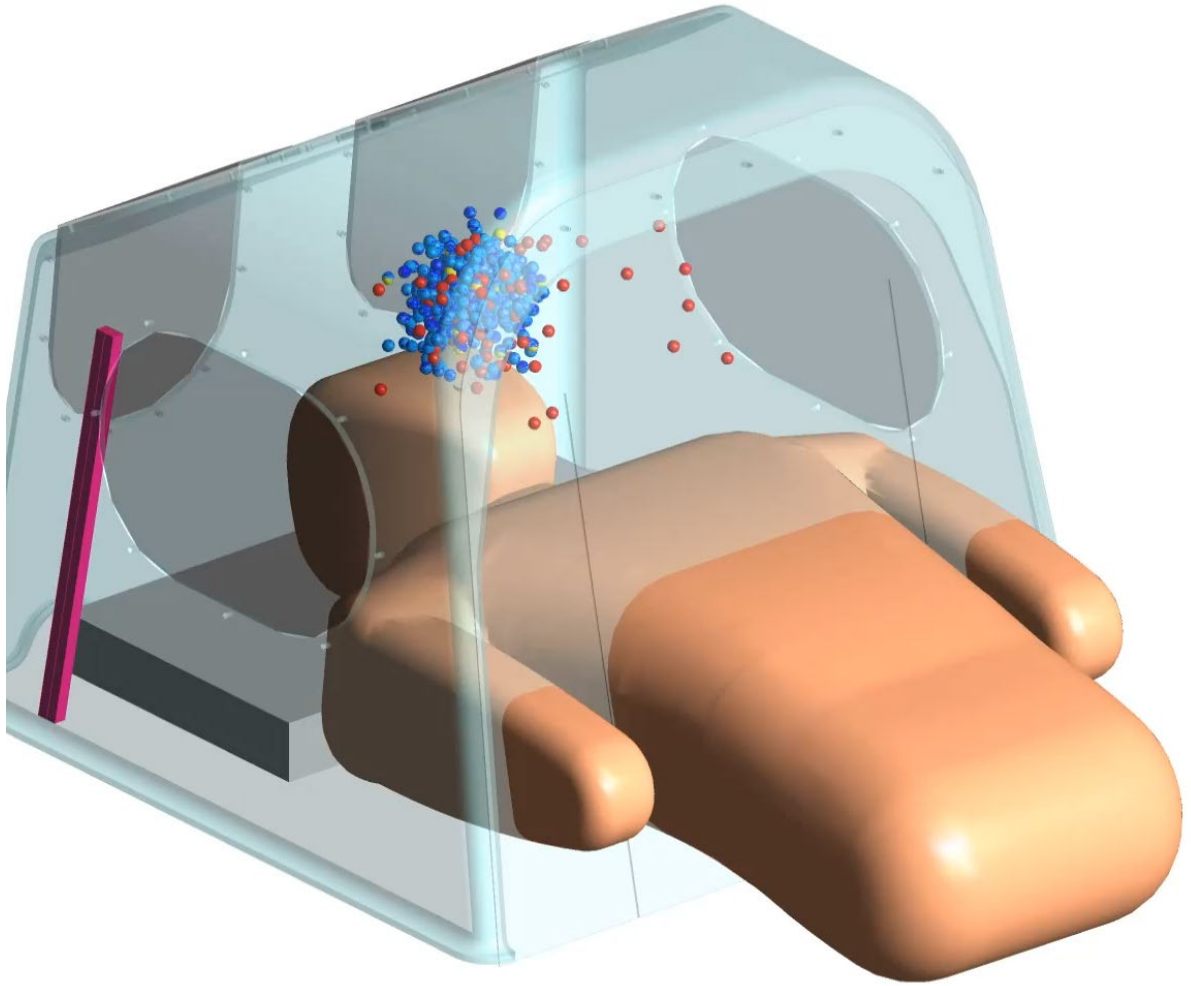
Shield designed to protect workers during aerosol generating procedures.

CFD supported design of shield and extraction system.



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Can we use public transport safely? Is it safer than the alternative?

What ventilation systems exist on different transport modes, and how effective are they at removing pollutants?

Does opening the windows on a tram or local train help? Should the doors stay open longer?

Photograph: Tom Page, Wikimedia Commons

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Knock-on impacts of reduced public transport use:

- Increased inequalities
- Increased air pollution
- Climate change
- Increased physical inactivity and obesity
- Slower economic recovery

Photograph: Tom Page, Wikimedia Commons

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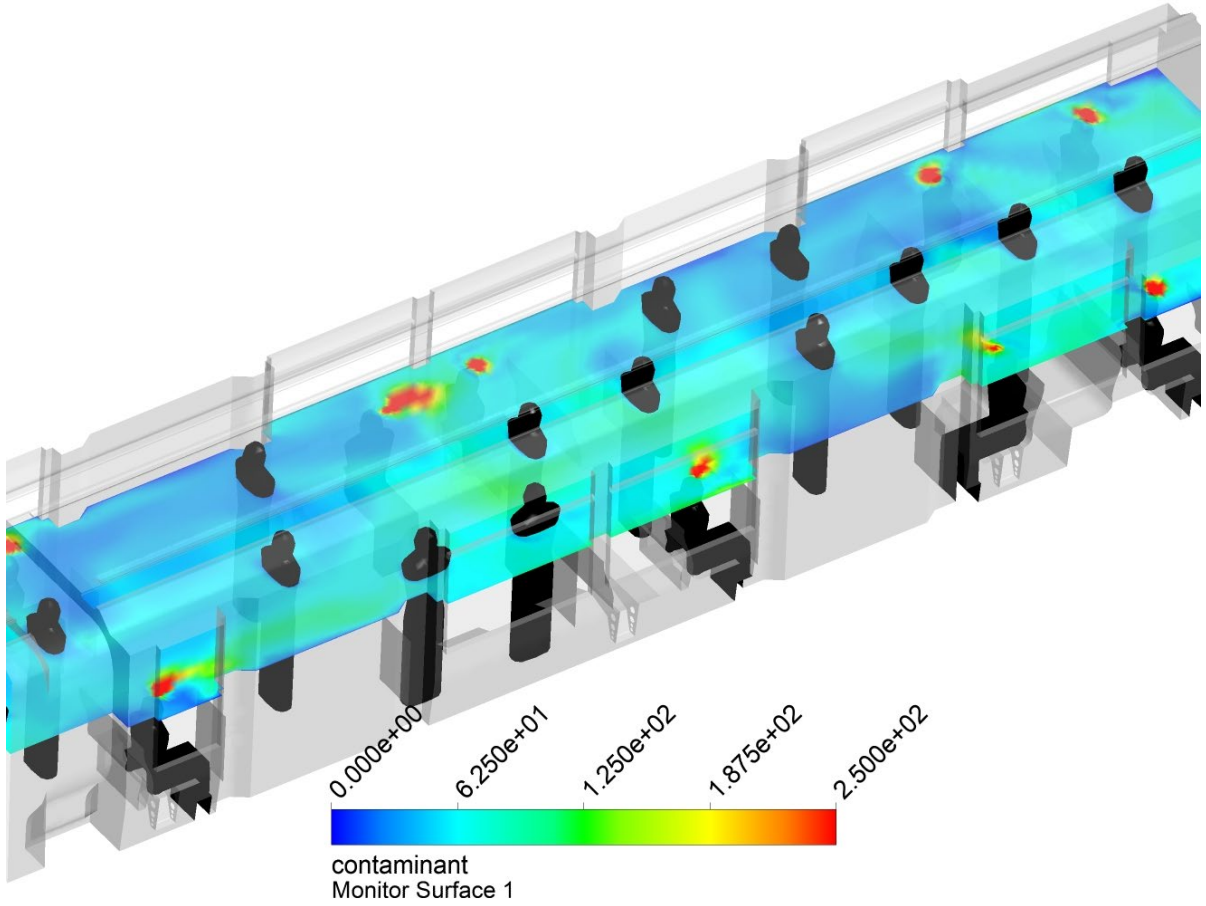
Used CFD to model interaction of exhaled breath with ventilation system

Assessed risks and benefits of potential intervention measures

Risks quantified using assessment methodology developed by international group of academics

Supported Metrolink's planning for safely increasing passenger loads



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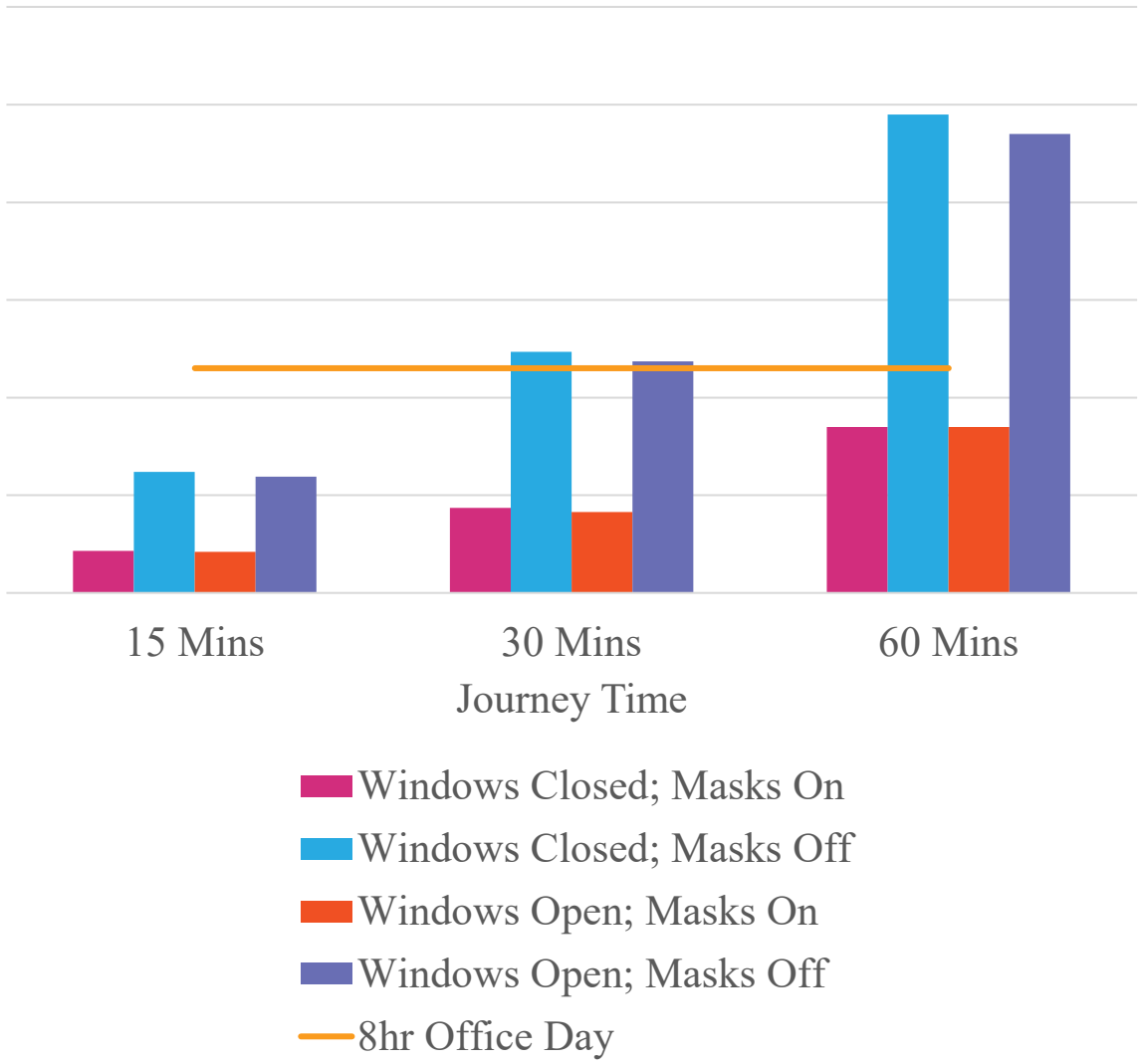

Ultraviolet Germicidal Irradiation

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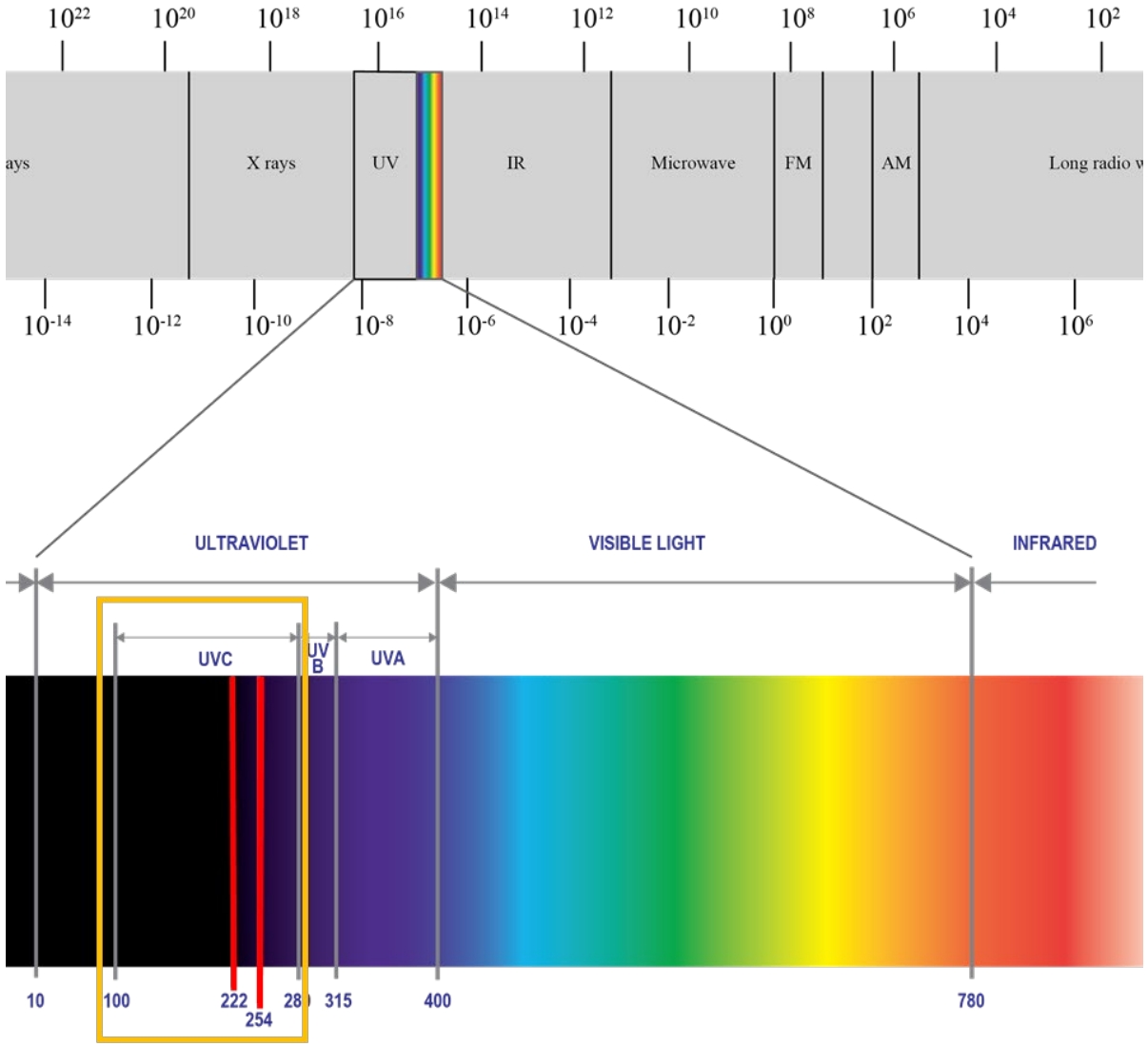

- UVGI works by **damaging the pathogen's genetic source code – in essence blocking transcription of the genetic "alphabet" of the virus.**
- A virus must **hijack a host cell's genetic machinery** to "reproduce" itself.
- For that to happen, **the encoded viral genome sequence must make sense.**

Ultraviolet Germicidal Irradiation

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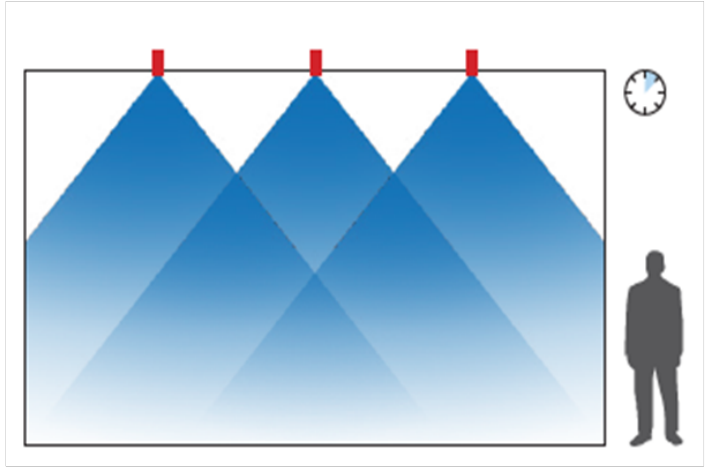
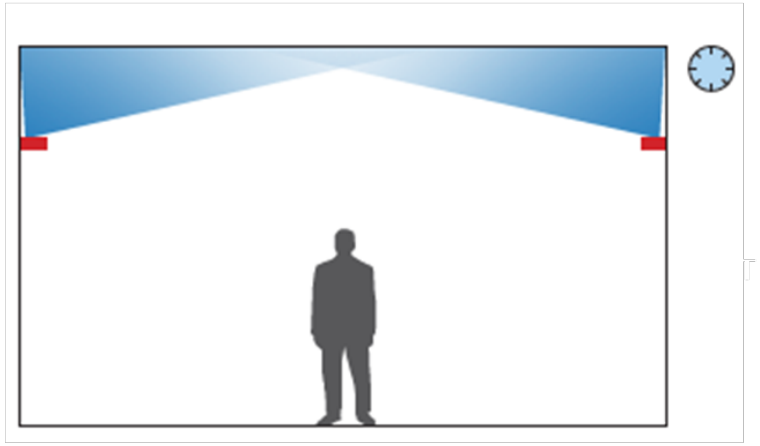
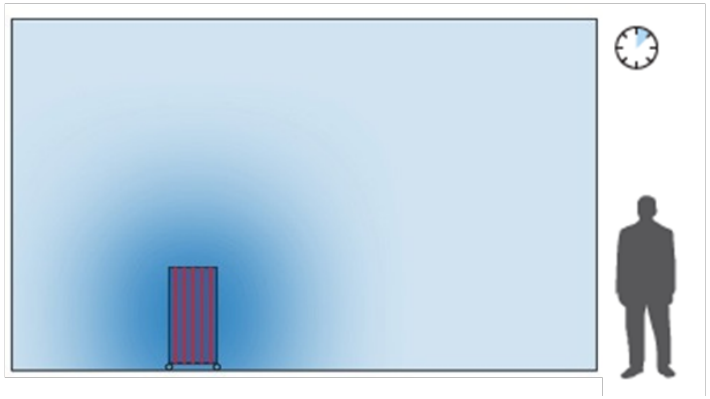
General Direct Treatment



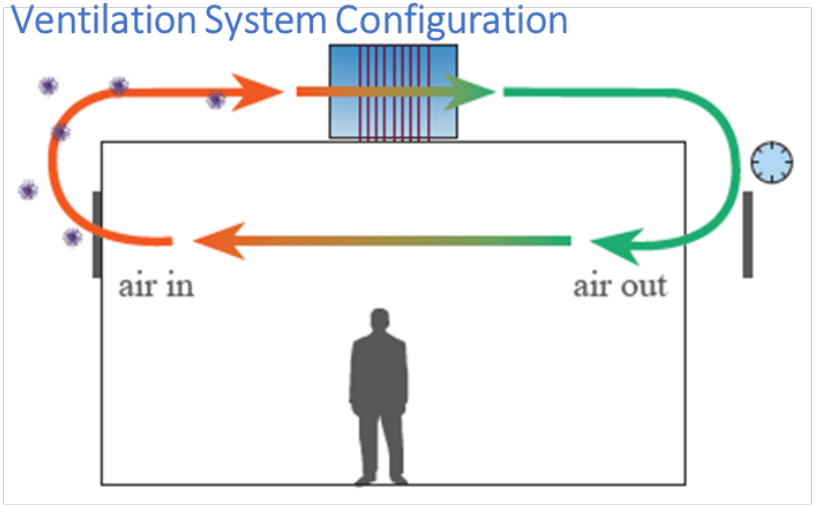
Indirect Uplight



Movable Approach



Ventilation System Configuration



Ultraviolet Germicidal Irradiation

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Hospital waiting room with UVGI installation courtesy of Signify

- Is a **maximum fresh air solution** (max ACH) sustainable long term?
  - Maintenance
  - Energy
  - Carbon
- Emerging models of alternative metrics of efficacy, **equivalent air changes per hour (eACH)** allowing comparison of approaches.
- Challenge around airborne **HAIs are broader and longer term** than SARS-CoV-2 alone.

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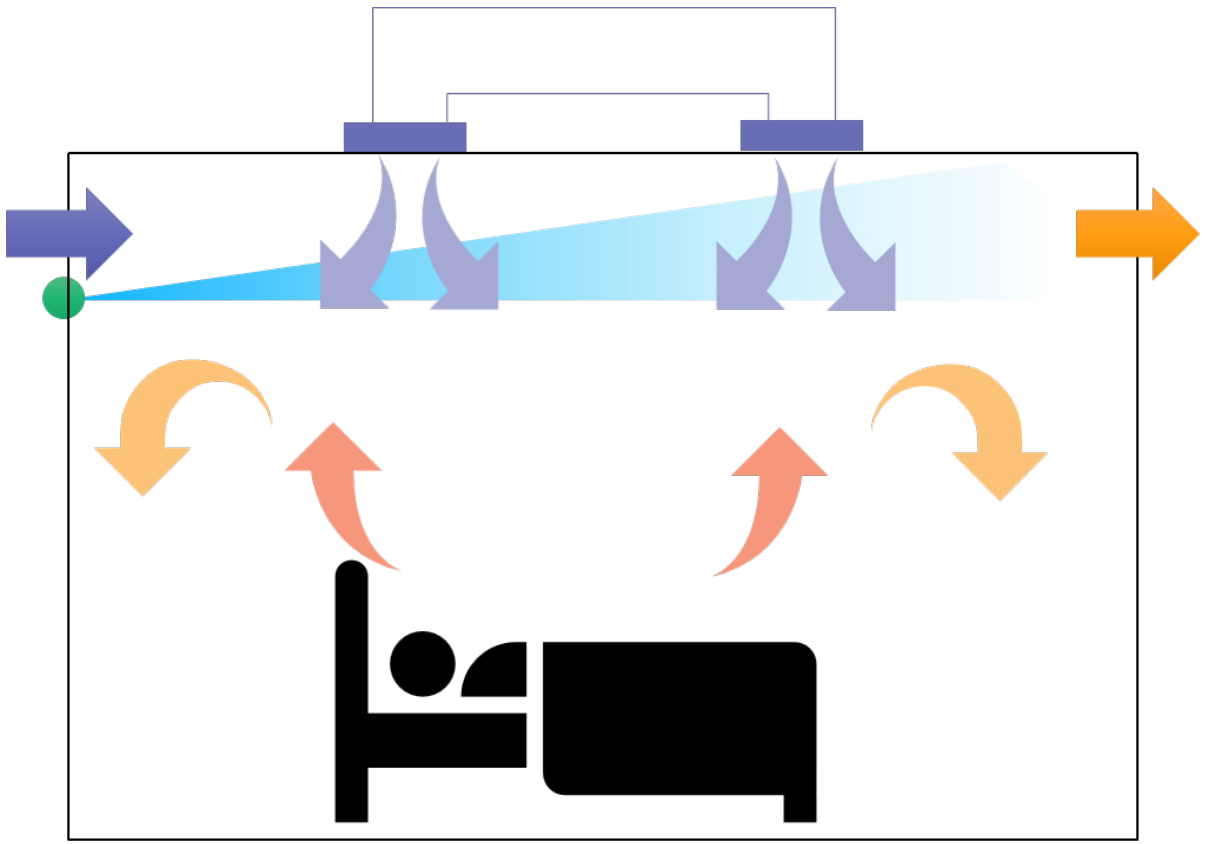

"Well-mixed" models guide relative benefits of:

- Reduced occupancy
- Masking
- Increased fresh air
- Air filtration
- UVGI

How can we apply these models to more complex spaces?

Ultraviolet Germicidal Irradiation

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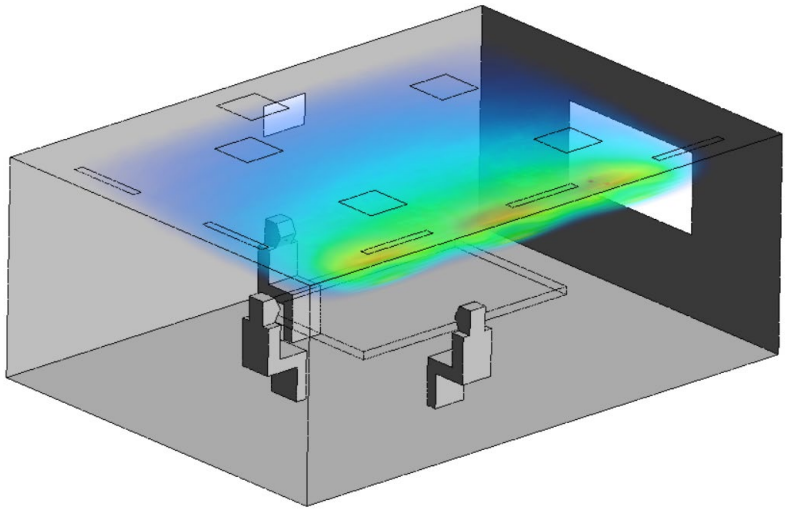

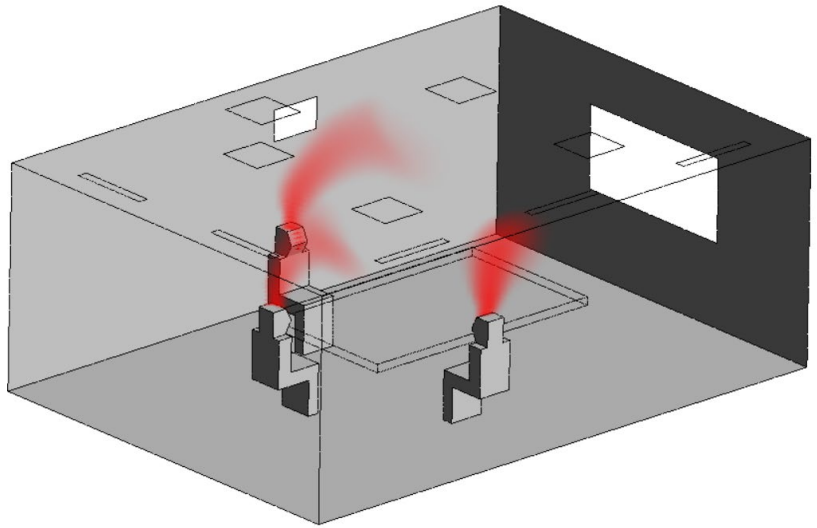

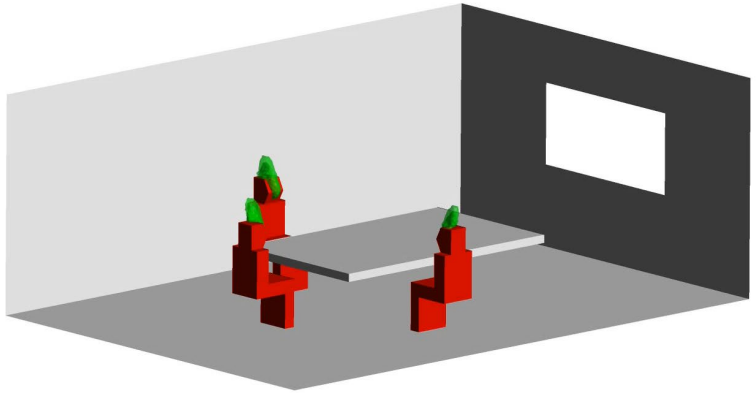

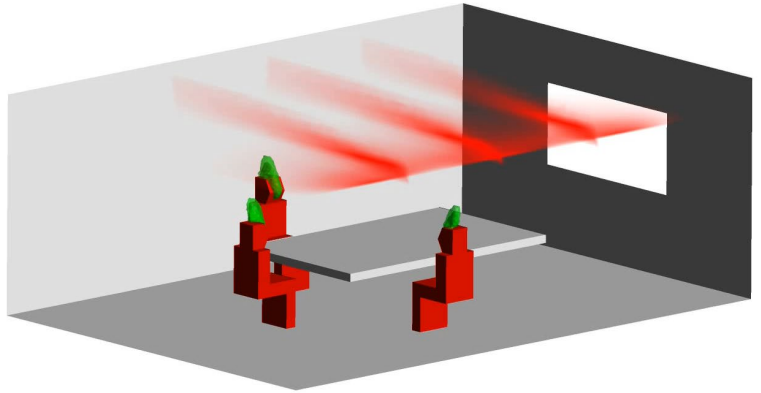

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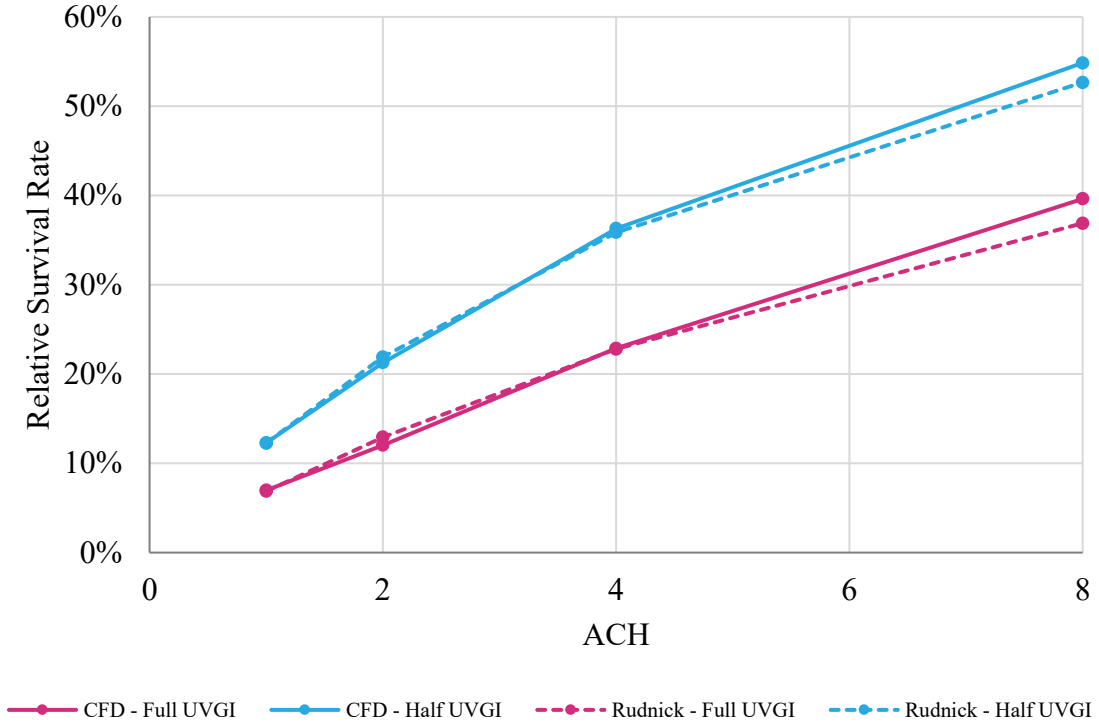
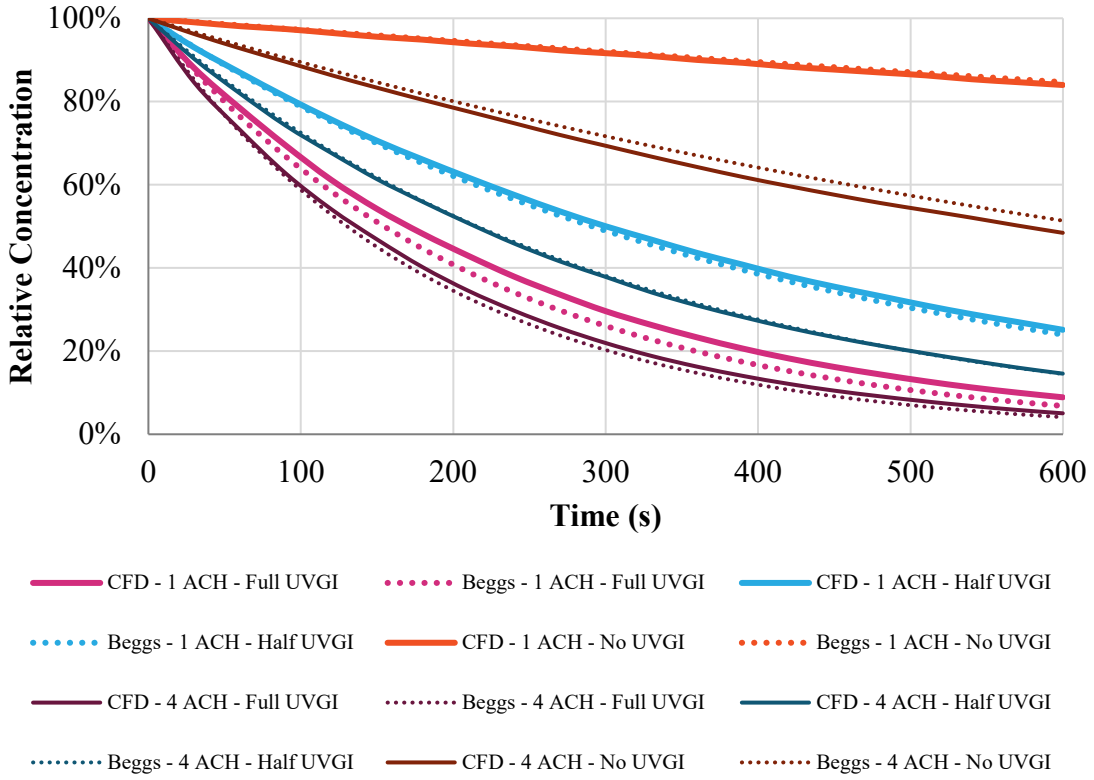


Steady-State Pathogen Survival Rates



Transient Pathogen Decay

CFD + Crowd Movement

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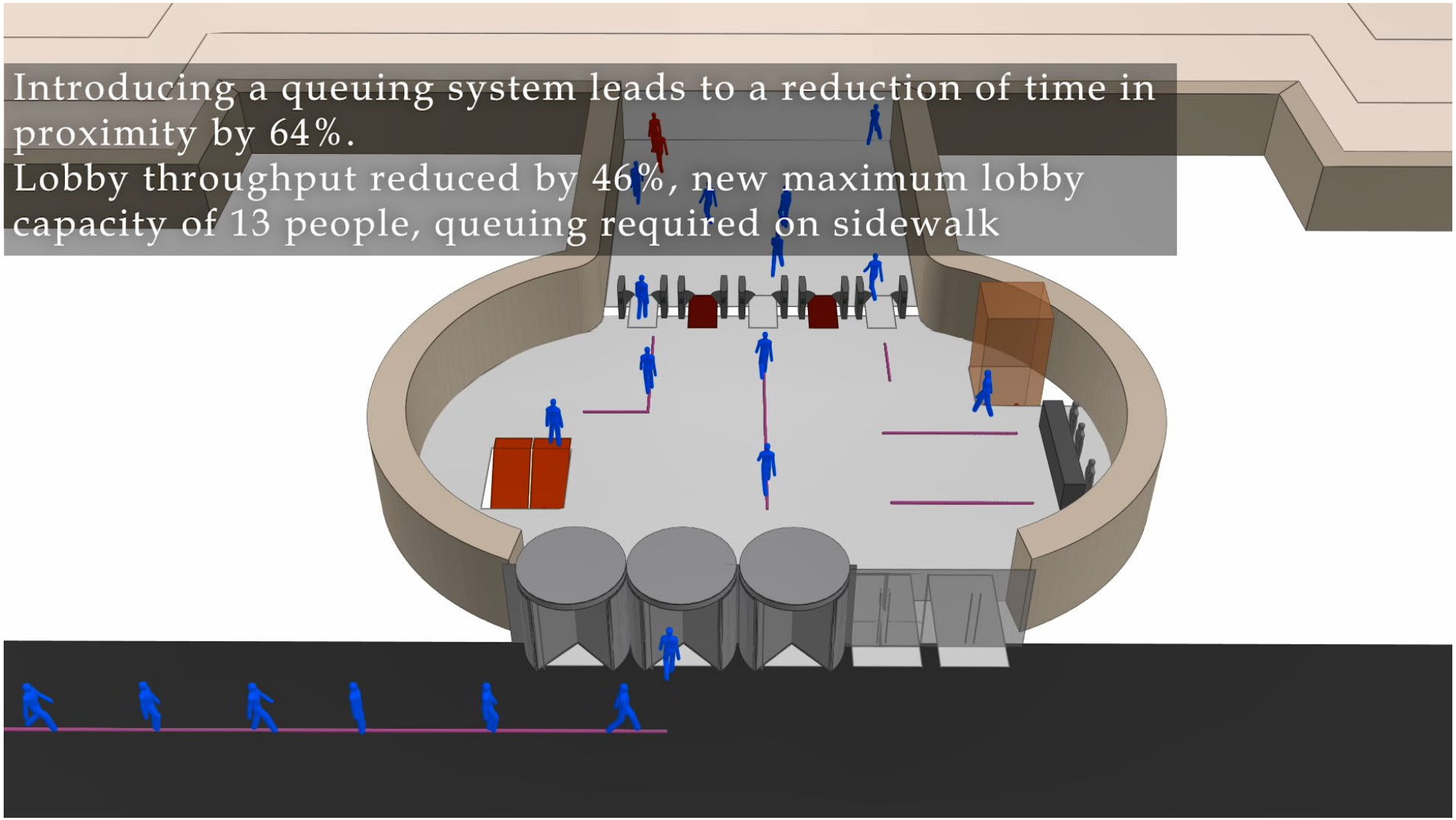

CFD + Crowd Movement

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Moving beyond traditional static CFD models.

Integrating crowd modelling gives insight into transient risk variation.

Potential implications for hospital waiting areas, transport hubs, etc.

CFD + Crowd Movement

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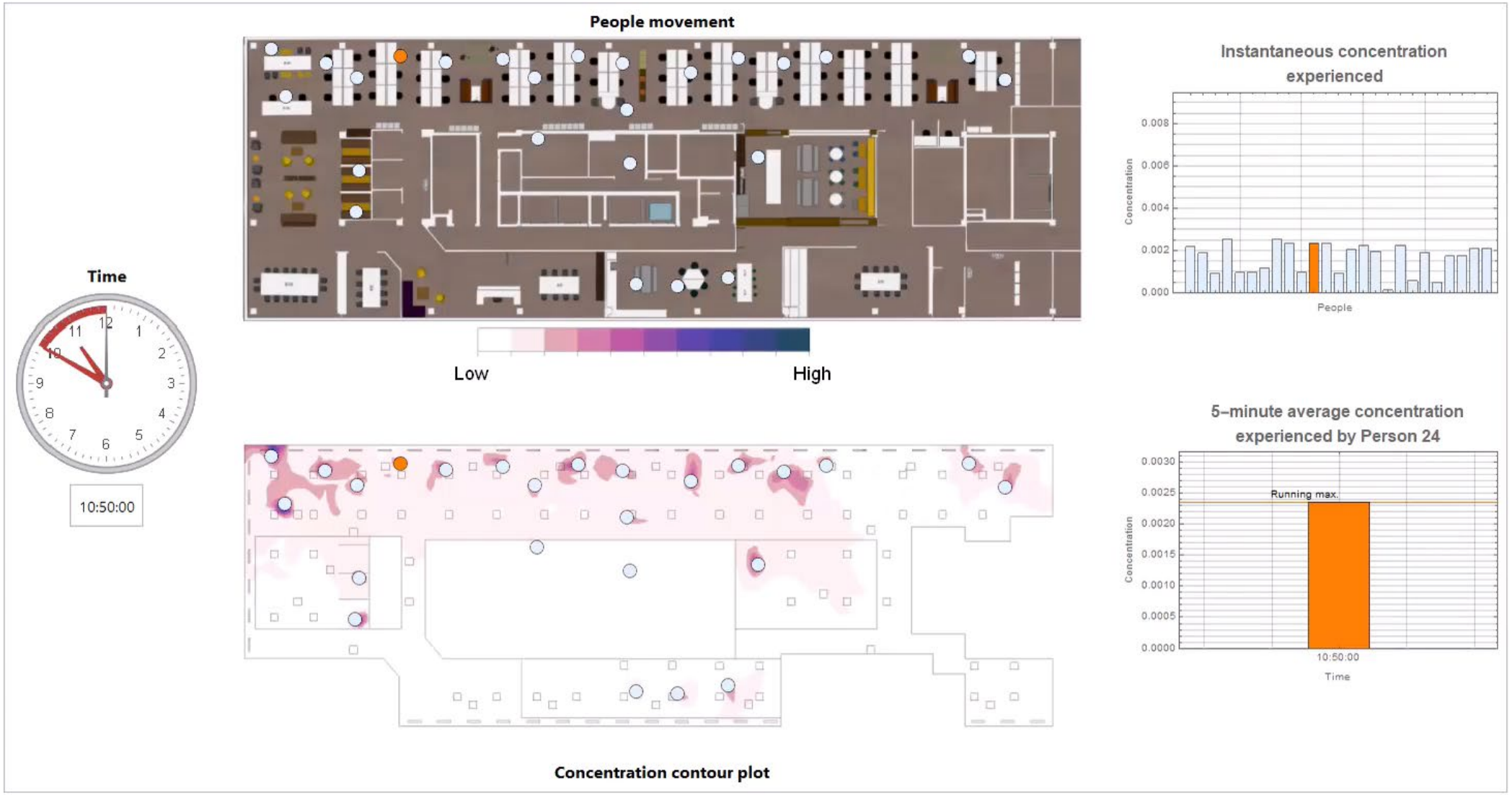

Conclusions

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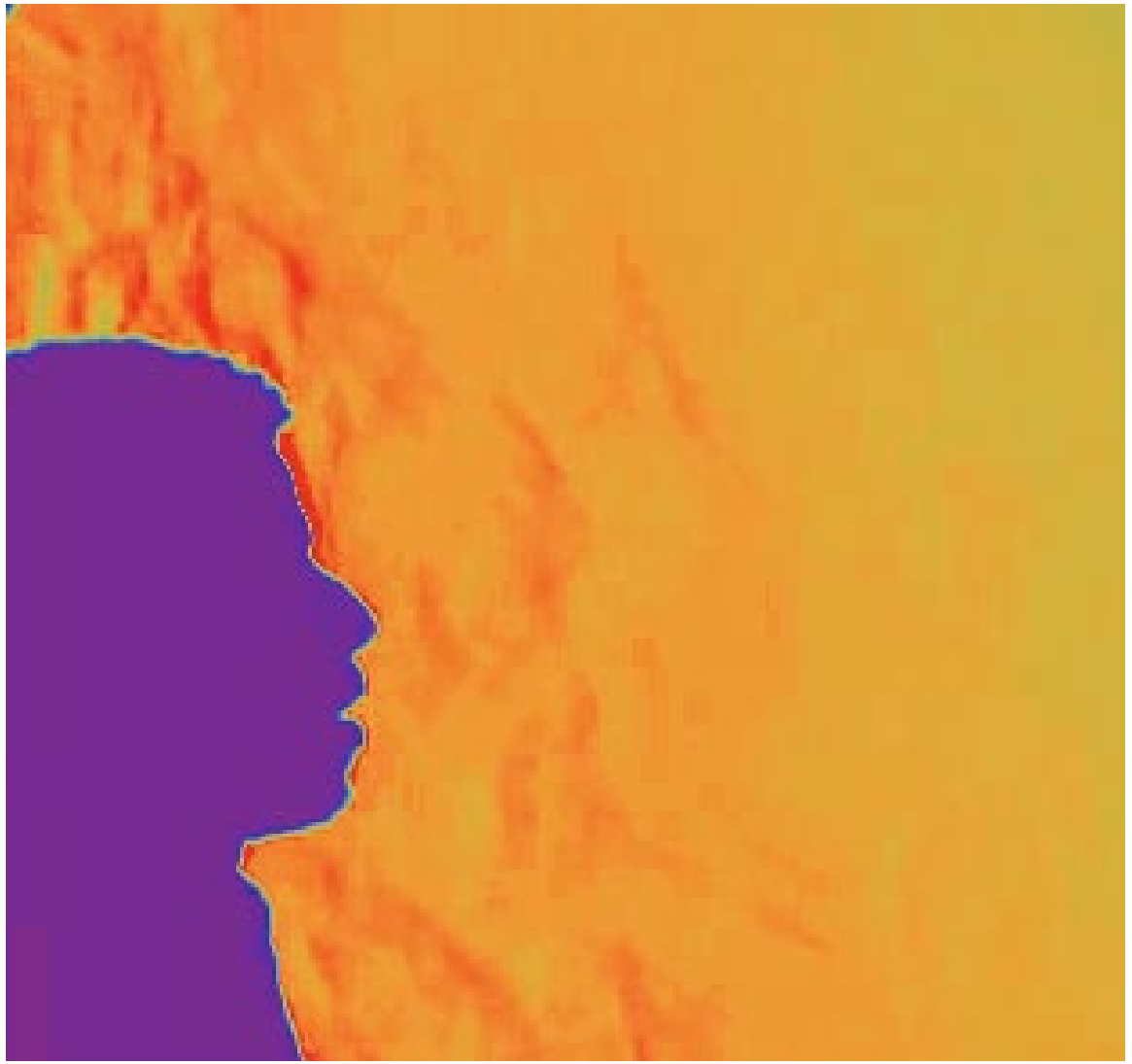
- Fluid dynamics is fundamental to understanding airborne/aerosol transmission
- Tools available to engineers can provide new and powerful insights
- Combining fluid dynamics with other fields, such as lighting and crowd modelling, can provide a new level of detail and understanding



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