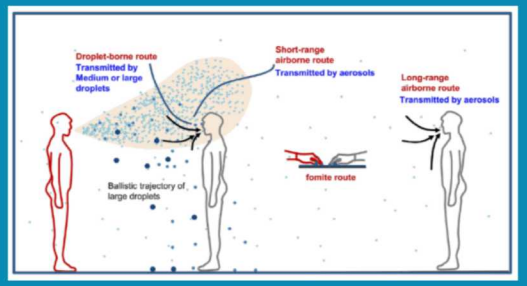
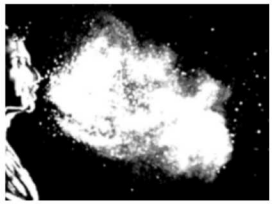
Sandia Talk – July 14, 2020

SAND2020-6826PE

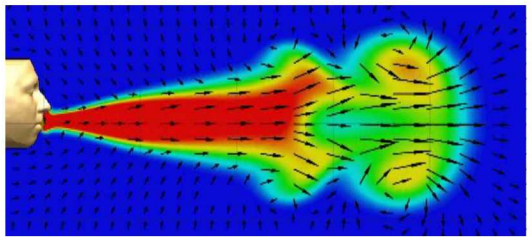
Modeling Airborne Transmission of SARS-CoV-2 (COVID-19)

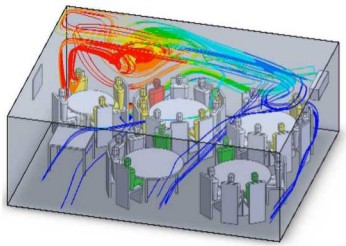


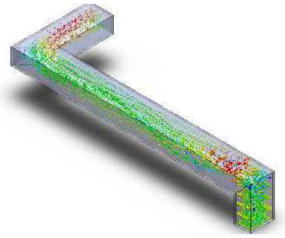
Wei and Li (2016)



Bourouiba et al. (2014)







Clifford K. Ho, Sr. Scientist, Org. 8820

Project funded by the COVID-19 LDRD program

Overview

- Introduction and Objectives
- Physics of Coughs and Sneezes
- Modeling Airborne Pathogen Transmission
- Conclusions

Overview

- Introduction and Objectives
- Physics of Coughs and Sneezes
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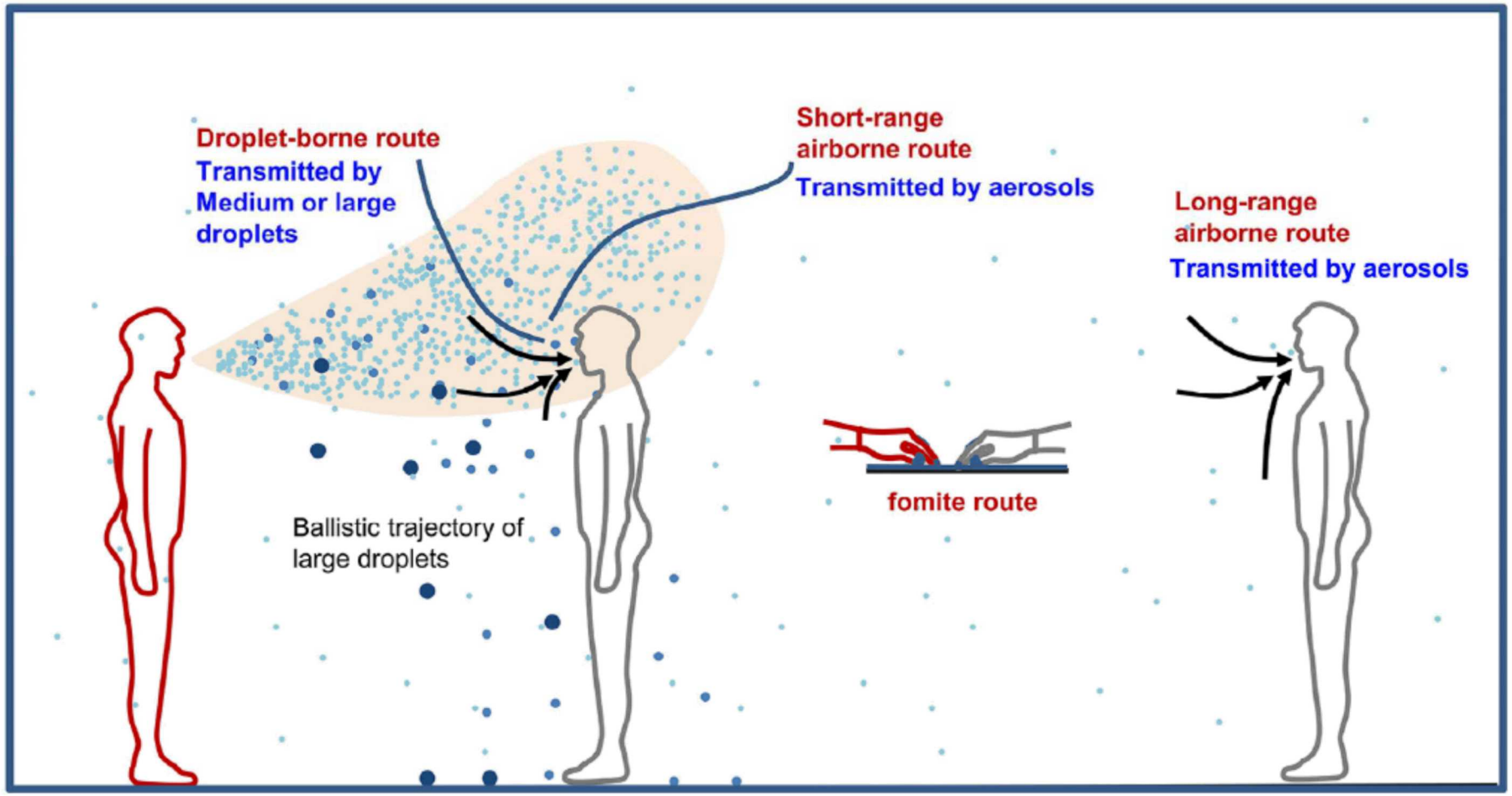
- Conclusions

Is 6 feet of “social distancing” sufficient?

Introduction - Pathogen Transmission Routes

J. Wei, Y. Li / American Journal of Infection Control 44 (2016) S102-S108



- Large droplets (>100 μm) : Fast deposition due to the domination of gravitational force
- Medium droplets between 5 and 100 μm
- Small droplets or droplet nuclei, or aerosols (< 5 μm): Responsible for airborne transmission

Introduction – Airborne Transmission of COVID-19?

January 24, 2020
COVID-19 outbreak in restaurant in Guangzhou, China

CDC Centers for Disease Control and Prevention
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Volume 26, Number 7—July 2020

Research Letter

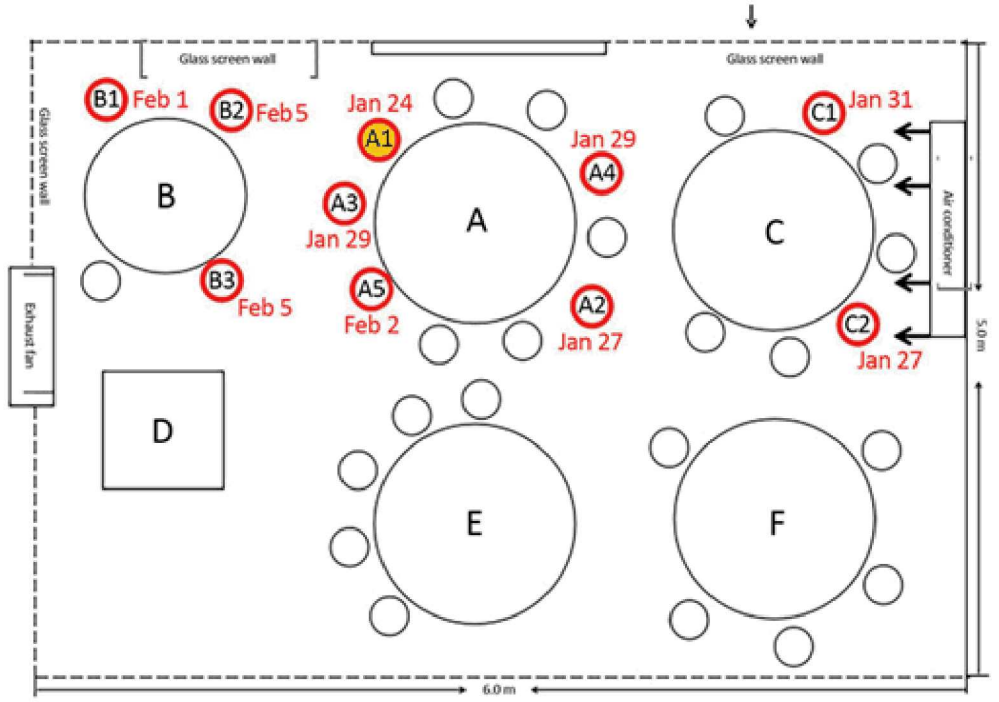
COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020

Jianyun Lu[1], Jieni Gu[1], Kuibiao Li[1], Conghui Xu[1], Wenzhe Su, Zhisheng Lai, Deqian Zhou, Chao Yu, Bin Xu✉, and Zhicong Yang✉

Author affiliations: Guangzhou Center for Disease Control and Prevention, Guangzhou, China (J. Lu, K. Li, C. Xu, W. Su, C. Yu, Z. Yang); Guangzhou Yuexiu District Center for Disease Control and Prevention, Guangzhou,

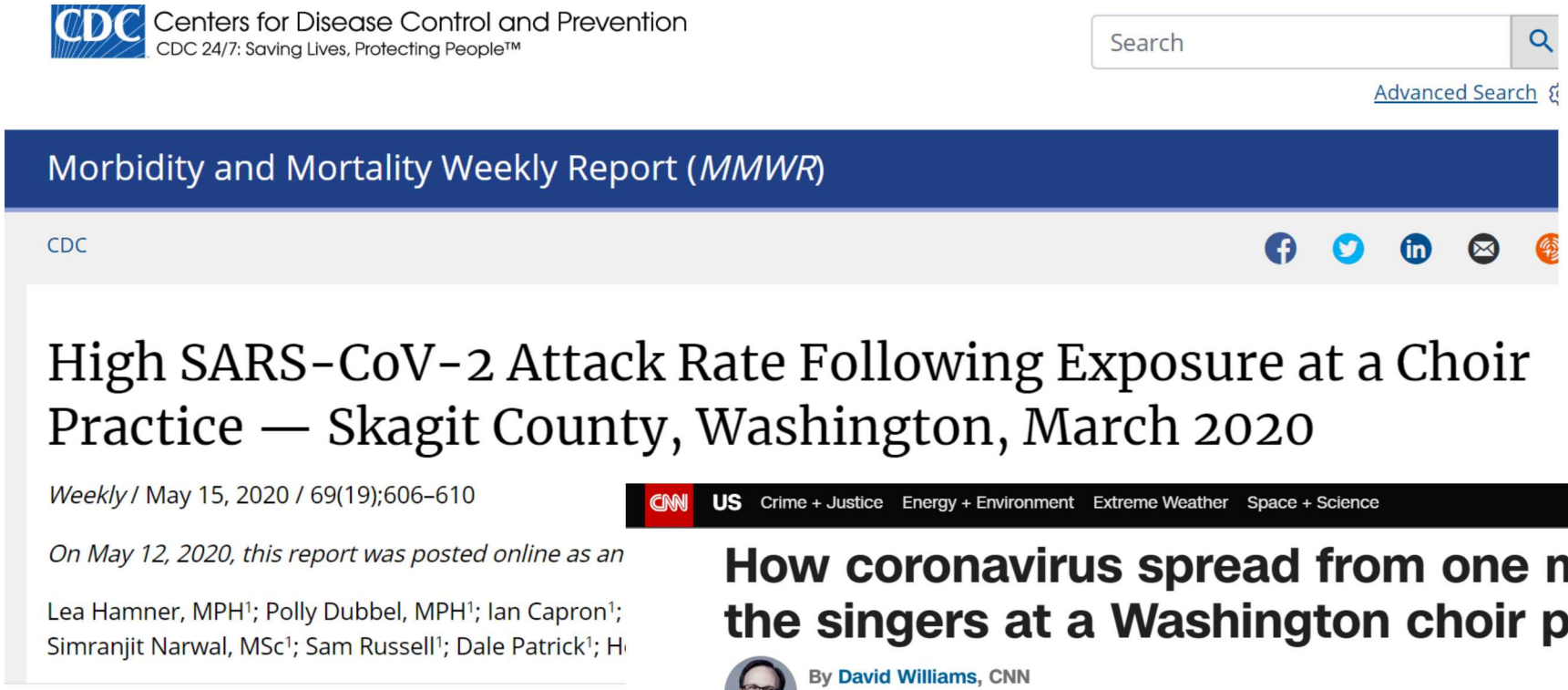
On This Page

Research Letter



Introduction – Airborne Transmission of COVID-19?

March 2020
COVID-19 outbreak during choir practice



Introduction – Airborne Transmission of COVID-19?

April - May 2020
Peer-reviewed studies provide strong evidence

Science

PERSPECTIVES

Cite as: K. A. Prather *et al.*, *Science* 10.1126/science.abc6197 (2020).

Reducing transmission of SARS-CoV-2

Kimberly A. Prather[1], Chia C. Wang,[2,3] Robert T. Schooley[4]

[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92037, USA. [2]Department of Chemistry, National Sun Yat-sen University, Kaohsiung, Taiwan 804, Republic of China. [3]Aerosol Science Research Center, National Sun Yat-Sen University, Kaohsiung, Taiwan 804, Republic of China. [4]Department of Medicine, Division of Infectious Diseases and Global Public Health, School of Medicine, University of California San Diego, La Jolla, CA 92093, USA. Email: kprather@ucsd.edu

Masks and testing are necessary to combat asymptomatic spread in aerosols and droplets

fected individuals. However, a large proportion of the spread of coronavirus disease 2019 (COVID-19) appears to be occurring through airborne transmission of aerosols produced by asymptomatic individuals during breathing and speaking (*1*–*3*). Aerosols can accumulate, remain infectious

JOURNAL of MEDICINE

SPONDENCE

Stability of SARS-CoV-2
as Compared with SARS-CoV-1

ymptomatic.[3,4] Our results in-
l and fomite transmission of
usible, since the virus can re-
nfectious in aerosols for hours

Introduction – Objectives and Needs

> Need quantitative assessments of potential airborne exposure risks for different expiratory events and scenarios

Overview

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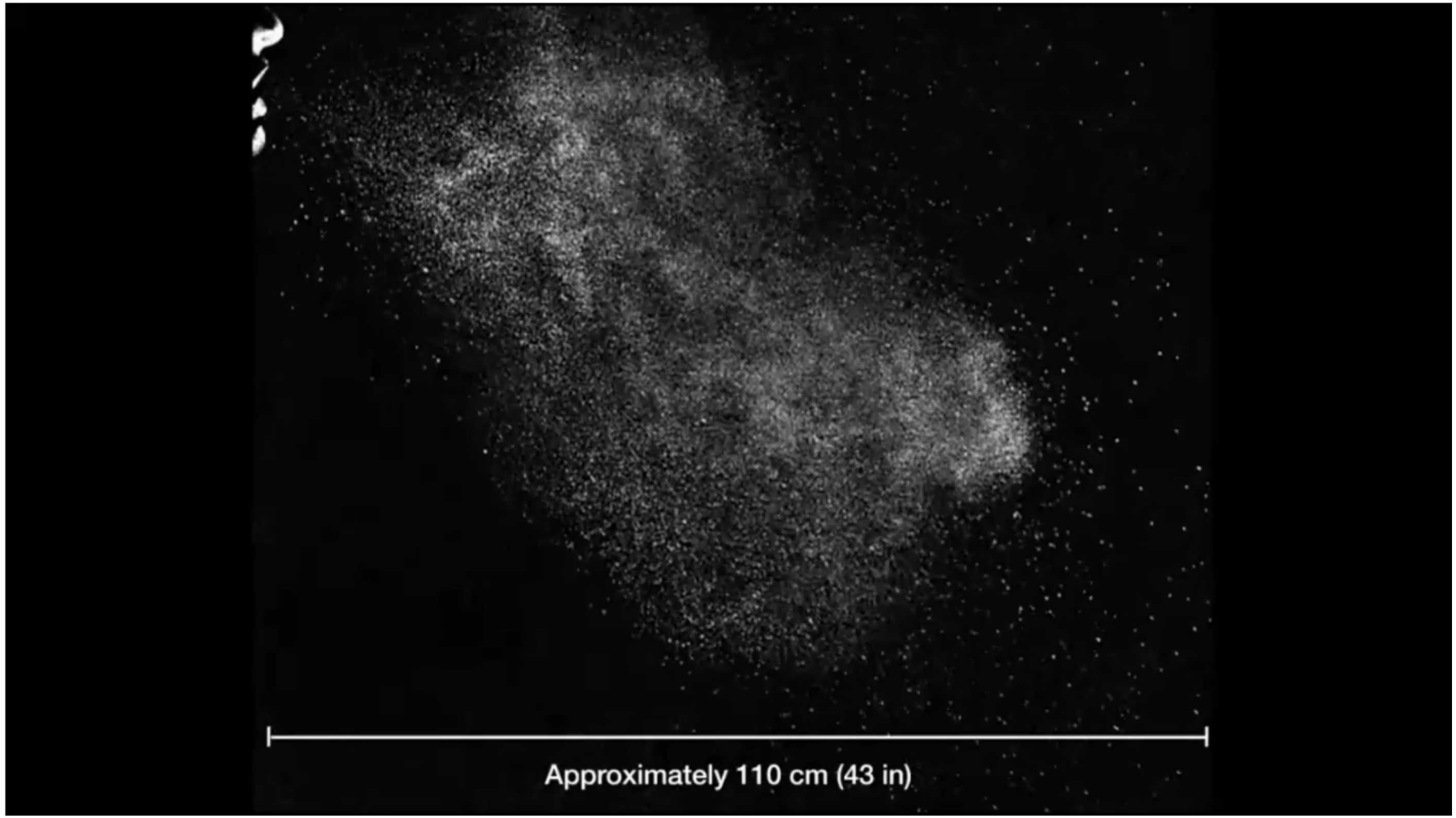
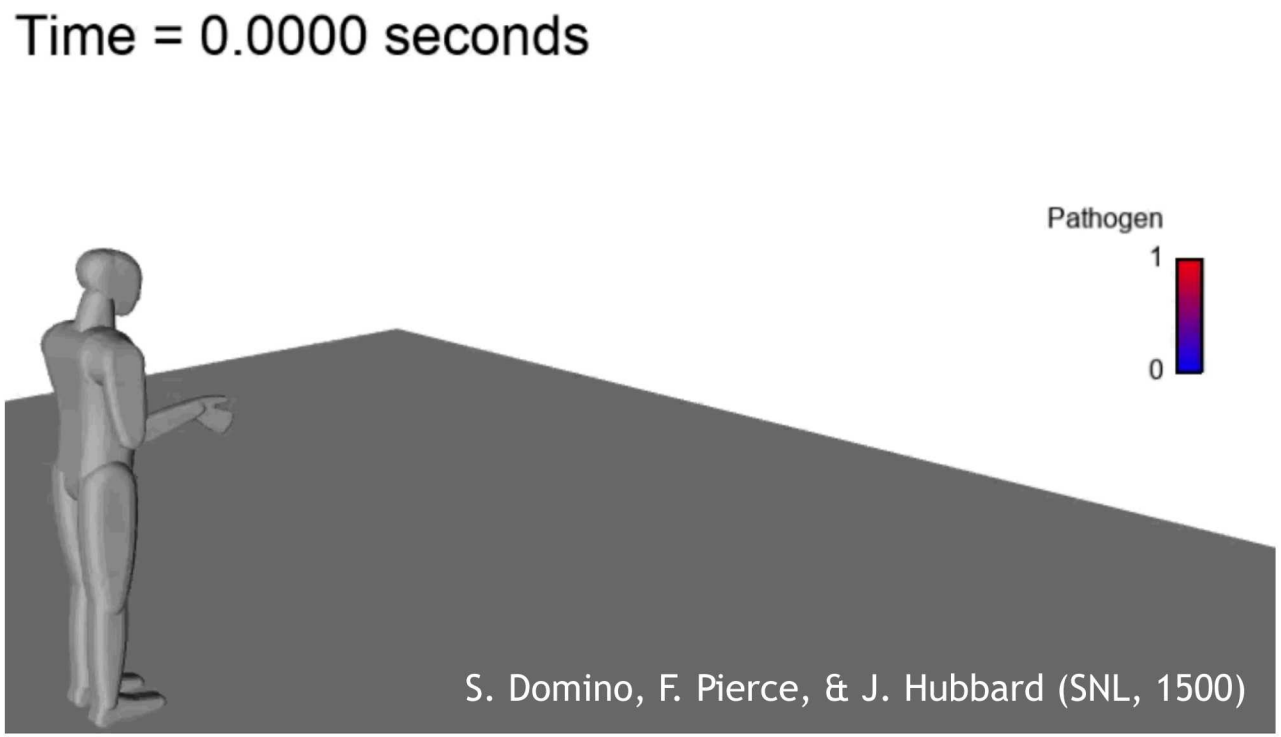
Video of a Sneeze



Video supplement to **Bourouiba, L.,** Turbulent gas clouds and respiratory pathogen emissions: potential implications for reduction transmission of COVID-19, *JAMA*, published online March 26, 2020, doi: 10.1001/jama.2020.4756. https://youtu.be/piCWFgwysu0

Simulations of a Cough

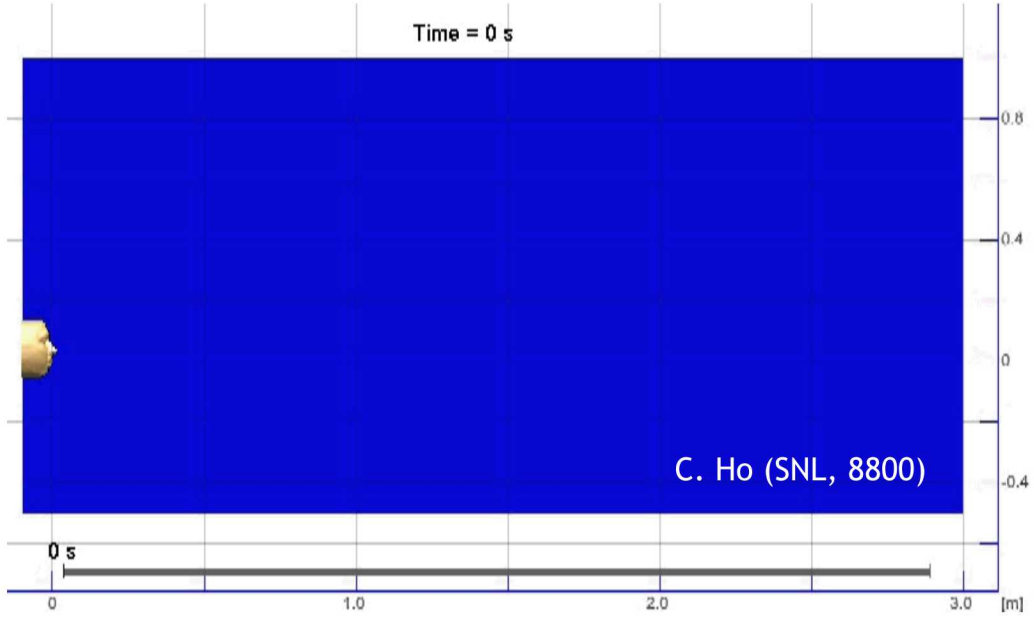
Large Eddy Simulation of Evaporating Particles*



*Dynamic Smagorinsky large-eddy simulation on unstructured meshes using low-dissipation numerics

(see Domino et al., An assessment of atypical mesh topologies for low-Mach large-eddy simulation, Computers and Fluids, 179, 2018).

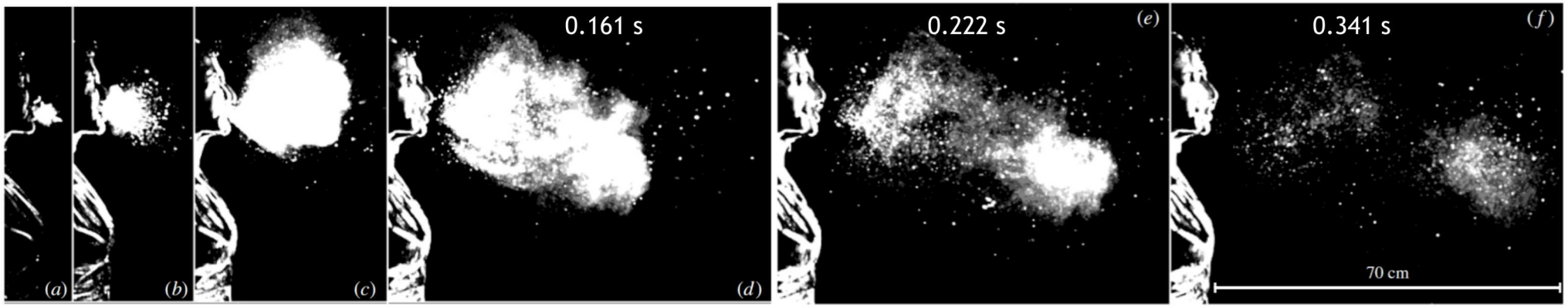
Simulation of Exhaled Water Vapor Concentrations**

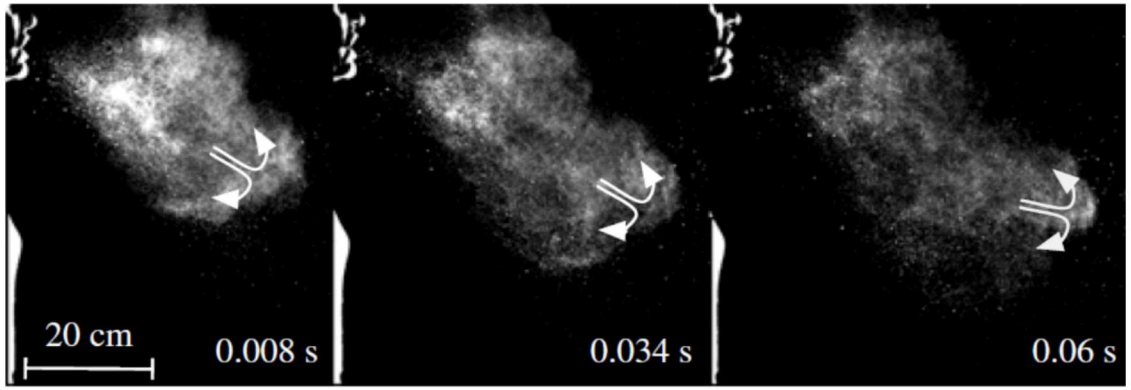


**Transient Favre-Averaged Navier Stokes equations using k-ε turbulence model

Projects funded by COVID-19 LDRD

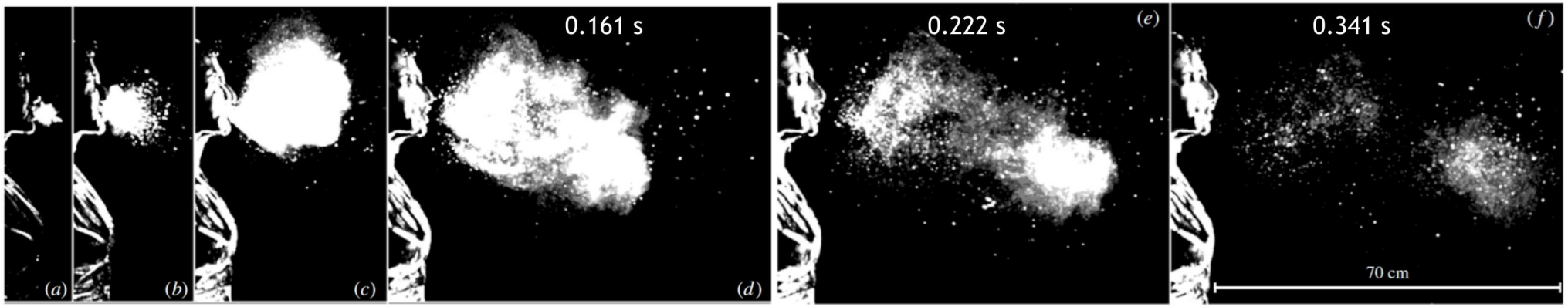
Simulations vs. Experiments

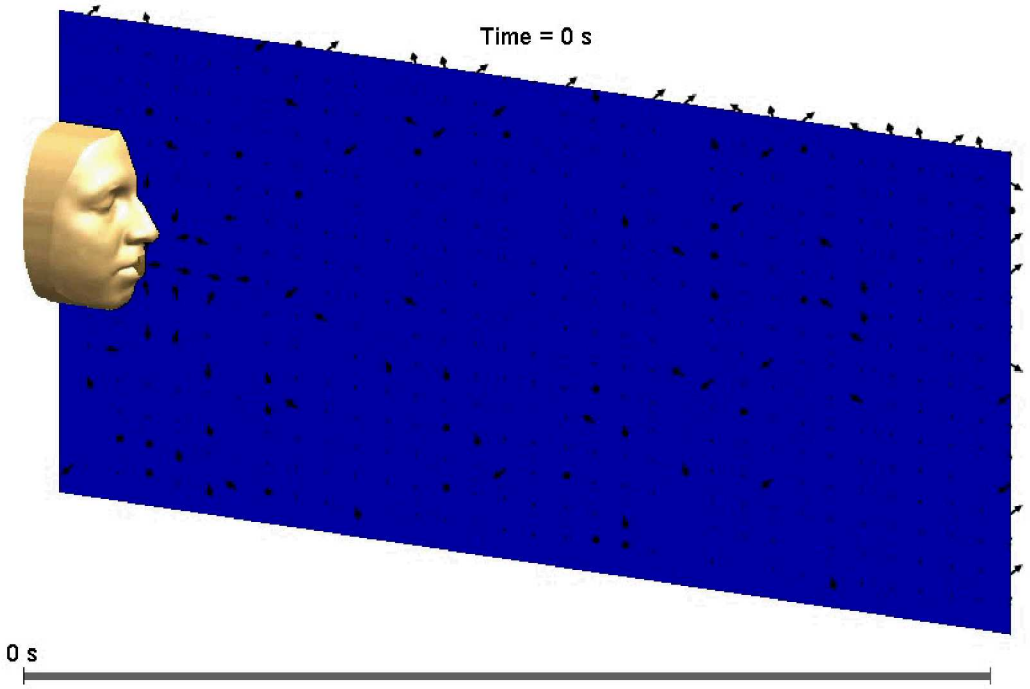


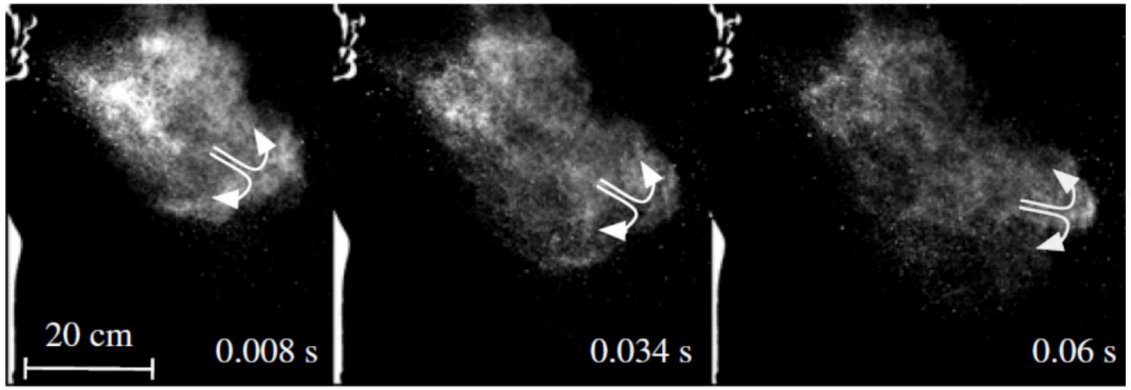


Sneeze visualizations from Bourouiba et al. (2014)

Simulations vs. Experiments







Sneeze visualizations from Bourouiba et al. (2014)

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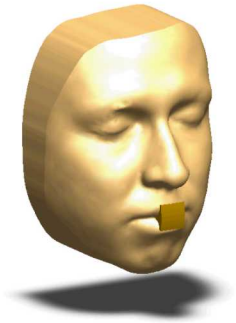
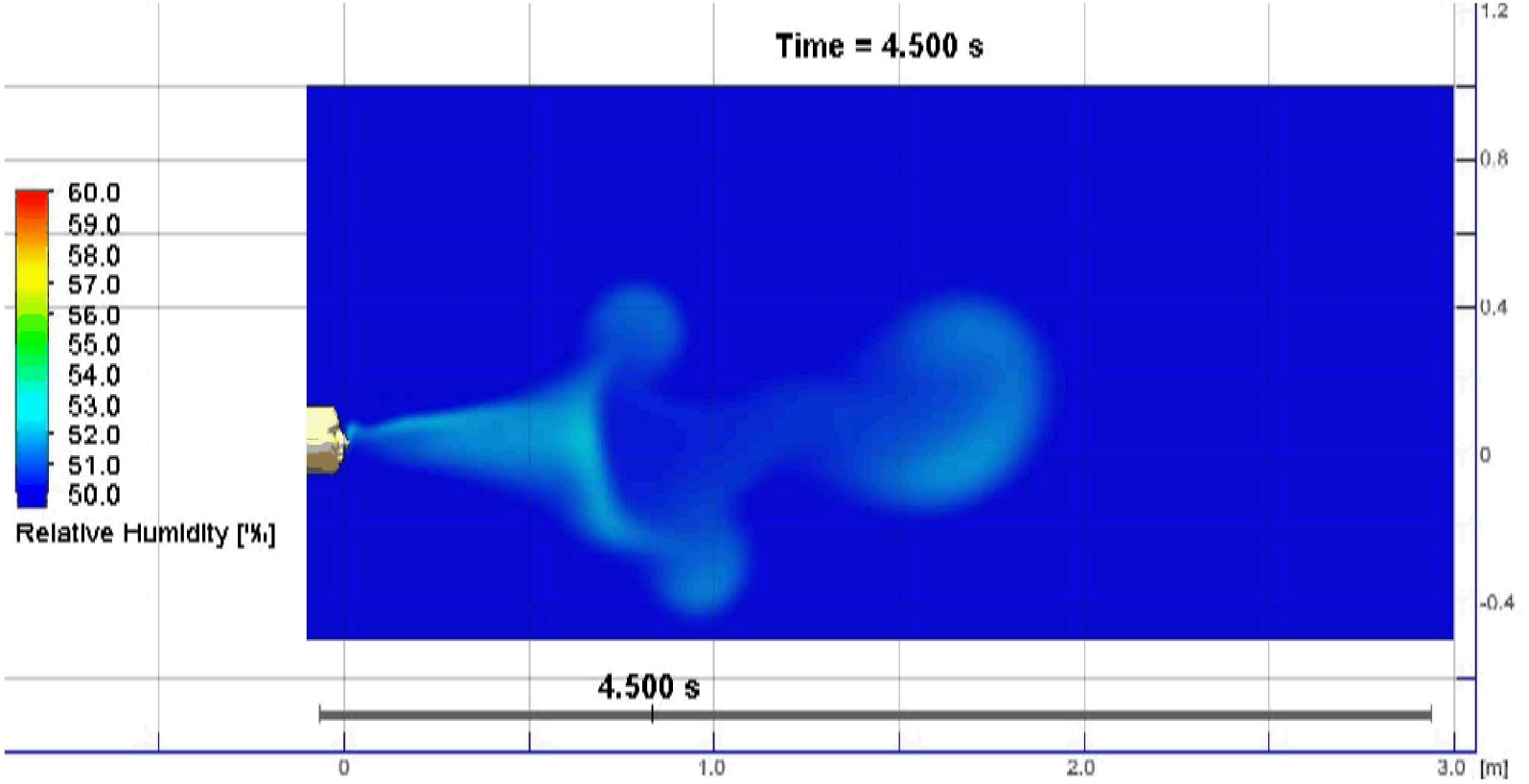
Impact of Face Coverings

Impact of Face Mask

Cough/Sneeze with No Mask

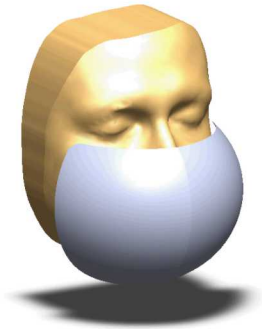


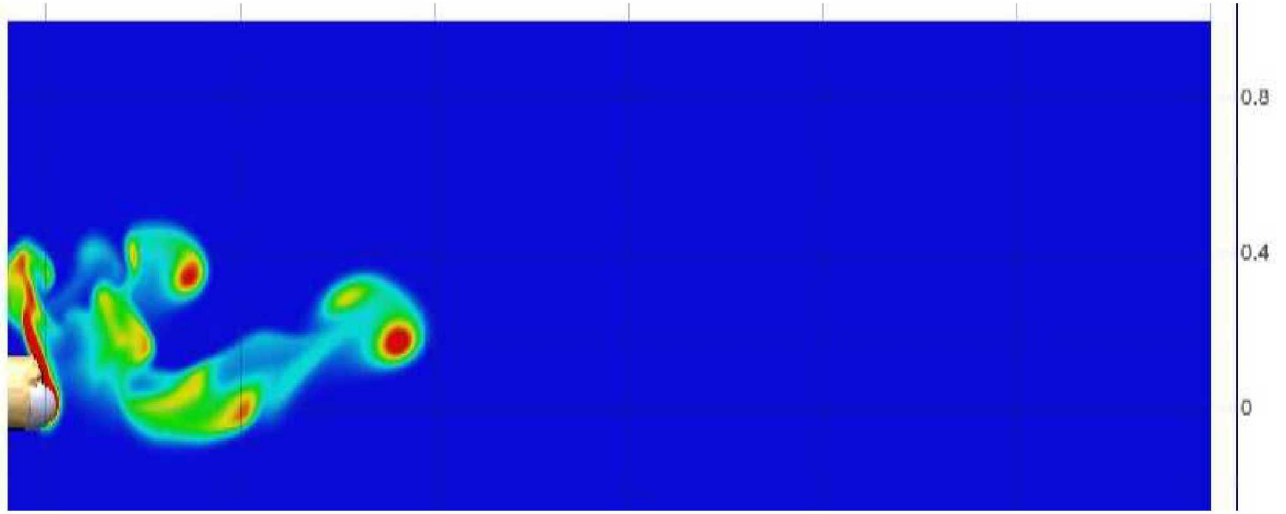


Cough/Sneeze With Mask

Mask material equivalent to MERV* 11 filter (1-inch)

Neglects pathogen filtering effects

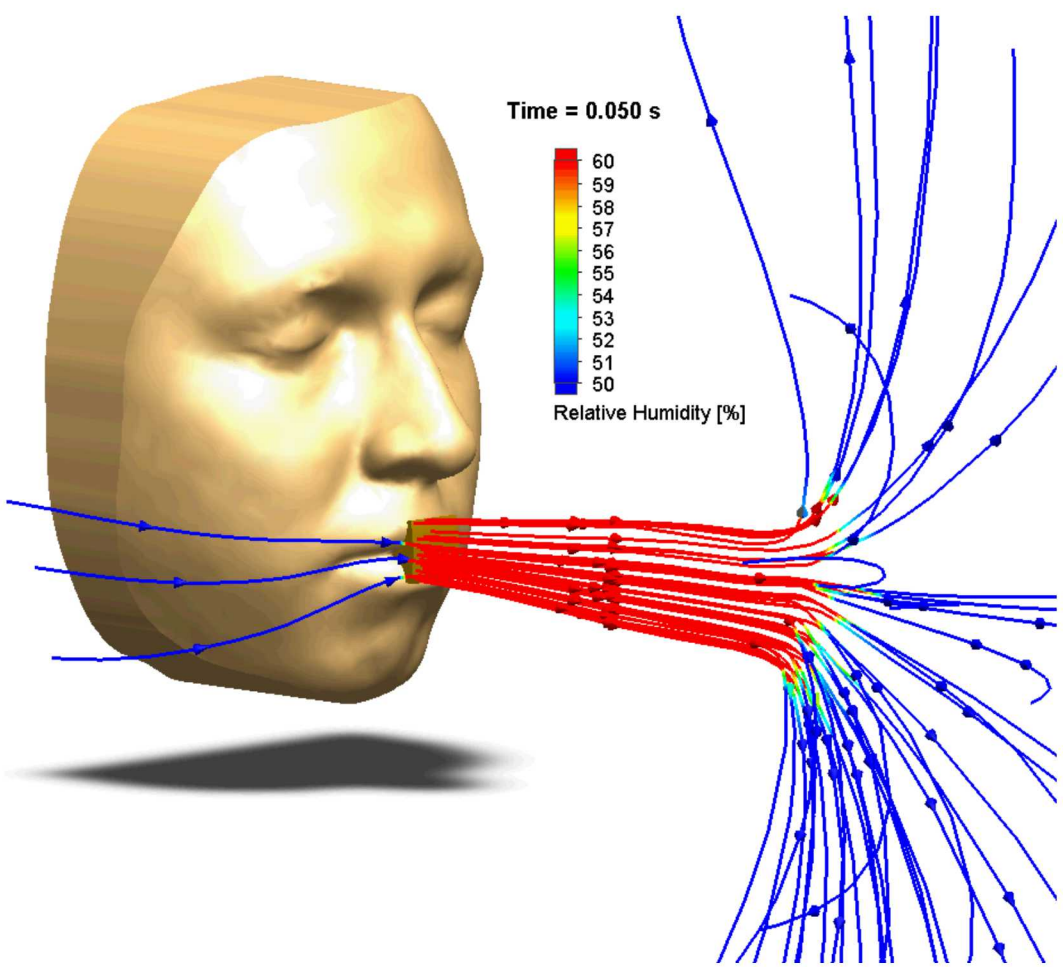




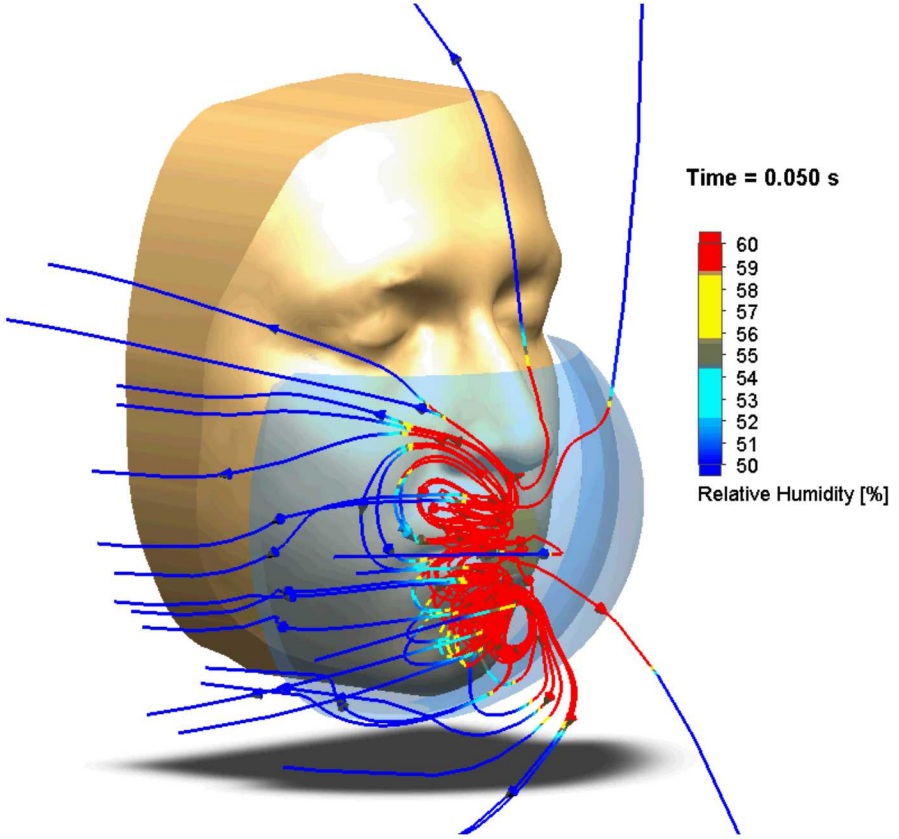
*Minimum Efficiency Reporting Value

Impact of Face Mask – Flow Trajectories

Flow trajectories without mask at 0.05 s

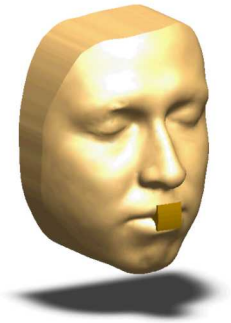


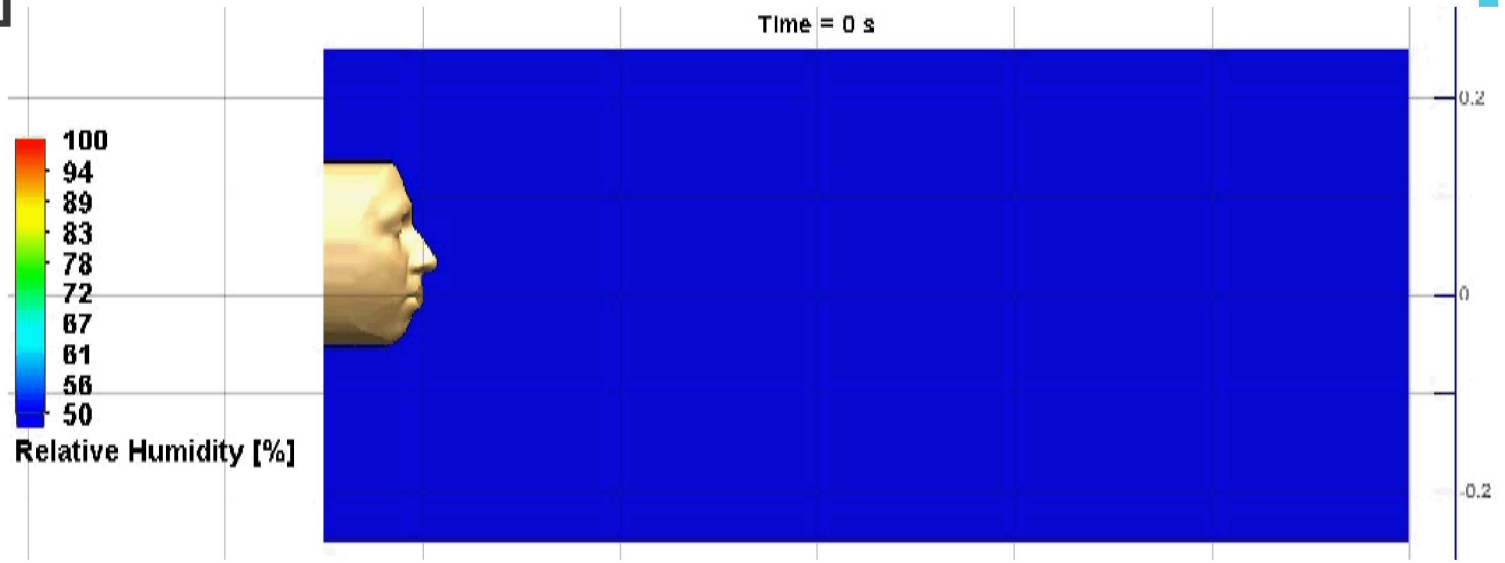
Flow trajectories with mask at 0.05 s



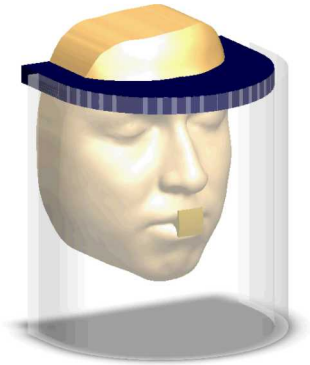
Impact of Face Shield

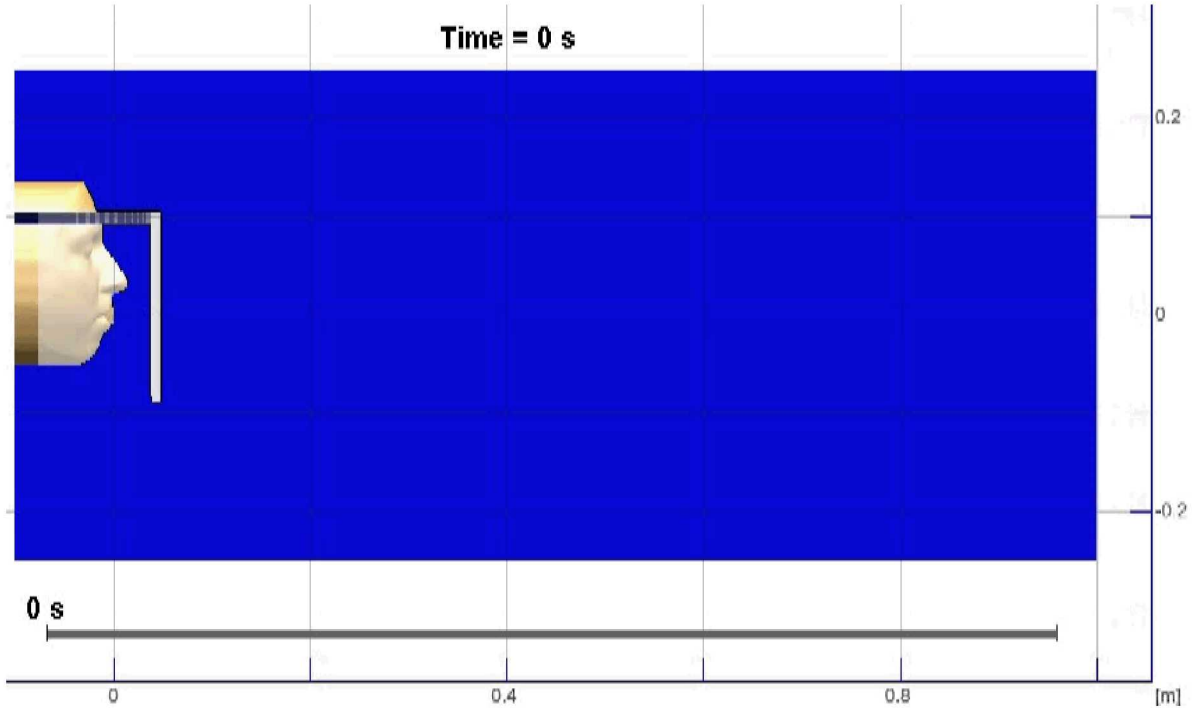
Cough/Sneeze with No Mask





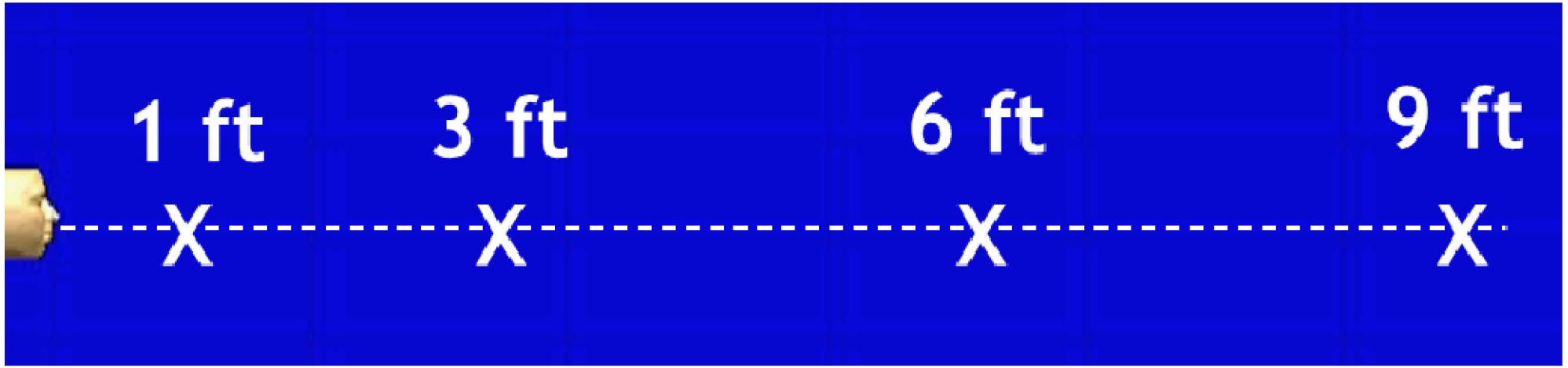
Cough/Sneeze With Face Shield



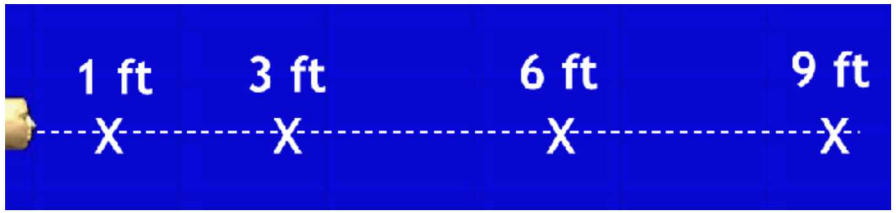


Impact of Airflow on Exposure Risk and Transmission

Comparison of Exposure Probabilities for a Cough/Sneeze

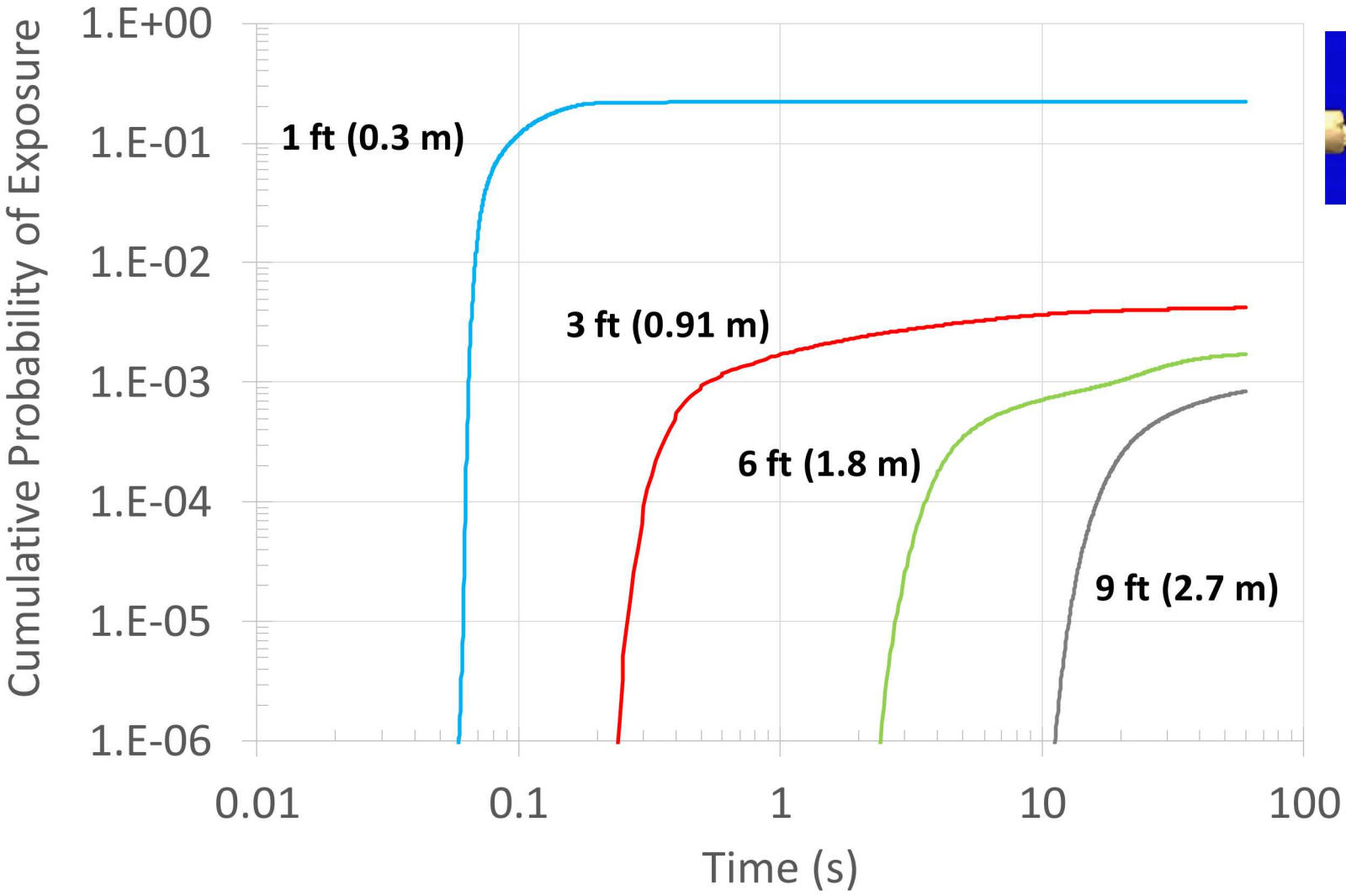


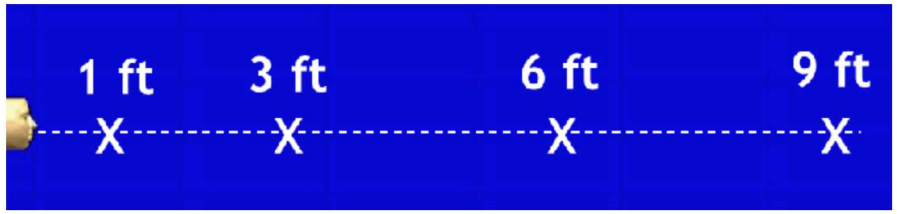
Comparison of Exposure Probabilities for a Cough/Sneeze

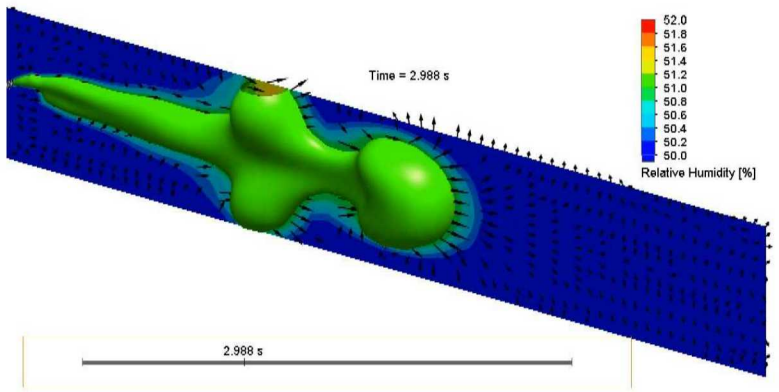


Comparison of Exposure Probabilities for a Cough/Sneeze

Quiescent

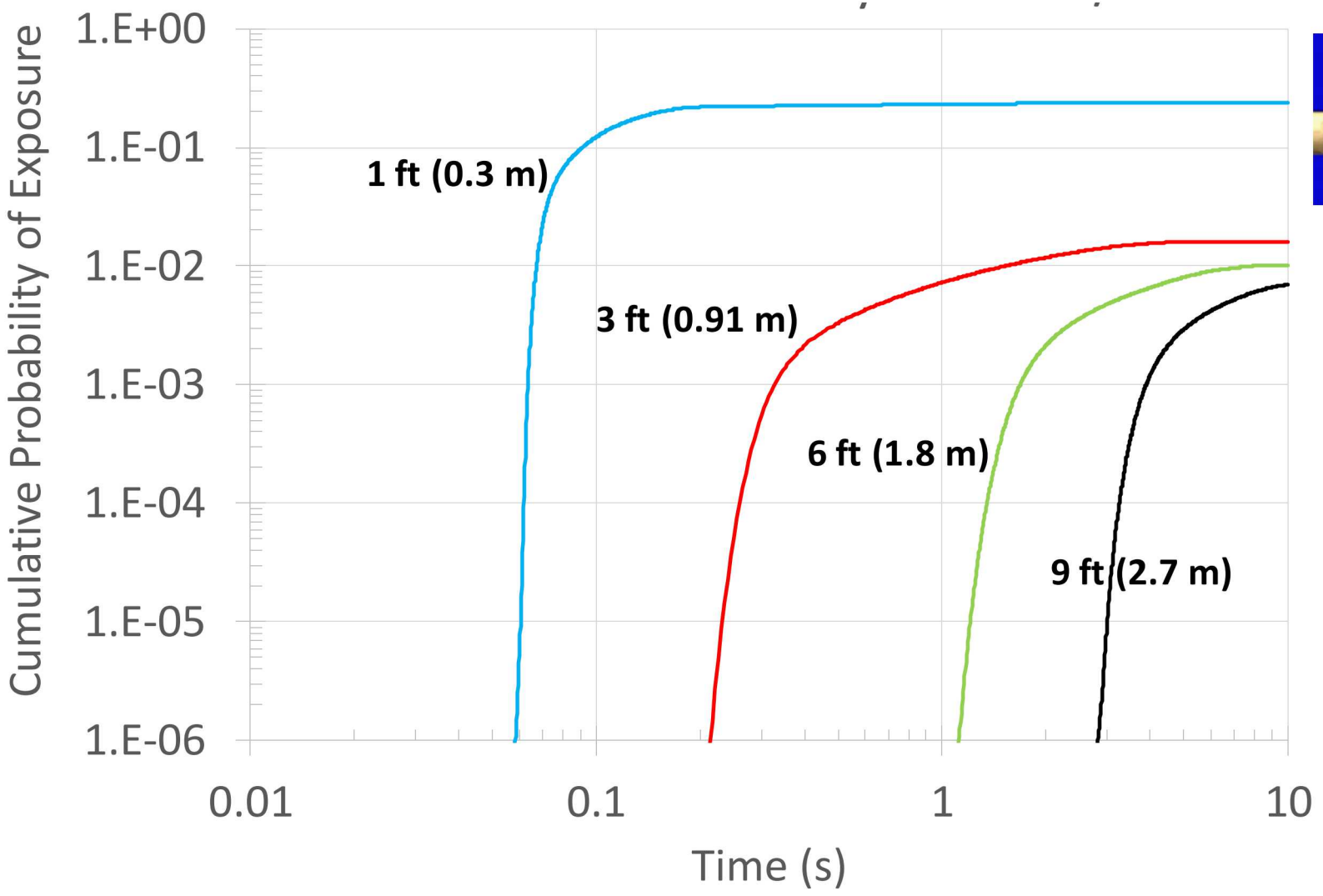


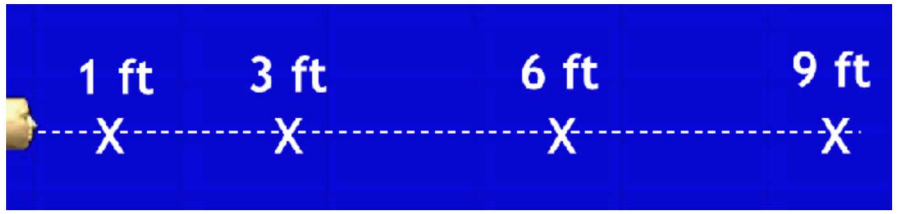




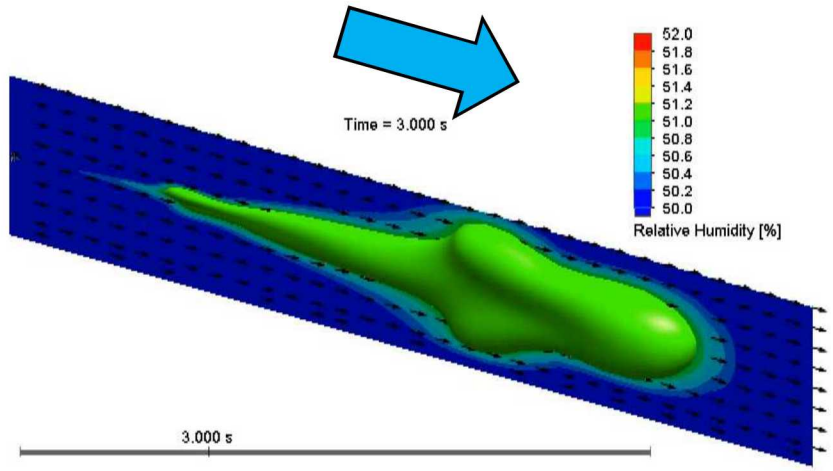
Comparison of Exposure Probabilities for a Cough/Sneeze

Downwind





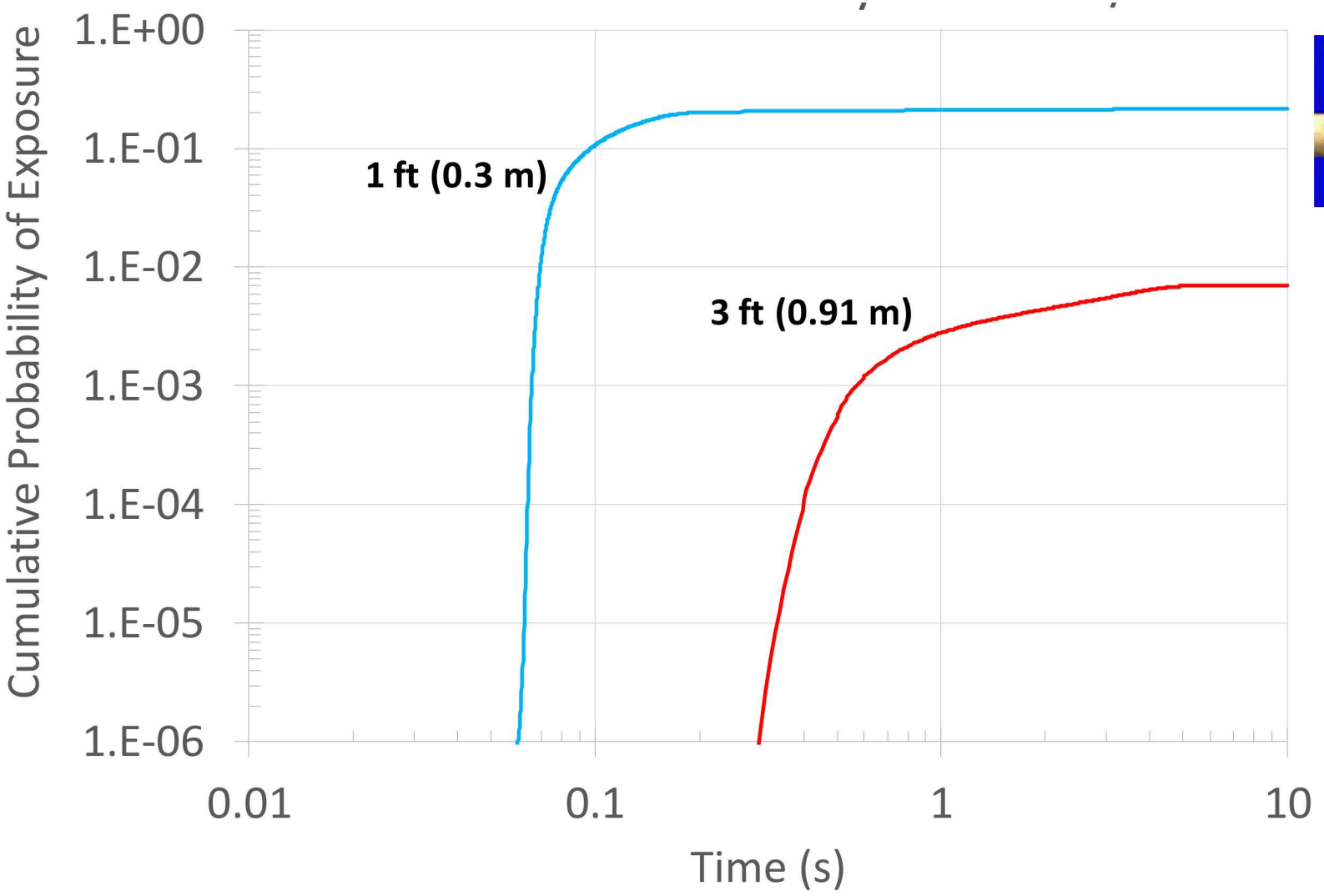
0.25 m/s* downwind

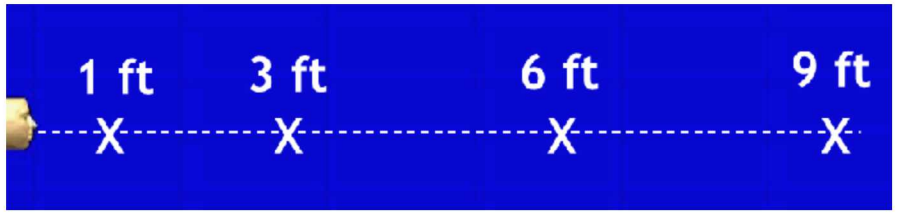


*0.25 m/s is maximum indoor air velocity for thermal comfort (ASHRAE)

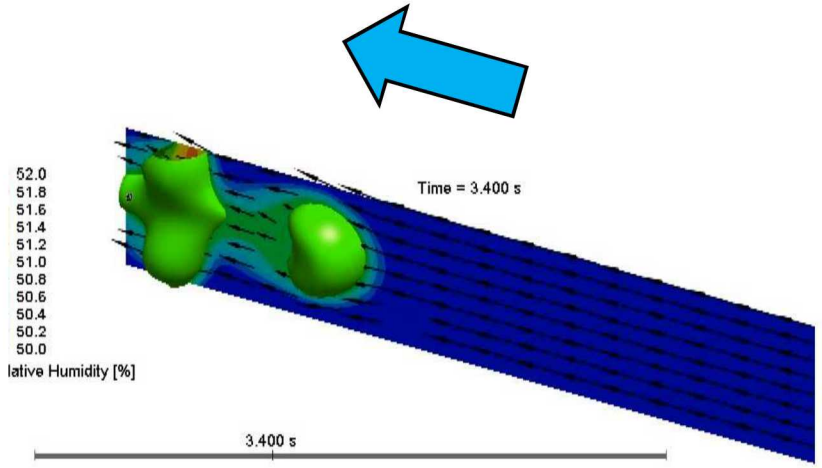
Comparison of Exposure Probabilities for a Cough/Sneeze

Upwind





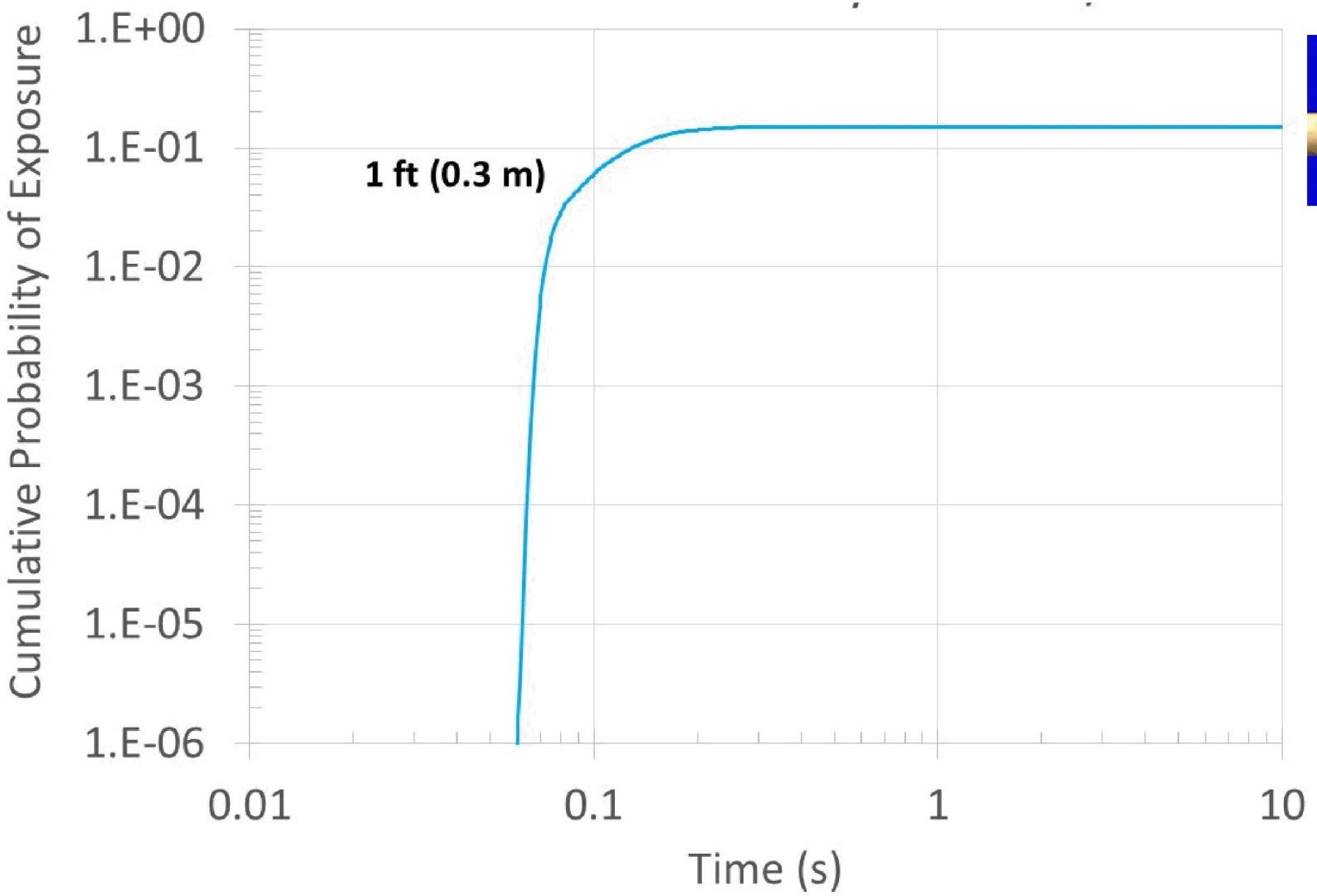
0.25 m/s* upwind

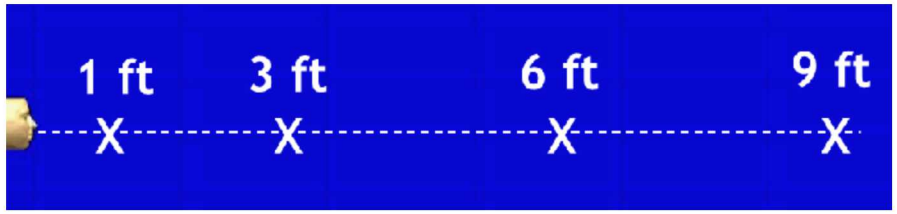


*0.25 m/s is maximum indoor air velocity for thermal comfort (ASHRAE)

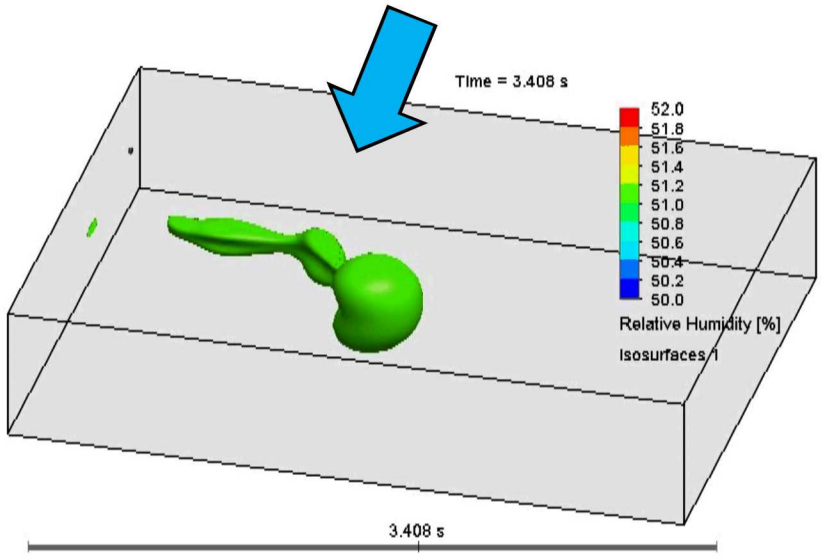
Comparison of Exposure Probabilities for a Cough/Sneeze

Crosswind





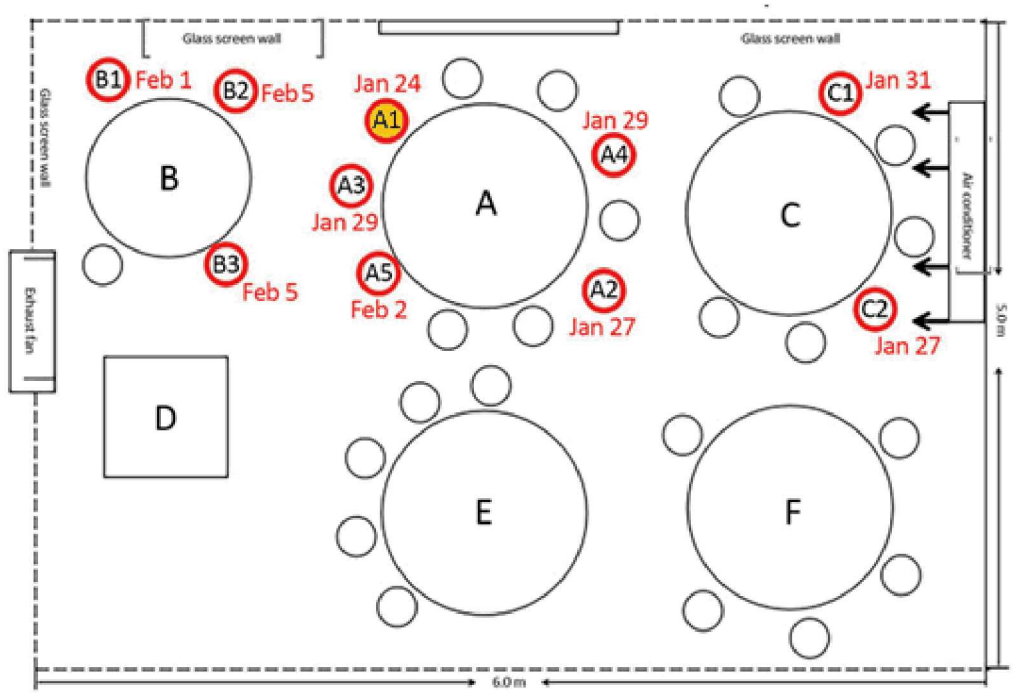
0.25 m/s* crosswind



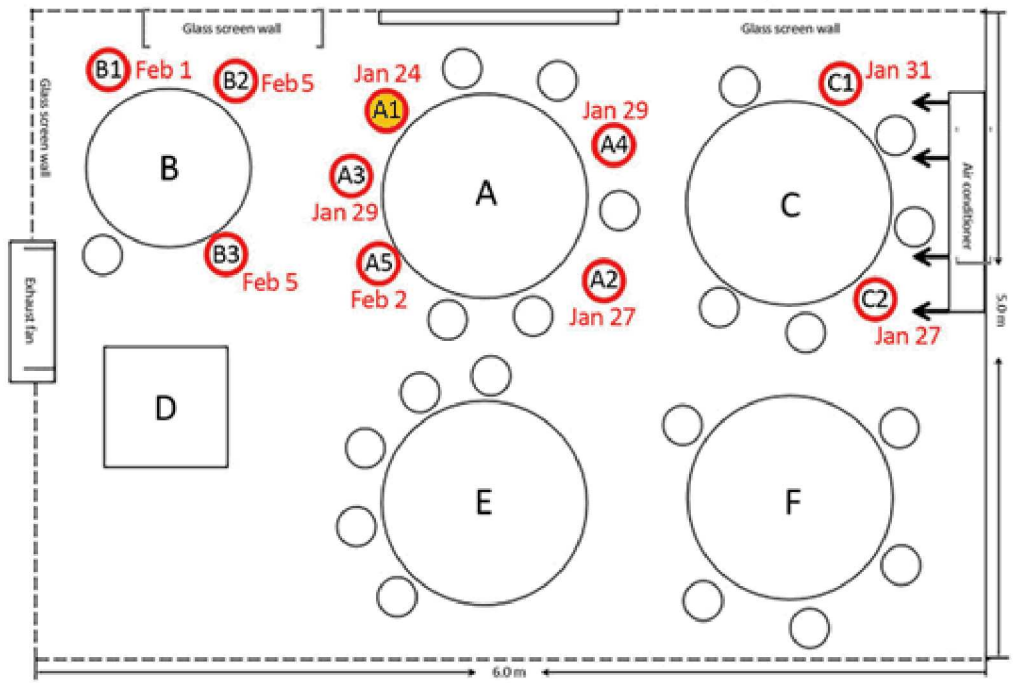
*0.25 m/s is maximum indoor air velocity for thermal comfort (ASHRAE)

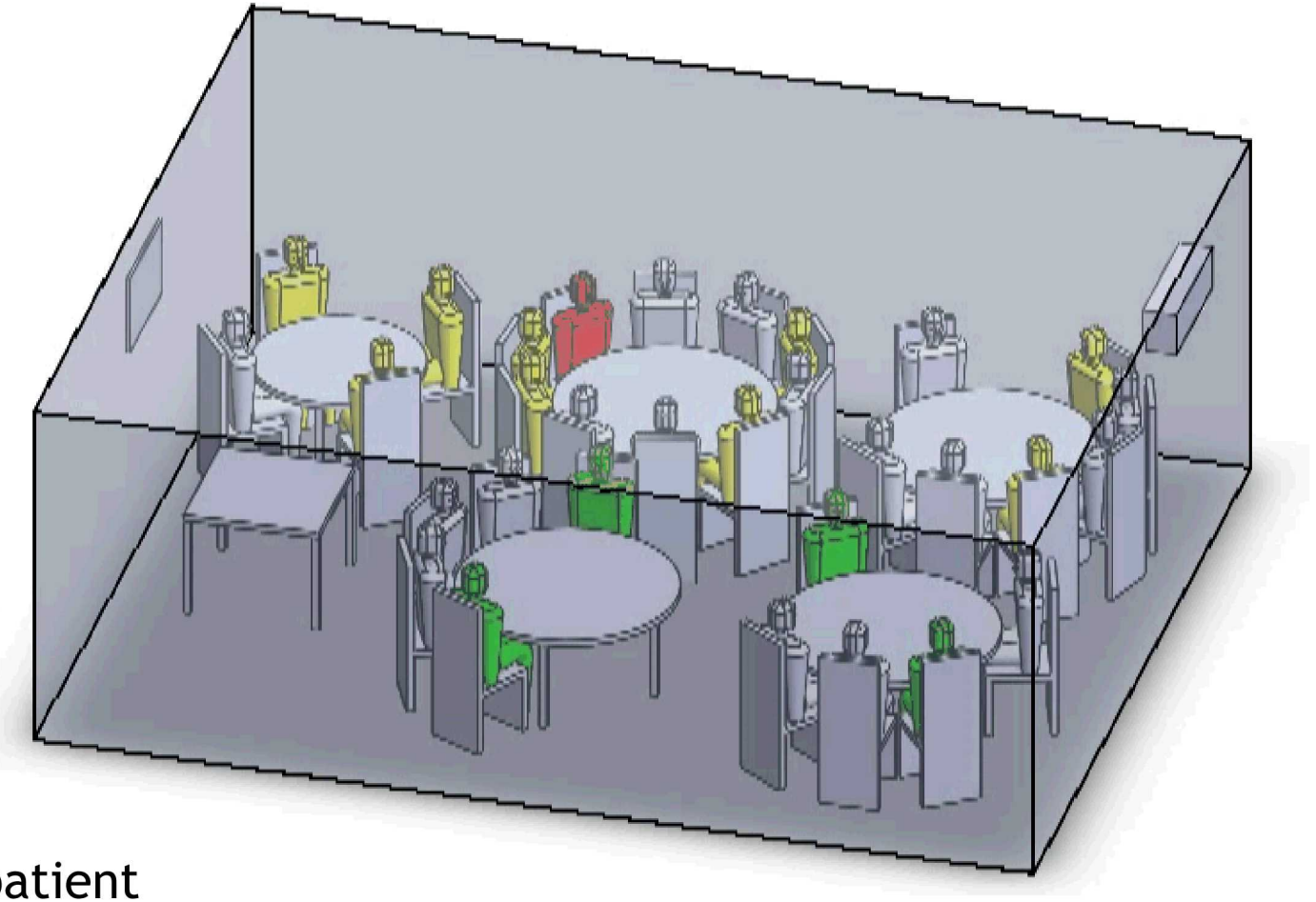
COVID-19 Outbreak in Restaurant in Guangzhou, China

COVID-19 Outbreak in Restaurant in Guangzhou, China



COVID-19 Outbreak in Restaurant in Guangzhou, China

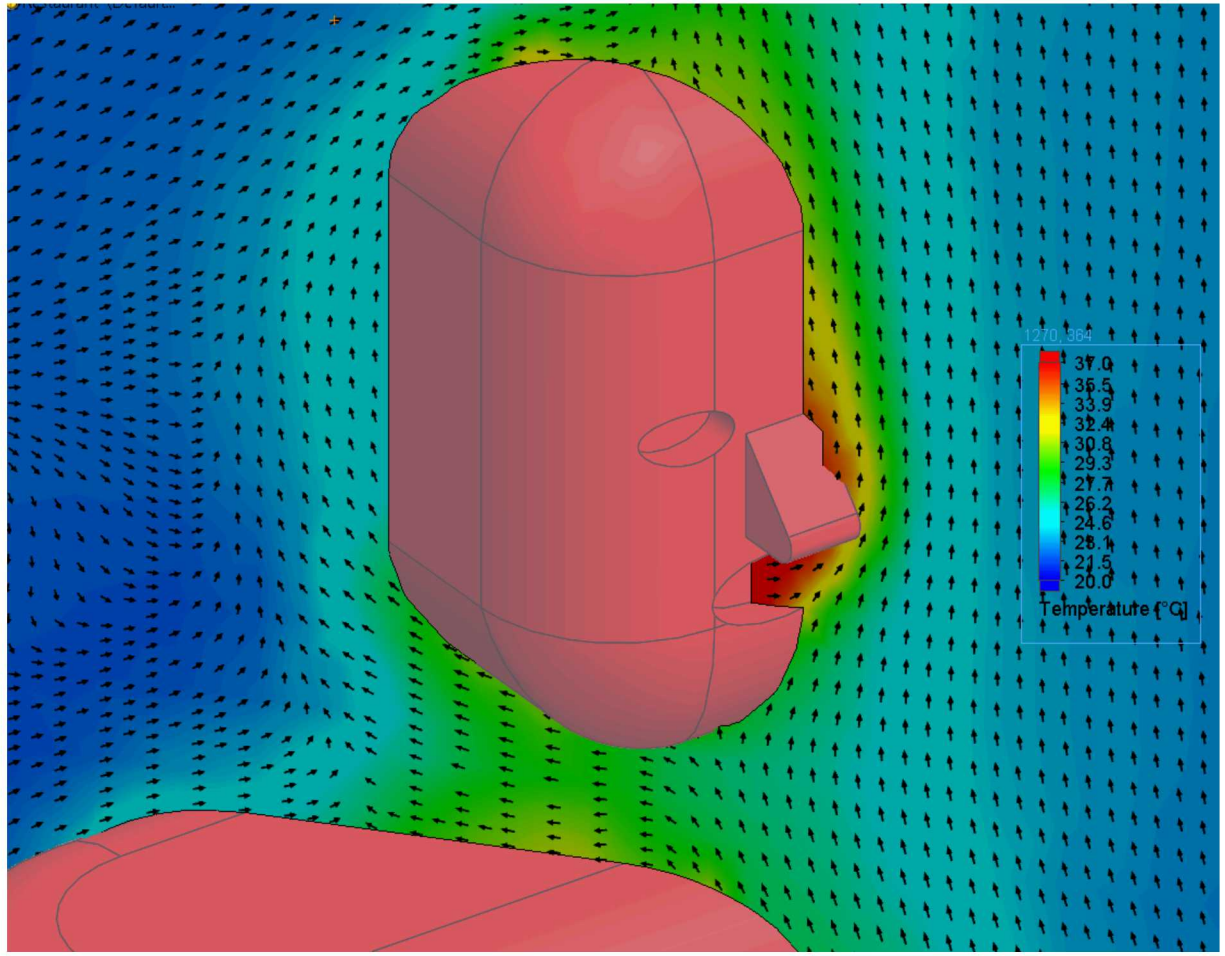




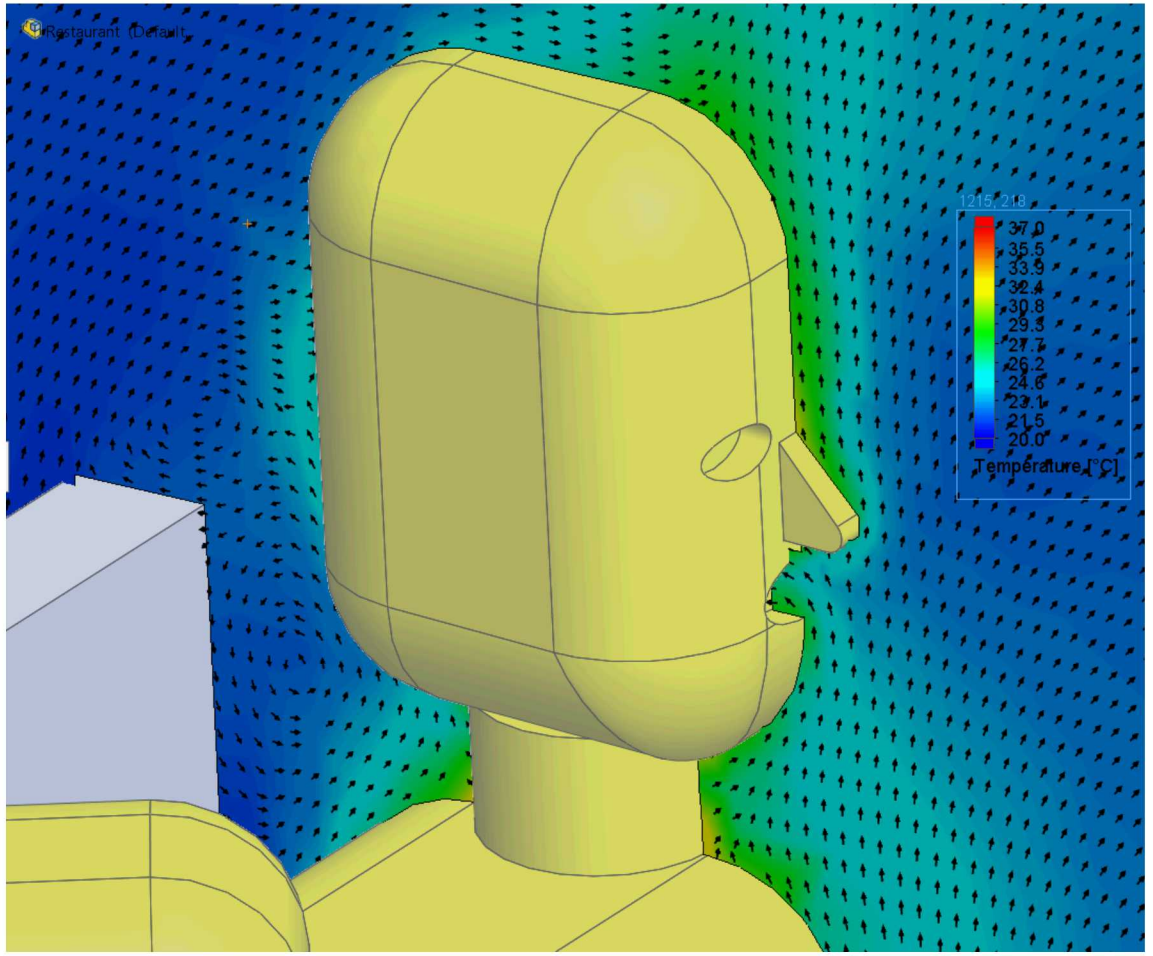
Red = Index patient
Yellow = Infected receptors
Green = Uninfected receptor

Exhaling and Inhaling

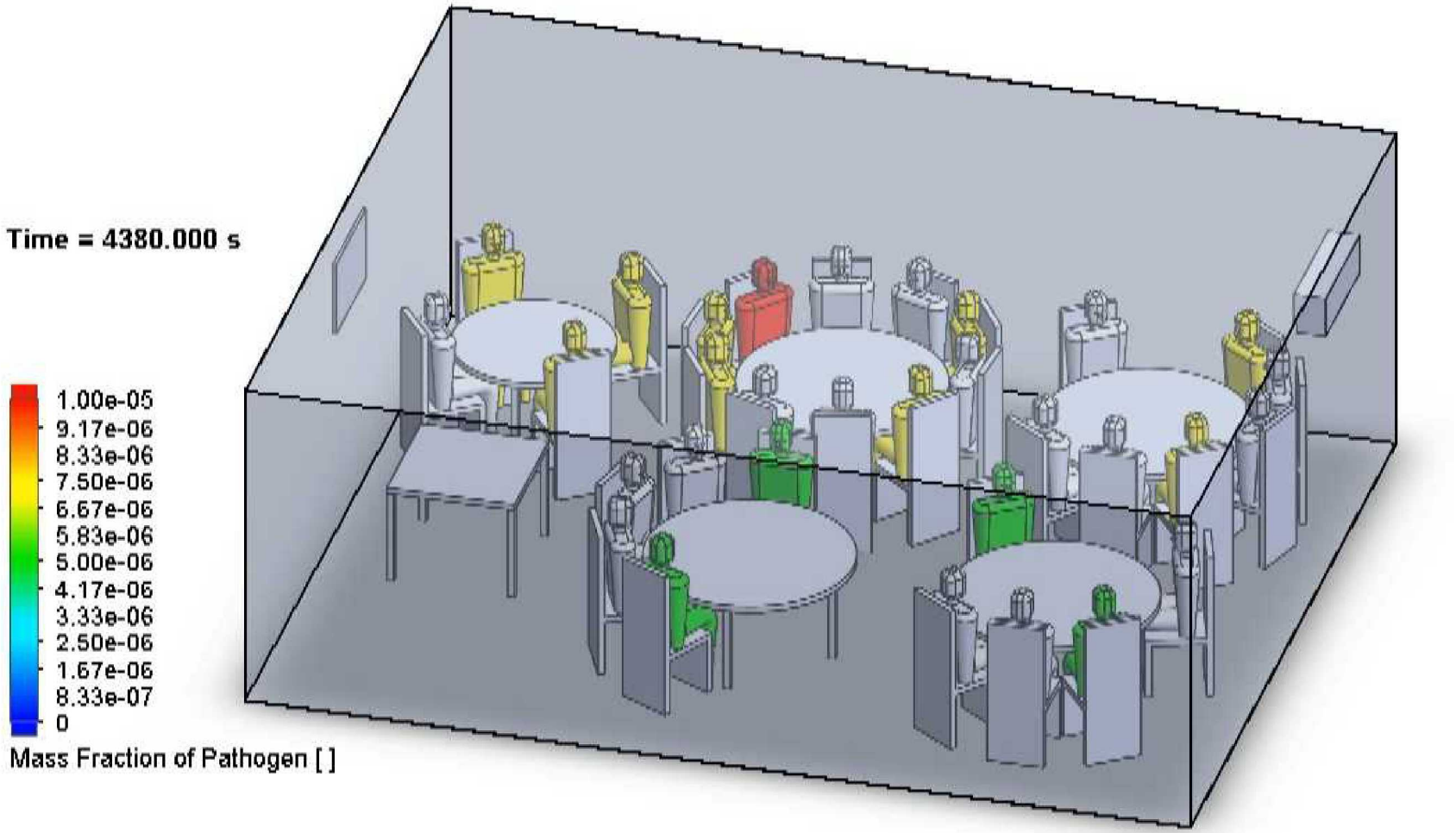
Source Exhalation



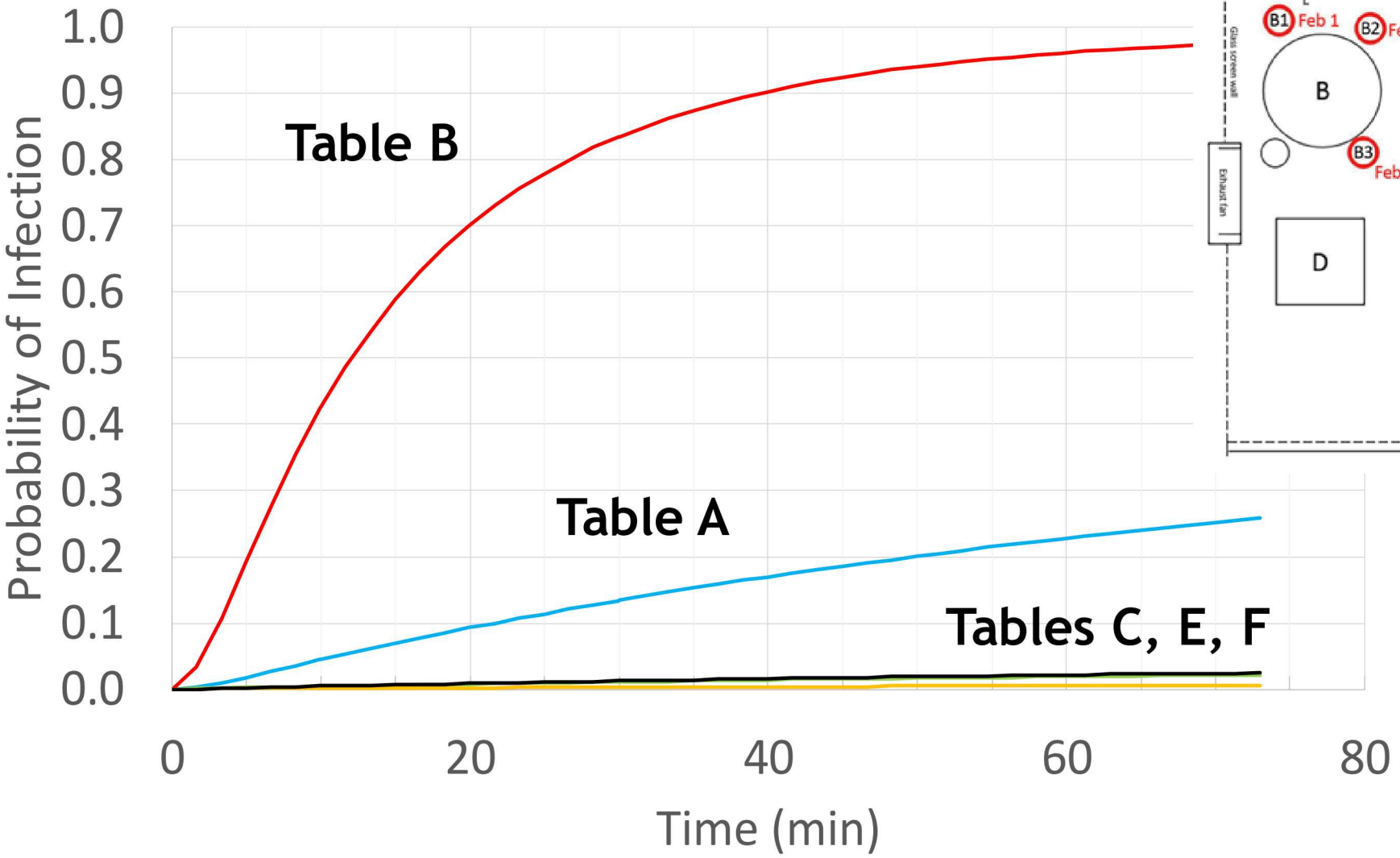
Receptor Inhalation

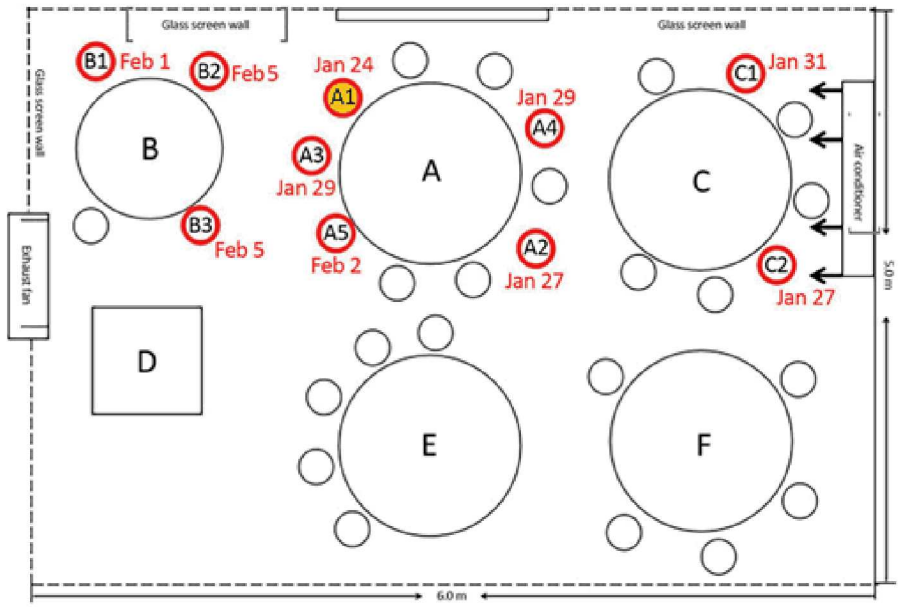


Spatial Distribution of Pathogen Mass Fraction



Probability of Infection





Overview

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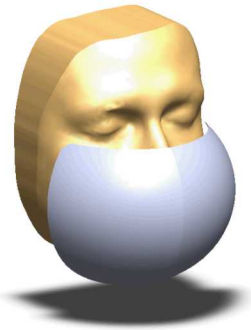
Is 6 feet of “social distancing” sufficient?

“It depends”

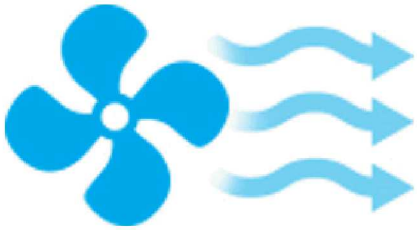
Factors that Impact COVID-19 Airborne Transmission

Think **"FAST"**

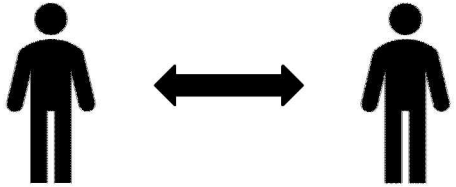
- **F** – Face Coverings



- **A** – Airflow/ventilation (fresh air)



- **S** – Social distancing



- **T** – Time of exposure