Computer simulations as a tool for better indoor air

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VTT Technical Research Centre of Finland Ltd

VTT – *beyond the obvious*

VTT is a visionary research and innovation partner for companies and society.

VTT is one of Europe's leading research institutions.

We are owned by the Finnish state.

We advance the utilization and commercialization of research and technology in commerce and society.

261 M€
total revenue

2,213
employees

43 %
turnover from abroad

32 %
doctors and licentiates

Established
1942

Ownership steering: Ministry of Economic Affairs and Employment

VTT Clean Air Solutions

Cleaner air for people and processes

Challenges we address:

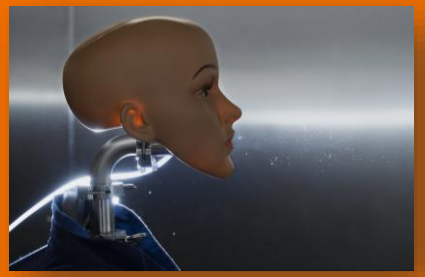
- Airborne contamination control
- Pandemic preparedness and response

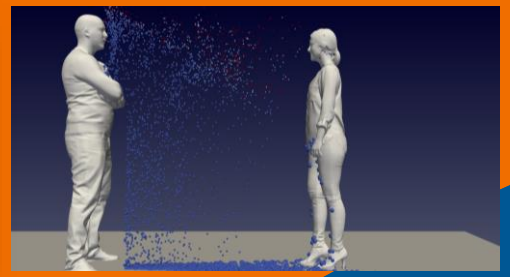
Solutions we provide:

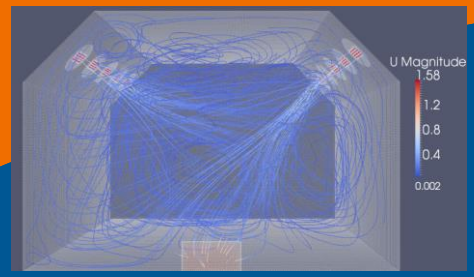
- Indoor health safety solutions and concepts
- Sustainable HVAC, air filtration, air purification and decontamination technologies

Impacts we deliver:

- Increase the healthiness and the productiveness of people
- Healthy, resilient and sustainable built environment







COVID-19 pandemic

EXCELLENCE IN PANDEMIC RESPONSE AND ENTERPRISE SOLUTIONS

www.pandemicresponse.fi

COVID-19 statistics

772,000,000 cases

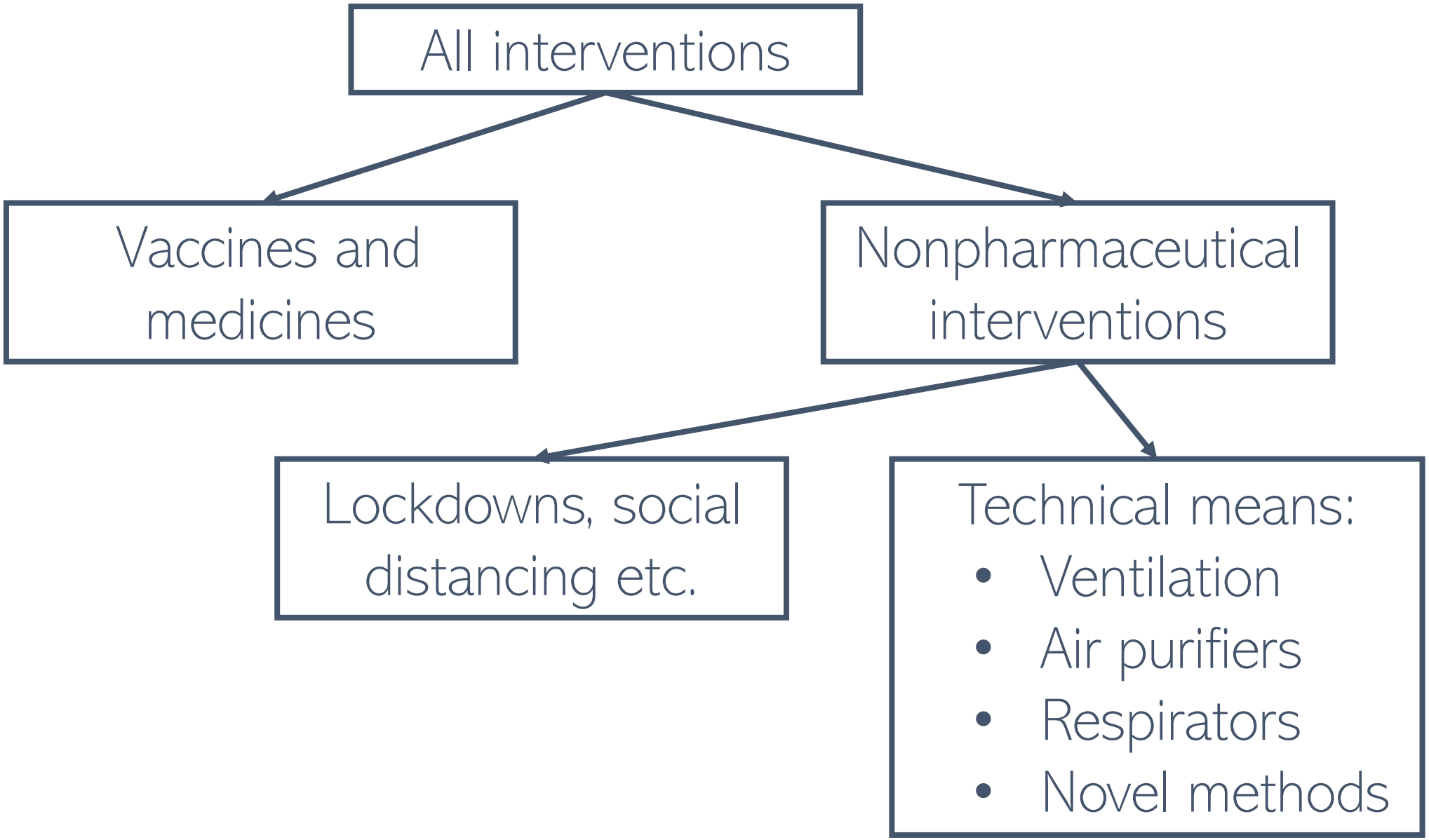
6,990,000 deaths

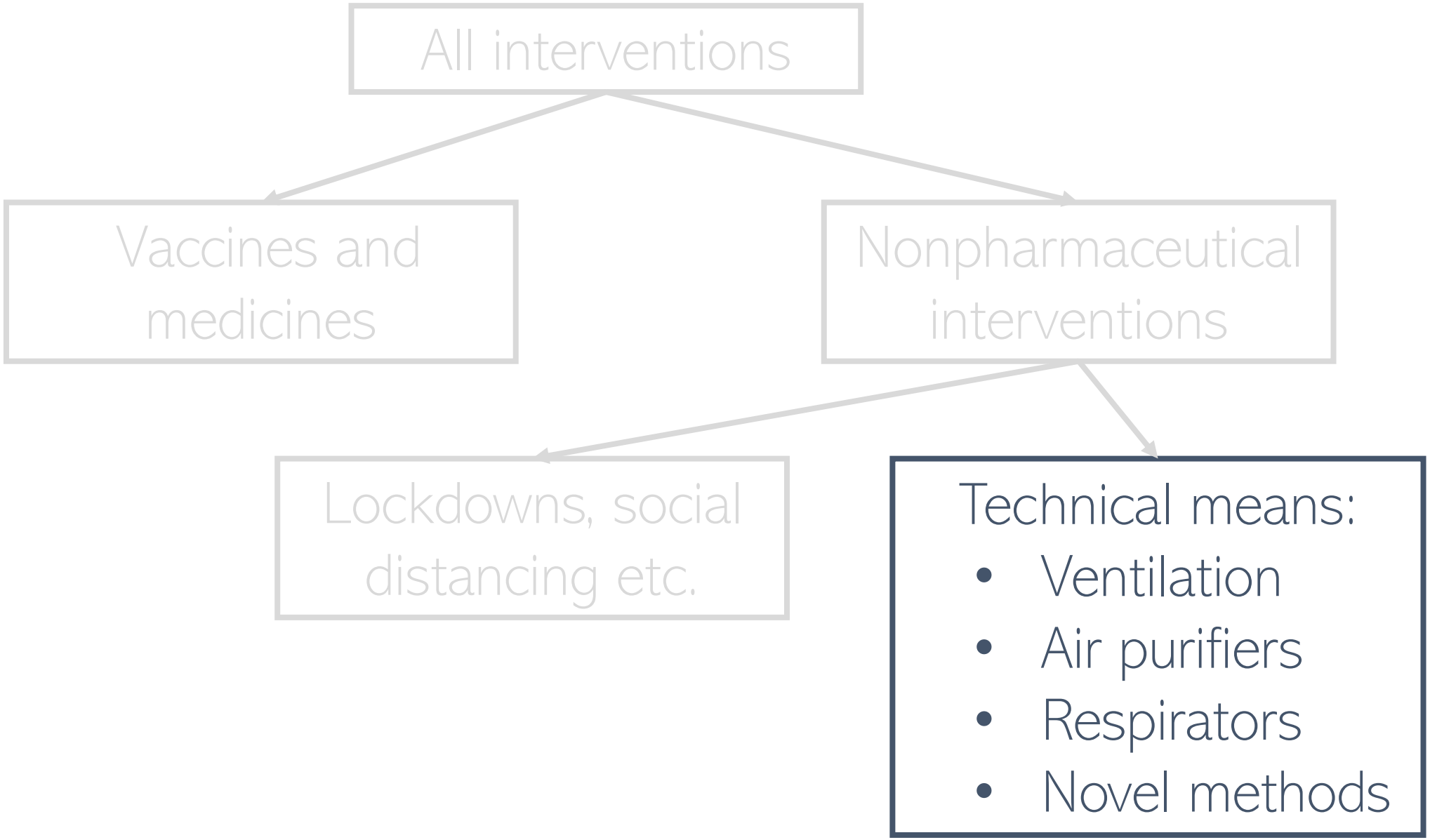
13,600,000,000 vaccine doses

Up to
$14,000,000,000,000
by the end of 2023
in the US alone

Almost
$2,000 for every
citizen of the planet

What can we do?


All interventions
Vaccines and medicines
Nonpharmaceutical interventions
Lockdowns, social distancing etc.
Technical means:
• Ventilation
• Air purifiers
• Respirators
• Novel methods


All interventions
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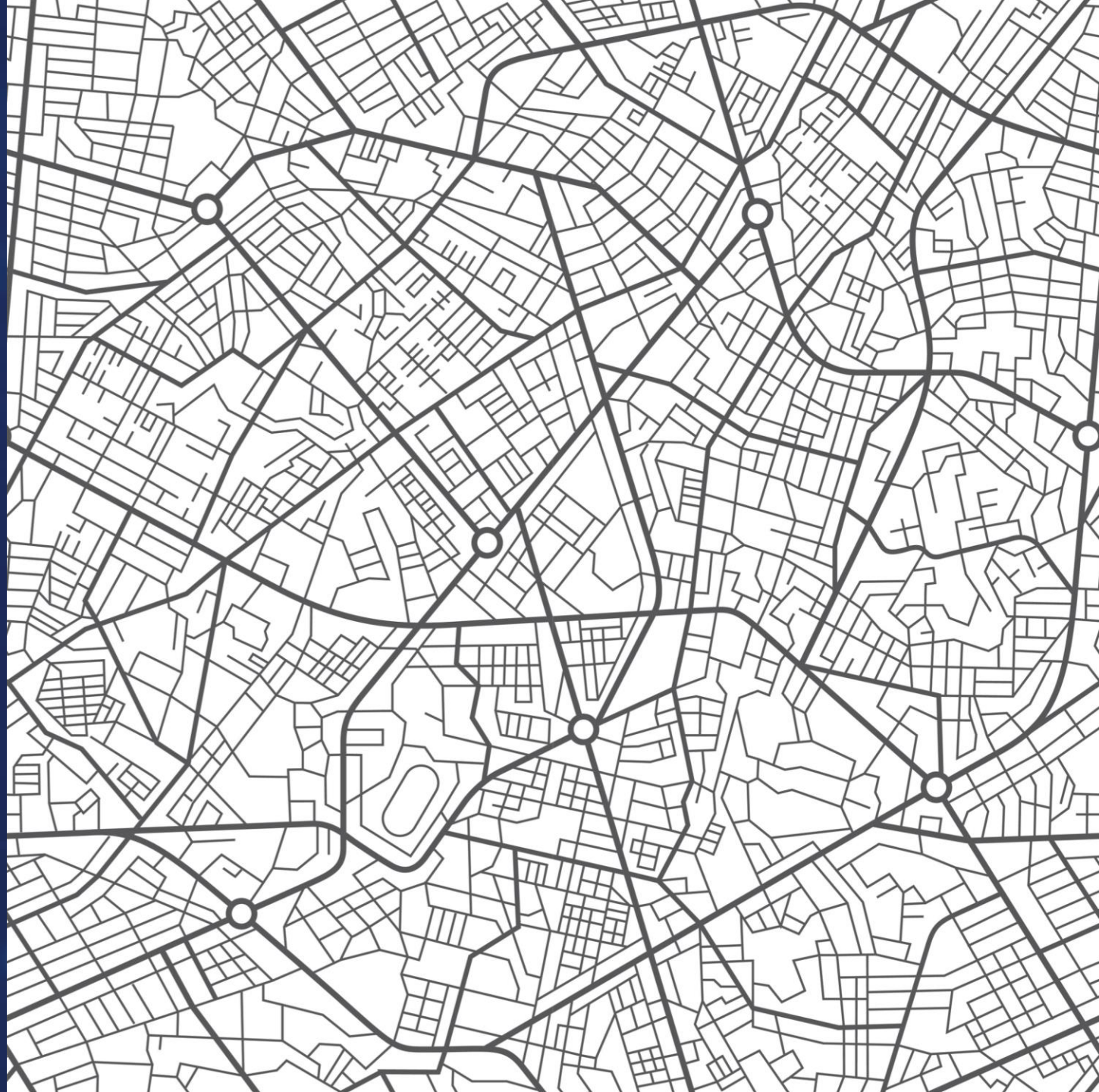
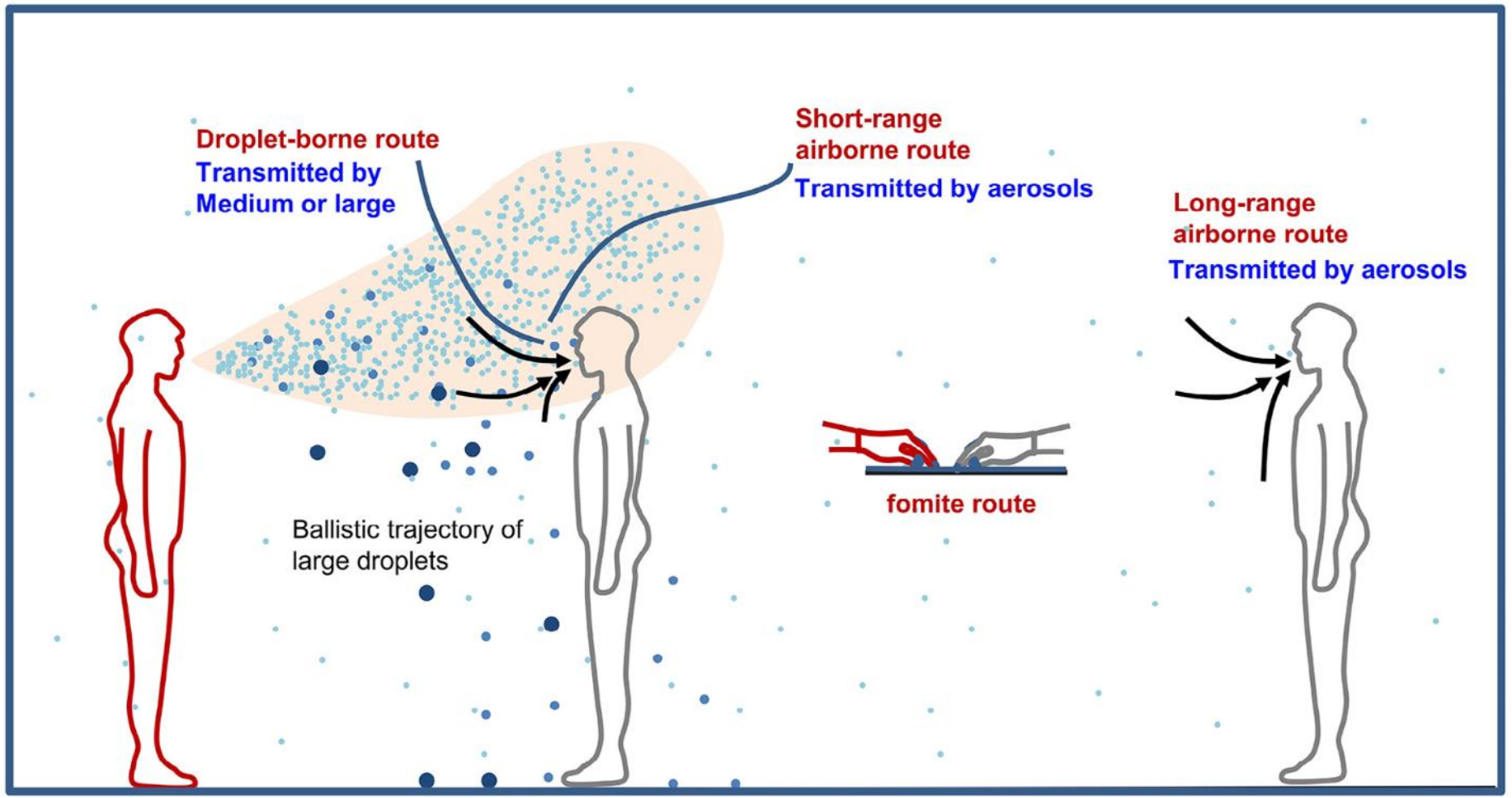
Airborne transmission

Transmission routes



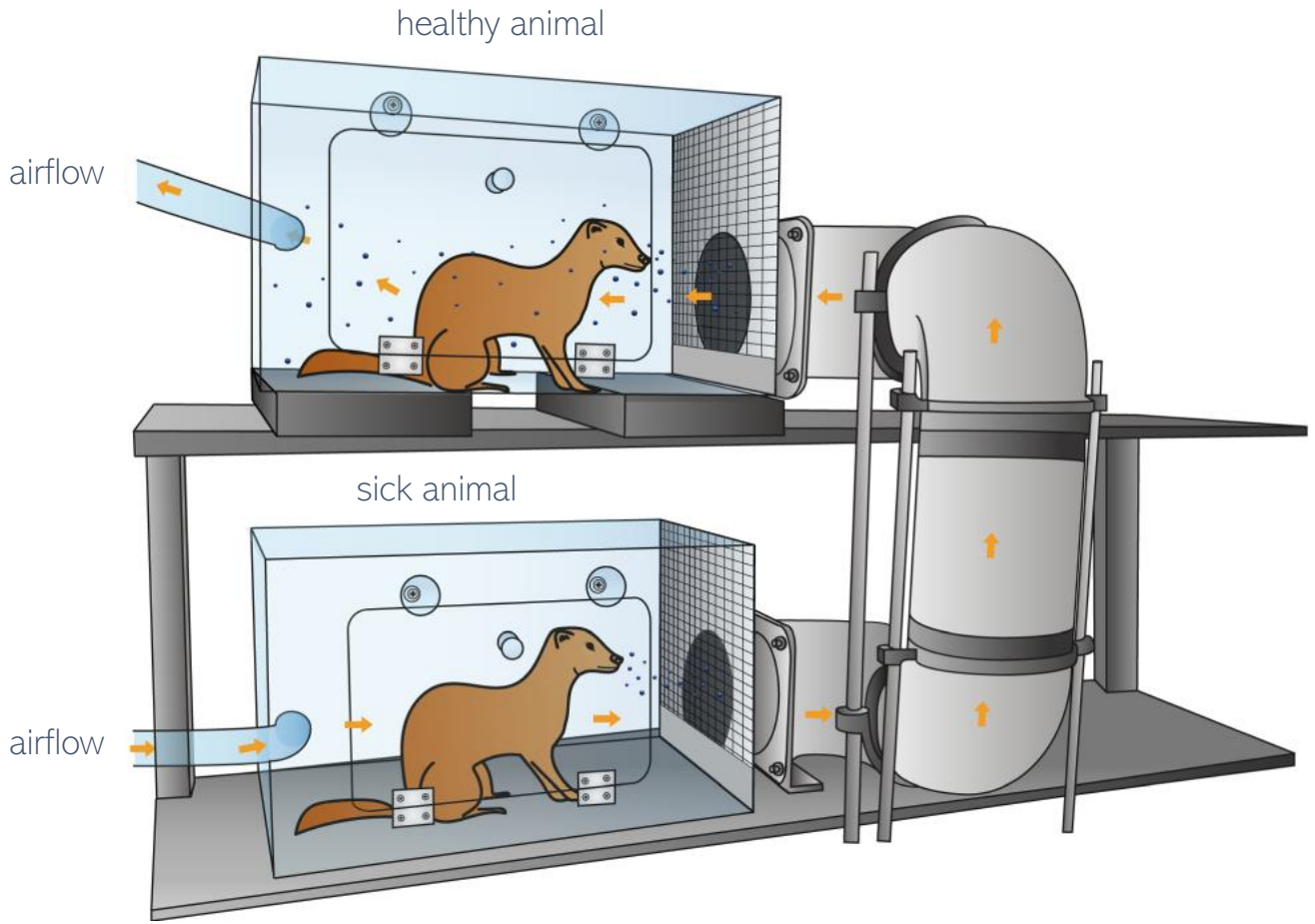
Transmission routes



Wei, Jianjian, and Yuguo Li. 'Airborne Spread of Infectious Agents in the Indoor Environment'. American Journal of Infection Control, Indoor Air as a Vehicle for Human Pathogens, 44, no. 9, Supplement (2 September 2016): S102–8.

COVID-19, airborne or not?

Ferret test, spring 2021



1. Droplet and surface infection impossible
2. A healthy animal fell ill
3. It must be an aerosol infection

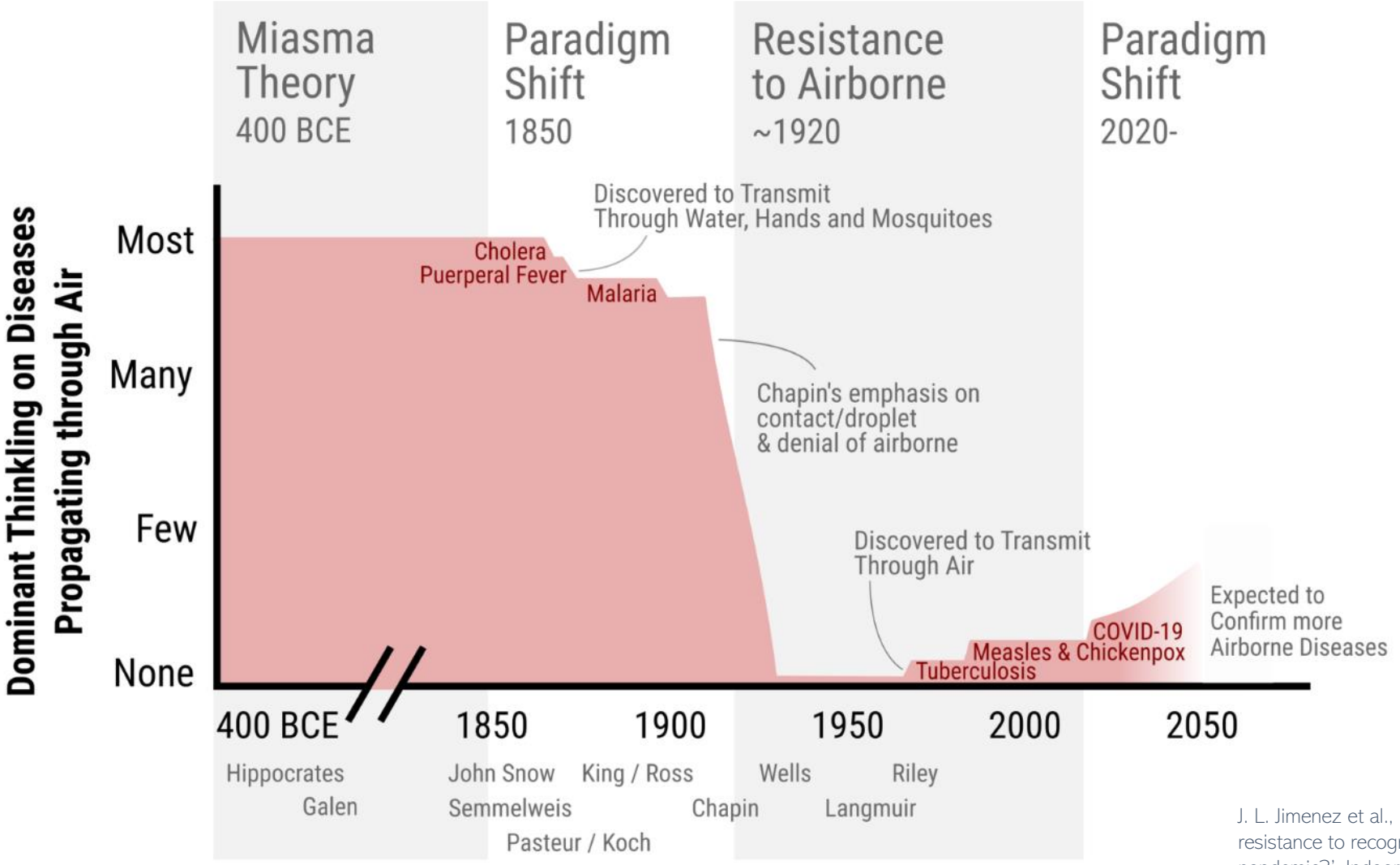
J. S. Kutter et al., 'SARS-CoV and SARS-CoV-2 are transmitted through the air between ferrets over more than one meter distance', Nature Communications, vol. 12, no. 1, Art. no. 1, Mar. 2021.

Other evidence

- Transmission of SARS-CoV-2 is higher indoors than outdoors
  - is substantially reduced by indoor ventilation
- Viable SARS-CoV-2 has been detected in the air
- Quarantine hotels
  - long-range transmission
- Infections in hospitals, where there have been
  - strict contact-and-droplet precautions
  - use of personal protective equipment designed to protect against droplet but not aerosol exposure
- SARS-CoV-2 has been identified in air filters and building ducts in hospitals
  - such locations could be reached only by aerosols

T. Greenhalgh, J. L. Jimenez, K. A. Prather, Z. Tufekci, D. Fisman, and R. Schooley, 'Ten scientific reasons in support of airborne transmission of SARS-CoV-2', The Lancet, Apr. 2021.

Other respiratory infections – airborne too?



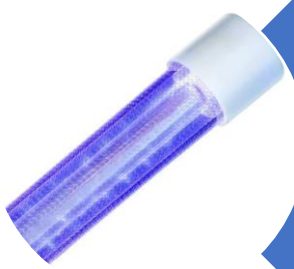
J. L. Jimenez et al., 'What were the historical reasons for the resistance to recognizing airborne transmission during the COVID-19 pandemic?', Indoor Air, vol. 32, no. 8, p. e13070, 2022.

What can we do?

What can we do?

Move Pathogens from Inside to Outside

Collect Pathogens



Inactivate Pathogens

What can we do?

Computational fluid dynamics (CFD)

Computational fluid dynamics (CFD)

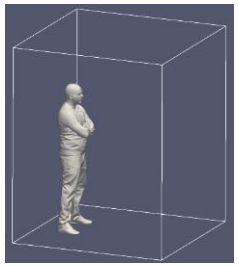
- Navier-Stokes equations:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

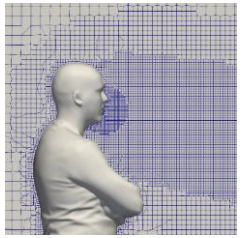
$$\frac{\partial}{\partial t}(\rho\,\mathbf{u}) + \nabla \cdot (\rho\,\mathbf{u} \otimes \mathbf{u}) = -\nabla p + \mu\,\nabla^2 \mathbf{u} + \tfrac{1}{3}\mu\,\nabla(\nabla \cdot \mathbf{u}) + \rho \mathbf{g}$$

Computational fluid dynamics (CFD)

Domain



Discretization



Airflow

Particles

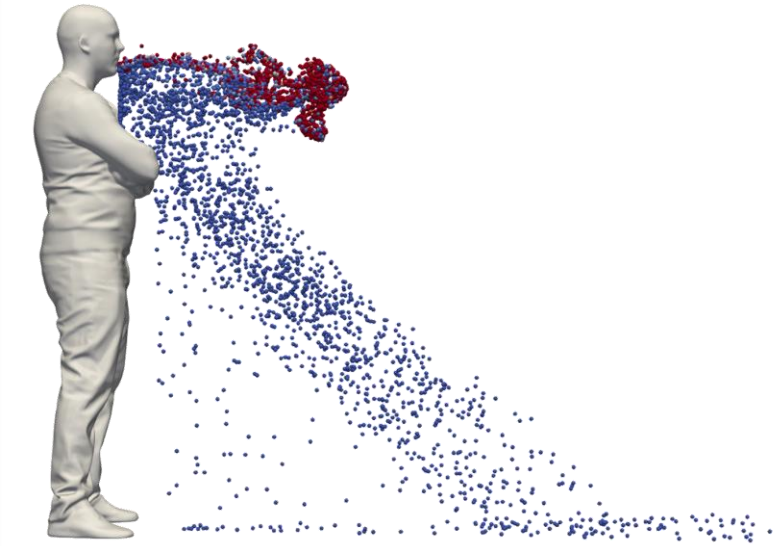
Forces:

- Drag
- Buoyancy
- Virtual mass
- History
- Etc.

HPC*

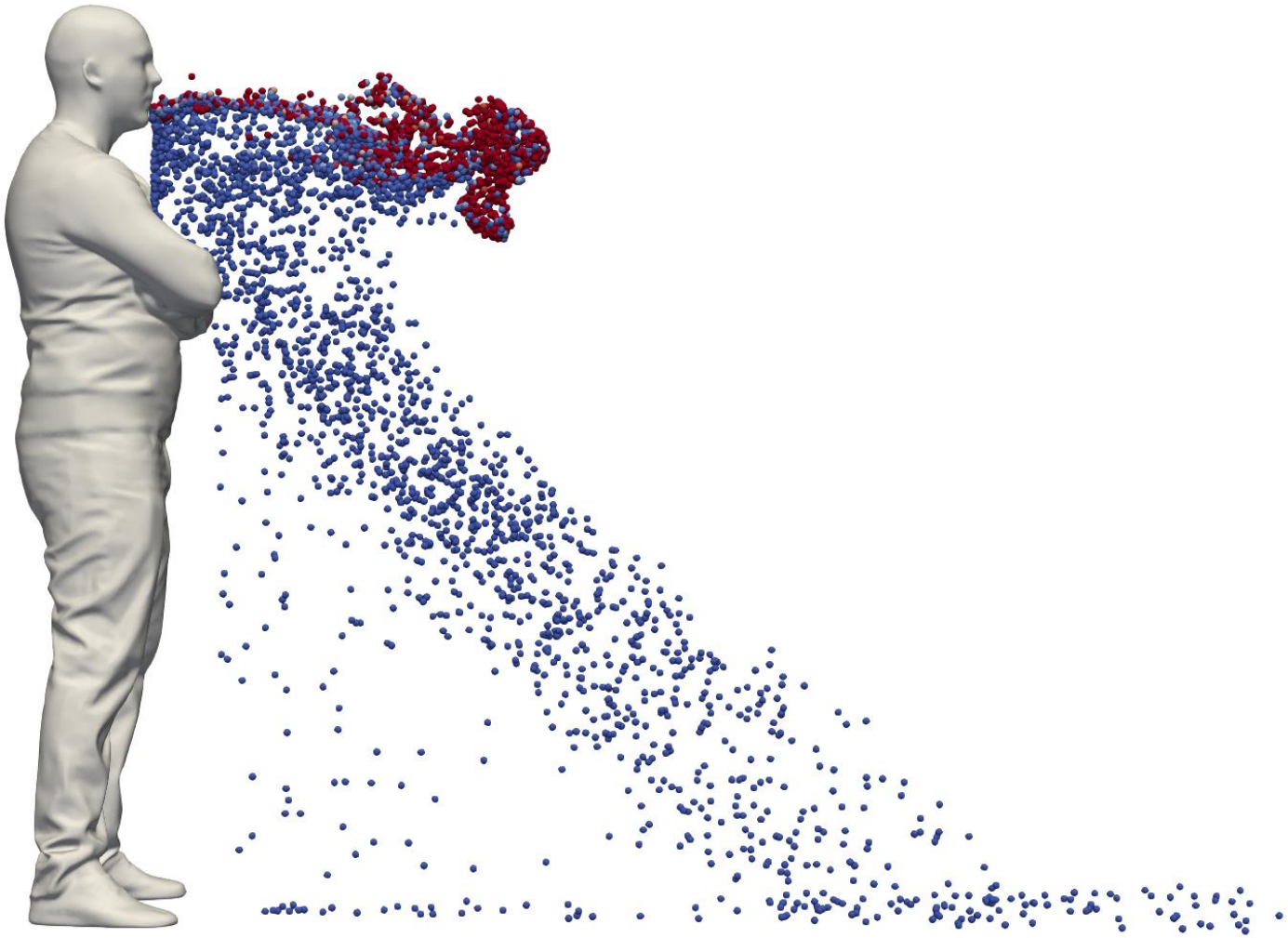
Hundreds or thousands of CPU cores

Days or weeks

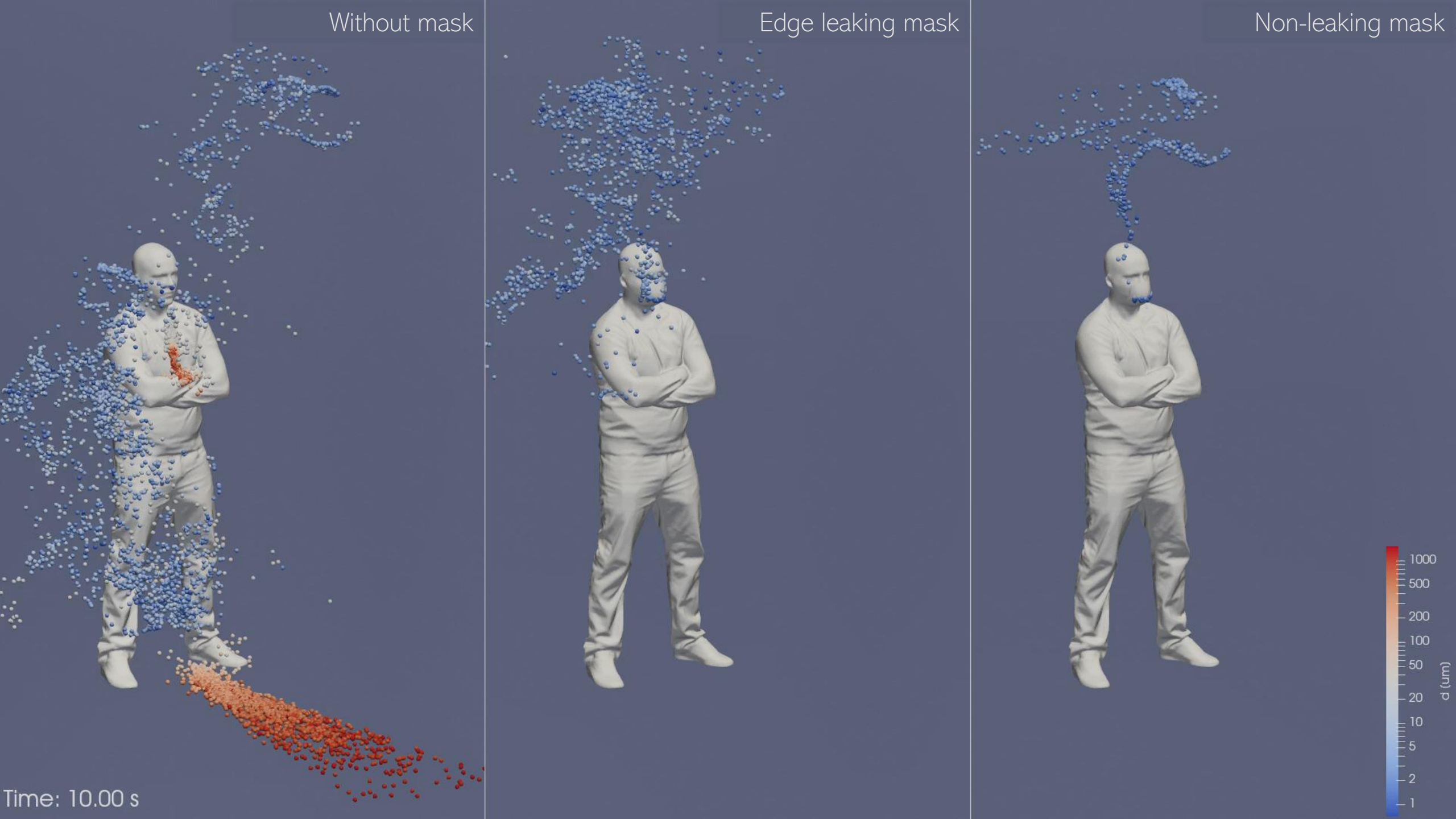


*High Performance Computing

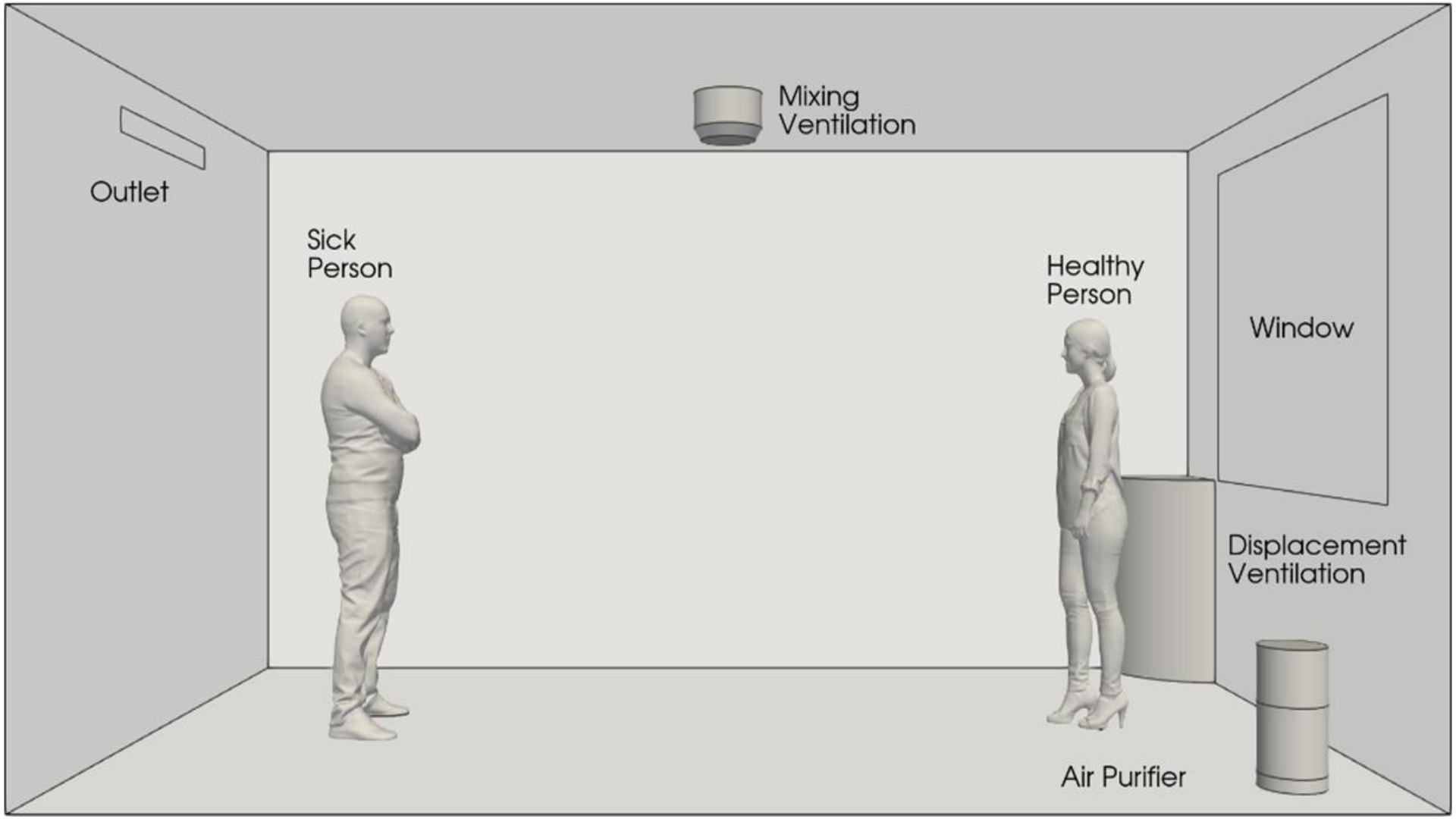
Computational fluid dynamics (CFD)

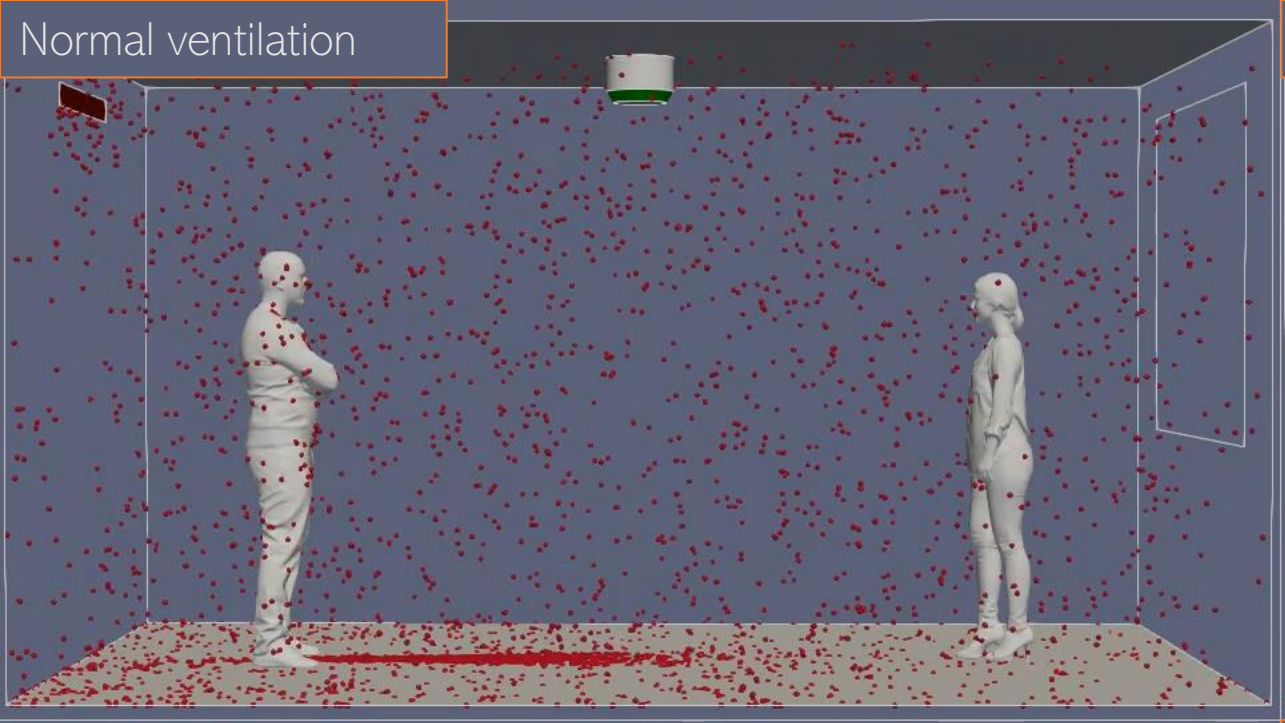


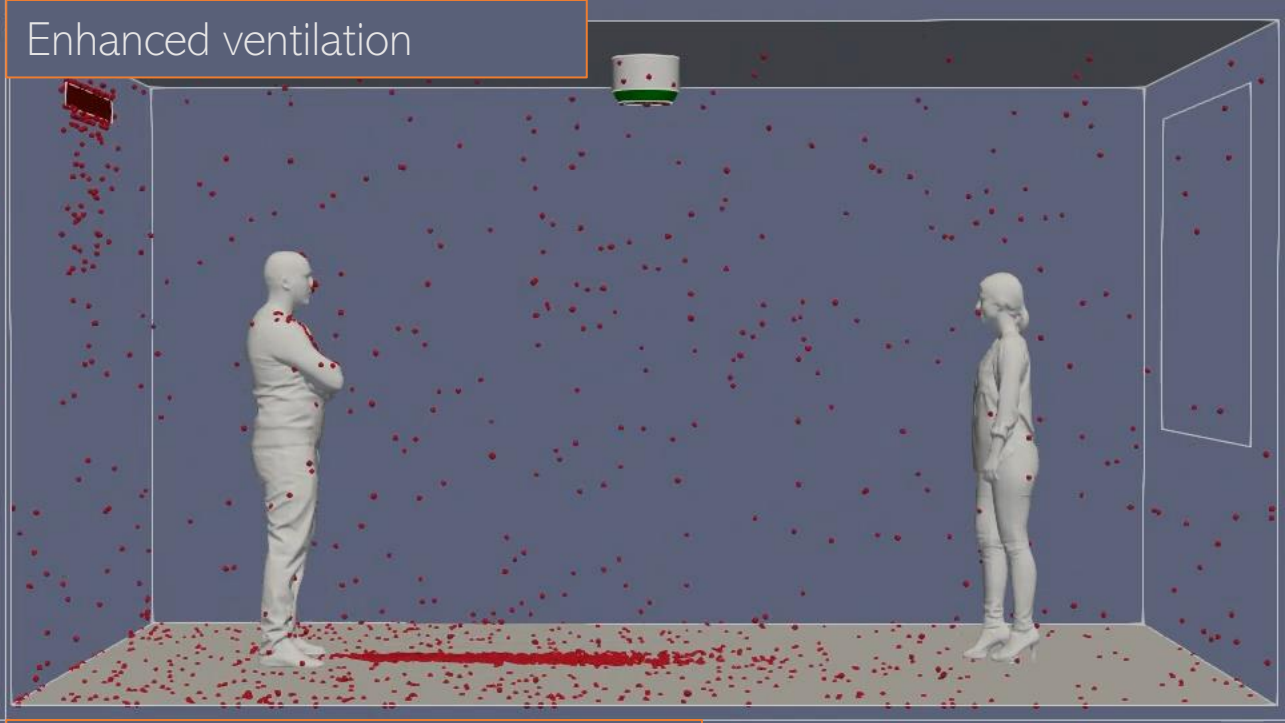
- Red = dry
- Blue = moist

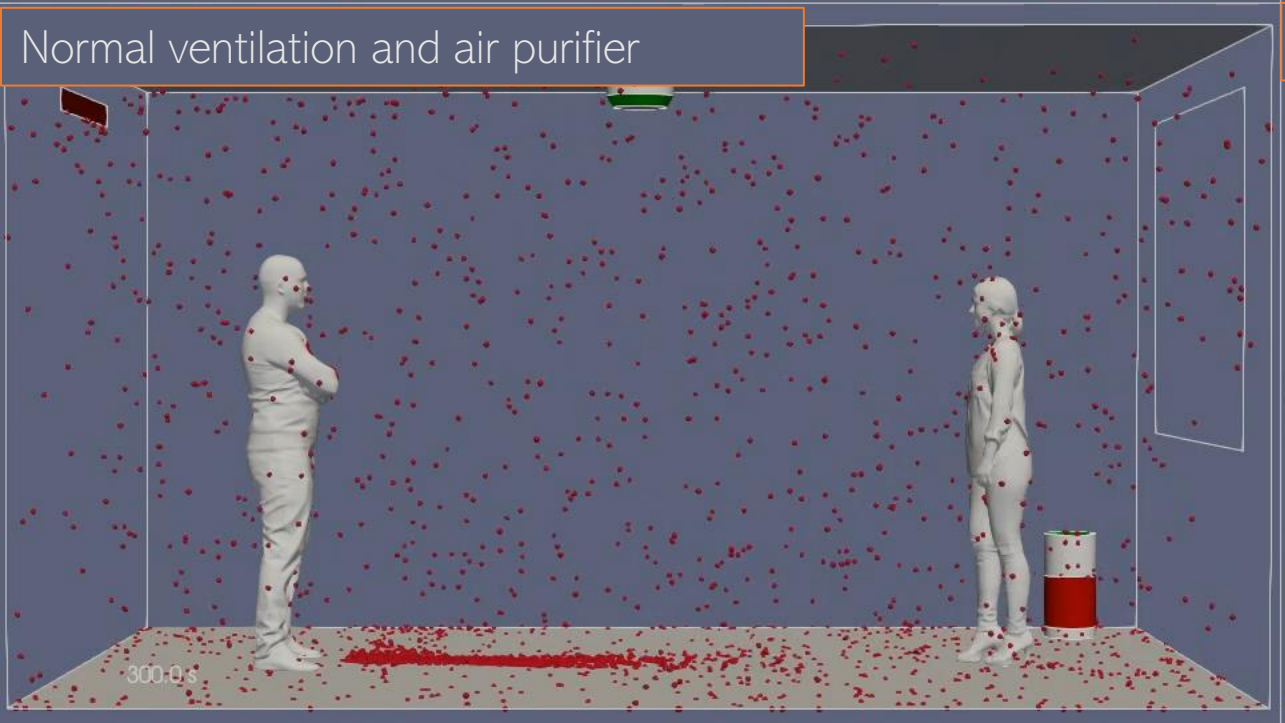

Without mask
Edge leaking mask
Non-leaking mask
Time: 10.00 s
1000
500
200
100
50
20
10
5
2
1
d (um)

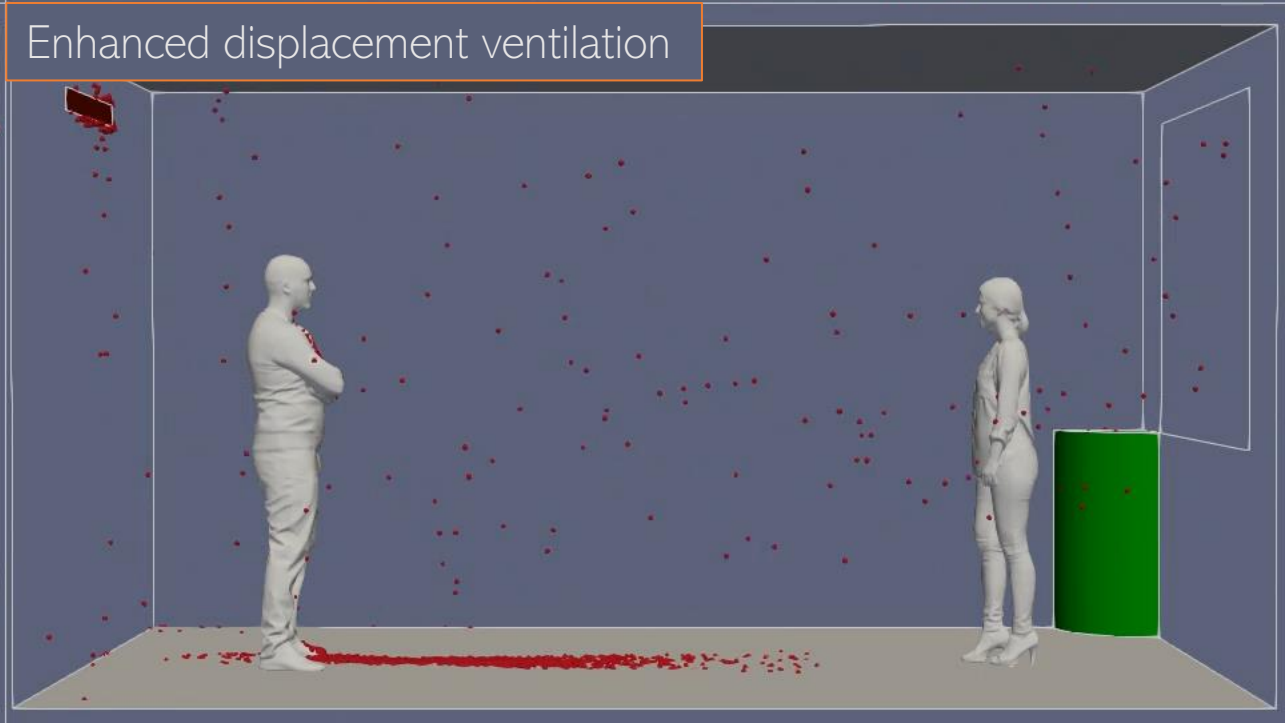
Example


Mixing
Ventilation
Outlet
Sick
Person
Healthy
Person
Window
Displacement
Ventilation
Air Purifier

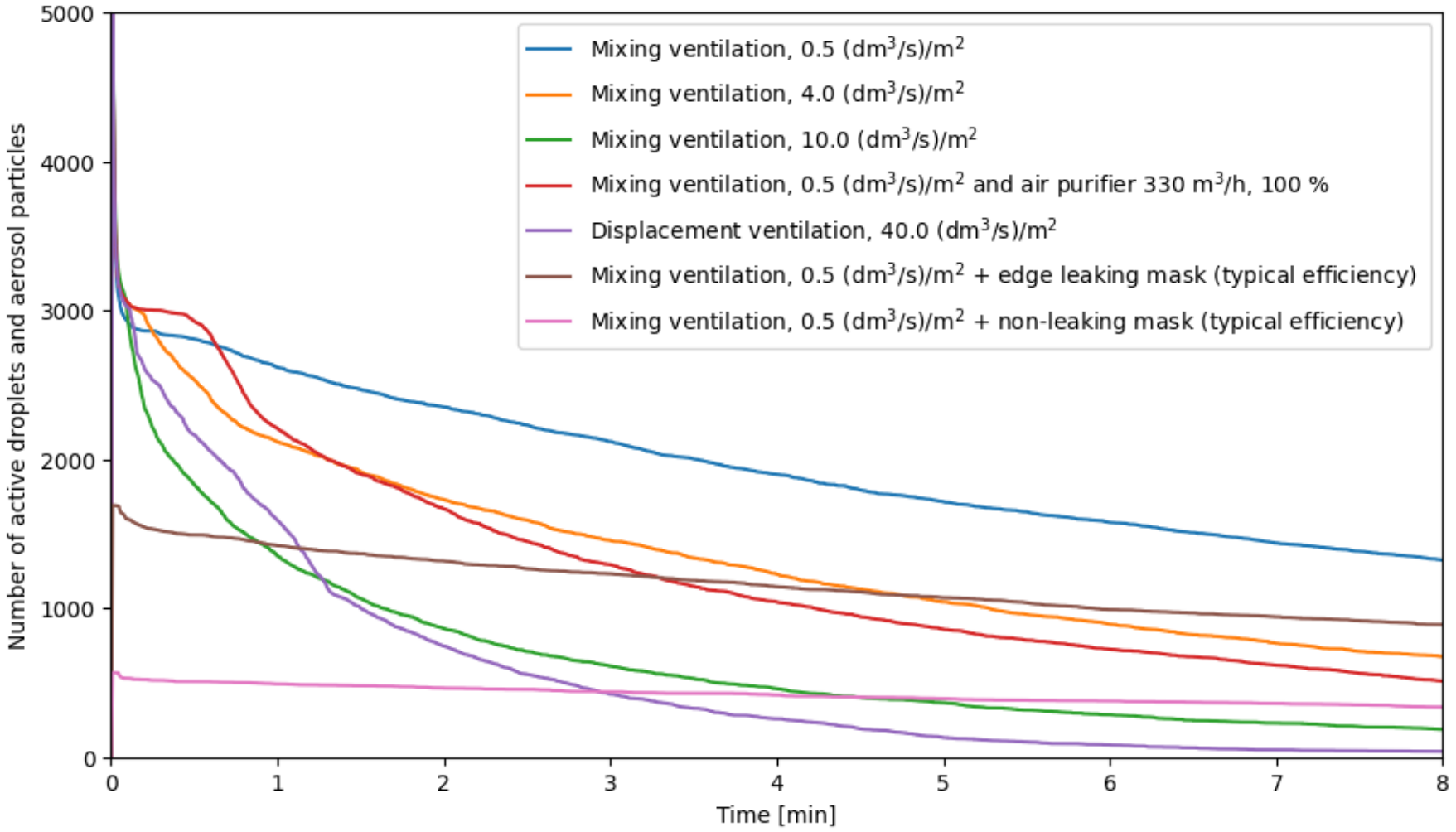

Normal ventilation


Enhanced ventilation

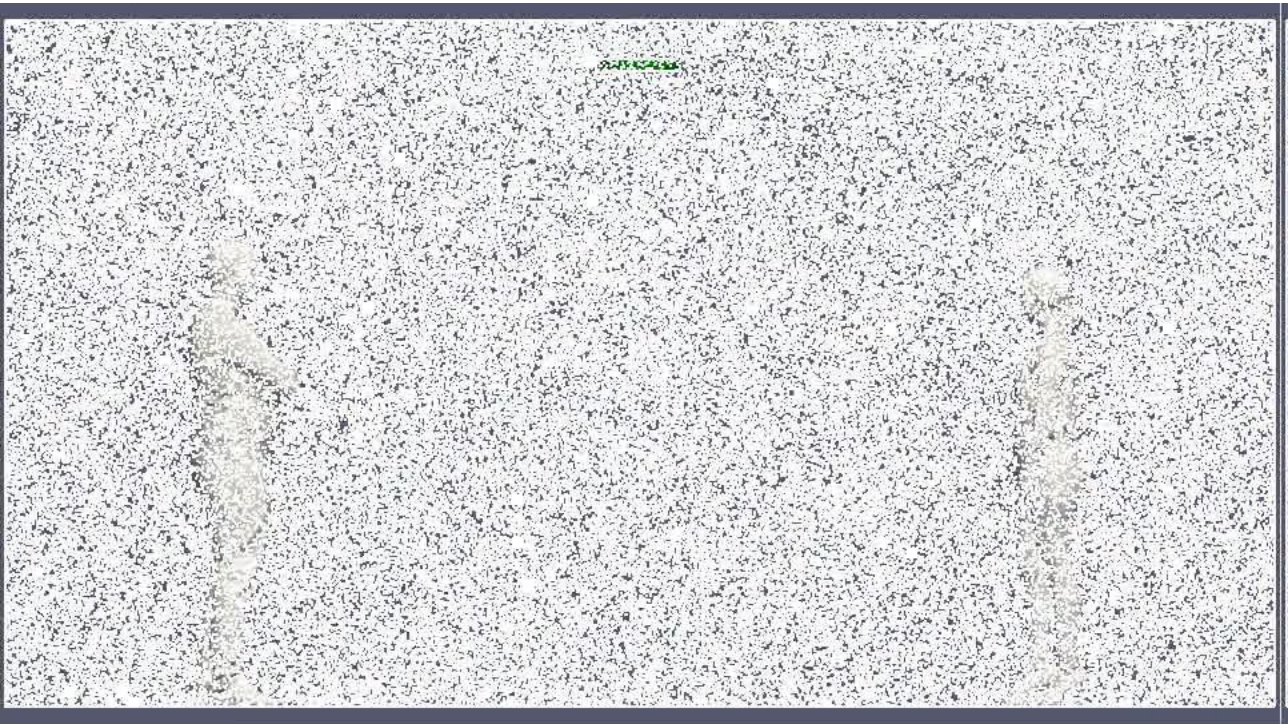

Normal ventilation and air purifier


Enhanced displacement ventilation

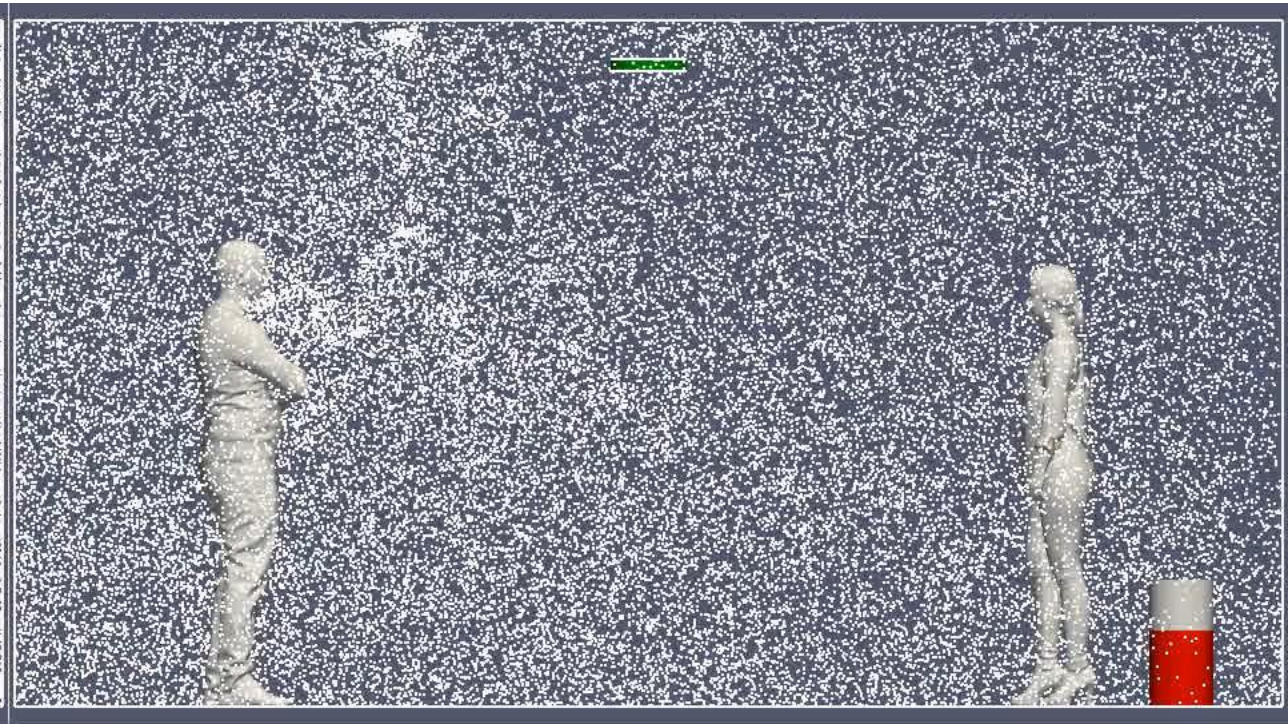
Number of particles in air



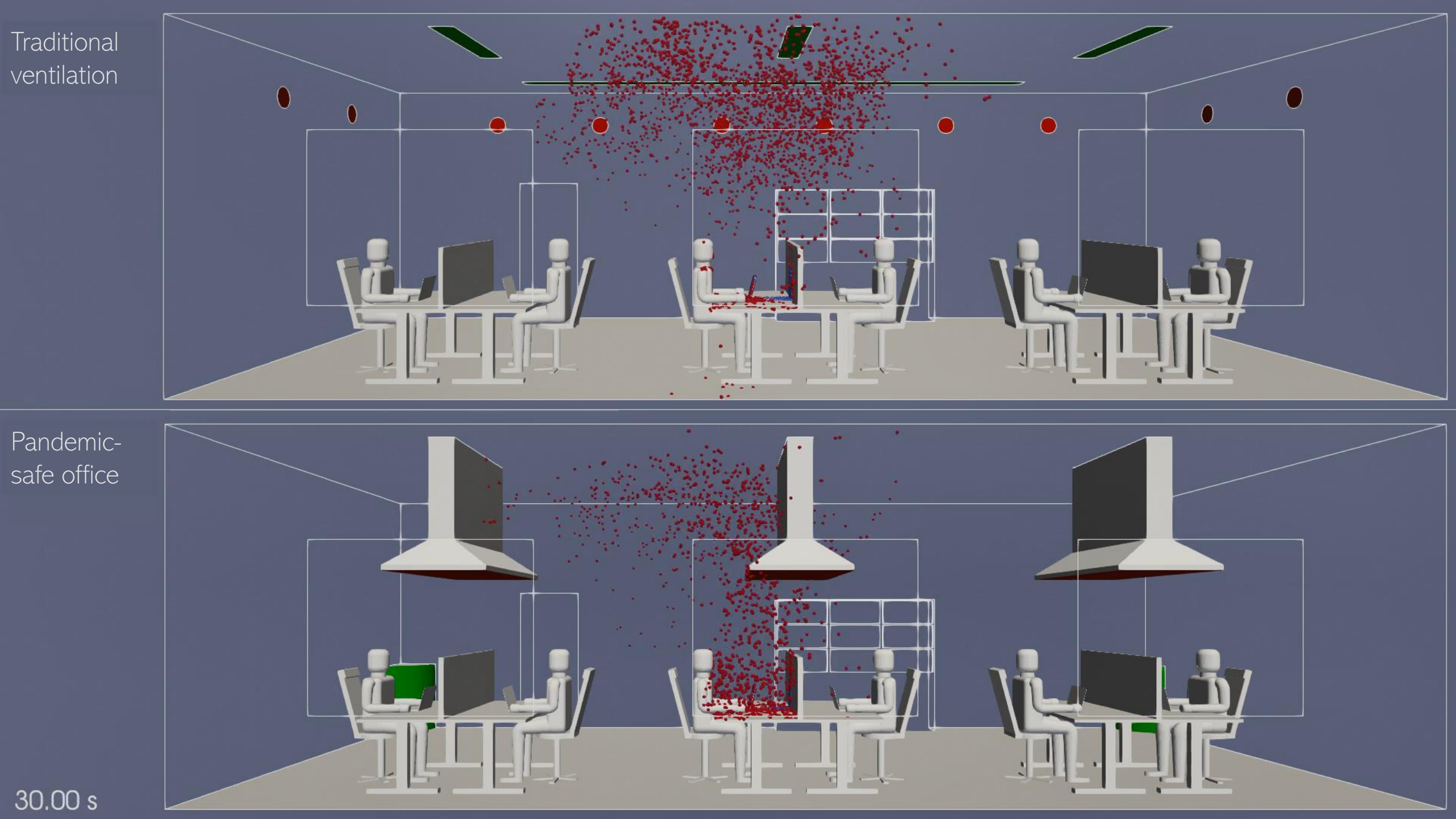
Breathing



Without air purifier

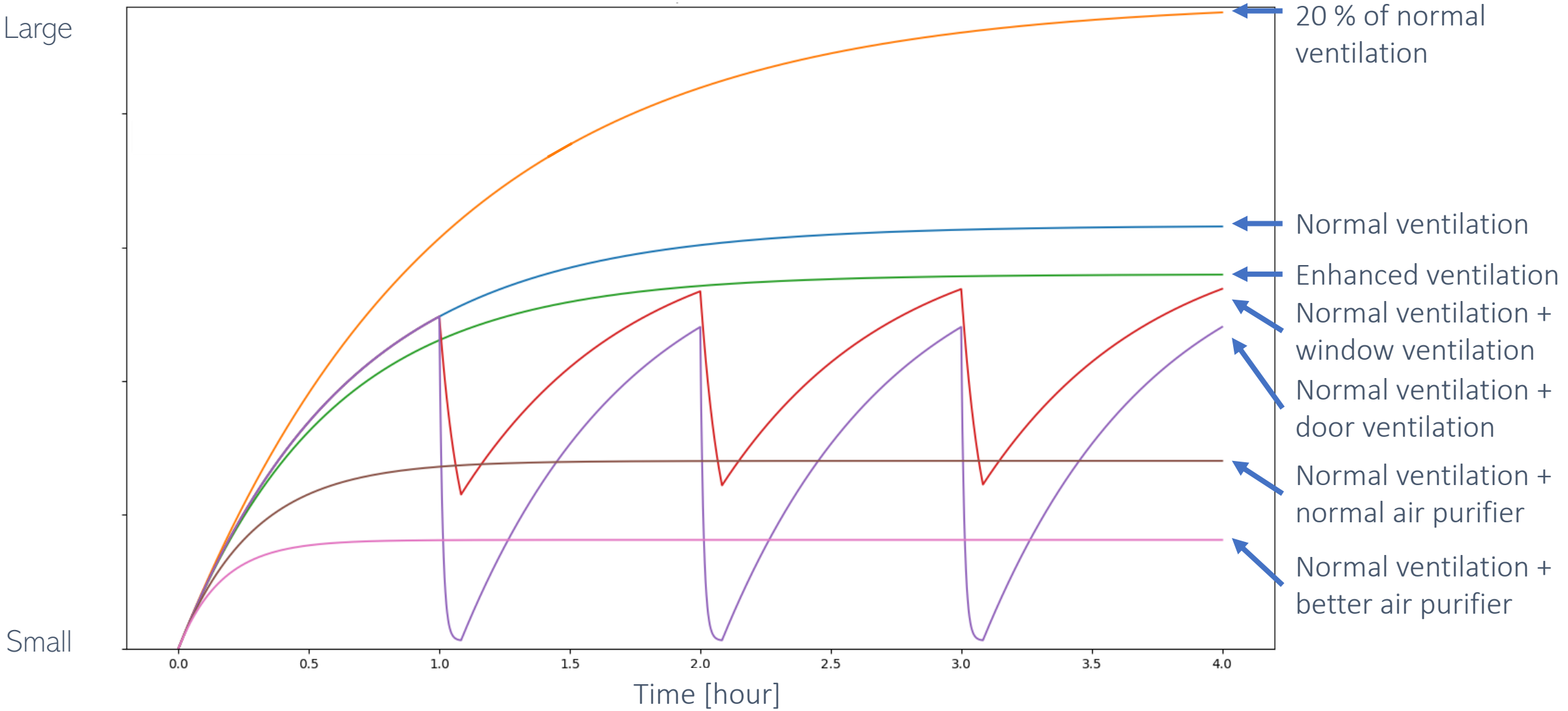


With air purifier


Traditional ventilation
Pandemic-safe office
30.00 s

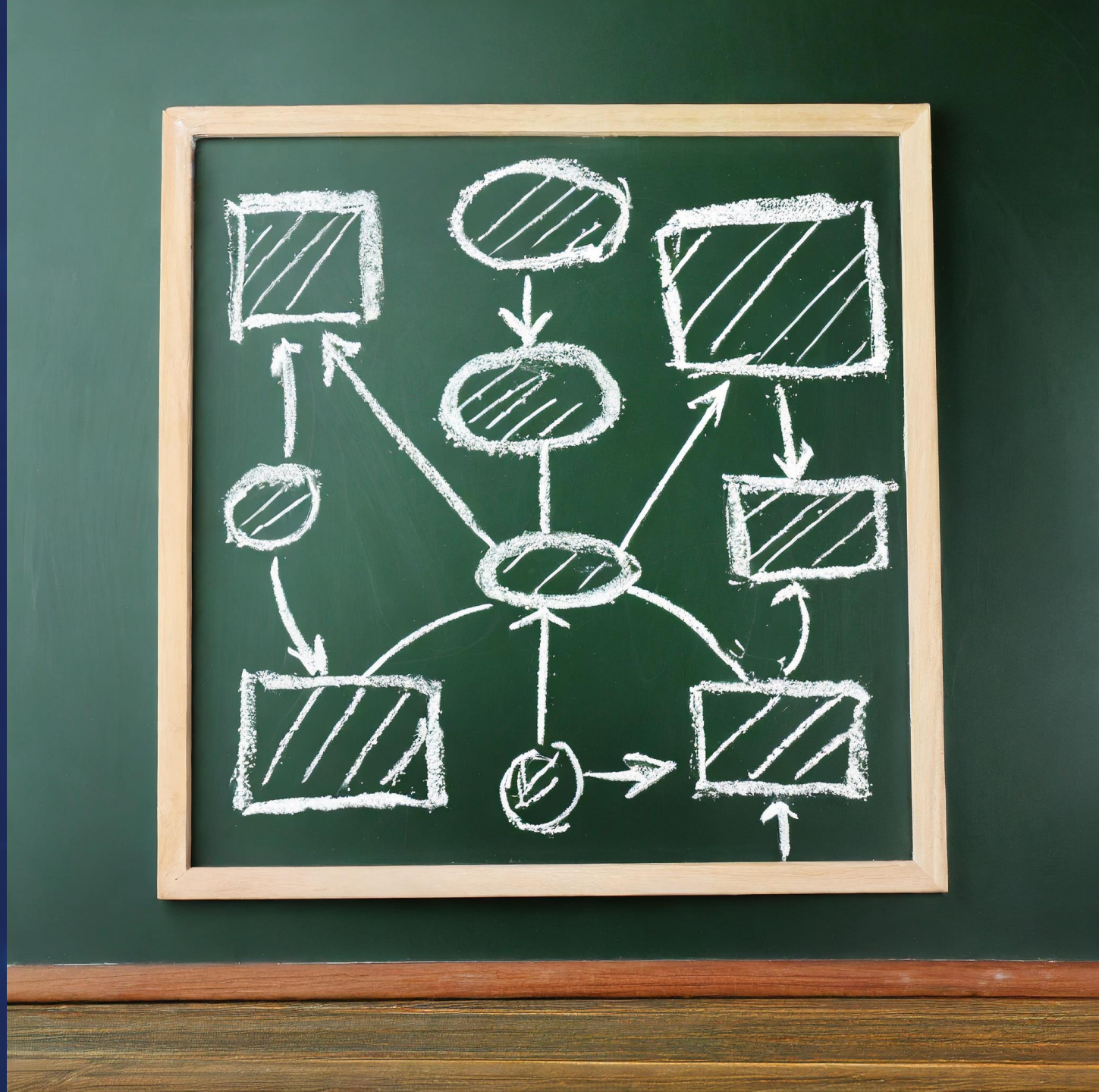
Alternative approach

Probability of infection (via airborne route)



Modelling can be used in airborne research

Summary



Summary

1. COVID-19 is airborne
2. Airborne transmission is preventable
3. Modelling helps to understand and prevent airborne transmission

Thank You!

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