On the Effects of Face Masks, Distance and Building HVAC Systems in the Spread of Infectious Aerosol

6-30-2020

Henry Johnstone, P.E.

GLHN Architects & Engineers, Inc.

GLHN
ARCHITECTS & ENGINEERS, INC

Meet Sam Spu.

Sam is a two-dimensional figure.

1.

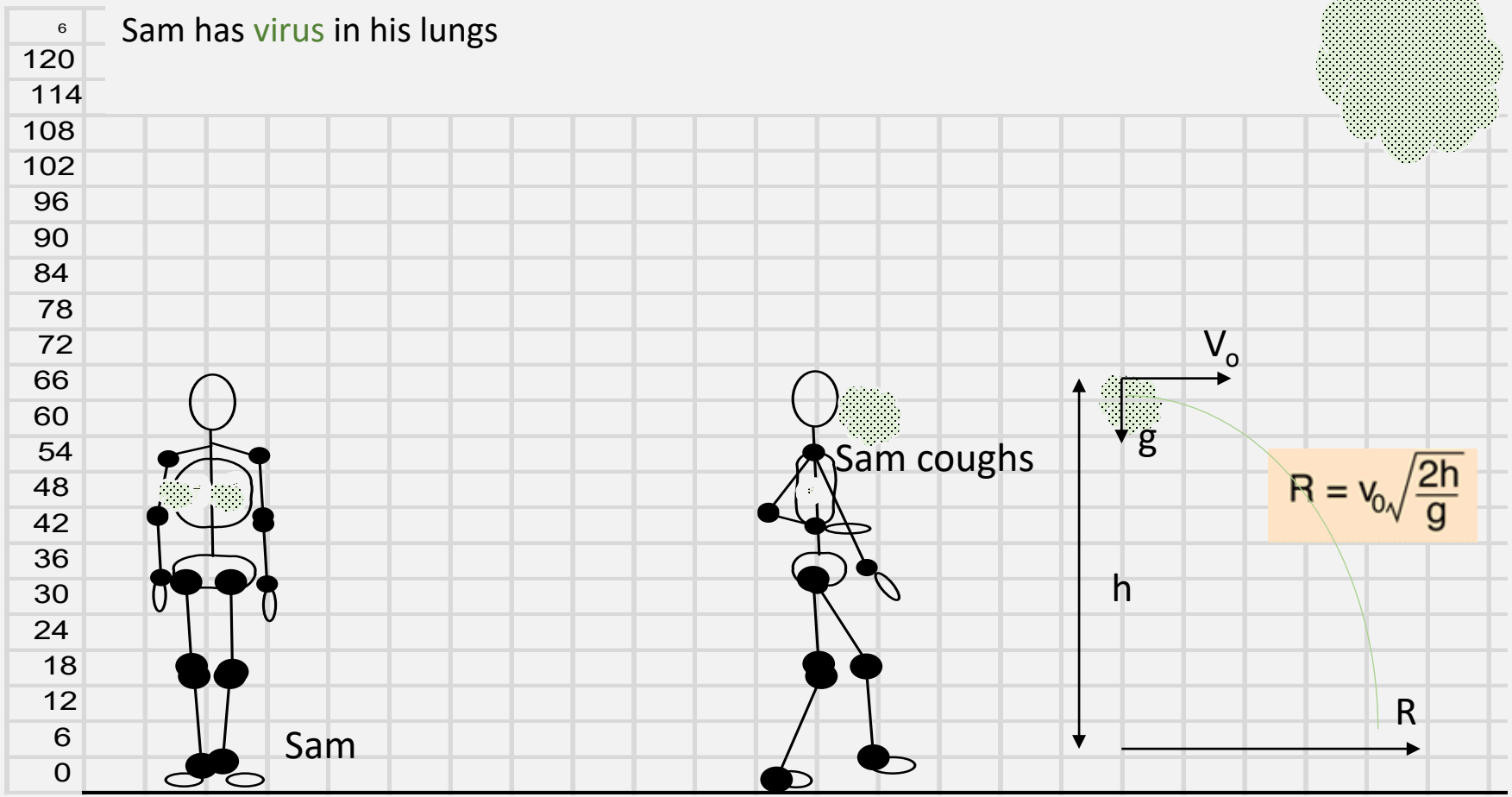
He lives within an excel spreadsheet, spaced in a 6” x 6” grid.

He wishes he lived in a 3-dimensional computational model surrounded by a finer mesh.

That model would solve multiple series of coupled partial differential equations like Navier Stokes, using fully-coupled Eulerian-Lagrangian techniques.

For right now, Sam lives in an engineer’s spreadsheet that uses only simple algebra.

Sam has virus in his lungs



This blob represents fluid particles contained within the warm, moist, turbulent cloud of gas that is our breath.

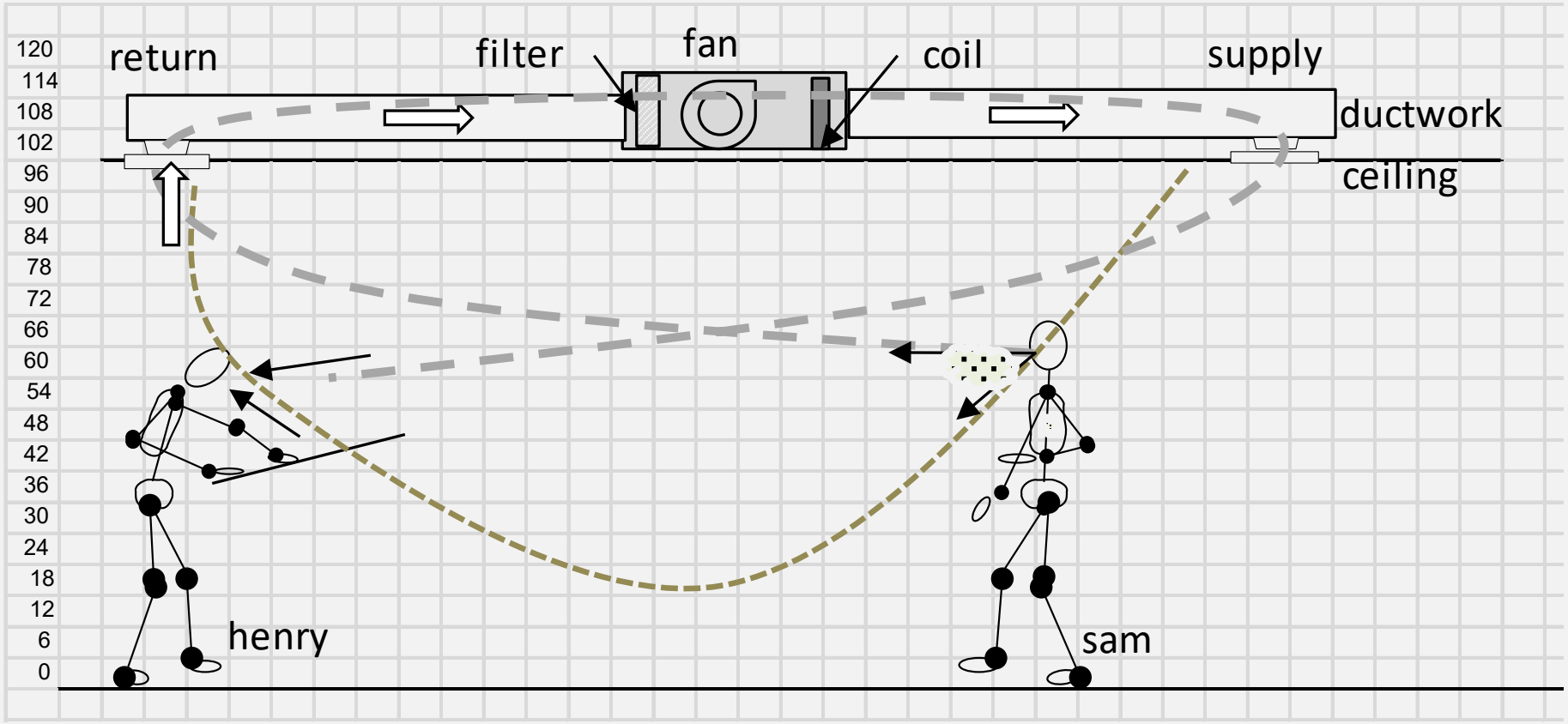
Corona virus has been observed to attach to fluids within the lungs and airways. These droplets are expelled from one human, through respiration, coughing, or sneezing. If the virulent particles are drawn into the airways of another person, they can initiate an infection. An infection that multiplies.

This is one way a virus spreads.

2.

Henry is at the drafting board. Henry designs heating, ventilating and air conditioning systems for public buildings.
He is interested to know if he might be breathing in Sam's virus.
That could happen if either
a. the virus gets sucked into the air conditioning return ductwork and blown at him out the supply grille, or,
b. the room air currents induced by the HVAC system sweep the virus into his face.

A series of cartoons follow his line of inquiry.



A simple HVAC system recirculates room air through a set of filters, a blower fan and a coil. The coil adds heat or cool to maintain temperature in the room.

There are many different types, features and relevant characteristics of HVAC systems that may be described in later panels.

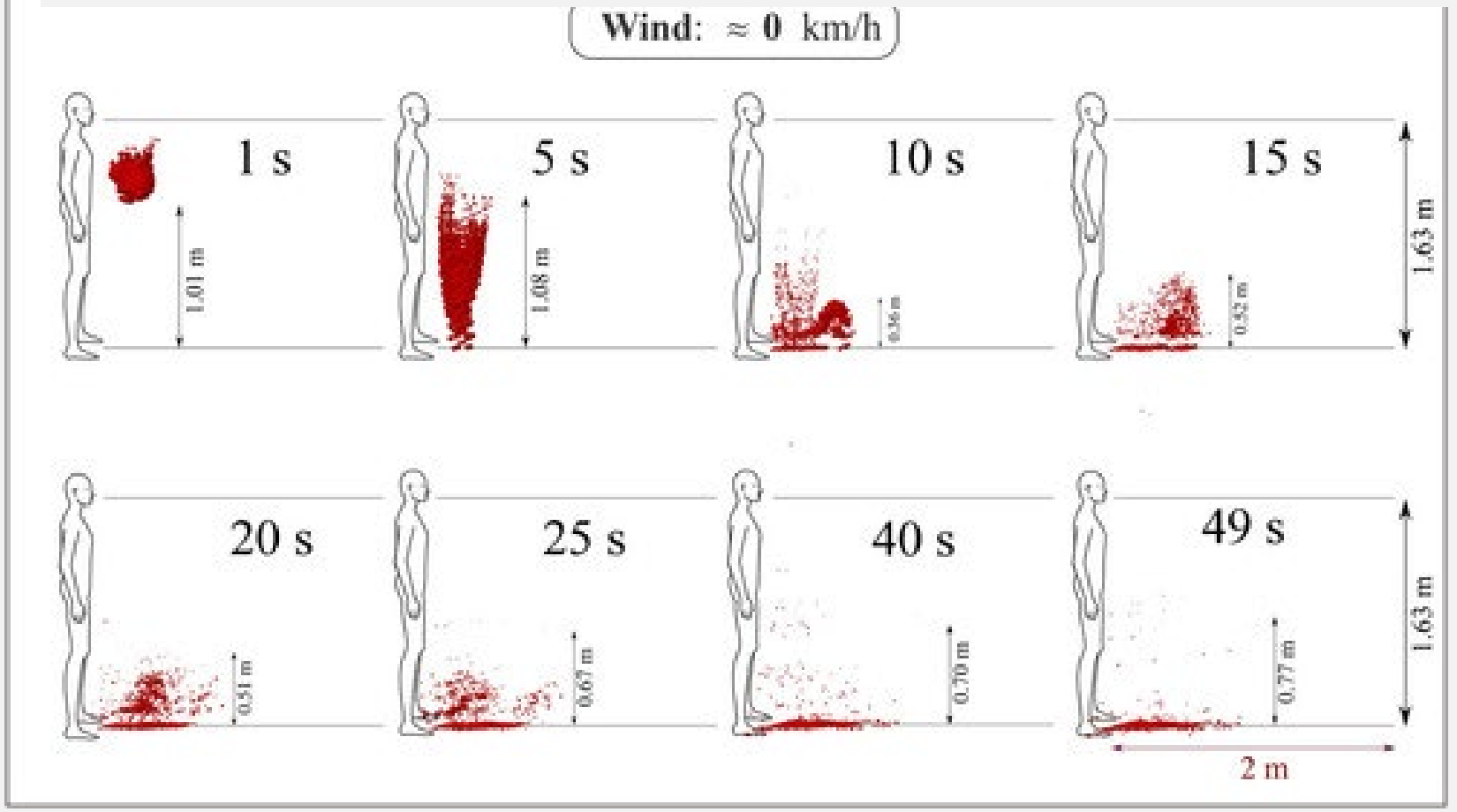
This is CFD Man. He just sneezed. Henry took this image from a recent paper on the internet:

"On coughing and airborne droplet transmission to humans"

Physics of Fluids **32**, 053310 (2020); https://doi.org/10.1063/5.0011960 Talib Dbouk[a] *and* Dimitris Drikakis[b] University of Nicosia, Nicosia CY-2417, Cyprus

3. This paper is written by academic engineers, running a sophisticated Computational Fluid Dynamics (CFD) model. The authors seem (to Henry) to know what they are doing in solving this problem in fluid dynamics. Read their paper. It is well done. It is based on scientific method. It considers relative humidity, turbulent dispersion forces, droplet phase-change, evaporation, and droplet-droplet, droplet-air interactions. Very complex. This is their solution to a simplest case. No wind, neutral environment.

CFD Man sneezes- where do the droplets go?

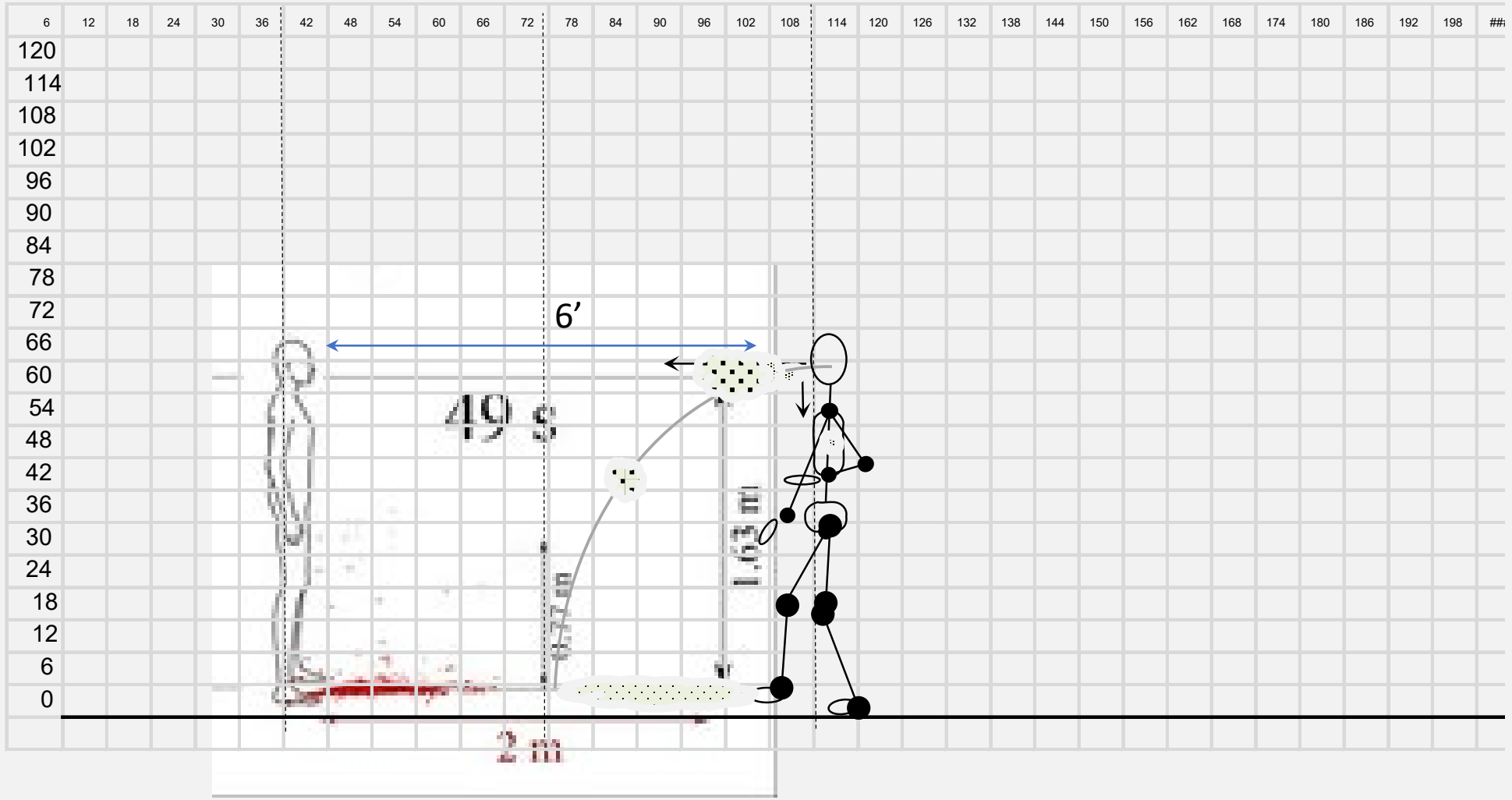


Henry thinks of this as a "droplet bomb": particles, filaments, slimes, drops aerosols, mist. Saliva, mucus, pus, spittle…The stuff that ends up in your hand or on your sleeve when you sneeze into it. You know.

Only these droplets are really invisibly small and are expelled every time we breath out, more so when we sing or shout or cough or sneeze.

This happens with or without Virus.

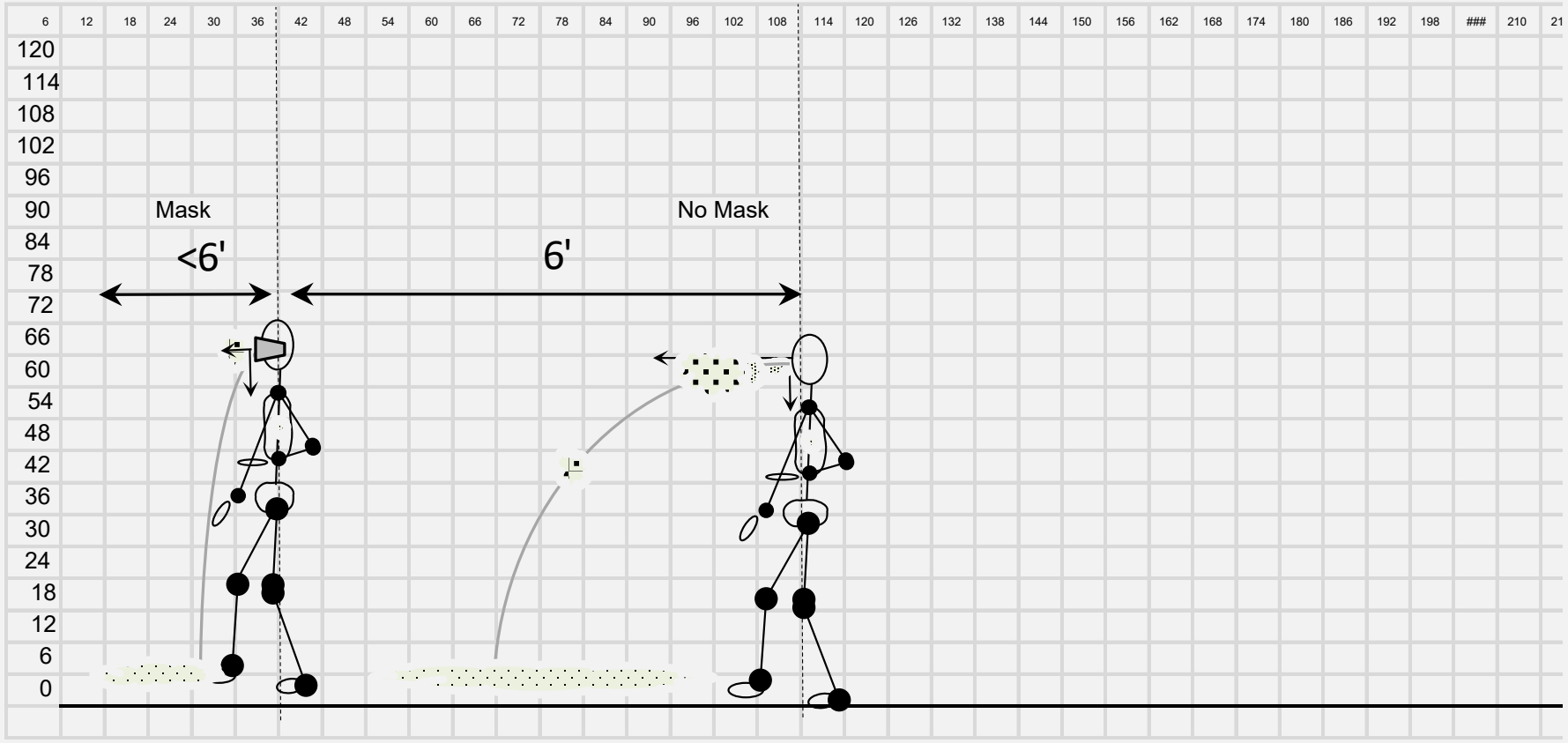
4. CFD man meets Sam Spu.
In the windless case, fluid droplets fall to the floor in less than a minute.
The farthest the particles go out radially is on the order of 6 feet.
6 feet is considered minimum “Social Distance”.



5.

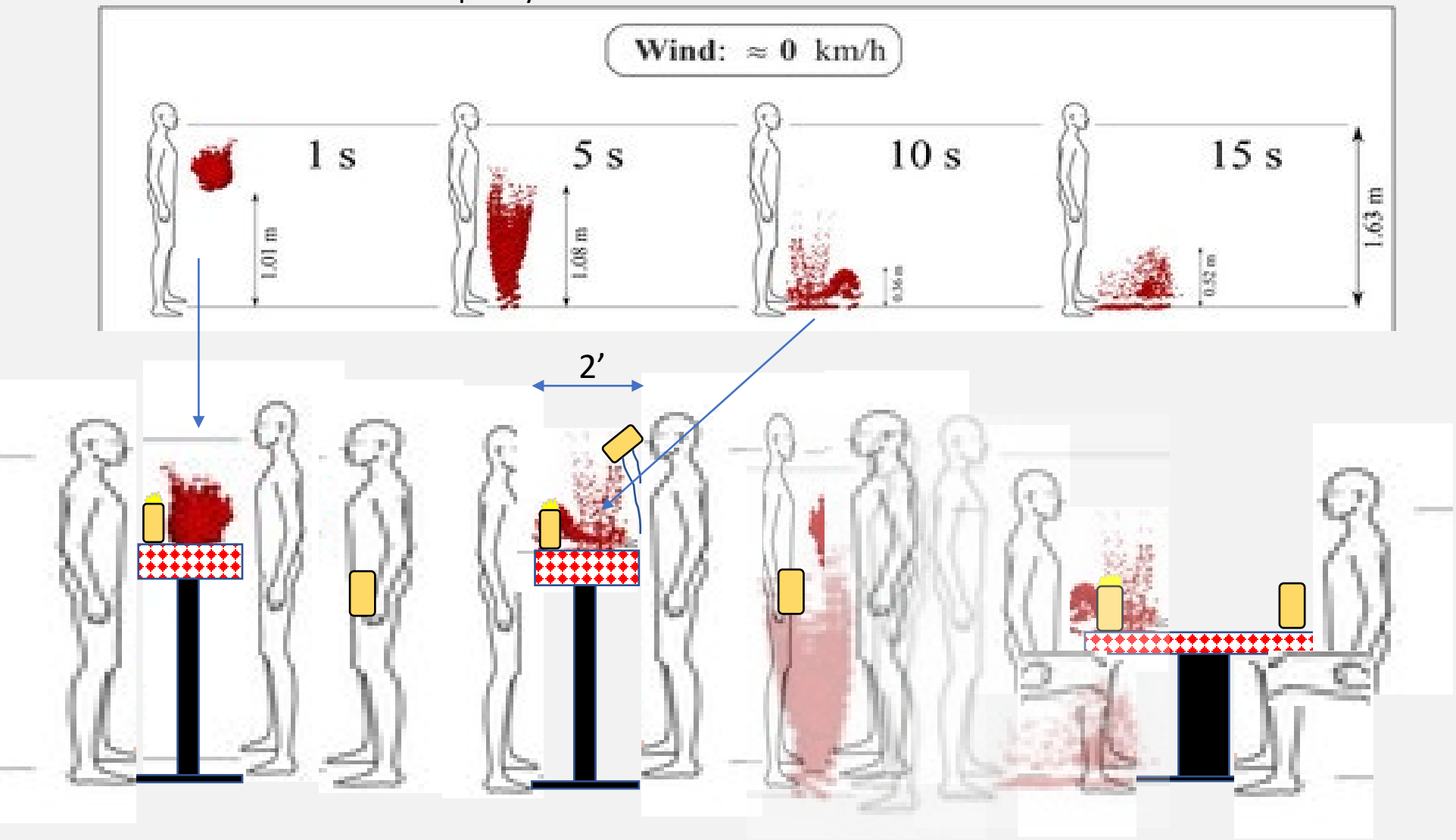
Sam puts on a mask.
Some droplets and aerosols are absorbed in the mask, some get through.
How much gets through? Depends on mask material, design and fit.
But, even with lousy mask material, **the horizontal velocity of the discharge jet gets much smaller**.
How did Henry conclude that?
He tried to blow out a match with a mask on.

Mask drastically reduces the range of the droplet bomb - “a vector of virus shed”.



6.

Henry imagines CFD Man joining his mates in a crowded bar. A couple of them are not aware they have virus.
It is difficult, and not cool, to drink beer while wearing a mask, and they do not wear masks.
The air conditioning is poor, there is no wind and little ventilation.
The red dots represent location and density of the droplet bombs that occur when they breath out.
The result is not pretty.



CFD Man has not hung with his mates for a long time.

It is loud, they are close, they talk loudly, call for another round, karaoke "I Will Survive", another couple rounds, hilarious jokes and uncontrolled coughing. At closing time they stumble back to their friends and families.

Would Social Distancing and Masks have reduced spread of virus?

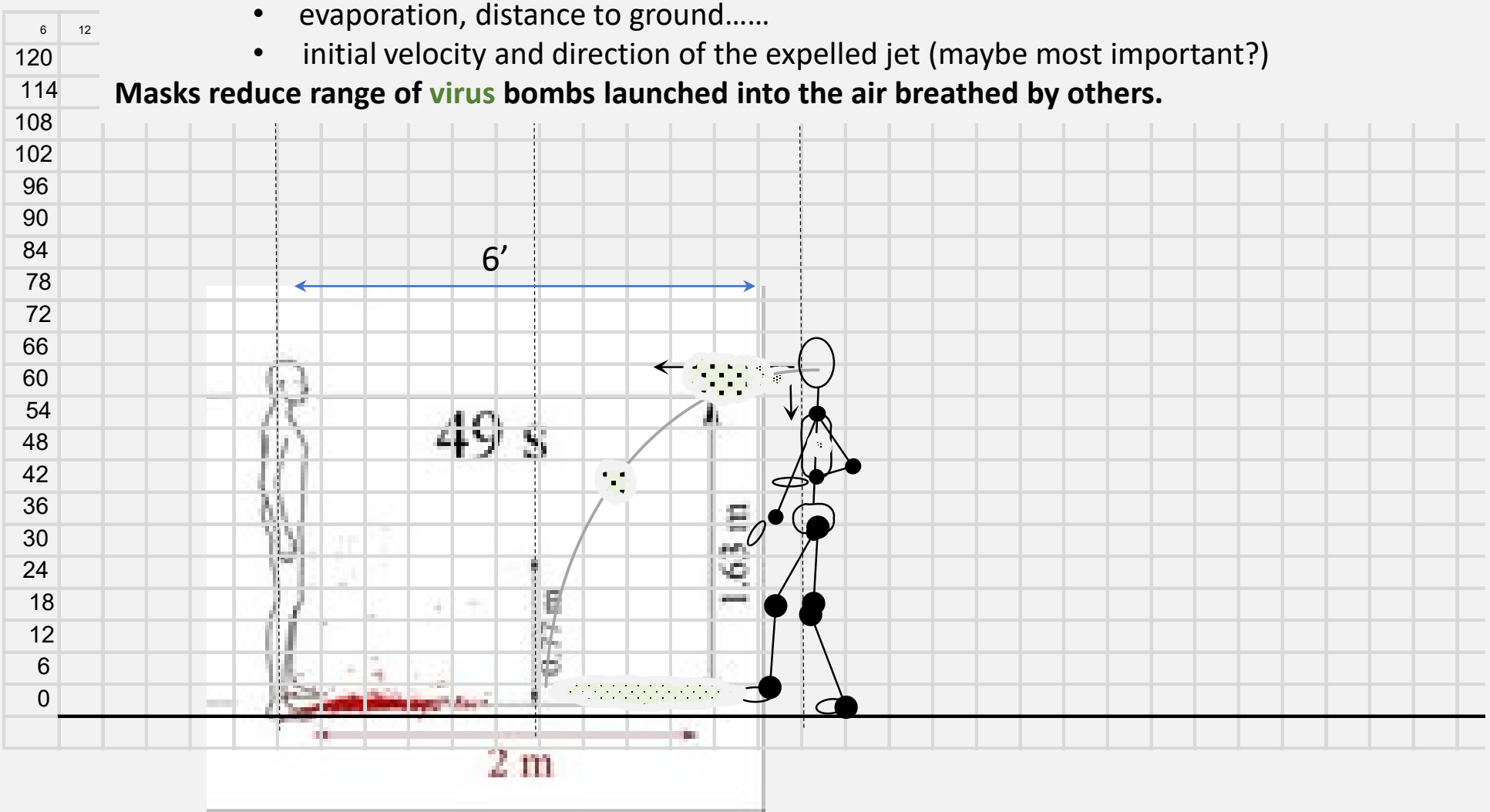
7.

But… these pictures are overly simplified. Reality is much more complicated than the zero wind, neutral ambient condition. Many factors matter. Finer droplets have been observed to be held aloft, hanging in the air for 10 or more minutes.

Factors involved in hang time?

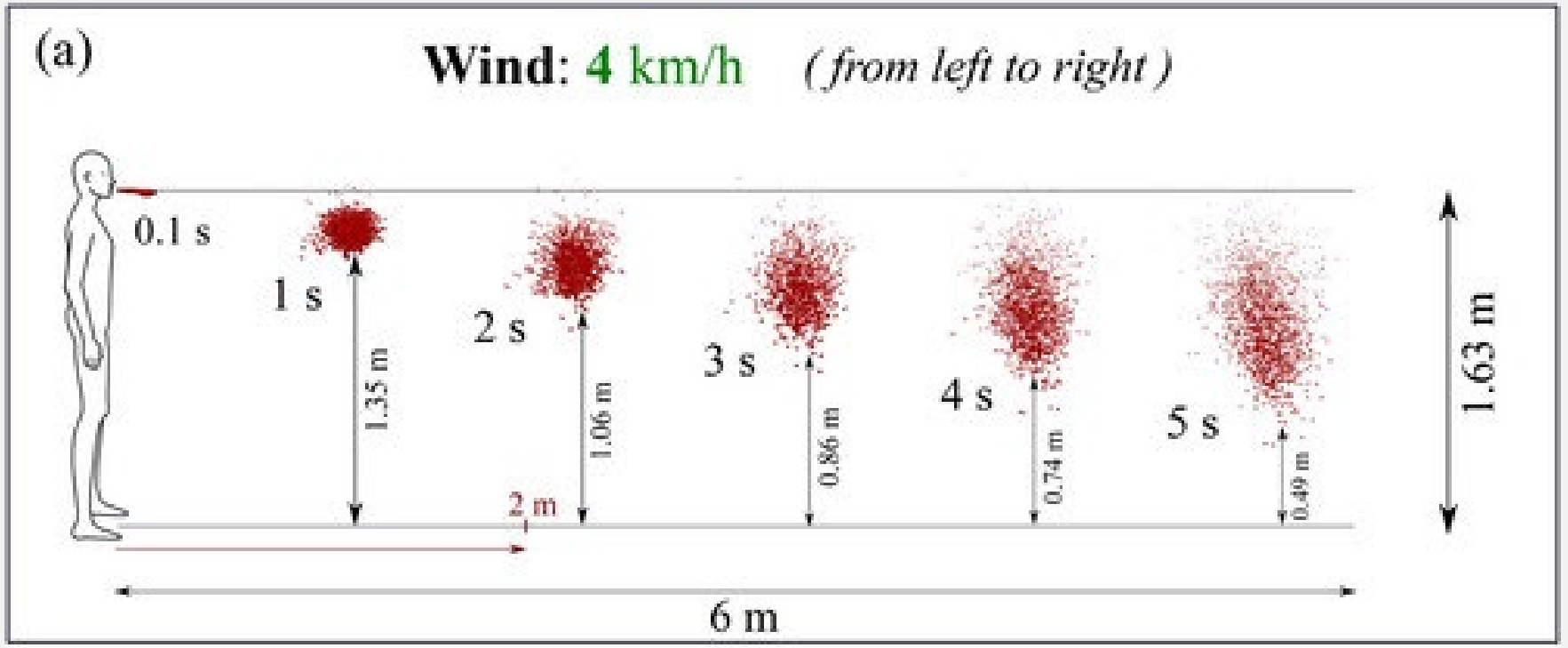
- fluid composition and size of droplets, mist, aerosol
- ambient wind velocity and direction
- relative temperature and humidity
- evaporation, distance to ground……
- initial velocity and direction of the expelled jet (maybe most important?)

Masks reduce range of virus bombs launched into the air breathed by others.

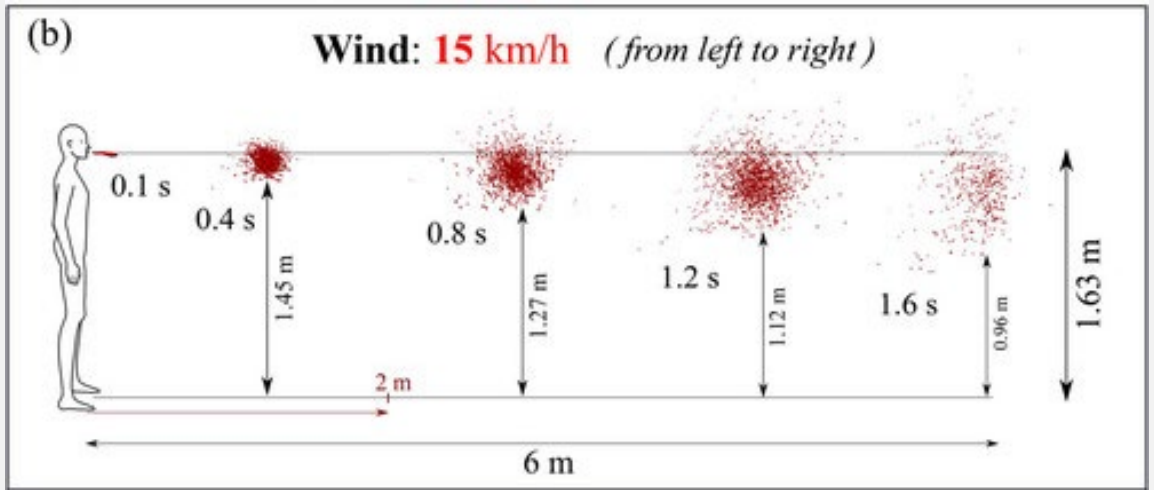


The Computational Fluid Dynamics model looked at the effect of a back wind on droplet carry.
It was developed by engineering science and fluid mechanics researchers Dbouk and Drikakis.

8.

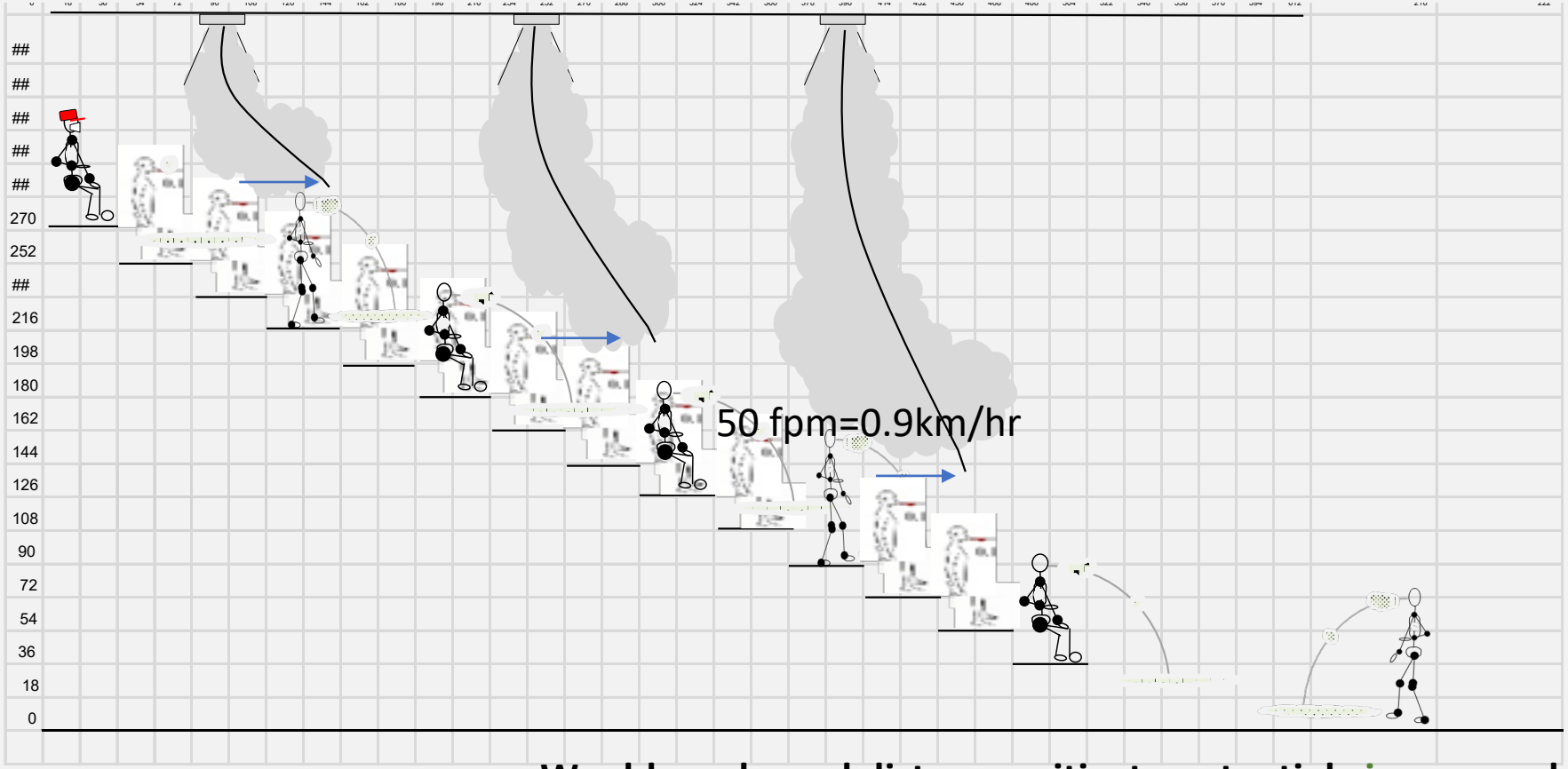


6 m = 19.7 ft.
4 km/hr = 220 feet/min (fpm)
Much of the droplet cloud is still above 4 ft elevation at 20 ft distant from the source.
The cloud stays up longer as the wind speed picks up.



9.

Good news: HVAC design for air motion in indoor spaces is typically on the order of 50 ft/min.
This only corresponds to 1 km/hr- so not as bad as in the 20’ throw projected in the CFD physics model.
But – horizontal throw with a backwind is still more than the 6’ predicted in the “no wind” condition.
Now consider a steeply pitched public event space, like a civic arena.
Cool supply air from overhead rolls down the pitched seats at head level, from behind at 50 ft/min.
Horizontal component of wind now couples with dropping floor to dump droplet bombs onto the heads and laps of folks below.



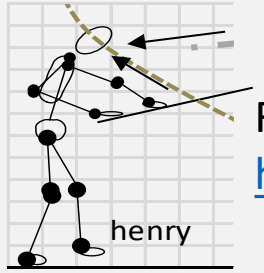
CFD Man’s mates bring the Spu clan to a hockey game. Somebody has virus. Lots of shouting and chanting. National Anthem sung vigorously. Ref makes a bad call. A fight on the ice. “Hey goalie, you suck”. Crowd goes wild.

Only the fan in a red cap at the top wears a mask. Smartest guy in the room.

Would masks and distance mitigate potential virus spread by droplet bombs?

10. There could be more . . . future installments?

- Ratio of outside air and recirculated indoor air on concentration of virus.
- Importance of ventilation effectiveness - mixed vs displacement ventilation.
- Significance of relative humidity (ASHRAE recommendations) - room humidifiers.
- Effectiveness of UV light in space vs UV light in air handling system.
- Types and location of filtration.
- Relative merits of various air handler typologies.
- Architectural challenges in maintaining distancing.



Respond to Henry?
hjohnsto@glhn.com