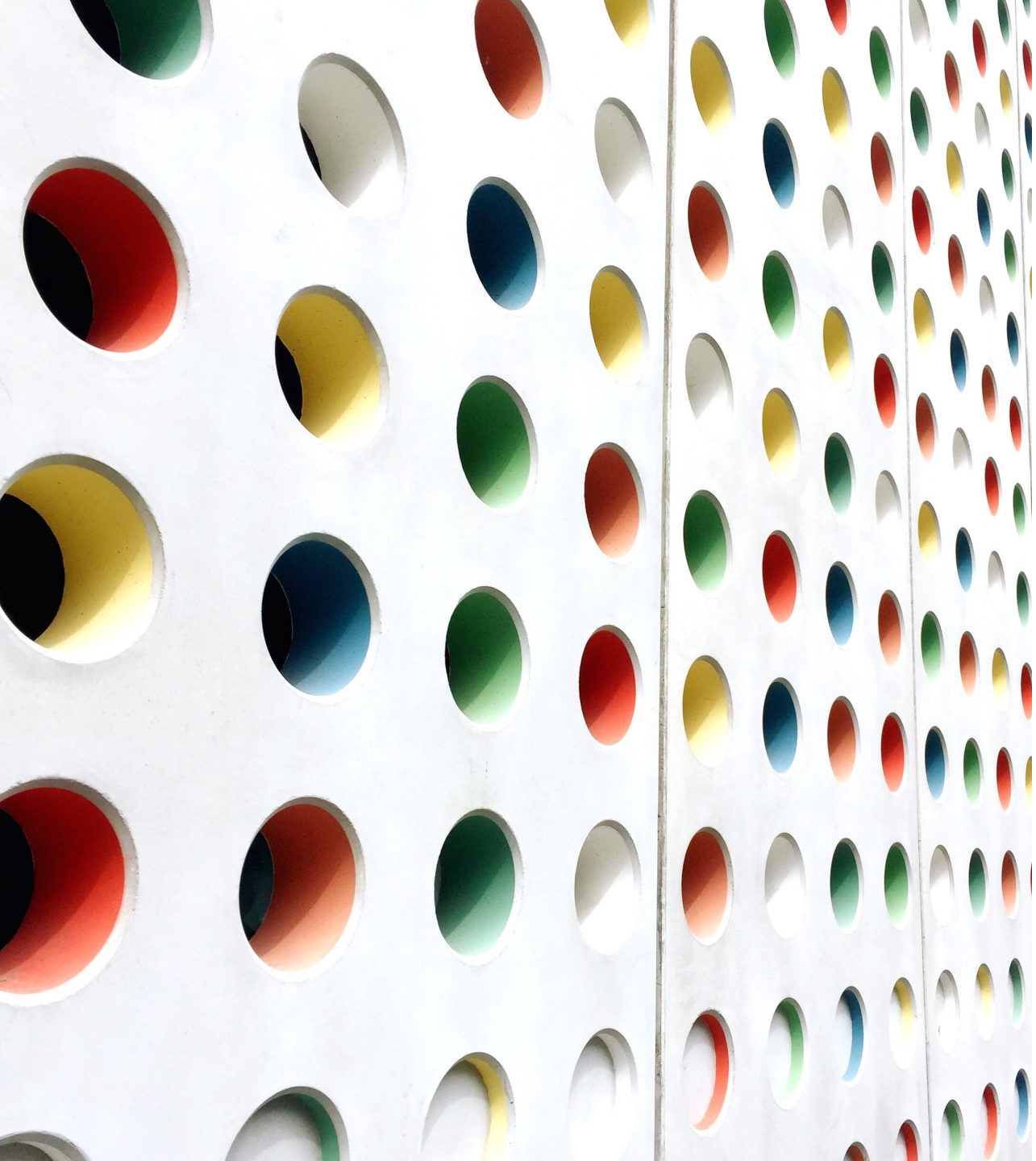


From A to B – Simulation of Atmospheric Pathway

Dr. Paolo Zannetti, QEP

President, EnviroComp Consulting, Inc. and the EnviroComp Institute

www.envirocomp.com www.envirocomp.org

VIRTUAL WORKSHOP ON COVID-19: CHALLENGES IN RESEARCH AND EDUCATION

HTTPS://WWW.ASTFE.ORG/COURSES/COVID-19/

AUGUST 31, 2020

AMERICAN SOCIETY OF THERMAL AND FLUIDS ENGINEERS (ASTFE)

How does person A infect person B?

Many “theories” are found in the scientific literature and the media (Last one I read: imported frozen foods…)

There seems to be a consensus that liquid droplets from coughing and sneezing are a major (perhaps the dominant) cause of SARS-CoV-2 infection

I would add shouting and chanting because ➔

THE WALL STREET JOURNAL.

WORLD

The Soccer Match that Kicked Off Italy's Coronavirus Disaster

Decision to hold Atalanta-Valencia Champions League match in February accelerated spread of pandemic

On Dec. 1, 2019, a patient in Wuhan, China, started showing symptoms of what doctors determined was a new coronavirus. Since then, the virus has spread across the world. Here's how the virus grew to a global pandemic. Photo: Alberto Pizzoli/Agence France-Presse/Getty Images

By Joshua Robinson
Updated April 1, 2020 2:32 pm ET

PRINT TEXT 130

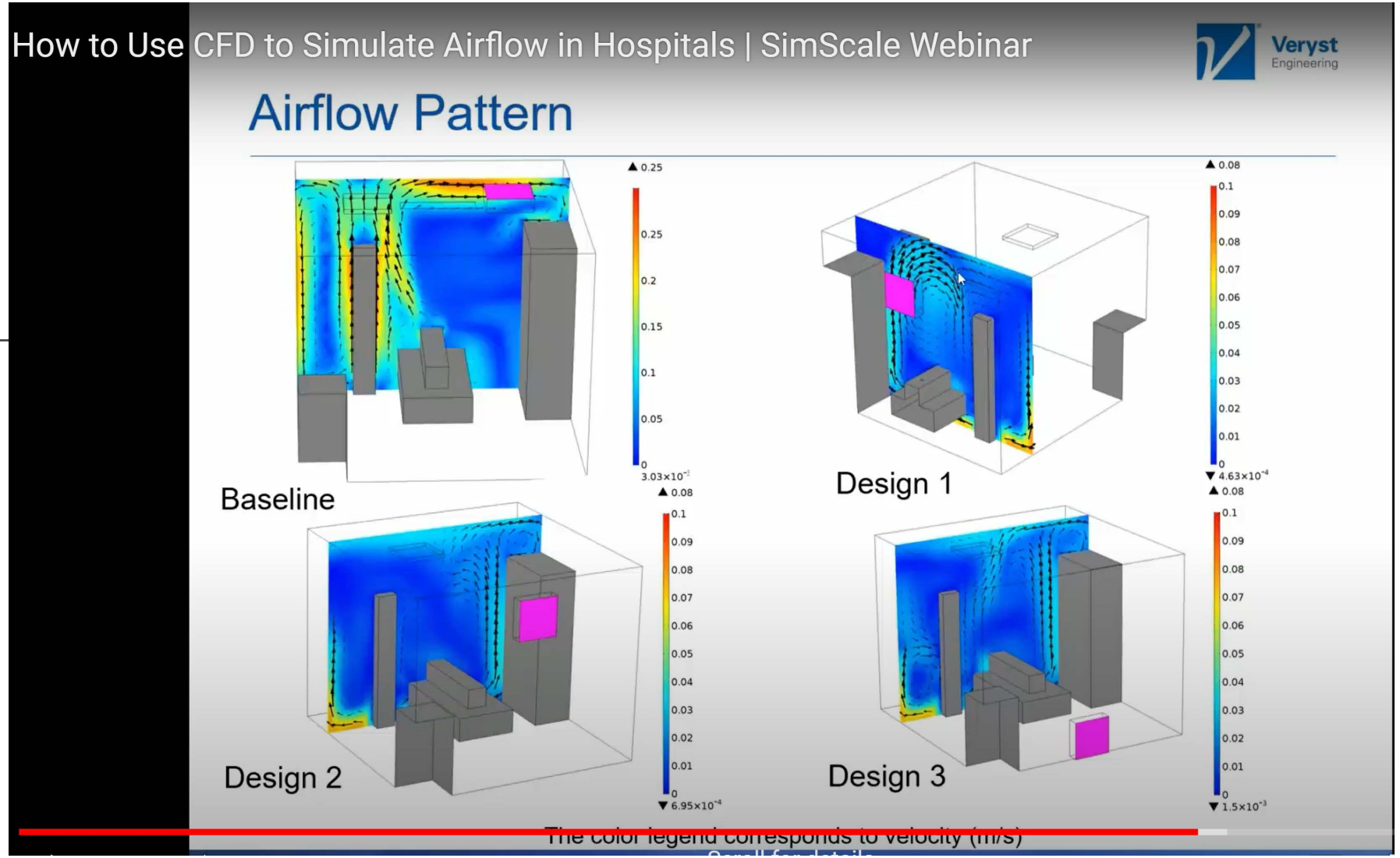
On the afternoon of Feb. 19, Andrea Pontiggia was heading from Bergamo, Italy, to the biggest soccer match of his life—along with 40,000 of his closest friends.

Computer Simulation of Atmospheric Trajectories of Droplets

1. Indoor vs. Outdoor
2. Emission of droplets from Person A
3. Simulation of the main 3D Air Flow
4. Addition of turbulent fluctuations (mostly outdoor)
5. Gravitational settling, as a function of diameter and density of the droplet
6. Partial evaporation (change in droplet diameter)
7. Deposition of droplets; contact / inhalation by Person B

3D Air Flow Indoor

E.g.: How to Use CFD to Simulate Airflow in Hospitals | SimScale Webinar
https://www.youtube.com/watch?v=dWQPDy87skQ



3D Air Flow

Outdoor

Meteorological models are available to simulate the main air flow, e.g.:

CALMET (diagnostic) http://www.src.com/

WRF (prognostic) https://www.mmm.ucar.edu/weather-research-and-forecasting-model

For microscale effects of obstacles, CFD models can be used, e.g.:

FLUENT (expensive)

https://www.ansys.com/products/fluids/ansys-fluent

OpenFOAM (open source)

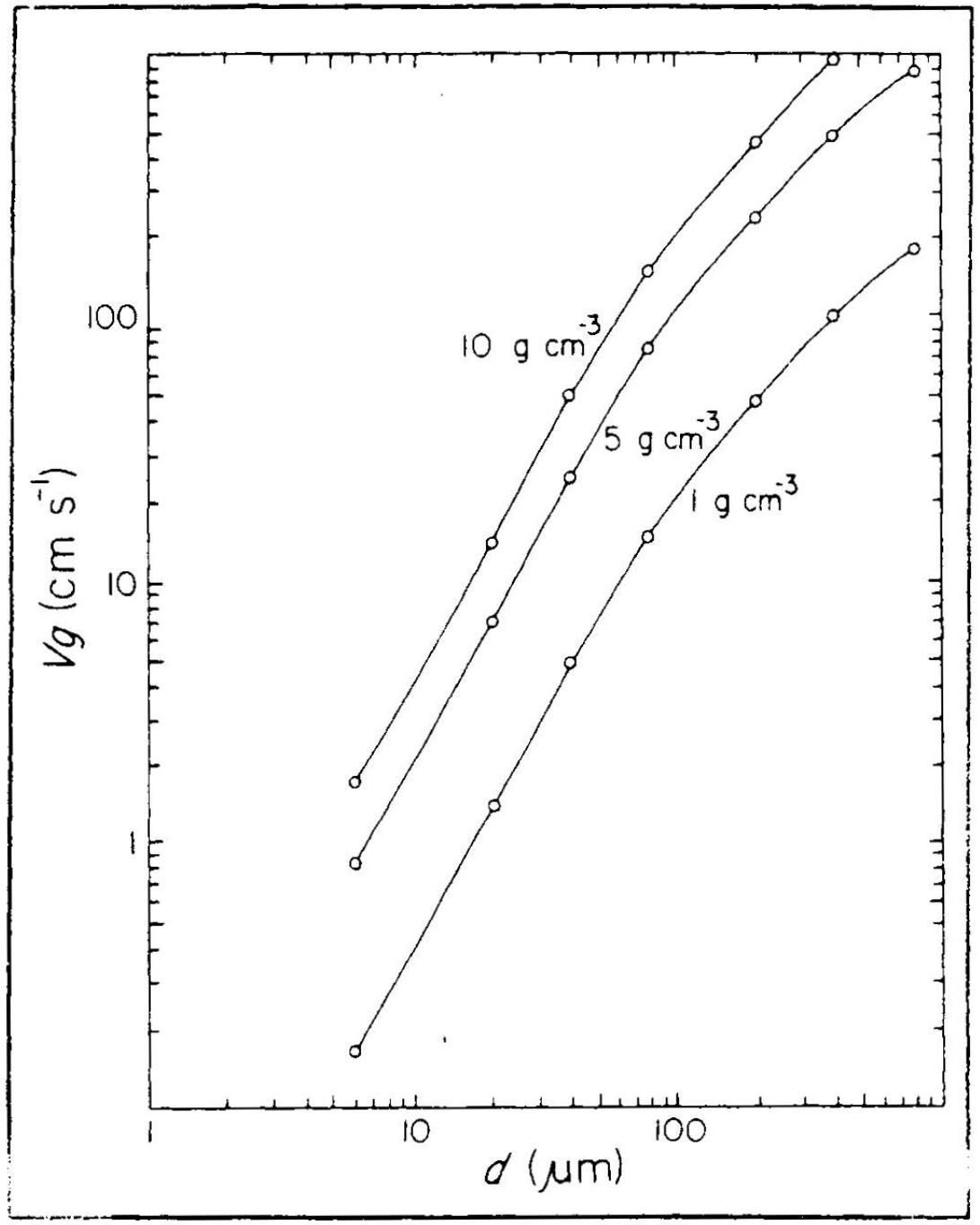
https://openfoam.com/

https://www.openfoam.com/news/openfoam-covid-response.php

Atmospheric Turbulence (Outdoor)

Turbulent dispersion can be simulated by adding semi-random wind fluctuations calculated with Monte-Carlo computer methods. E.g., see the LAPMOD system
https://www.enviroware.com/lapmod/ (open source)

Gravitational Settling Velocity - depending on diameter and density of the droplet



Further Complication: EVAPORATION

Liquid in a droplet may evaporate ➔ change in droplet diameter ➔ change in gravitational settling velocity

Evaporation formulas/algorithms are available, e.g., those developed for aerial spray of pesticides (AgDRIFT and AGDISP)
https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

Evaporation rate depends upon ambient temperature and relative humidity

Videos of Computer Simulations

TOP: coughing without a mask

BOTTOM: coughing into a cloth mask

https://play.vidyard.com/z4hoghY3GpSQa7Vcu5GTSV

A person coughs in a grocery store

https://youtu.be/WZSKoNGTR6Q

Running

https://youtu.be/99yx2wScgJA

CONCLUSIONS

- GOOD: We possess the mathematical/numerical tools to simulate all the physical phenomena
- BAD: Uncertainties are very large, e.g.:
  - Number of droplets emitted and size distribution
  - Infectious SARS-CoV-2 dose of each droplet
  - Initial & Boundary conditions (especially indoor)
- WE CAN ONLY SIMULATE HYPOTHETICAL SCENARIOS – Modeling validation & calibration seem very difficult to perform

Thanks!

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Question for the Panel

Deaths / 1M pop (western countries/regions) (23 Aug 2020)
https://www.worldometers.info/coronavirus/#countries

Lombardy (Italy)	1675
NY State (USA)	1669
Belgium	861
Spain	617
UK	610
Italy	586
Sweden	575
USA	545
France	467
Netherlands	362
Ireland	359
California (USA)	307
Switzerland	231
Portugal	176
Germany	111

Do we have any explanation for these numbers? E.g.:

- Belgium vs. Germany !?! One order of magnitude!
- Italy and Sweden have very similar numbers, in spite of completely different approaches (lockdown, masks)!

Additional Information

Airborne Transmission of SARS-CoV-2: A Virtual Workshop

The National Academies of Sciences, Engineering, and Medicine

Aug 26 - 27, 2020

(A recording of the event will be posted shortly)

https://www.nationalacademies.org/event/08-26-2020/airborne-transmission-of-sars-cov-2-a-virtual-workshop